BS EN 61000-4-6:2014

BSI Standards Publication

Electromagnetic compatibility (EMC)

Part 4-6: Testing and measurement techniques — Immunity to conducted disturbances, induced by radio-frequency fields

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National foreword

This British Standard is the UK implementation of EN 61000-4-6:2014. It is identical to IEC 61000-4-6:2013. It supersedes BS EN 61000-4-6:2009 which will be withdrawn on 27 November 2016.

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

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

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English version

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

Compatibilité électromagnétique (CEM) - Partie 4-6: Techniques d'essai et de mesure - Immunité aux perturbations conduites, induites par les champs radioélectriques
(CEI 61000-4-6:2013)

Elektromagnetische Verträglichkeit (EMV) - Teil 4-6: Prüf- und Messverfahren - Störfestigkeit gegen leitungsgeführte Störgrößen, induziert durch hochfrequente Felder
(IEC 61000-4-6:2013)

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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

Foreword

The text of document 77B/691/FDIS, future edition 4 of IEC 61000-4-6, 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 61000-4-6:2014.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2014-08-27
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2016-11-27

This document supersedes EN 61000-4-6:2009.

EN 61000-4-6:2014 includes the following significant technical changes with respect to EN 61000-4-6:2009:

a) use of the CDNs;

b) calibration of the clamps;

c) reorganization of Clause 7 on test setup and injection methods;

d) Annex A which is now dedicated to EM and decoupling clamps;

e) Annex G which now addresses the measurement uncertainty of the voltage test level;

f) informative Annexes H, I and J which are new.

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 61000-4-6:2013 was approved by CENELEC as a European Standard without any modification.

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

IEC 61000-4-3	NOTE	Harmonised as EN 61000-4-3.
CISPR 16-1-2	NOTE	Harmonised as EN 55016-1-2.
CISPR 16-1-4	NOTE	Harmonised as EN 55016-1-4.
CISPR 20	NOTE	Harmonised as EN 55020.

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

Publication	Year	Title	EN/HD	Year
IEC 60050 (Series)	-	International Electrotechnical Vocabulary (IEV)	-	-

CONTENTS

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 procedures related to conducted disturbances induced by radio-frequency fields.

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields

1 Scope

This part of IEC 61000 relates to the conducted immunity requirements of electrical and electronic equipment to electromagnetic disturbances coming from intended radio-frequency (RF) transmitters in the frequency range 150 kHz up to 80 MHz. Equipment not having at least one conducting wire and/or cable (such as mains supply, signal line or earth connection) which can couple the equipment to the disturbing RF fields is excluded from the scope of this publication.

NOTE 1 Test methods are defined in this part of IEC 61000 to assess the effect that conducted disturbing signals, induced by electromagnetic radiation, have on the equipment concerned. The simulation and measurement of these conducted disturbances are not adequately exact for the quantitative determination of effects. The test methods defined are structured for the primary objective of establishing adequate repeatability of results at various facilities for quantitative analysis of effects.

The object of this standard is to establish a common reference for evaluating the functional immunity of electrical and electronic equipment when subjected to conducted disturbances induced by RF fields. The test method documented in this part of IEC 61000 describes a consistent method to assess the immunity of an equipment or system against a defined phenomenon.

NOTE 2 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 should be applied or not, and if applied, they are responsible for determining the appropriate test levels and performance criteria.

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

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]

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
clamp injection
clamp injection is obtained by means of a clamp-on “current” injecting device on the cable

3.4
clamp injection device
clamp-on “current” injecting device on a cable being either a current clamp or an electromagnetic clamp

3.4.1
current clamp
transformer, the secondary winding of which consists of the cable into which the injection is made

3.4.2
electromagnetic clamp
EM clamp
injection device with combined capacitive and inductive coupling

3.5
common mode impedance
ratio of the common mode voltage and the common mode current at a certain port

Note 1 to entry: This common mode impedance can be determined by applying a unity common mode voltage between the terminal(s) or screen of that port and a reference plane (point). The resulting common mode current is then measured as the vectorial sum of all currents flowing through these terminal(s) or screen (see also Figures 8a) and 8b)).

3.6
coupling factor
ratio given by the open-circuit voltage (e.m.f.) obtained at the EUT port of the coupling (and decoupling) device divided by the open-circuit voltage obtained at the output of the test generator

3.7
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 and decoupling network (CDN)) or they can be in separate networks.

3.8
coupling/decoupling network
CDN
electrical circuit incorporating the functions of both the coupling and decoupling networks

3.9
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

3.10
test generator
generator (RF generator, modulation source, attenuators, broadband power amplifier and filters) capable of generating the required test signal

Note 1 to entry: See Figure 3.

3.11
electromotive force
e.m.f.
voltage at the terminals of the ideal voltage source in the representation of an active element

3.12
measurement result
$U_{\mathbf{mr}}$
voltage reading of the measurement equipment

3.13
voltage standing wave ratio
VSWR
ratio of a maximum to an adjacent minimum voltage magnitude along the line

4 General

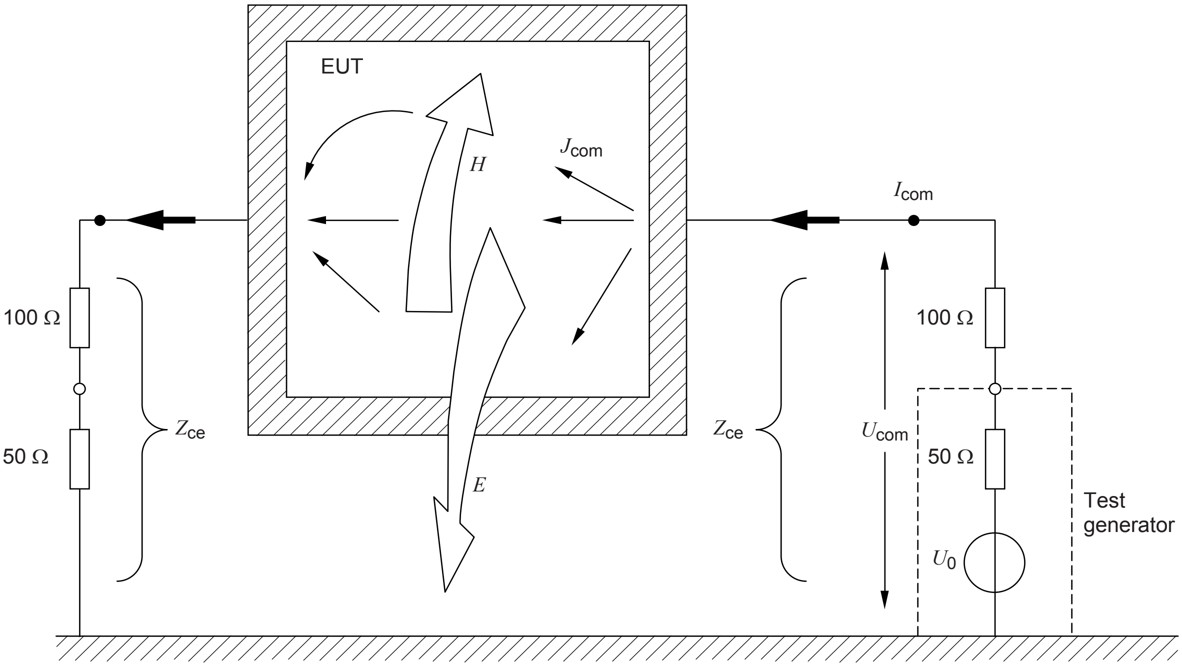
The source of disturbance covered by this part of IEC 61000 is basically an electromagnetic field, coming from intended RF transmitters, that may act on the whole length of cables connected to installed equipment. The dimensions of the disturbed equipment, mostly a sub-part of a larger system, are assumed to be small compared with the wavelengths of the interfering signals. The leads entering and exiting the EUT (e.g. mains, communication lines, interface cables) behave as passive receiving antenna networks and signal conduction paths for both intentional and unintentional signals.

Between those cable networks, the susceptible equipment is exposed to currents flowing “through" the equipment. Cable systems connected to an equipment are assumed to be in resonant mode ($\lambda/4$, $\lambda/2$ open or folded dipoles) and as such are represented by coupling and decoupling devices having a common mode impedance of 150 Ω with respect to a reference ground plane. Where possible the EUT is tested by connecting it between two 150 Ω common mode impedance connections: one providing an RF source and the other providing a return path for the current.

This test method subjects the EUT to a source of disturbance comprising electric and magnetic fields, simulating those coming from intentional RF transmitters. These disturbing fields (E and H) are approximated by the electric and magnetic near-fields resulting from the voltages and currents caused by the test setup as shown in Figure 1a).

The use of coupling and decoupling devices to apply the disturbing signal to one cable at a time, while keeping all other cables nonexcited (see Figure 1b)), can only approximate the real situation where disturbing sources act on all cables simultaneously, with a range of different amplitudes and phases.

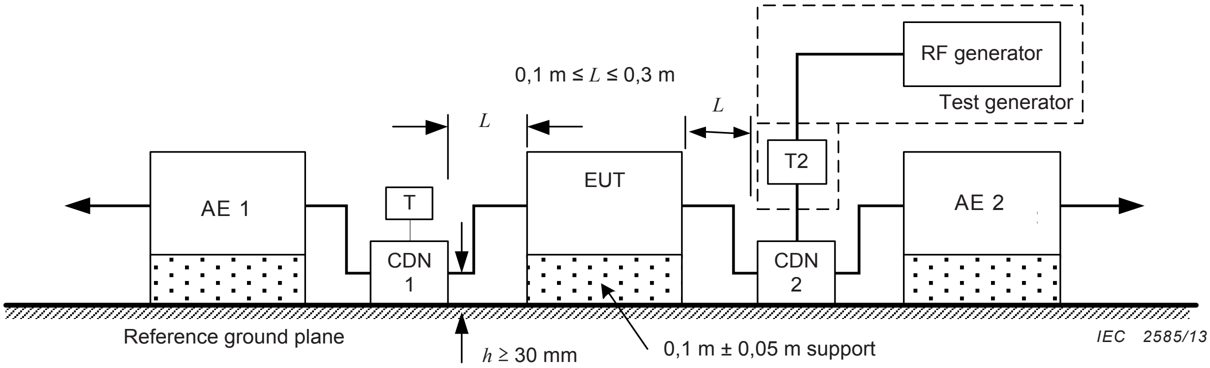
Coupling and decoupling devices are defined by their characteristics given in 6.2.1. Any coupling and decoupling device fulfilling these characteristics can be used. The CDNs in Annex D are only examples of commercially available networks.



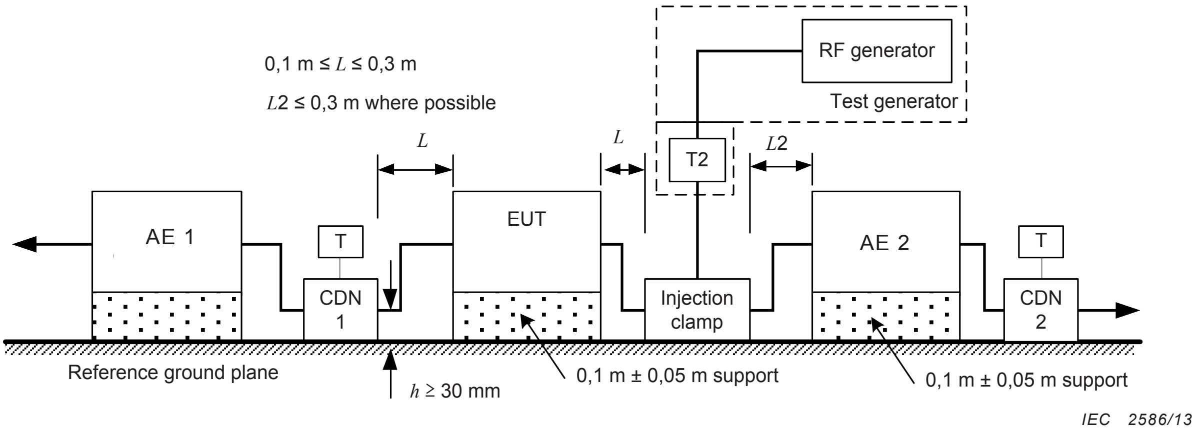
Z_{ce}	Common mode impedance of the CDN system, Z_{ce^e} = 150 Ω
U_0	Test generator source voltage (e.m.f.)
U_{com}	Common mode voltage between EUT and reference plane
I_{com}	Common mode current through the EUT
J_{com}	Current density on conducting surface or current on other conductors of the EUT
E, H	Electric and magnetic fields

NOTE The 100 Ω resistors are included in the CDNs. The left input is loaded by a (passive) 50 Ω load and the right input is loaded by the source impedance of the test generator.

a) Diagram showing EM fields near the EUT due to common mode currents on its cables



Schematic setup for immunity test used for CDN



Schematic setup for immunity test used for injection clamp

T	Termination 50 Ω
T2	Power attenuator (6 dB)
CDN	Coupling and decoupling network
Injection clamp:	Current clamp or EM clamp

b) Schematic setup for immunity test to RF conducted disturbances

Figure 1 – Immunity test to RF conducted disturbances

5 Test levels

According to this standard, tests are required for induced disturbances caused by electromagnetic fields coming from intentional RF transmitters in the frequency range 150 kHz to 80 MHz.

The open circuit test levels (e.m.f.) of the unmodulated disturbing signal, expressed in r.m.s., are given in Table 1.

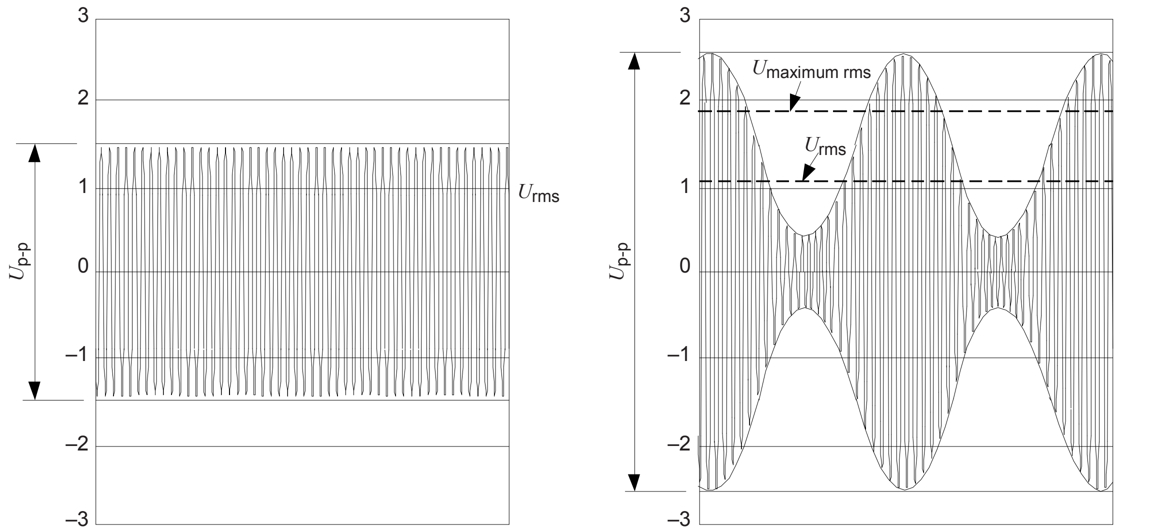
Table 1 – Test levels

Frequency range 150 kHz to 80 MHz		
Level	**Voltage level (e.m.f.)**	
	U_0 V	U_0 dB(μV)
1	1	120
2	3	129,5
3	10	140
X [a]	Special	
[a] "X" can be any level, above, below or in between the others. The level has to be specified in the dedicated equipment specification.		

The test levels are set at the EUT port of the coupling devices, see 6.4. For testing of the equipment, this signal is 80 % amplitude modulated with a 1 kHz sine wave to simulate actual threats. The effective amplitude modulation is shown in Figure 2. Guidance for selecting test levels is given in Annex C.

NOTE 1 IEC 61000-4-3 also defines test methods for establishing the immunity of electrical and electronic equipment against radiated electromagnetic energy. It covers frequencies above 80 MHz. Product committees can decide to choose a lower or higher transition frequency than 80 MHz (see Annex B).

NOTE 2 Product committees can select alternative modulation schemes.



a - Unmodulated RF signal
$U_{p\text{-}p}$ = 2,82 V
U_{rms} = 1,00 V
IEC 2587/13

b - Modulated RF – signal 80 % AM
$U_{p\text{-}p}$ = 5,09 V
U_{rms} = 1,12 V
$U_{maximum\ rms}$ = 1,80 V
IEC 2588/13

Figure 2 – Open circuit waveforms at the EUT port of a coupling device for test level 1

6 Test equipment and level adjustment procedures

6.1 Test generator

The test generator includes all equipment and components for supplying the input port of each coupling device with the disturbing signal at the required signal level at the appropriate injection point. A typical arrangement comprises the following items which may be separate or integrated into one or more test instruments (see 3.10 and Figure 3):

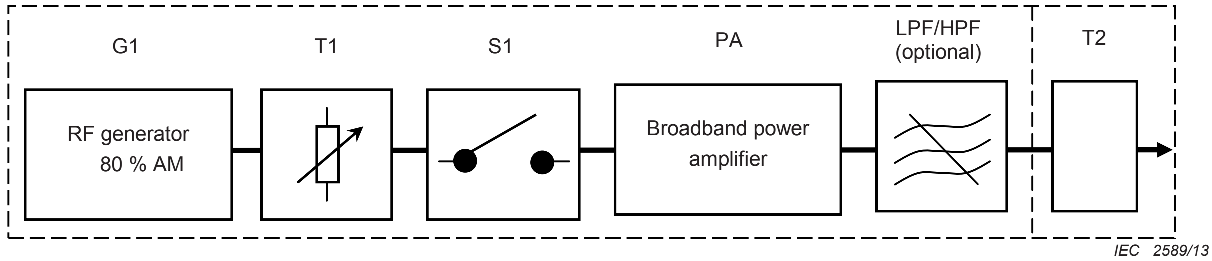
– RF generator(s), G1, capable of covering the frequency band of interest and of being amplitude modulated by a 1 kHz sine wave with a modulation depth of 80 %. They shall have manual control (e.g. frequency, amplitude, modulation index) or in the case of RF synthesizers, they shall be programmable with frequency-dependent step sizes and dwell times;
– attenuator T1, (typically 0 dB ... 40 dB) of adequate frequency rating to control the disturbing test source output level. T1 may be included in the RF generator and is optional;
– RF switch S1, by which the disturbing test signal can be switched on and off when measuring the immunity of the EUT. S1 may be included in the RF generator and is optional;
– broadband power amplifier(s), PA, may be necessary to amplify the signal if the output power of the RF generator is insufficient;
– low-pass filters (LPF) and/or high-pass filters (HPF) 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 in between the broadband power amplifier, PA, and the attenuator T2;
– attenuator T2, (fixed ≥ 6 dB), with sufficient power ratings. T2 is provided to reduce VSWR to the power amplifier caused by the mismatch of the coupling device.

NOTE T2 can be included in a CDN and can be left out if the output impedance of the broadband power amplifier remains within the specification under any load condition.

Characteristics of the test generator are given in Table 2.

Table 2 – Characteristics of the test generator

Output impedance	50 Ω, VSWR<1,5
Harmonics and distortion	within 150 kHz and 80 MHz, any spurious signal shall be at least 15 dB below the carrier level, measured at the EUT port of the coupling device. The -15 dBc can also be measured directly at the output of the amplifier.
Amplitude modulation	internal or external, $m = \left(80\ {}^{+5}_{-20}\right)\%$, with $m = 100 \times \dfrac{U_{\text{pp,max}} - U_{\text{pp,min}}}{U_{\text{pp,max}} + U_{\text{pp,min}}}$ 1 kHz ± 0,1 kHz sine wave
Output level	sufficiently high to cover test level (see also Annex E)
NOTE 1 For current clamps, the -15 dBc can be measured at either side of the test jig. NOTE 2 The harmonics and distortion are measured in continuous wave (CW) at 1,8 times the test level without modulation.	



G1	RF generator	T1	Variable attenuator
PA	Broadband power amplifier	T2	Fixed attenuator (6 dB)
LPF/HPF	Low pass filter and/or high pass filter (optional)	S1	RF switch

Figure 3 – Test generator setup

6.2 Coupling and decoupling devices

6.2.1 General

Coupling and decoupling devices shall be used for appropriate coupling of the disturbing signal (over the entire frequency range, with a defined common mode impedance at the EUT port) to the various cables connected to the EUT and for preventing applied test signals from affecting other devices, equipment and systems that are not under test.

The coupling and decoupling devices can be combined into one box (a CDN or an EM clamp) or can consist of several parts.

The preferred coupling and decoupling devices are the CDNs, for reasons of test reproducibility and protection of the AE. The main coupling and decoupling device parameter, the common mode impedance seen at the EUT port, is specified in Table 3. If CDNs are not applicable or available on the market, other injection methods can be used. Rules for selecting the appropriate injection method are given in 7.4.1. Other injection methods, due to their electrical properties, are unlikely to meet the parameters of Table 3.

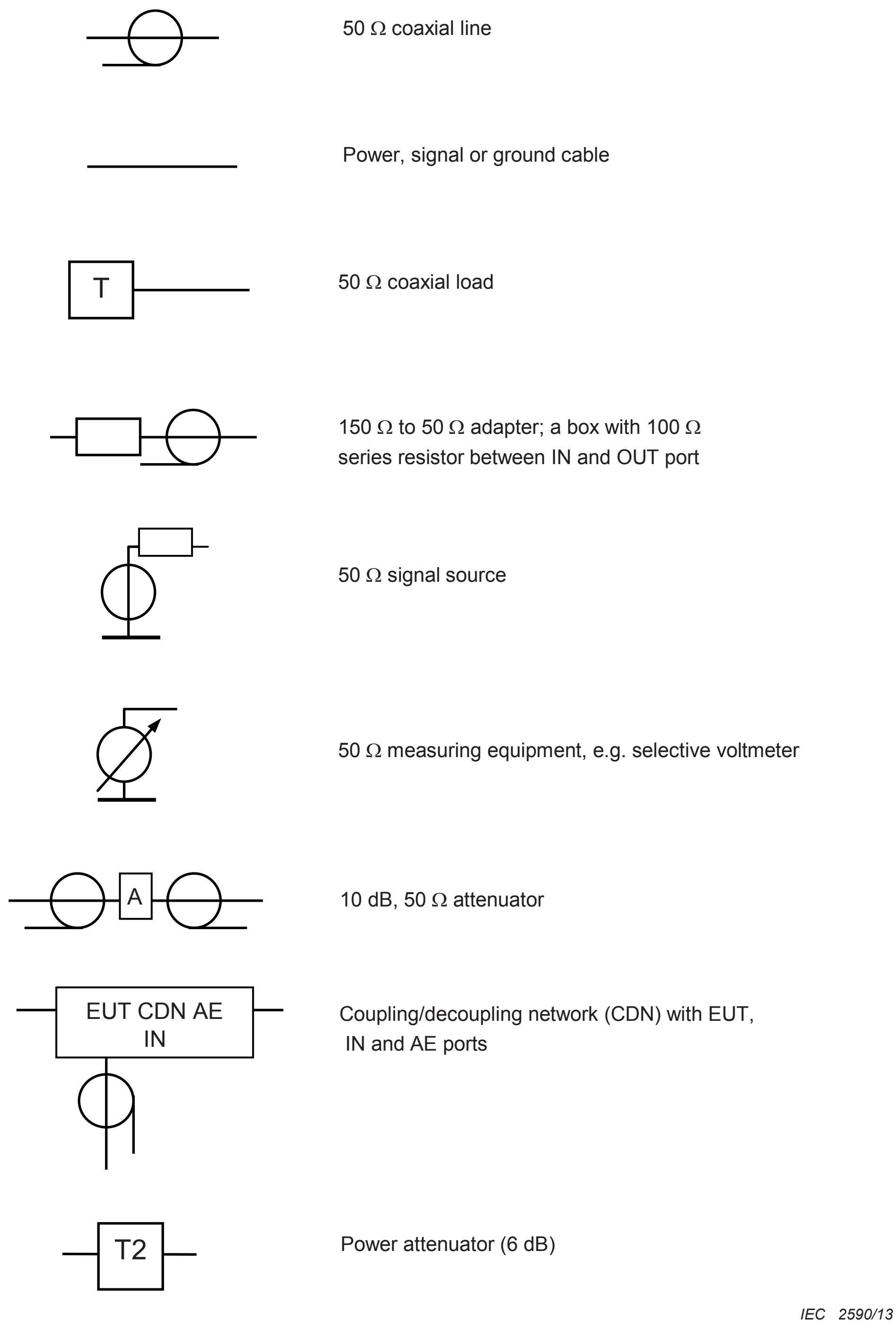
NOTE 1 A CDN may not be applicable if the internal signal attenuation has an unacceptable influence on the intended signal.

Table 3 – Main parameter of the combination of the coupling and decoupling device

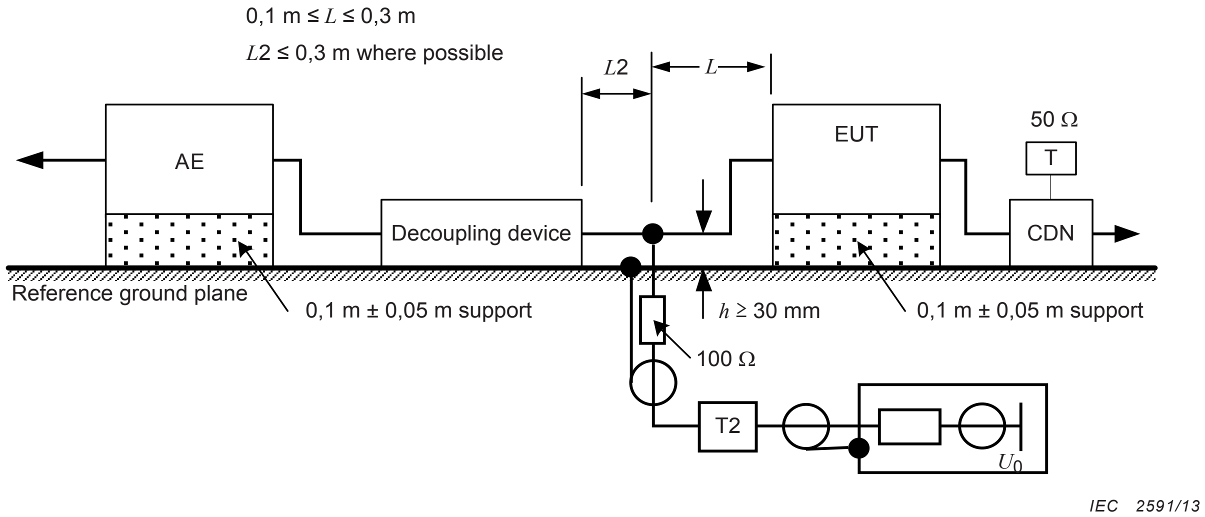
	Frequency band	
Parameter	0,15 MHz to 24 MHz	24 MHz to 80 MHz
$\lvert Z_{ce} \rvert$	150 Ω ± 20 Ω	150 Ω $^{+60\Omega}_{-45\Omega}$

NOTE 2 Neither the argument of Z_{ce} nor the decoupling factor between the EUT port and the AE port are specified separately. These factors are embodied in the requirement that the tolerance of $\lvert Z_{ce} \rvert$ shall be met with the AE port open or short-circuited to the reference ground plane.

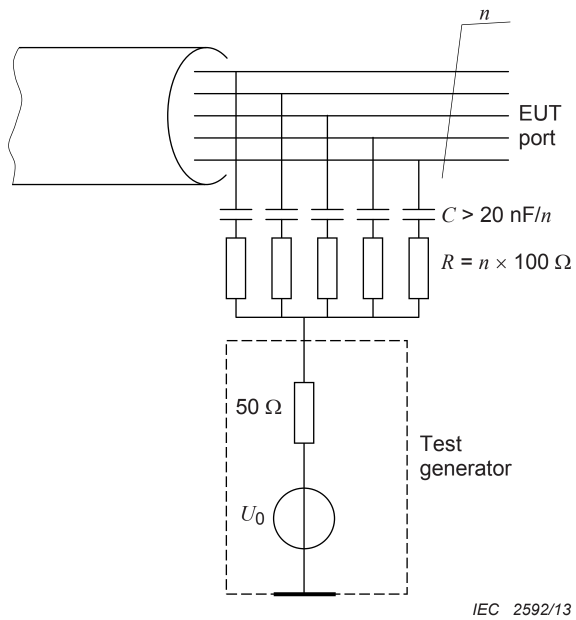
NOTE 3 Details for clamps are given in Annex A.



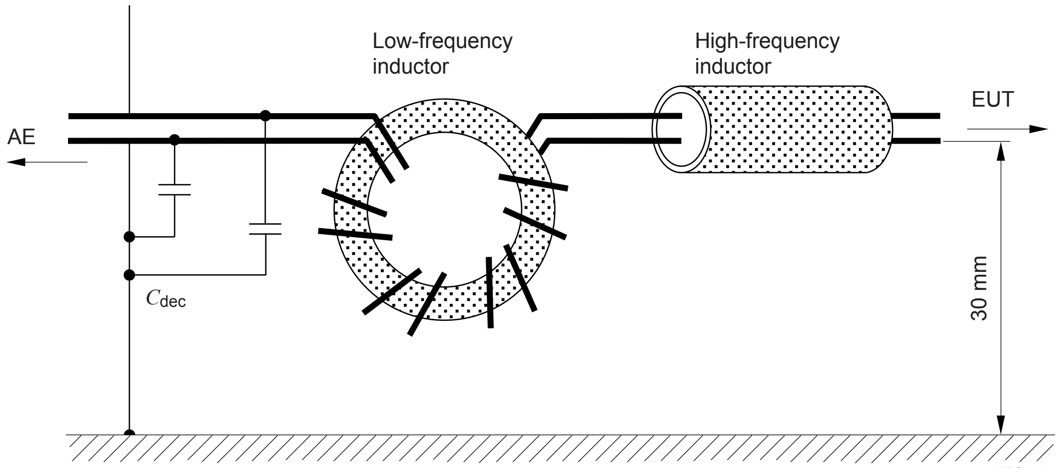
a) List of symbols used for the indicated setup principles



b) Principle of direct injection to screened cables



c) Principle of coupling to unscreened cables according to the CDN method



Example: Typically C_{dec} = 47 nF (only on unscreened cables), $L_{(150\ kHz)} \geq 280\ \mu H$

Low frequency inductor: 17 turns on a ferrite toroid material: NiZn, μ_R = 1 200

High frequency inductor: 2 to 4 ferrite toroids (forming a tube), material: NiZn, μ_R = 700

d) Principle of decoupling

Figure 4 – Principle of coupling and decoupling

6.2.2 Coupling/decoupling networks (CDNs)

6.2.2.1 General

These networks comprise the coupling and decoupling circuits in one box. Typical concepts of the CDNs are given in Figures 4c) and 4d). Table 4 summarizes the usage of the different types of CDNs as outlined in Annex D. The CDNs selected shall not unduly affect the functional signals (see advice given in Figure 12). Constraints on such effects may be specified in the product standards.

Table 4 – Usage of CDNs

Line type	Examples	CDN type
Power supply (a.c. and d.c.) and earth connection	AC mains, d.c. in industrial installations, earth connection	CDN-Mx (see Figure D.2)
Screened cables	Coaxial cables, cables used for LAN and USB connections, cables for audio systems	CDN-Sx (see Figure D.1)
Unscreened balanced lines	ISDN lines, telephone lines	CDN-Tx (see 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 Figures D.3 and D.6)

6.2.2.2 CDNs for power supply lines

CDNs are recommended for all power supply connections. However, for high power (current ≥ 16 A) and/or complex supply systems (multi-phase or various parallel supply voltages) other injection methods may be selected.

The disturbing signal shall be coupled to the supply lines, using type CDN-M1 (single wire), CDN-M2 (two wires) or CDN-M3 (three wires), or equivalent networks (see Annex D). Similar networks can be defined for a 3-phase mains system. The coupling circuit is given in Figure 4c).

The performance of the CDN shall not be unduly degraded by saturation of the magnetic material due to current drawn by the EUT. Wherever possible, the network construction should ensure that the magnetising effect of the forward current is cancelled by that due to the return current.

If in actual installations the supply wires are individually routed, separate CDN-M1 CDNs shall be used. All input ports shall be treated separately.

If the EUT is provided with functional earth terminals (e.g. for RF purposes or high leakage currents), they shall be connected to the reference ground plane:

- through the CDN-M1 when the characteristics or specification of the EUT permit. In this case, the (power) supply shall be provided through an appropriate CDN-Mx type network;
- when the characteristics or specification of the EUT do not permit the presence of a CDN-M1 network in series with the earth terminal for RF or other reasons, the earth terminal shall be directly connected to the reference ground plane. In this case the CDN-M3 network shall be replaced by a CDN-M2 network to prevent an RF short-circuit by the protective earth conductor. When the equipment was already supplied via CDN-M1 or CDN-M2 networks, these shall remain in operation;
- for a 3-phase supply, a similar adjustment needs to be done regarding the use of an appropriate CDN-Mx type network.

Warning: The capacitors used within the CDNs bridge live parts. As a result, high leakage currents may occur and safety connections from the CDN to the reference ground plane are mandatory (in some cases, these connections may be provided by the construction of the CDN).

6.2.2.3 CDNs for unscreened balanced lines

For coupling and decoupling disturbing signals to an unscreened cable with balanced lines, a CDN-T2, CDN-T4 or CDN-T8 shall be used as a CDN. Figures D.4, D.5 and D.7 in Annex D show these possibilities:

- 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).

Other CDN-Tx networks may be used if they are suitable for the intended frequency range and satisfy the requirements of 6.2.1. For example, the differential to common mode conversion loss of the CDNs should have a larger value than the specified conversion ratio of the cable to be installed or equipment connected to the installed cable. If different conversion ratios are specified for cable and equipment then the smaller value applies. Often, the clamp injection needs to be applied to multi-pair balanced cables because suitable CDNs might not be available.

6.2.2.4 CDNs for unscreened unbalanced lines

For coupling and decoupling disturbing signals to an unscreened cable with unbalanced lines, CDNs as described in Figure D.3 for a single pair and Figure D.6 for four pairs may be used.

If no CDN for the unscreened unbalanced line is applicable, follow the decision chart in Figure 12.

6.2.2.5 CDNs for screened cables

For coupling and decoupling disturbing signals to a screened cable, a Sx-type CDN is used. Figure D.1 is the example for a coaxial cable (S1).

To be able to treat a cable as a screened cable using CDNs for coupling of the disturbing signal, the screen shall be connected at both ends of the cable. If this condition is not met, then the cable should be treated as an unscreened cable.

6.2.3 Clamp injection devices

6.2.3.1 General

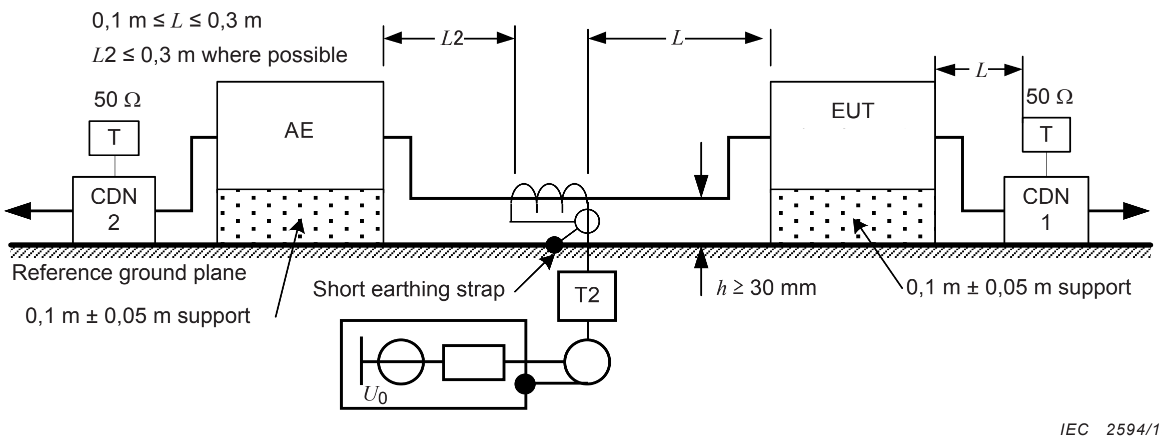
With clamp injection devices, the coupling and decoupling functions are separated. Coupling is provided by the clamp-on device while the common mode impedance and the decoupling functions are established at the AE. As such, the AE becomes part of the coupling and decoupling devices (see Figure 5). It should be noted that with clamp injection devices the AE is subject to the same injected current as the EUT and therefore needs to be immune to the test level used.

NOTE 1 When clamp injection methods are used, without complying with the common mode impedance requirements for the AE, the requirements of Z_{ce} may not be met. However, the injection clamps can provide acceptable test results when the guidance of 7.4.1 is followed.

NOTE 2 The EM clamp provides some decoupling above 10 MHz, see Annex A.

Instructions for proper application are given in 7.6.

When an EM clamp or a current clamp is used without fulfilling the constraints given in 7.6, the procedure defined in 7.7 shall be followed. The induced voltage is set in the same way as described in 6.4.1. In addition, the resulting current shall be monitored and limited to $I_{max.}$ In this procedure, a lower common mode impedance may be used, but the common mode current is limited to the value which would flow from a 150 Ω source.



The CDN connected to the AE, e.g. CDN-M1 connected to the dedicated earth terminal or CDN-M3, shall be terminated with 50 Ω at the input port (see 7.7).

Figure 5 – Principle of coupling and decoupling according to the clamp injection method

6.2.3.2 Current clamp

This device establishes an inductive coupling to the cable connected to the EUT. For example, with a 5:1 turn ratio, the transformed common mode series impedance can be neglected with respect to the 150 Ω established by the AE. In this case, the test generator's output impedance (50 Ω) is transformed into 2 Ω. Other turn ratios may be used.

The required performance of the current clamp is such that the increase of the transmission loss of the test jig, produced by the insertion of the current clamp, shall not exceed 1,6 dB. A circuit of the transmission loss verification setup is given in Figure 7.

NOTE 1 The verification of such performance can be done in two steps. During the first step, the current clamp is omitted and the voltage is recorded. During the second step, the current clamp is inserted and terminated at its input port by a 50 Ω load, and the voltage is measured. The difference between these two measurements is not to exceed 1,6 dB as defined above.

The signal level applied to the current injection clamp is set prior to the test. The test level setting procedure is given in 6.4.1 and Figure 6.

When using a current clamp, care should be taken to prevent the harmonics generated by the power amplifier from appearing at higher levels than the fundamental signal levels at the EUT port of the coupling device.

NOTE 2 It is commonly necessary to position the cable through the centre of the clamp to minimize capacitive coupling.

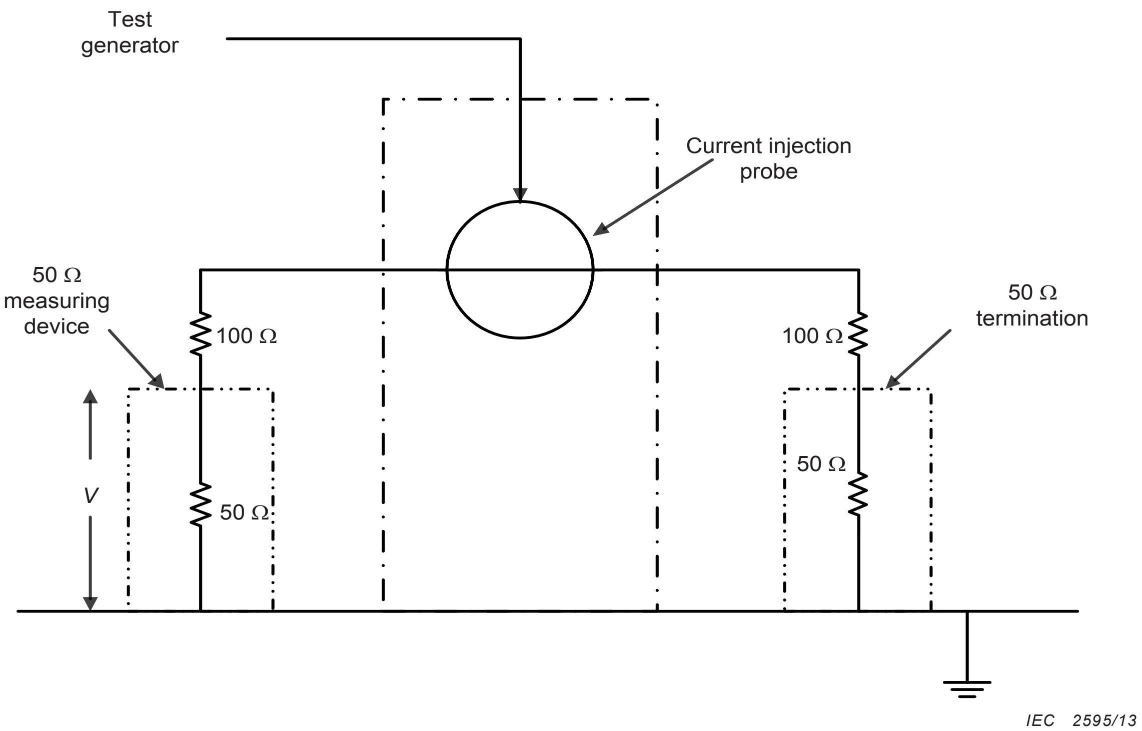


Figure 6 – Example of circuit for level setting setup in a 150 Ω test jig

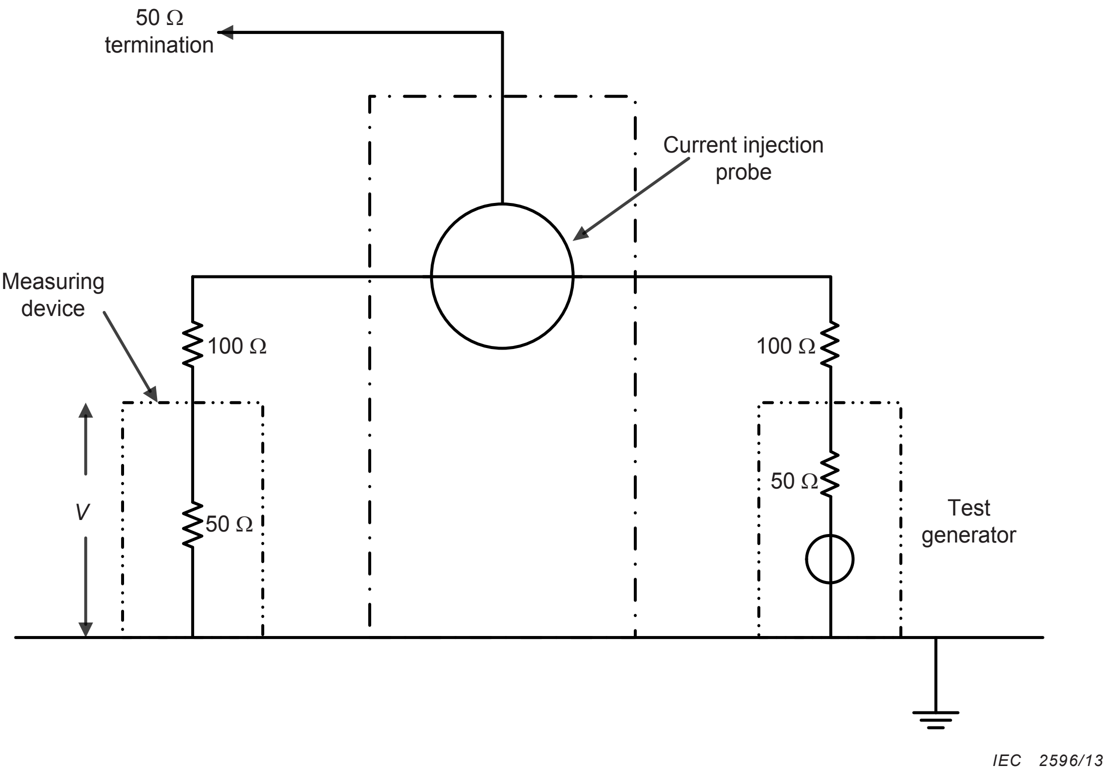


Figure 7 – Example circuit for evaluating the performance of the current clamp

6.2.3.3 EM clamp

The EM clamp establishes both capacitive and inductive coupling to the cable connected to the EUT. The construction and performance of the EM clamp are described in Annex A.

6.2.4 Direct injection devices

When using direct injection, the disturbing signal, coming from the test generator, is injected on to screened and coaxial cables via a 100 Ω resistor (even if the shield is ungrounded or grounded at one end only). In between the AE and the injection point, a decoupling device (see 6.2.5) shall be inserted as close as possible to the injection point (see Figure 4b)). To increase decoupling and to stabilize the circuit, a ground connection shall be made from the screen of the direct injection device's input port to the reference ground plane.

When making direct connection to foil screens, a proper caution should be exercised to ensure a good connection producing reliable test results.

6.2.5 Decoupling networks

Normally, the decoupling network comprises several inductors to create a high impedance over the frequency range. This is determined by the ferrite material used, and an inductance of at least 280 μH is required 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 (see Figure 4d)) 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 Annex A.

The CDNs as specified in Annex D can be used as decoupling networks with the RF input port left unloaded, unless stated otherwise elsewhere in this standard. When CDNs are used in this way, they shall meet the requirements of 6.2.5.

The decoupling networks shall be used on all cables not selected for the test, but connected to the EUT and/or AEs. For exceptions, see 7.3.

6.3 Verification of the common mode impedance at the EUT port of coupling and decoupling devices

6.3.1 General

Coupling and decoupling devices are characterized by the common mode impedance seen at the EUT port, $|Z_{ce}|$. Its correct value ensures the reproducibility of the test results. The common mode impedance of coupling and decoupling devices is calibrated using the setup shown in Figure 8.

The coupling and decoupling devices and the impedance reference plane (Figure 8a)) shall be placed on a reference ground plane. The size of the reference ground plane shall exceed the projected geometry of the setup on all sides by at least 0,2 m.

The impedance reference point shall be connected to the EUT port of the CDN as shown in Figure 8a). The magnitude of the common mode impedance seen at the connector on the impedance plane shall be measured.

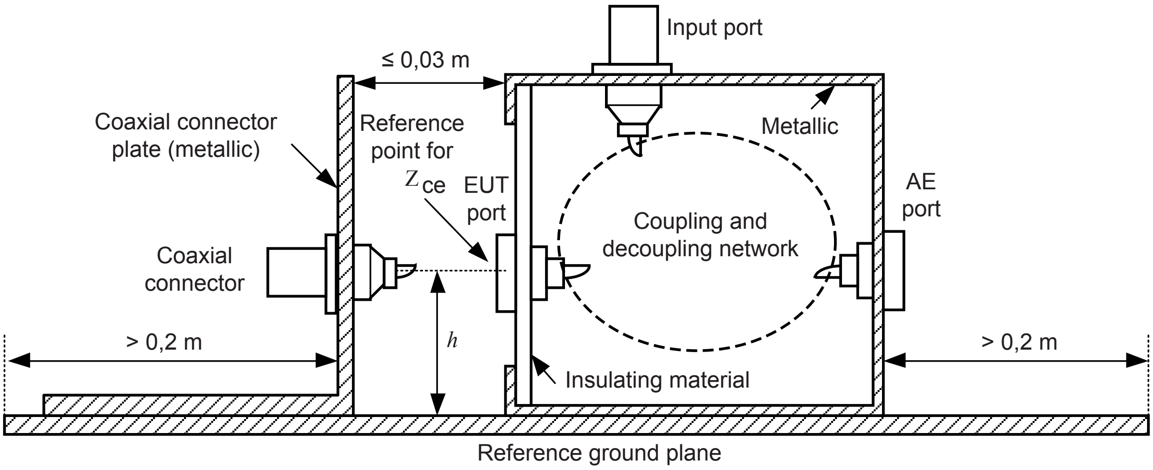
The CDNs shall meet the impedance requirements of Table 3 while the input port is terminated with a 50 Ω load and the AE port is sequentially loaded in common mode with a short-circuit and an open circuit condition as shown in Figure 8b). This requirement ensures sufficient attenuation and makes the setup of the AE, e.g. open or short-circuited inputs, insignificant.

If clamp injection or direct injection is used, it is unrealistic to verify the common mode impedance for each AE setup connected to the EUT. For clamp Injection it is generally sufficient to follow the procedure as given in 7.6. In all other cases the procedure defined in 7.7 shall be used. For direct injection it is generally sufficient to follow the procedure as given in 7.8.

6.3.2 Insertion loss of the 150 Ω to 50 Ω adapters

When the test generator is set up prior to testing, the test level shall be verified in a 150 Ω common mode impedance environment. This is achieved by connecting the appropriate common mode point to a 50 Ω measurement device via a 150 Ω to 50 Ω adapter as shown in Figure 8d). The construction of the adapter is shown in Figure 8e).

The adapters shall be placed on a reference ground plane, the size of which exceeds the projected geometry of this setup on all sides by at least 0,2 m. The insertion loss is measured according to the principle of Figure 8c). Its value shall be in the range of (9,5 ± 0,5) dB (theoretical value 9,5 dB caused by the additional series impedance when measured in a 50 Ω system). Attenuators with suitable VSWR (suggested: VSWR ≤ 1,2) at the inputs of receivers and outputs of generators are recommended.



– Reference ground plane: shall exceed the projection of the coupling and decoupling devices and other components by at least 200 mm.

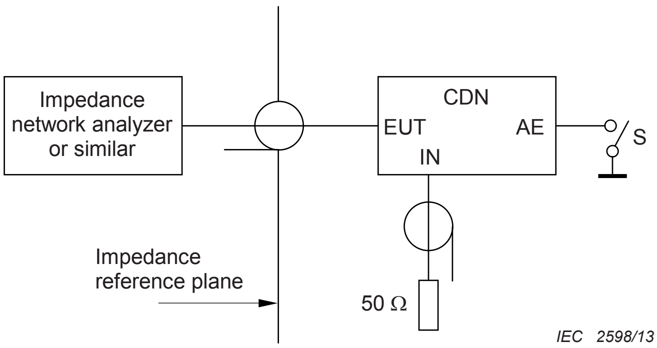
– The coaxial connector shall be connected horizontally to the EUT port.

– The height h of the EUT port depends on the individual CDN, which may vary from 30 mm to 100 mm; particular large current CDNs have an EUT port located higher above the reference ground plane.

– Connector plate (with the coaxial connector): 100 mm × 100 mm for h = 30 mm and 150 mm × 150 mm for other values of h.

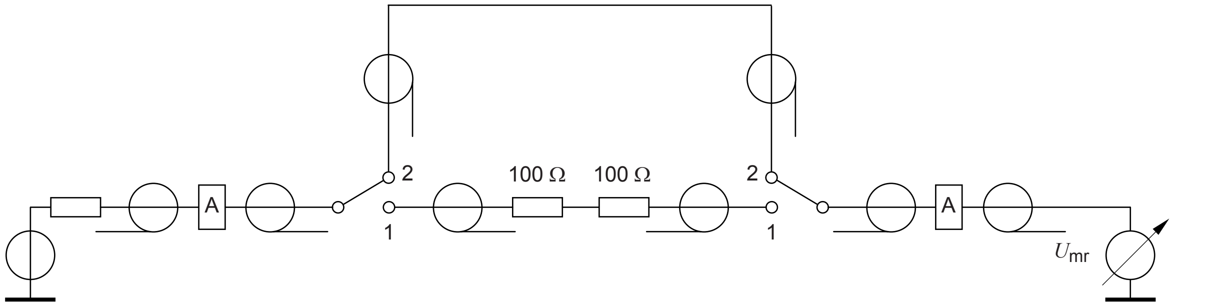
– Both connector plates shall be made out of copper, brass or aluminium and shall have a good RF contact.

a) Example of the setup geometry to verify the impedance characteristics of the coupling and decoupling devices



The impedance requirement shall be met with the open and closed switch S (see 6.3).

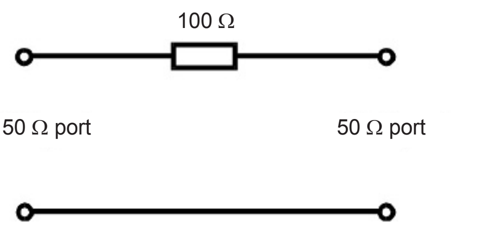
b) Setup principle to verify Z_{ce} of the coupling and decoupling device

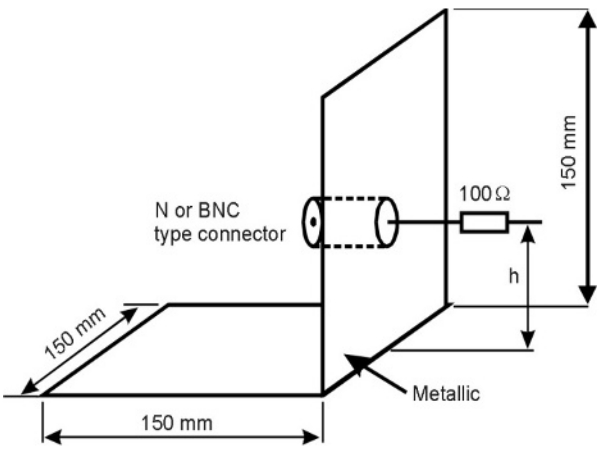


Insertion loss = U_{mr} (switches position 2) – U_{mr} (switches position 1)

dB dB(μV) dB(μV)

c) Setup principle for measuring the insertion loss of two 150 Ω to 50 Ω adapters





NOTE Low inductance resistor:
Power rating ≥ 2,5 W

d) Circuit of the 150 Ω to 50 Ω adapter

NOTE Identical to Figure 8a) (connector plate), but with 100 Ω low inductance resistor added.

e) Example: construction diagram of the 150 Ω to 50 Ω adapter (150 mm × 150 mm example)

Figure 8 – Details of setups and components to verify the essential characteristics of coupling and decoupling devices and the 150 Ω to 50 Ω adapters

6.4 Setting of the test generator

6.4.1 General

For the correct setting of the unmodulated test level the procedure in 6.4.2 shall be applied. It is assumed that the test generator, the coupling and decoupling devices and the 150 Ω to 50 Ω adapter comply with the requirements of 6.1, 6.2.1 and 6.3.1.

Two procedures can be used for the level setting:

– the output power of the test generator can be determined by measurement of the amplifier output power (forward power, as measured using a directional coupler);

– as long as the stability of the test equipment (especially the amplifier) can be guaranteed, the RF generator output can also be set by reproducing the level setting data.

6.4.2 Setting of the output level at the EUT port of the coupling device

The test generator shall be connected to the RF input port of the coupling device. The EUT port of the coupling device shall be connected in common mode through the 150 Ω to 50 Ω adapter to a measuring equipment having a 50 Ω input impedance. The AE port of the coupling device shall be loaded in common mode with a 150 Ω to 50 Ω adapter, terminated with 50 Ω. The setup is given in Figure 9c) for all coupling and decoupling devices.

NOTE 1 With direct injection, the 150 Ω load at the AE port is not required as the screen is connected to the reference ground plane at the AE port side.

NOTE 2 With clamp injection, current clamps are generally bi-directional and hence do not have an EUT port and AE port. These devices are calibrated by using a test jig as shown in Figure 6.

Warning: During the setting of the test generator, all connections to the EUT and AE ports of the coupling and decoupling devices other than those required (see Figure 9), shall be disconnected either to avoid short-circuit conditions or to avoid destruction of the measurement equipment.

Using the above mentioned setup and the following measurement procedure, the test generator shall be adjusted to yield the following reading on the measuring equipment.

Procedure to be followed for each coupling device:

a) apply a forward power (without modulation) to the coupling device so that the voltage obtained equals U_{mr} at the output port of the 150 Ω to 50 Ω adapter;

   record the level of the RF generator P_{gen}, and/or the forward power at the output of the power amplifier P_{for} and the voltage U_{mr} at the output port of the 150 Ω to 50 Ω adapter;

b) increase the frequency by a maximum of 1 % of the present frequency;

c) repeat steps a) and b) until the next frequency in the sequence would exceed the highest frequency (for example 80 MHz) in the range of the test;

d) using the recorded level of the RF generator P_{gen}, forward power P_{for} and voltage U_{mr} obtained in a), calculate the forward power and/or RF generator power necessary to create the required voltage at the EUT port of the coupling device;

e) to ensure that the amplifier is not saturated the test generator shall be adjusted to produce the desired test level U_{mr} using the data obtained from step d). The steps 1) to 4) need only be done for the highest test level to be used:

   1) increase the level of the RF generator by 5,1 dB;
   2) record the new output power delivered to the coupling device $P_{\text{for,inc}}$ or the voltage at the output port of the 150 Ω to 50 Ω adapter $U_{\text{mr,inc}}$;
   3) calculate the difference $P_{\text{for,inc}}$-P_{for} or $U_{\text{mr,inc}}$-U_{mr} (log. scale);
   4) if the difference is between 3,1 dB and 7,1 dB then the amplifier is in tolerance and the test system is sufficient for testing at the selected test level. If the difference is less than 3,1 dB or more than 7,1 dB then the amplifier is non linear and is not suitable for testing.

Annex J provides information on test generator compression and amplifier non linearity.

In the setting process step a) the voltage U_{mr} shall be:

$$U_{\text{mr}} = U_0/6 \begin{pmatrix} +19\% \\ -16\% \end{pmatrix}, \text{ in linear quantities, or}$$

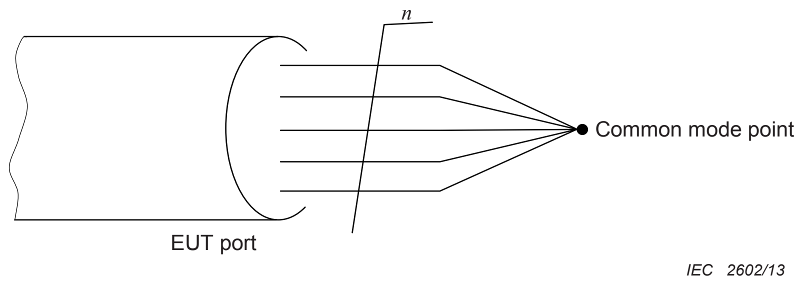
$$U_{\text{mr}} = U_0 - 15{,}6 \text{ dB} \pm 1{,}5 \text{ dB}, \text{ in logarithmic quantities.}$$

NOTE 3 U_0 is the test voltage specified in Table 1 and U_{mr} is the measured voltage as defined in 3.12 and Figure 9. To minimize testing errors, the output level of the test generator is set by setting U_{mr} with 150 Ω loads (for instance with the 150 Ω to 50 Ω adapter and 50 Ω termination) and not by setting U_0.

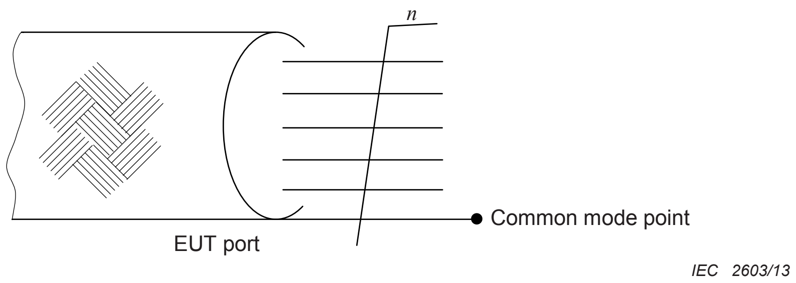
NOTE 4 The factor 6 (15,6 dB) arises from the e.m.f. value specified for the test level. The matched load level is half the e.m.f. level and the further 3:1 voltage division is caused by the 150 Ω to 50 Ω adapter terminated by the 50 Ω measuring equipment.

NOTE 5 In case of test instrumentation without amplifier output power control, the procedure is repeated for each coupling device and each target test level. For test systems with amplifier output power control or by following the procedure for amplifier linearity given in Annex K, the procedure of 6.4.2 is done for each coupling device at the highest target test level only.

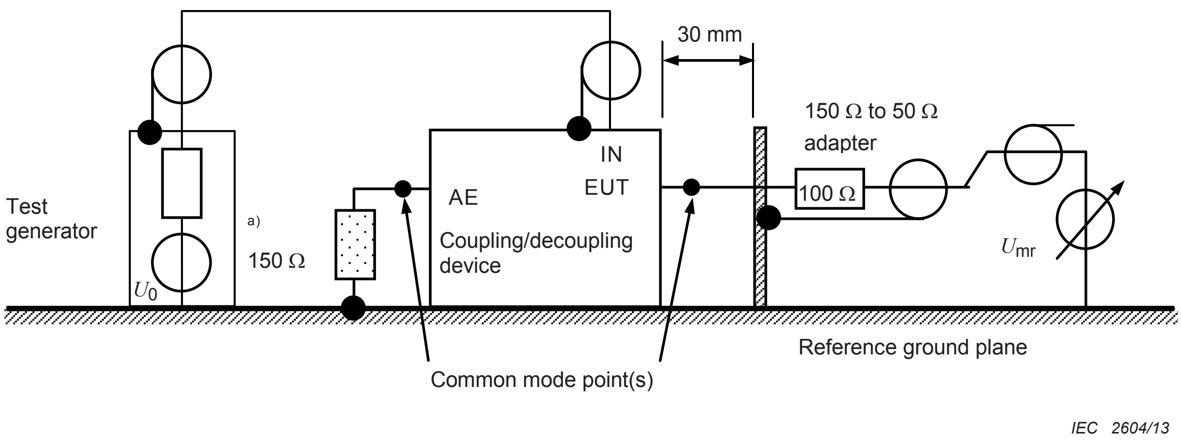
The control parameters of the test generator setting (software parameters, attenuator setting, etc.) shall be recorded and used for testing.



a) Definition of a common mode point with unscreened cables



b) Definition of a common mode point with screened cables



Examples of coupling and decoupling devices:

– CDNs;
– direct injection network (with decoupling);
– clamp injection device (EM clamp).

[a] The 150 Ω loading, e.g. a 150 Ω to 50 Ω adapter terminated with a 50 Ω load at the AE port shall only be applied to unscreened cables (screened cables have their screens connected to the reference ground plane at the AE side).

c) Setup for level setting at the EUT port of coupling/decoupling devices

Figure 9 – Setup for level setting

7 Test setup and injection methods

7.1 Test setup

The equipment to be tested is placed on an insulating support of 0,1 m ± 0,05 m height above a reference ground plane. A non conductive roller/caster in the range of 0,1 m ± 0,05 m above the reference ground plane can be used as an alternative to an 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. Grounding of the equipment shall be consistent with the manufacturer's installation instructions.

Where coupling and/or decoupling devices are required, they shall be located between 0,1 m and 0,3 m from the EUT (this distance is denoted L in this standard). This distance is to be measured horizontally from the projection of the EUT on to the reference ground plane to the coupling and/or decoupling device. See Figures 5, 10 and 11. Subclauses 7.2 to 7.8 provide more detailed information.

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

7.2 EUT comprising a single unit

The EUT shall be placed on an insulating support 0,1 m above the reference ground plane. For table-top equipment, the reference ground plane may be placed on a table (see Figure 10).

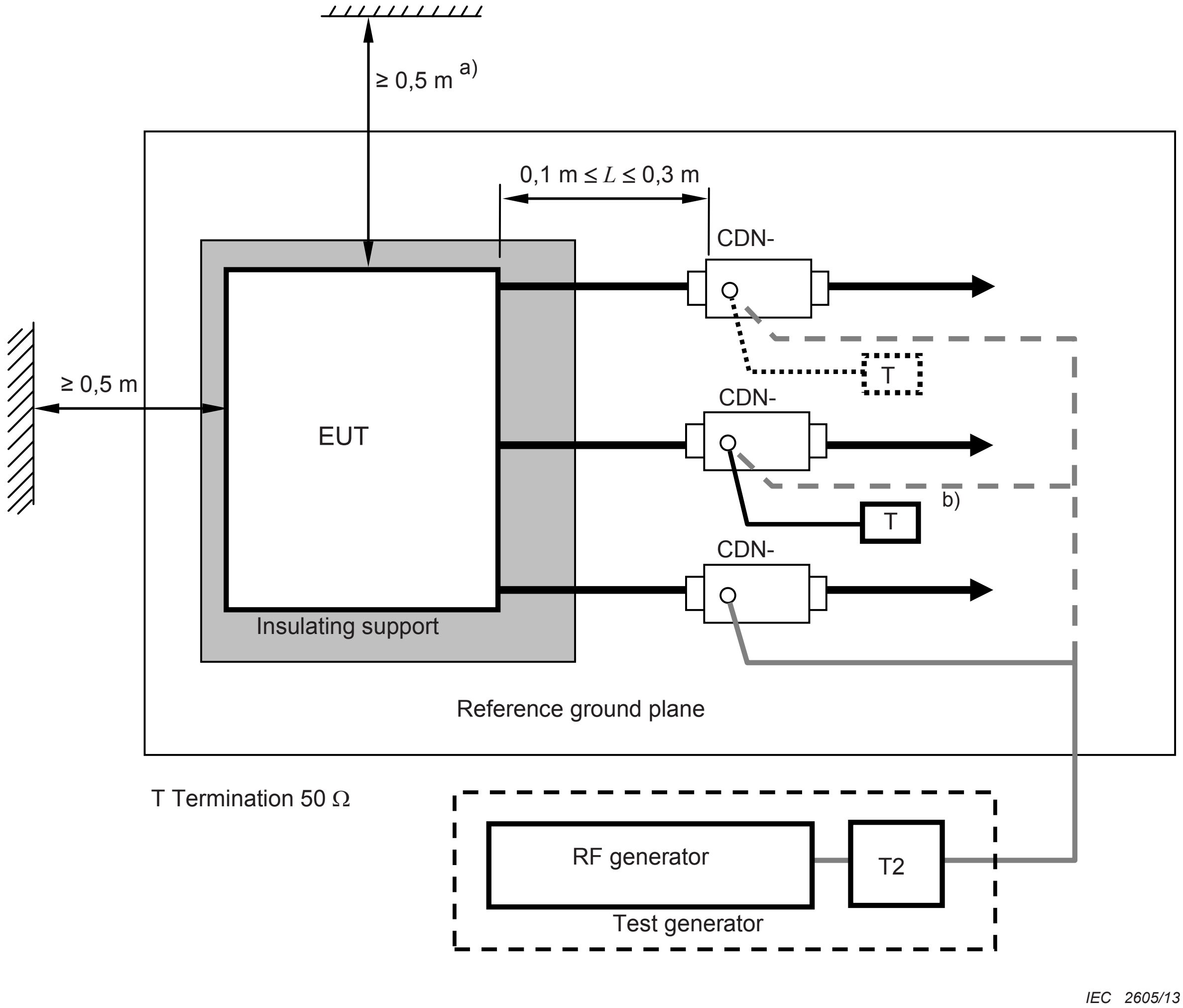
On all cables to be tested, coupling and decoupling devices shall be inserted (see 7.4.3). The coupling and decoupling devices shall be placed on the reference ground plane, making direct contact with it at a distance of 0,1 m to 0,3 m from the EUT. The cables between the coupling and decoupling devices and the EUT shall be as short as possible and shall not be bundled or wrapped. Their height above the reference ground plane shall be at least 30 mm.

The interface cable between the EUT and the AE should be the shortest available.

If the EUT is provided with other earth terminals, when allowed, they shall be connected to the reference ground plane through CDN-M1, see 6.2.2.2 (i.e. the AE port of the CDN-M1 is then connected to the reference ground plane).

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.

AE required for the defined operation of the EUT according to the specifications of the product committee, e.g. communication equipment, modem, printer, sensor, etc., as well as AE necessary for ensuring any data transfer and assessment of the functions, shall be connected to the EUT through coupling and/or decoupling devices. As far as possible, the number of cables to be tested may be limited; however, all types of physical ports should be submitted to injection.



a) The EUT clearance from any metallic objects other than test equipment shall be at least 0,5 m.

b) Only one of the CDNs not used for injection shall be terminated with 50 Ω, providing only a return path. All other CDNs shall be configured as decoupling networks.

Figure 10 – Example of test setup with a single unit EUT (top view)

7.3 EUT comprising several units

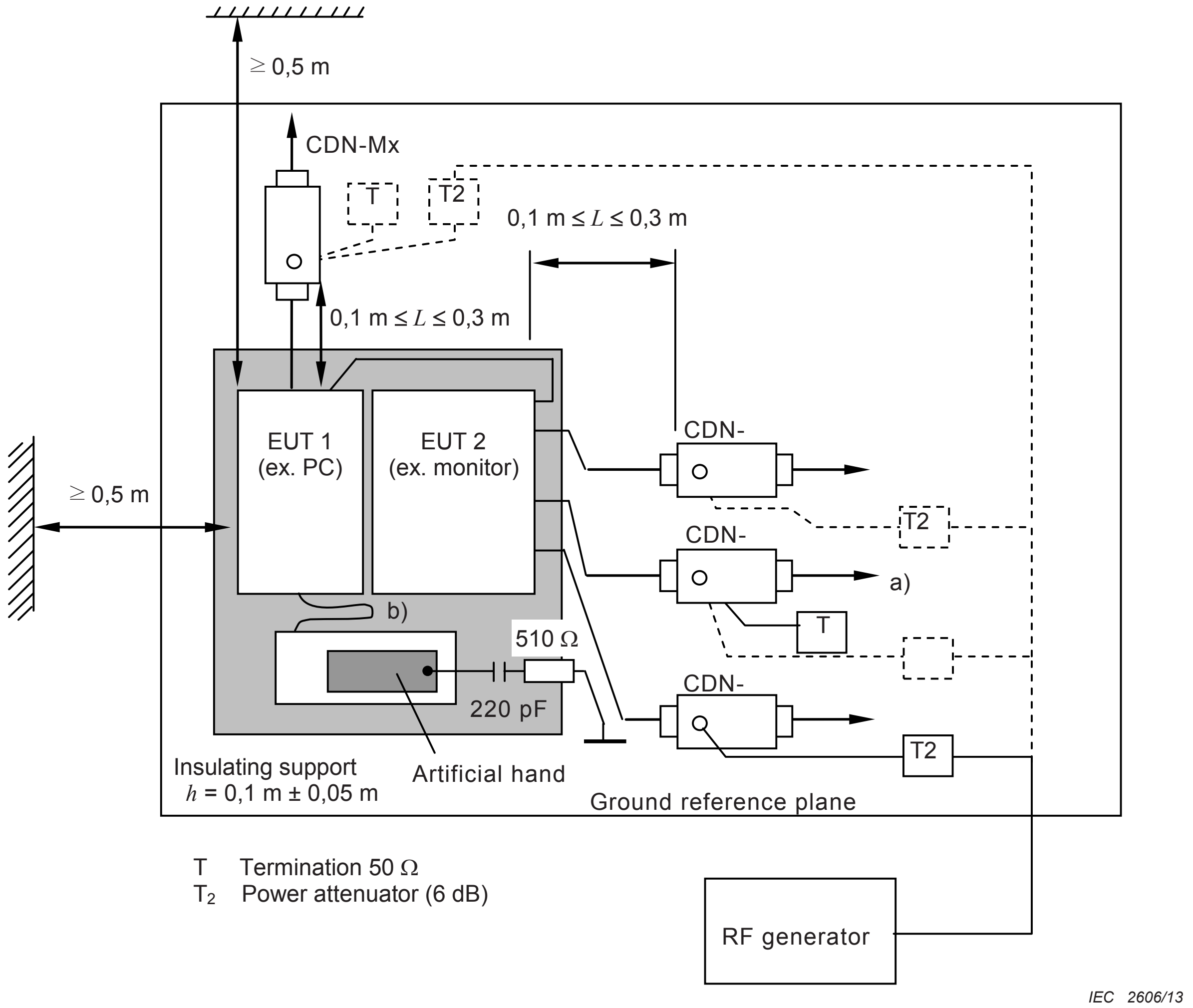
Equipment comprising several units, which are interconnected, shall be tested using one of the following methods.

– **Preferred method**: Each sub-unit shall be treated and tested separately as an EUT (see 7.2), considering all others as AE. Coupling and decoupling devices (or CDNs) shall be placed on the cables (according to 7.4.1) of the sub-units considered as the EUT. All sub-units shall be tested in turn.

– **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 one EUT. No conducted immunity test shall be performed on their interconnecting cables, these cables being regarded as internal cables of the system. See Figure 11.

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. All other cables shall be tested according to the rules of 7.4 to 7.8.

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



a) 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.

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

Figure 11 – Example of a test setup with a multi-unit EUT (top view)

7.4 Rules for selecting injection methods and test points

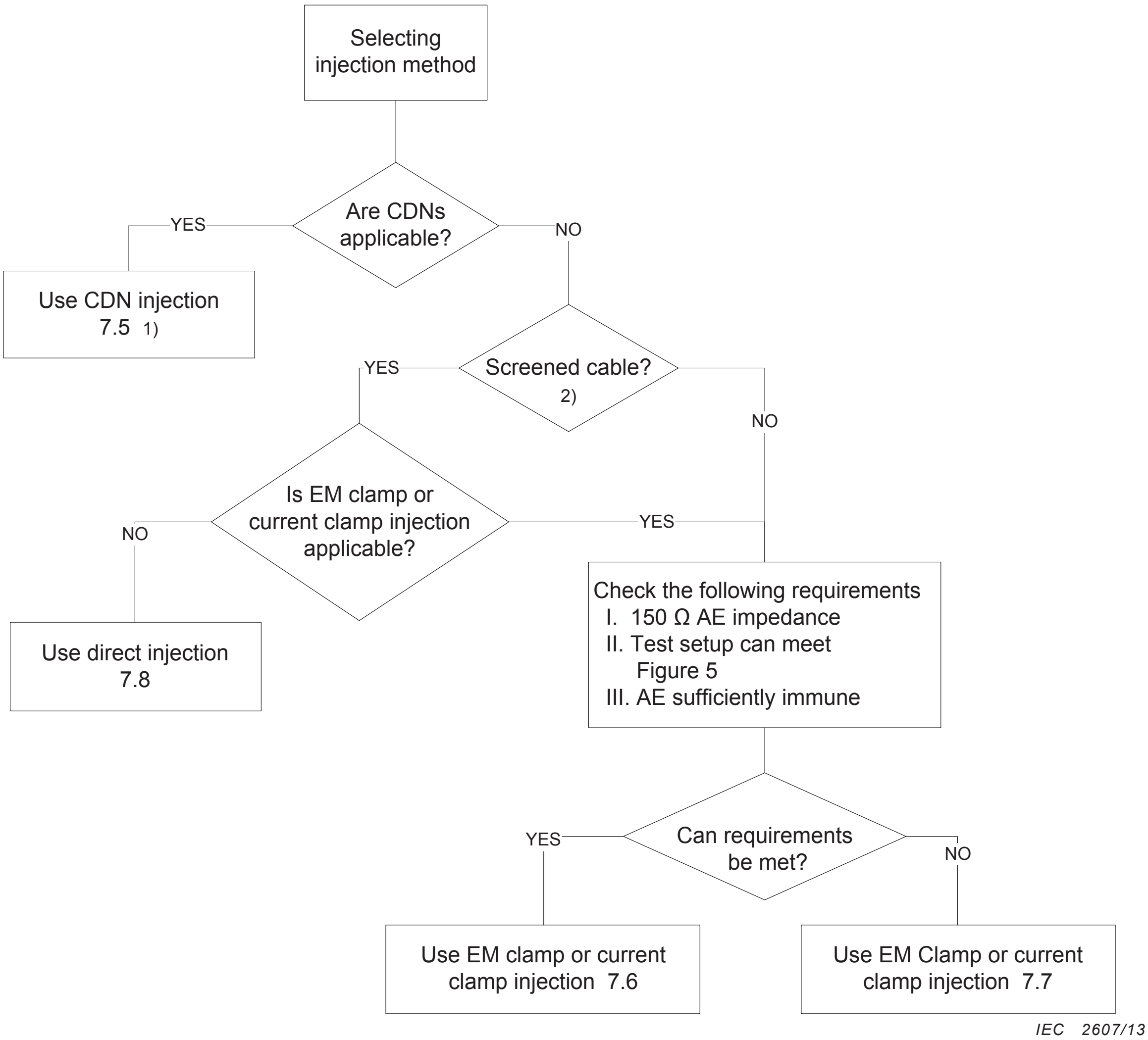
7.4.1 General

To select the type and number of cables to be provided with coupling and decoupling devices, the physical configuration of typical installation conditions shall be considered, e.g. the likely length of the longest cables.

For all tests, the total cable length between the EUT and AE (including the internal cabling of any CDN being used) shall not exceed the maximum length specified by the manufacturer of the EUT.

7.4.2 Injection method

Figure 12 gives rules for selecting the injection method.



1) See Table 4.

2) See 6.2.4.

Figure 12 – Rules for selecting the injection method

Where not specified herein, the EUT including selected cables for testing shall be configured, installed, arranged and operated in a manner consistent with typical applications. CDNs not listed in this standard, but meeting the requirements of this standard, may also be used.

When several cables coming from the EUT are in close proximity over a length of more than 10 m or are routed from the EUT to other equipment in a cable tray or conduit, they should be treated as one cable.

If a product committee decides that a certain kind of coupling and decoupling device is more appropriate for cables connected to a particular family of products, then that choice (justified on a technical basis) takes precedence. These devices shall be described in the product standard. Examples of CDNs are described in Annex D.

7.4.3 Ports to be tested

In any one test, only two 150 Ω networks are required. The network used for injection of the test signal can be moved between different ports as they are tested. When a CDN is removed from a port, it may be replaced by a decoupling network.

If the EUT has multiple identical ports (same input or output electronic circuits, loads, connected equipment, etc.), at least one of these ports shall be selected for testing to ensure that all different types of ports are covered.

7.5 CDN injection application

When using the CDN injection, the following measures need to be taken.

a) If the AE is directly connected to the EUT (e.g. no decoupling on the connection between them as shown in Figure 13a)) then it is to be placed on an insulating support 0,1 m ± 0,05 m above the reference ground plane and grounded via a terminated CDN.

   If the EUT has multiple AEs directly connected to it, only one AE shall be terminated in this manner. Other directly connected AEs shall have all other connections decoupled. This ensures that there is only one loop terminated with 150 Ω at each end.

b) 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.

c) One CDN shall be connected to the port intended to be tested and one CDN with 50 Ω termination shall be connected to another port. Decoupling networks shall be installed on all other ports to which cables are attached. In this manner there is only one loop terminated with 150 Ω at each end.

d) The CDN to be terminated shall be chosen according to the following priority:

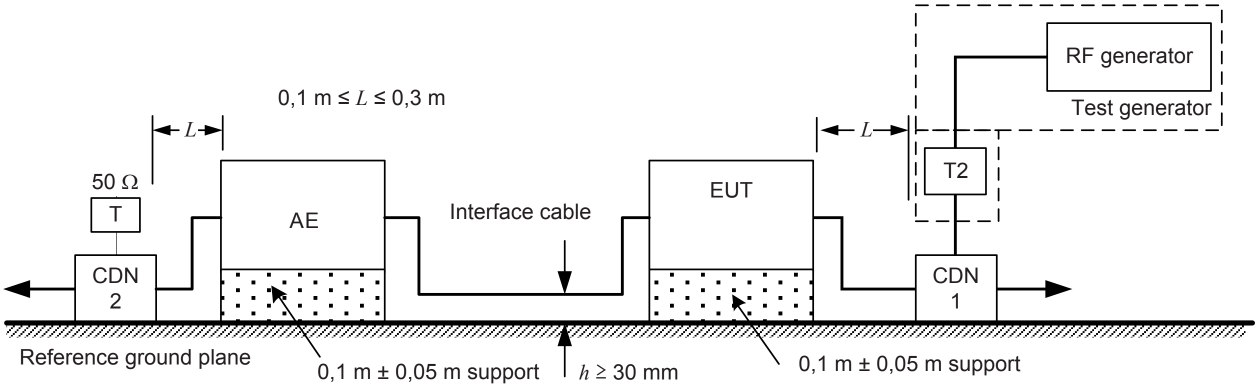
   1) CDN-M1 used for connection of the earth terminal;
   2) CDN-M3, CDN-M4, or CDN-M5 used for mains (class I equipment);
   3) CDN-Sn (n = 1,2,3…): if the EUT has several CDN-Sn ports, the port which is closest to the port selected for injection (shortest geometrical distance) shall be used;
   4) CDN-M2 used for mains (class II equipment);
   5) Other CDN connected to the port which is the closest to the port selected for injection (shortest geometrical distance).

   NOTE Annex I gives guidance for an alternative CDN injection process for specific products.

e) If the EUT has only one port, that port is connected to the CDN used for injection.

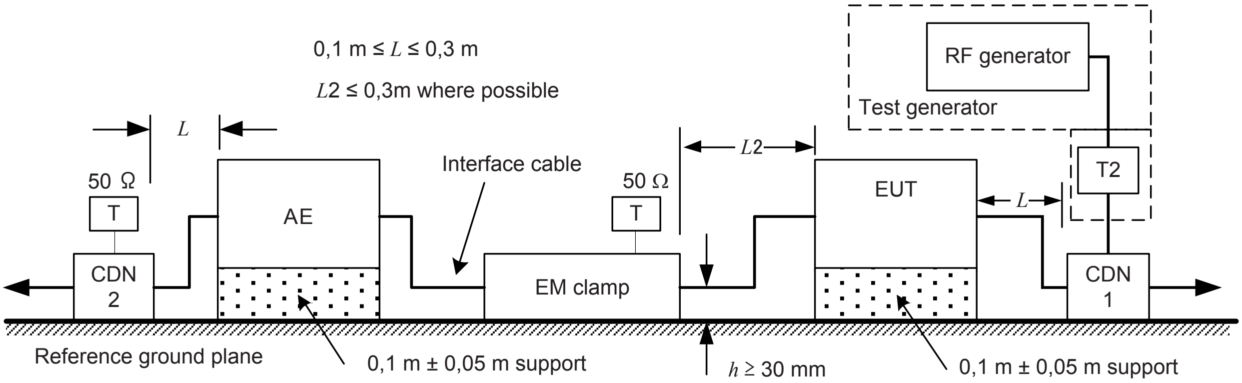
f) If the EUT has two ports and only one CDN can be connected to the EUT, the other port shall be connected to an AE that has one of its other ports connected to a CDN terminated with 50 Ω in accordance with the above mentioned priority. All other connections of the AE shall be decoupled (see Figure 13a)). 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 (see Figure 13b)).

g) If the EUT has more than two ports and only one CDN 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 is set at 1 m if possible.

a) Schematic setup for a 2-port EUT connected to only 1 CDN



b) Example: schematic setup when AE shows errors during the test

T: Termination 50 Ω

T2: Power attenuator (6 dB)

CDN: Coupling and decoupling network

Figure 13 – Immunity test to 2-port EUT (when only one CDN can be used)

7.6 Clamp injection application when the common mode impedance requirements can be met

When using clamp injection, the AE setup shall present the common mode impedance as required in 6.2.1 as closely as possible (see Annex H). Each AE used with clamp injection shall represent the functional installation conditions as closely as possible. To approximate the required common mode impedance the following measures need to be taken.

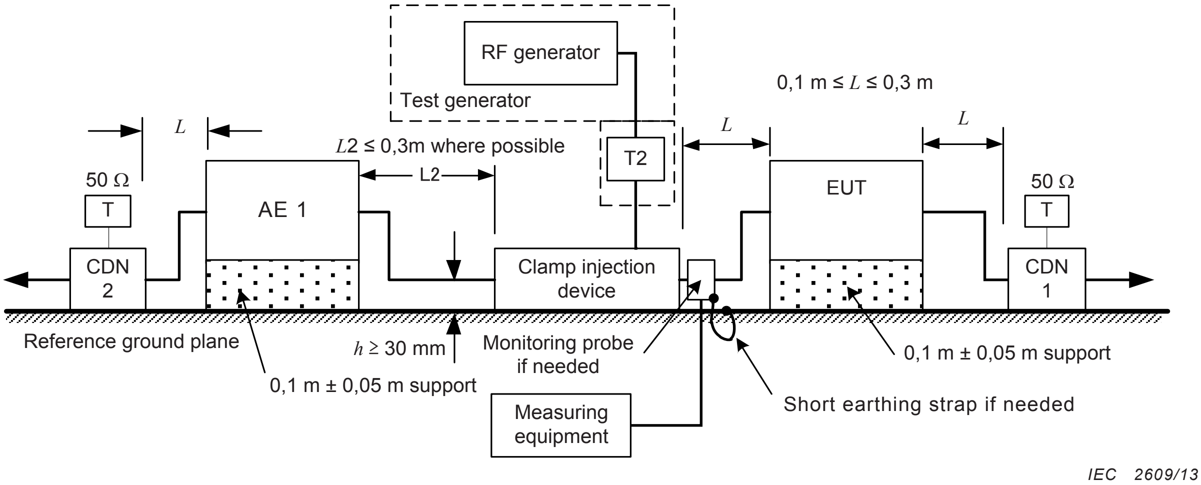
- Each AE, used with clamp injection, shall be placed on an insulating support 0,1 m above the reference ground plane.
- The clamp shall be placed on the cable to be tested. The clamp shall be supplied with the test generator level previously established during the level setting procedure.
- During a test, a ground connection shall be made from the screen of the input port of the current injection clamp or from the earth bar of the EM clamp, to the reference ground plane (see Figures 14 and 15).
- A decoupling network shall be installed on each cable between the EUT and AE except the cable under test.
- All cables connected to each AE, other than those being connected to the EUT, shall be provided with decoupling networks, see 6.2.5 and Figure 5.

– The decoupling networks connected to each AE (except those on cables between the EUT and AE) shall be applied no further than 0,3 m from the AE (distance: $L2$). The cable(s) between the AE and the decoupling network(s) or in between the AE and the injection clamp shall not be bundled nor wrapped and shall be kept at a height of 30 mm or more above the reference ground plane (Figure 5).

– At one end of the cable under test is the EUT, and at the opposite end is the AE. Multiple CDNs can be connected to the EUT and to the AE; however, only one CDN on each of the EUT and AE shall be terminated in 50 Ω. The termination of the CDN shall be chosen according to the priority in 7.5.

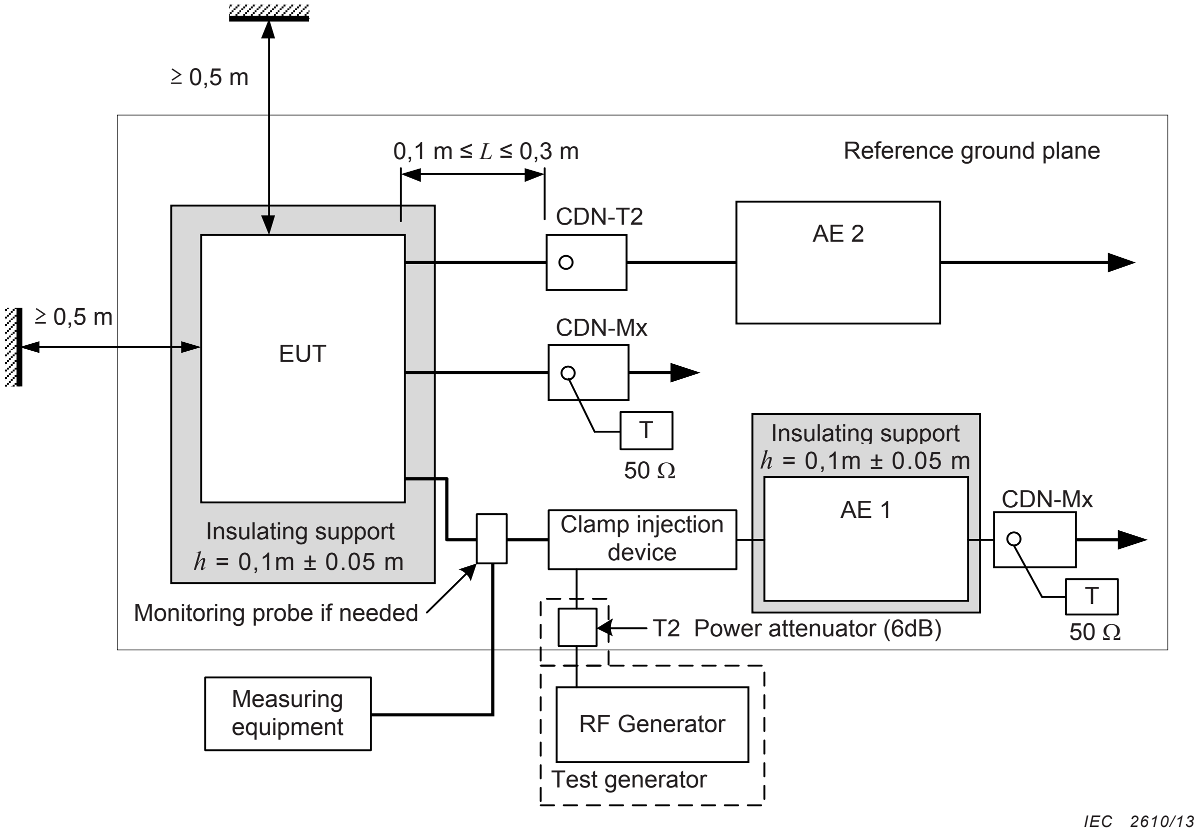
– When several clamps are used, the injection is carried out on each cable selected for testing one by one. The cables which are selected for testing with the injection clamp but not actually exercised shall be decoupled in accordance with 6.2.5.

In all other cases the procedure given in 7.7 should be followed.



NOTE Regarding the use of monitoring probes, see 7.7.

Figure 14 – General principle of a test setup using clamp injection devices



NOTE Regarding the use of monitoring probes, see 7.7.

Figure 15 – Example of the test unit locations on the ground plane when using injection clamps (top view)

7.7 Clamp injection application when the common mode impedance requirements cannot be met

When using clamp injection, and the common mode impedance requirements cannot be met at the AE side, it is necessary that the common mode impedance of the AE be less than or equal to the common mode impedance of the EUT port being tested. If not, measures shall be taken (e.g. by using a CDN-M1 or 150 Ω resistor from the AE to ground) at the AE port to satisfy this condition and to prevent resonances. In this procedure, only the relevant differences with those measures mentioned in 7.6 are given.

– Each AE and EUT used with clamp injection shall represent the functional installation conditions as closely as possible, e.g. the EUT shall either be connected to the reference ground plane or placed on an insulating support (see Figures 14 and 15).
– By means of a current monitoring probe (having low insertion loss), inserted in between the injection clamp and the EUT, the current resulting from the induced voltage (set according to 6.4.1) shall be monitored. If the current exceeds the nominal circuit value I_{max} given below, the test generator level shall be reduced until the measured current is equal to the I_{max} value:

$$I_{max} = U_0/150\ \Omega$$

The modified test voltage level applied shall be recorded in the test report.

To ensure reproducibility, the test setup shall be fully described in the test report.

7.8 Direct injection application

When using direct injection to screened cables, the following measures need to be taken.

– The EUT shall be placed on an insulating support of 0,1 m height above the reference ground plane.
– On the cable being tested, a decoupling network shall be located between the injection point and the AE, as close as possible to the injection point. A second port shall be loaded with 150 Ω (CDN with 50 Ω termination). This port shall be chosen according to the priority in 7.5. On all other cables attached to the EUT decoupling networks shall be installed. (When left open, a CDN is considered a decoupling network.)
– The injection point shall be located between 0,1 m and 0,3 m from the geometric projection of the EUT on to the reference ground plane.
– The test signal shall be injected directly on to the shield of the cable through a 100 Ω resistor (see 6.2.4).

When making direct connection to foil screens, a proper caution should be exercised to ensure a good connection producing reliable test results.

8 Test procedure

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

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

NOTE 1 Generally, this test can be performed without using a shielded enclosure. This is because the disturbance levels applied and the geometry of the setups are not likely to radiate a high amount of energy, especially at the lower frequencies.

The test shall be performed with the test generator connected to each of the coupling devices (CDN, EM clamp, current clamp) in turn. All other cables not under test shall either be disconnected (when functionally allowed) or provided with decoupling networks or unterminated CDNs only.

A low-pass filter (LPF) and/or a high-pass filter (HPF), (e. g. 100 kHz cut-off frequency) 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 inserted after the test generator before setting the test level (see 6.1 and 6.4.1).

The frequency range is swept from 150 kHz to 80 MHz, using the signal levels established during the setting process, and with the disturbance signal 80 % amplitude modulated with a 1 kHz sine wave, pausing to adjust the RF signal level or to change coupling devices as necessary. Where the frequency is swept incrementally, the step size shall not exceed 1 % of the preceding frequency value. The dwell time of the amplitude modulated carrier at each frequency shall not be less than the time necessary for the EUT to be exercised and to respond, but shall in no case be less than 0,5 s. The sensitive frequencies (e.g. clock frequencies or frequencies identified by the manufacturer or obtained as outcome of the test) shall be analyzed in addition to the stepped frequencies.

NOTE 2 Since the EUT can be disturbed by transients occurring during frequency stepping, provisions need to be made to avoid such disturbance. For example, before the frequency change, the strength of the signal can be decreased a few dB below the test level.

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

The use of a special exercising program is recommended.

Testing shall be performed according to a test plan.

It may be necessary to carry out some investigatory testing in order to establish some aspects of the test plan.

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 EUT, 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 EUT 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, e.g. brand name, product type, serial number;
– the size of the EUT;
– 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, e.g. 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 sweep frequency, dwell time and frequency steps;
– 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
(normative)

EM and decoupling clamps

A.1 EM clamps

A.1.1 General

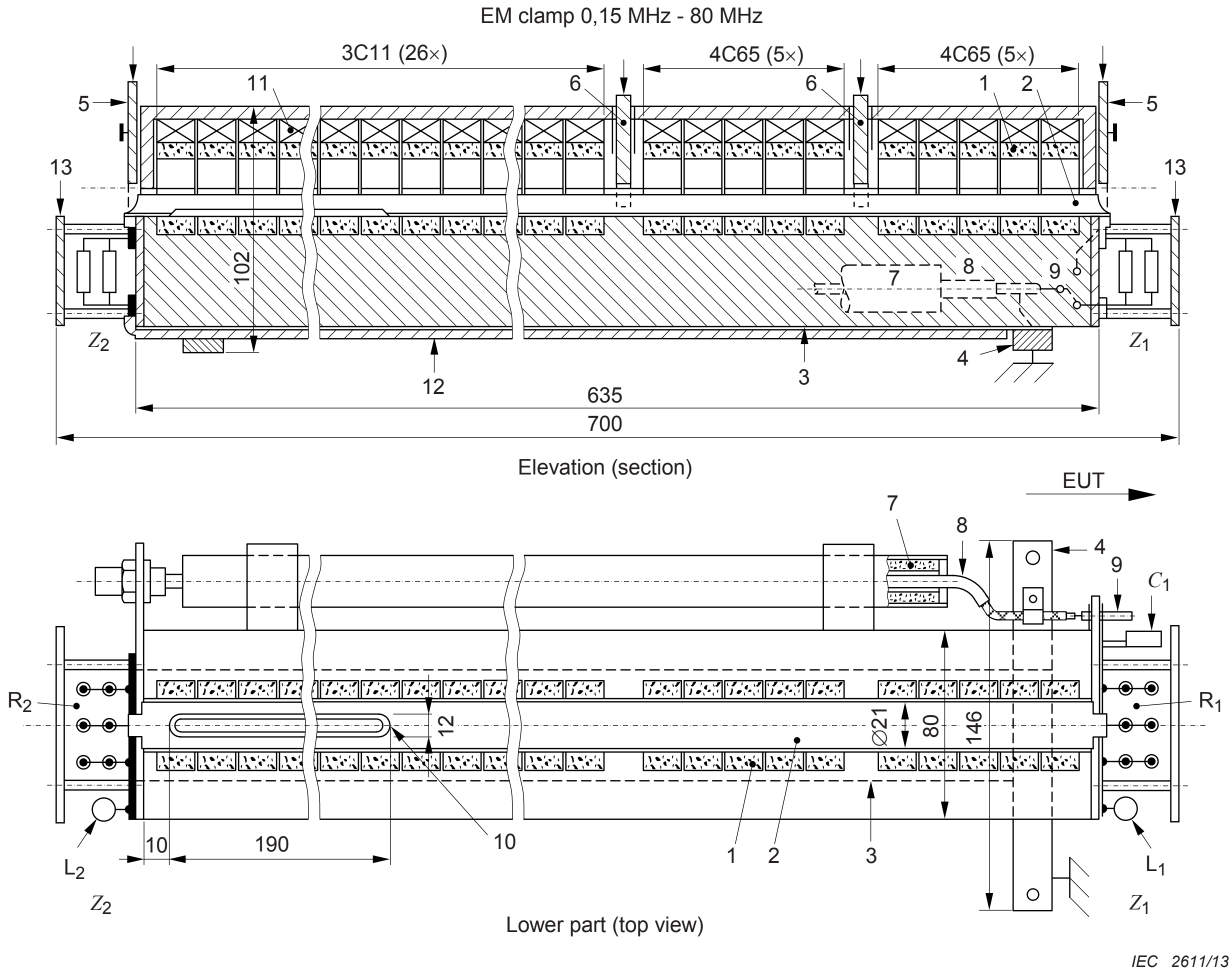
Annex A deals with the requirements of EM clamps. The EM clamp (in contrast to the conventional current injection clamp) has directivity above several tens of MHz.

A.1.2 Typical specification of EM clamps

EM clamps are used for injection into cables. The requirements are:

– operating frequency range: 0,15 MHz to 80 MHz;
– length: 650 mm ± 50 mm;
– height of clamp opening center above ground plane: 50 mm to 70 mm;
– clamp opening diameter: 20 mm ± 2 mm;
– clamp reference point (distance from outer dimension to first core): < 30 mm;
– the construction and concept of the EM clamp are given in Figures A.1 and A.2;
– typical characteristics of impedance can be found in Figure A.7;
– typical characteristics of decoupling factor can be found in Figure A.8;
– typical characteristics of coupling factor can be found in Figure A.11.

NOTE Other physical dimensions of the clamp can be used (e.g. to test larger diameter cables) providing the clamp itself meets the requirements defined in A.2.



Dimensions in millimetres

Components

1 Ferrite ring cores ∅ 36 mm × ∅ 23 mm × 15 mm
10 rings, type 4C65, NiZn, $\mu \approx 100$
26 rings, type 3C11, MnZn, $\mu \approx 4\,300$

2 Semi-cylinder of copper foil glued to the groove

3 Lower conductor plate

4 Earth bar

5/6 Devices for pressing the cable under test into the groove
Parts from insulating material with pressure springs (not shown)

7 Ferrite tube, 4C65

8 Coaxial cable, 50 Ω with BNC connector

9 Switch for the disconnection of Z_1

10 Slot for part no. 2

11 Elastic fixing of ferrite (upper semi-ring)

12 Lower insulating plate

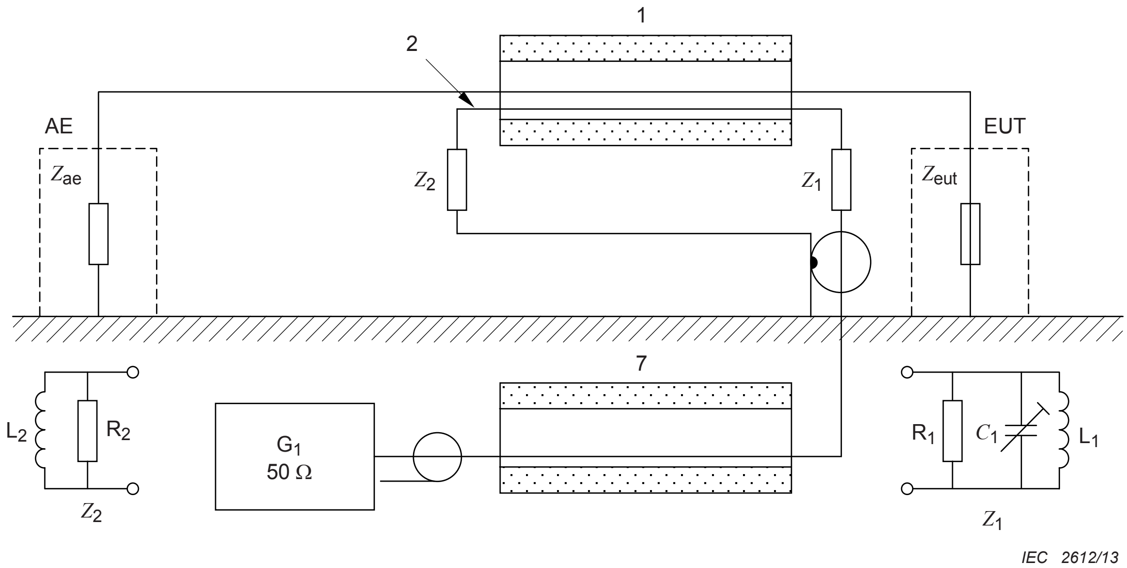
13 Protection plate for Z_1, Z_2

EUT Equipment under test

Z_1 Series impedance: C_1: 20 pF – 100 pF, L_1: 0,15 µH, R_1: 50 Ω / 12 W

Z_2 Series impedance: L_2: 0,8 µH, R_2: 50 Ω / 12 W

Figure A.1 – Example: Construction details of the EM clamp



Components

1	Ferrite tube (clamp) length 0,6 m, ∅ 20 mm, consisting of 10 rings, 4C65 (μ ≈ 100) at the EUT side and 26 rings 3C11 (μ ≈ 4 300) at the AE side
2	Semi cylinder of copper foil
7	Ferrite tube (μ ≈ 100) included in the EM clamp construction
Z_1, Z_2	Built-in to optimize the frequency response and directivity
G_1	Test generator

Principle of the EM clamp:

– magnetic coupling by the ferrite tube (item 1);

– electric coupling by close proximity between EUT cable and copper foil (item 2).

Figure A.2 – Example: Concept of the EM clamp

A.2 EM clamp characterization

A.2.1 Specification of the clamp test jig

A test jig used for measuring the S-parameters of clamps shall have a cylindrical metal rod above a metal plate (reference ground plane) as shown in Figures A.4 and A.5. The test jig consists of three sections: one section forming a transmission line in the jig between the two reference planes and two reference planes with lossless 50 Ω adapters, see Figures A.3 to A.5. For the characterization of the EM clamp, a single metal rod is used. The length of the metal rod ($L_A + L_B + L_{reference}$) is set to allow the dimensions of Figure A.5 to be satisfied.

The diameter d of the cylindrical rod shall be 4 mm. The height h above the ground plane is defined by the dimensions of the clamp. Typical values are 50 mm up to 70 mm. The measurement shall be performed at the height defined by the construction of the clamp using the centre position of the clamp opening.

The distance between the clamp reference point (1st core) and the vertical flange of the jig L_A and L_B shall be 30 mm ± 5 mm (see Figure A.5). The size of the reference ground plane shall exceed the projected geometry of the setup on all sides by at least 0,2 m.

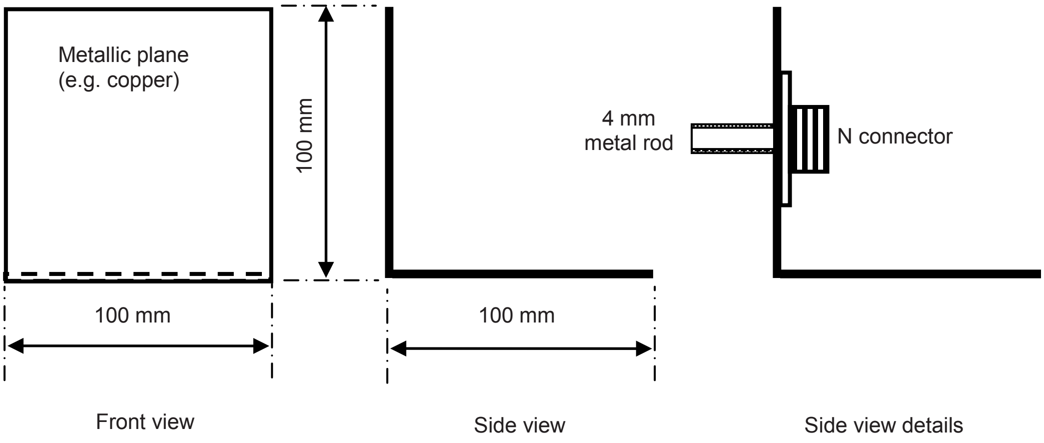


Figure A.3 – Dimension of a reference plane

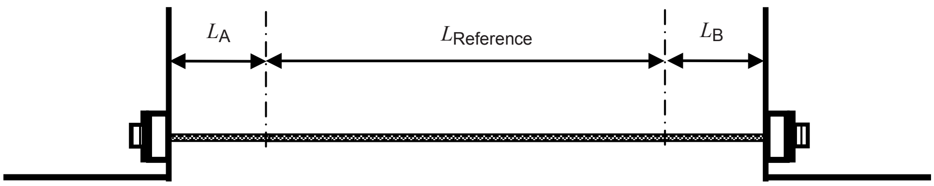


Figure A.4 – Test jig

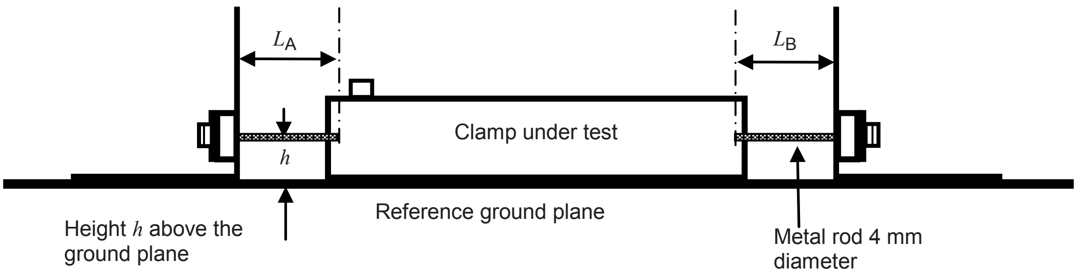


Figure A.5 – Test jig with inserted clamp

A.2.2 Clamp characterization

A.2.2.1 Impedance

A.2.2.1.1 Measurement setup

The test jig as defined in A.2.1 shall be used for the impedance measurement. The clamp (i.e. injection port) shall be terminated with a 50 Ω load and placed into the test jig, see Figure A.6. For impedance measurement the EM clamp is treated as a 2-port device which can be characterized by its S-parameters S_{11}, S_{12}, S_{21} and S_{22} measured in a 50 Ω system using a network analyzer. Prior to the measurement the network analyzer shall be normalized at the cable ends (to be connected to the jig) using a standard Through-Open-Short-Matched (TOSM) method with an appropriate calibration kit. The length between the cable end and the clamp reference point shall be respected by a port offset of the vector network analyzer (VNA) or by other means.

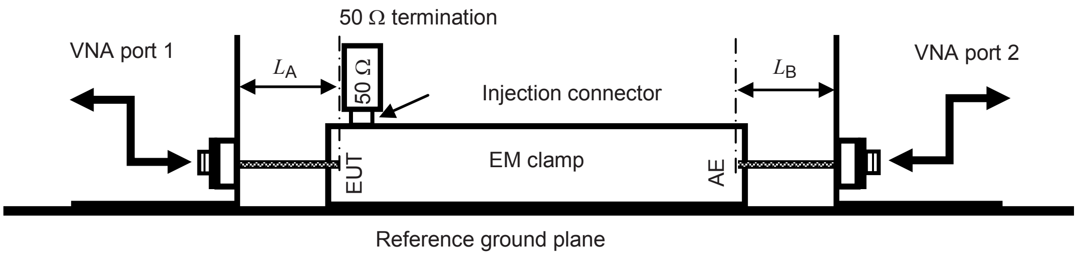


Figure A.6 – Impedance / decoupling factor measurement setup

A.2.2.1.2 Transformation

The S-parameters obtained from the network analyzer measurement as described in A.2.2.1.1 are measured in a 50 Ω system. However, the characteristic impedance Z'_{ref} of the test jig is typically different from 50 Ω. It is determined by the height of the clamp opening above the ground plane. Using ABCD transformation, a set of transformed parameters independent from Z_{ref} can be obtained using the following equations:

NOTE All calculations are performed with complex numbers.

$$Z_{\text{ref}} = 50\ \Omega \tag{A.1}$$

$$A = \frac{(1+S_{11})(1-S_{22})+S_{12}S_{21}}{2S_{21}} \tag{A.2}$$

$$B = \frac{(1+S_{11})(1+S_{22})-S_{12}S_{21}}{2S_{21}} Z_{\text{ref}} \tag{A.3}$$

$$C = \frac{(1-S_{11})(1-S_{22})-S_{12}S_{21}}{2S_{21}} / Z_{\text{ref}} \tag{A.4}$$

$$D = \frac{(1-S_{11})(1+S_{22})+S_{12}S_{21}}{2S_{21}} \tag{A.5}$$

Based on the ABCD parameters a set of S-parameters based on the characteristic impedance Z'_{ref} of the test jig can be calculated.

$$Z'_{\text{ref}} = 60\ \Omega \cosh^{-1}\left(\frac{2h}{d}\right), \tag{A.6}$$

where

d: is the jig conductor diameter (defined to be 4 mm)

h: is the height of the centre of the jig conductor above the ground plane

$$B' = B / Z'_{\text{ref}} \tag{A.7}$$

$$C' = C \cdot Z'_{\text{ref}} \tag{A.8}$$

$$S'_{11} = \frac{A + B' - C' - D}{A + B' + C' + D} \tag{A.9}$$

$$S'_{12} = \frac{2(AD - BC)}{A + B' + C' + D} \tag{A.10}$$

$$S'_{21} = \frac{2}{A + B' + C' + D} \tag{A.11}$$

$$S'_{22} = \frac{-A + B' - C' + D}{A + B' + C' + D} \tag{A.12}$$

A.2.2.1.3 Impedance calculation

The input impedance is given by

$$Z_{\text{in}} = Z'_{\text{ref}} \frac{1 + S'_{11}}{1 - S'_{11}} \tag{A.13}$$

Figure A.7 gives typical examples of the impedance curve for three different EM clamps.

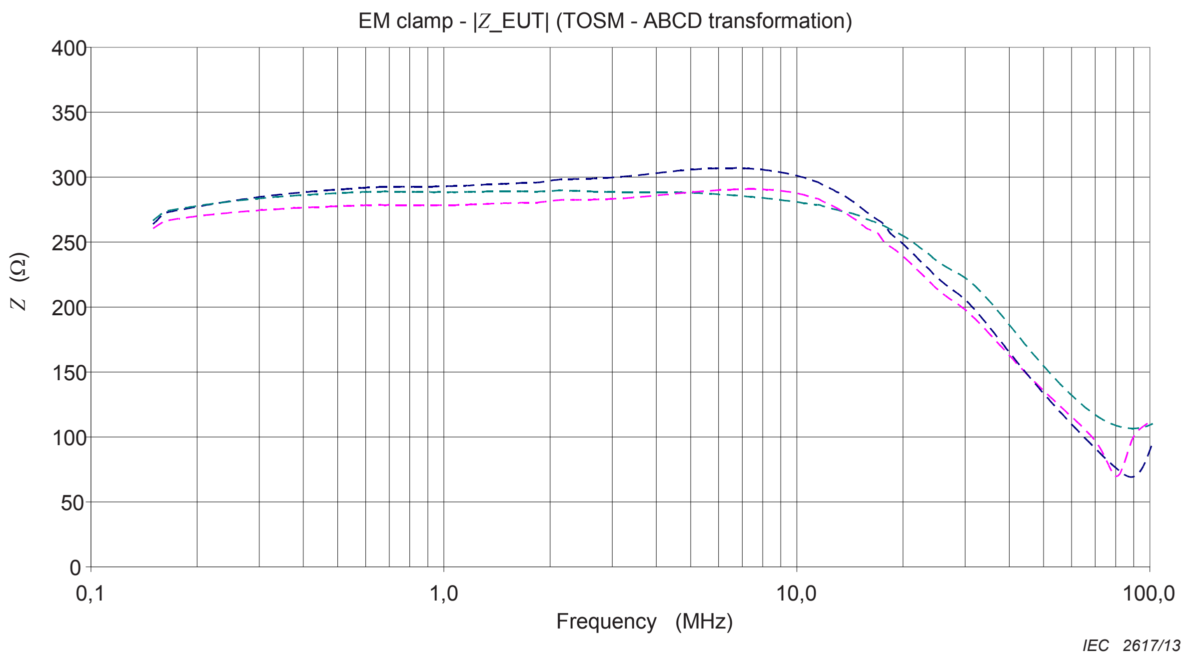


Figure A.7 – Typical examples for clamp impedance, 3 typical clamps

NOTE The impedance measured according to this procedure is valid for the case where the far end of the device is terminated by Z_{ref}. This value may be different when using the clamp in immunity test setups due to the real AE impedance.

A.2.2.2 Decoupling factor between EUT and AE

The measurement setup and the transformation shall be applied as described in A.2.2.1.1 and A.2.2.1.2. The decoupling factor is calculated by

$$a[\mathrm{dB}] = 20\log_{10}\left(ABS\left(S'_{21}\right)\right) \tag{A.14}$$

Figure A.8 gives typical examples of the decoupling factor curve for three different EM clamps.

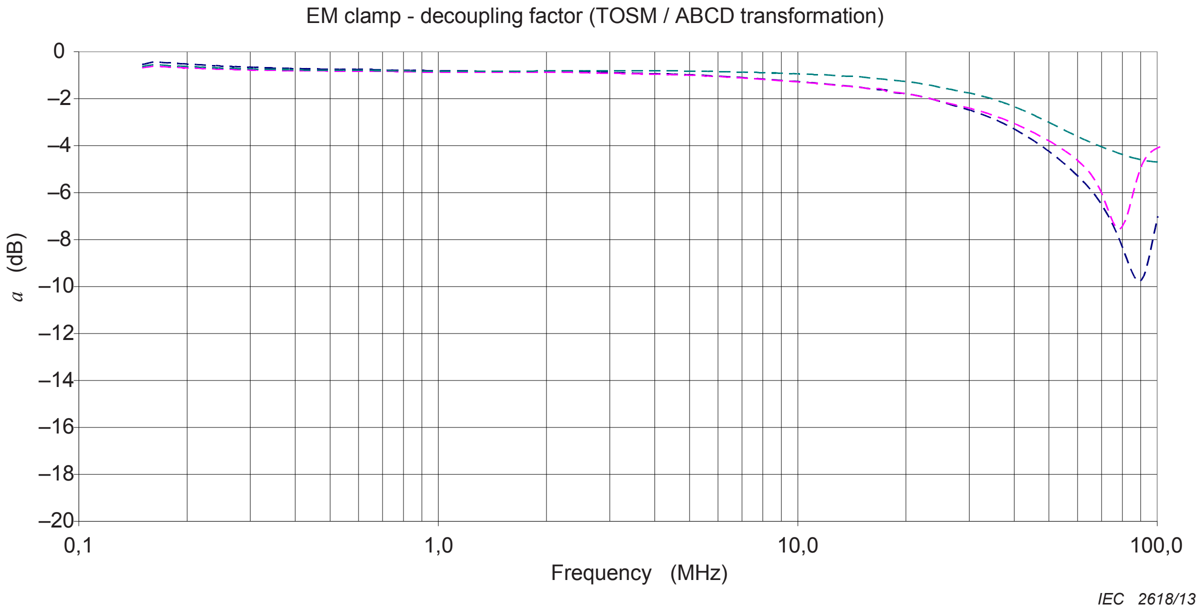


Figure A.8 – Typical examples for decoupling factors, 3 typical clamps

A.2.2.3 Coupling factor

The coupling factor shall be measured in a 150 Ω system according to the setup shown in Figure A.10. The test jig as described in A.2.1 shall be used with the following modifications: The height of the cylindrical rod shall be adjusted to be in the bottom position of the clamp opening. Furthermore 150 Ω to 50 Ω adapters shall be inserted in the reference planes. Prior to the measurement the setup shall be normalized by connecting the reference planes of the jig back to back, see Figure A.9. The use of two 10 dB attenuators as shown in Figures A.9 and A.10 is recommended.

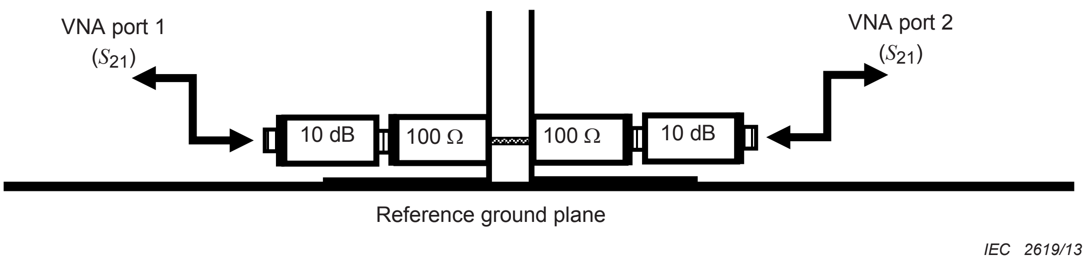


Figure A.9 – Normalization setup for coupling factor measurement

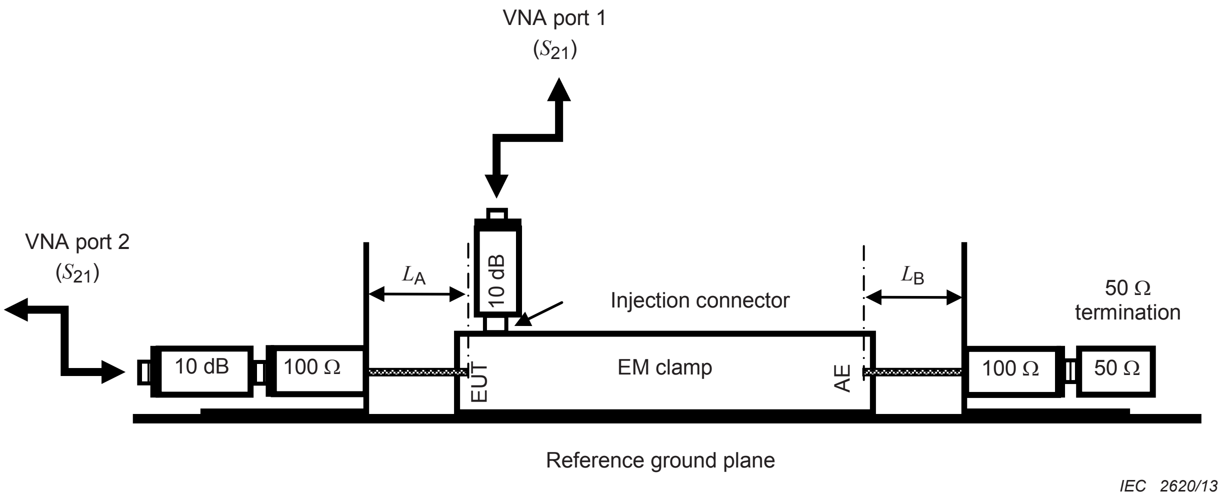


Figure A.10 – S_{21} coupling factor measurement setup

Figure A.11 gives typical examples of the coupling factor curve for three different EM clamps.

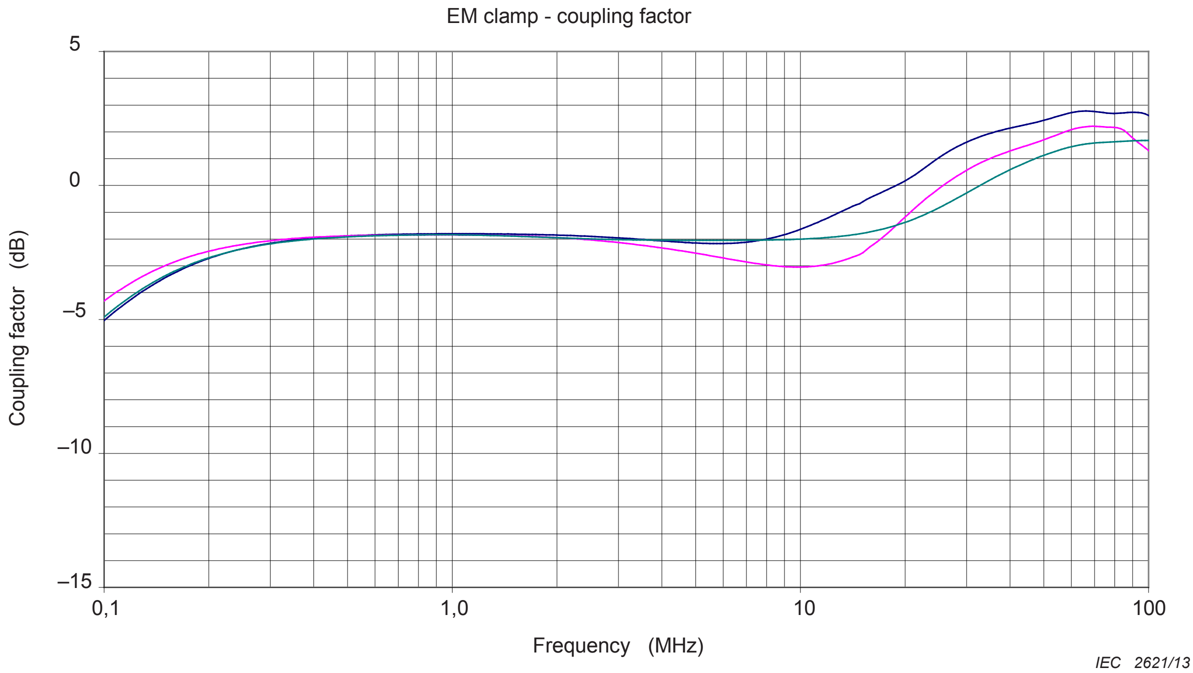


Figure A.11 – Typical examples for coupling factor, 3 typical clamps

A.3 Decoupling clamp characterization

A.3.1 Impedance

A.3.1.1 Measurement setup

The test jig as defined in A.2.1 shall be used for the impedance measurement. The decoupling clamp shall be placed into the test jig, see Figure A.12. For impedance measurement the decoupling clamp is treated as a 2-port device which can be characterized by its S-parameters S_{11}, S_{12}, S_{21} and S_{22} measured in a 50 Ω system using a network analyzer. Prior to the measurement the network analyzer shall be normalized at the cable ends (to be connected to the jig) using a standard TOSM method with an appropriate calibration kit. The length between the cable end and the decoupling clamp reference point shall be respected by a port offset of the network analyzer or by other means.

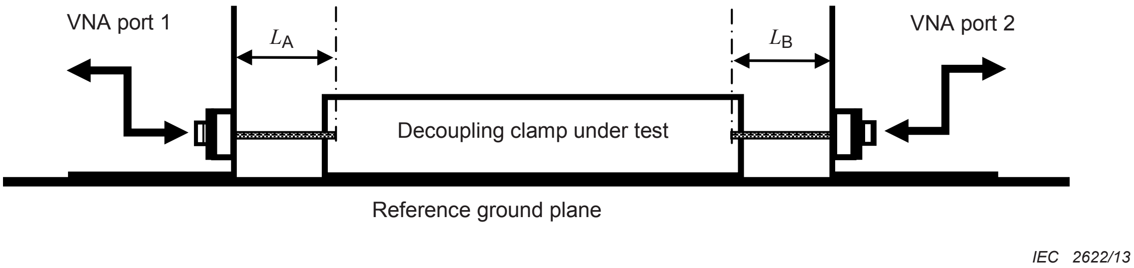


Figure A.12 – Decoupling clamp characterization measurement setup

A.3.1.2 Impedance calculation

The transformation as described in A.2.2.1.2 shall be applied. The input impedance is given by

$$Z_{\text{in}} = Z'_{\text{ref}} \frac{1 + S'_{11}}{1 - S'_{11}} \tag{A.15}$$

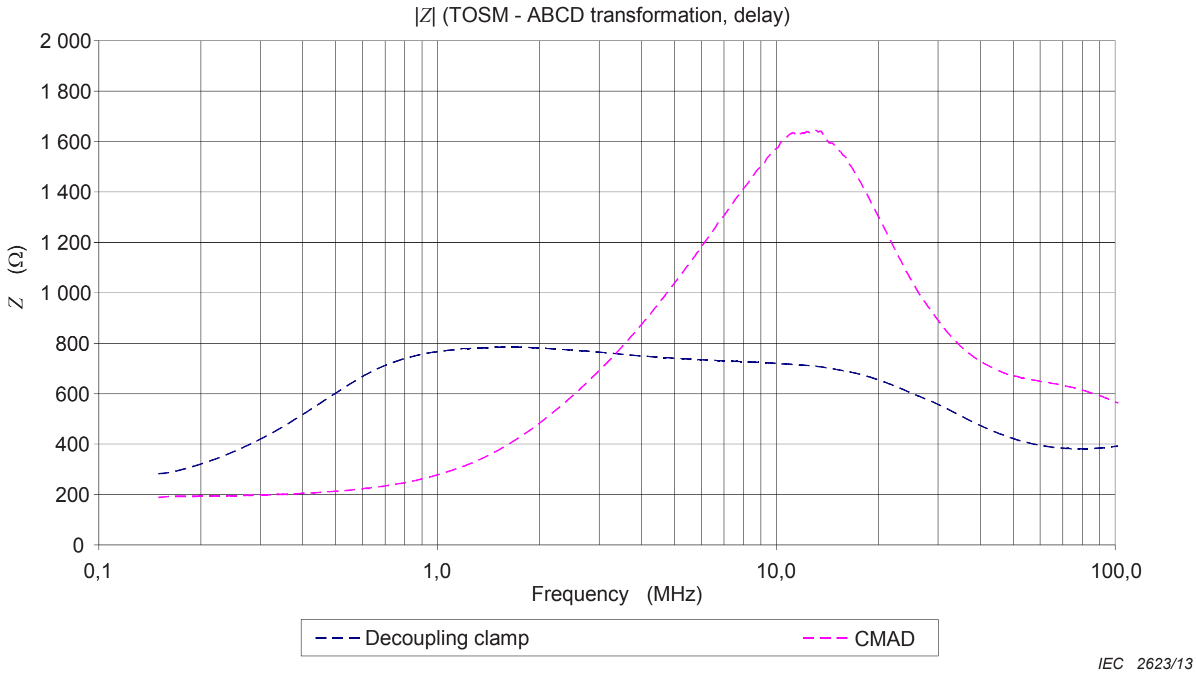


Figure A.13 – Typical examples for the decoupling clamp impedance

NOTE The impedance measured according to this procedure is valid for the case where the far end of the device is terminated by Z_{ref}. This value may be different when using the clamp in immunity test setups due to the real AE impedance.

A.3.2 Decoupling factor

The measurement setup and the transformation shall be applied as described in A.3.1.1 and A.2.2.1.2. The decoupling factor is calculated by

$$a[\mathrm{dB}] = 20\log_{10}\left(ABS\left(S'_{21}\right)\right) \tag{A.16}$$

NOTE The common mode absorption device (CMAD) (CISPR 16-1-4) is designed for good decoupling between 30 MHz and 200 MHz and might therefore be less suitable for the lower frequency range indicated in this part of IEC 61000.

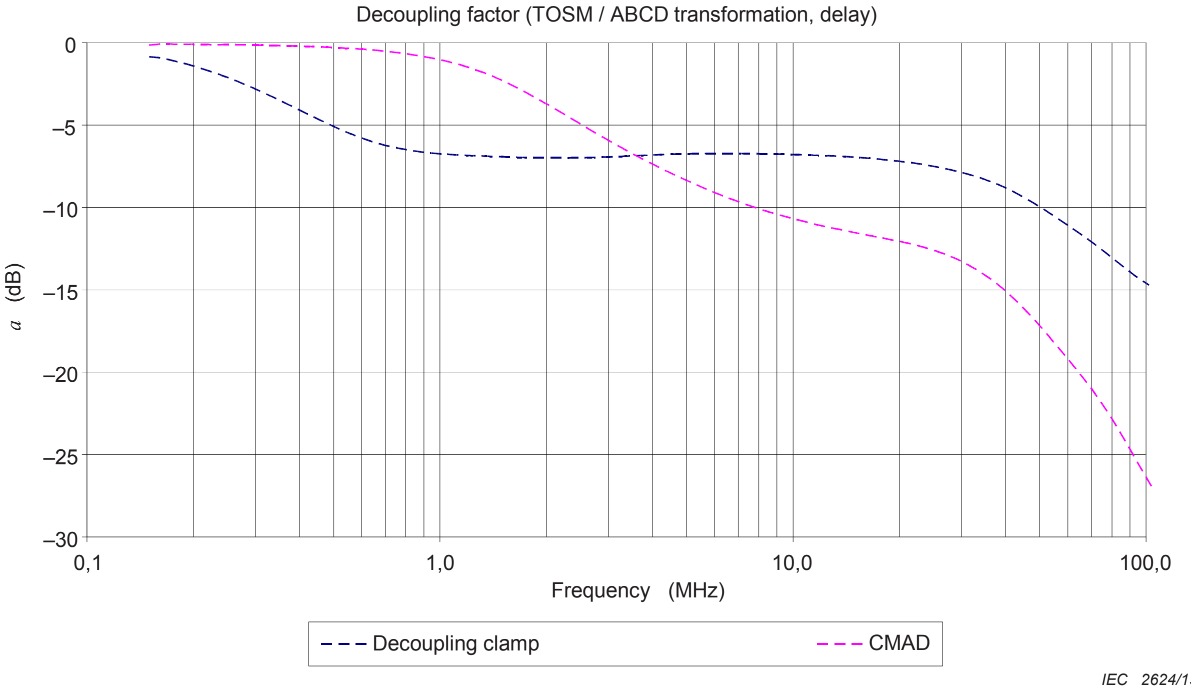


Figure A.14 – Typical examples for decoupling factors

Annex B
(informative)

Selection criteria for the frequency range of application

Although the requirements in this standard are specified for the frequency range 150 kHz up to 80 MHz, the applicable frequency range depends on the normal installation and operation conditions of the equipment to be tested. For example, a small battery-powered equipment with total dimensions less than 0,4 m and without any metallic cable(s) connected thereto, does not need to be tested below 80 MHz because it is unlikely that the induced RF energy resulting from the disturbing EM field will upset the device.

In general, the stop frequency will be 80 MHz. In some cases, where small sized equipment is considered (dimension < $\lambda/4$), dedicated product standards may prescribe that the stop frequency is extended up to a maximum of 230 MHz. The coupling and decoupling devices in this case shall then meet the parameter of common mode impedance seen at the EUT port specified in Table B.1 below. When using this test method up to higher frequencies, results are influenced by the size of equipment, the type(s) of interconnecting cables used, and the availability of special CDNs, etc. Further guidance for proper application should be supplied in the dedicated product standards.

Table B.1 – Main parameter of the combination of the coupling and decoupling device when the frequency range of test is extended above 80 MHz

	Frequency band		
Parameter	0,15 MHz to 24 MHz	24 MHz to 80 MHz	80 MHz to 230 MHz
$\lvert Z_{ce} \rvert$	150 Ω ± 20 Ω	$150\ \Omega\ ^{+60\ \Omega}_{-45\ \Omega}$	150 Ω ± 60 Ω
Neither the argument of Z_{ce} nor the decoupling factor between the EUT port and the AE port are specified separately. These factors are embodied in the requirement that the tolerance of $\lvert Z_{ce} \rvert$ shall be met with the AE port open or short-circuited to the reference ground plane. When clamp injection methods are used, without complying with the common mode impedance requirements for the AE, the requirements of Z_{ce} may not be met. However, the injection clamps can provide acceptable test results when the guidance of 7.7 is followed.			

The start frequency depends on whether the equipment including its connected cables is capable of receiving a large amount of RF energy from the disturbing EM field.

Three different situations are considered.

a) Battery-powered equipment (dimension < $\lambda/4$) which has no connection(s) to ground nor to any other equipment and which is not used during battery charging, does not need to be tested according to this standard. If the equipment will be operated during battery charging, case b) or c) applies.

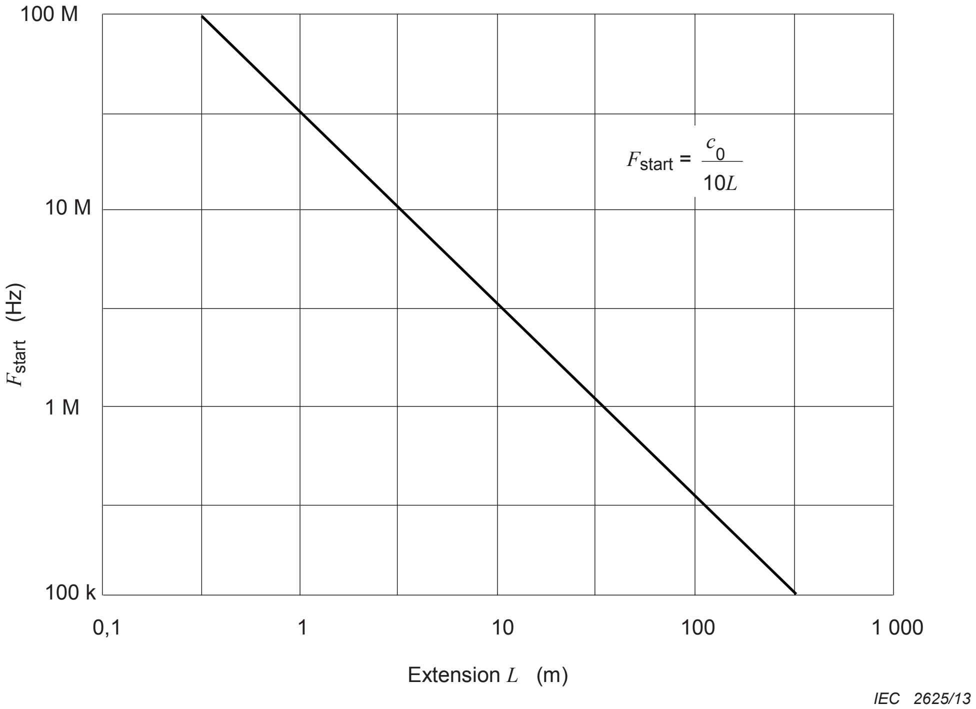
   For battery-powered equipment (dimension ≥ $\lambda/4$), its size, including the maximum length of the cables connected, determine the start frequency, as shown in Figure B.1.

b) Equipment connected to a (power) mains network but not connected to any other equipment or cables.

   The power supply is provided via a coupling and decoupling device and the equipment is loaded by an artificial hand. The start frequency is 150 kHz.

c) Equipment connected to a (power) mains network which is also connected via control and I/O or telecommunication cables to other insulated or non-insulated equipment.

   The start frequency is 150 kHz.



c_0 = 3×10^8 m/s

L = cable length + equipment size

Examples:

- For a cable connected to a keyboard (extended dimension ≥ λ/4) powered from a battery-operated personal computer, with a coiled cable having a length of 4 m, the start frequency should be 6,67 MHz. The keyboard should be covered by the artificial hand. For a mouse having just 2 m of cable, the start frequency would be 15 MHz, etc.
- A pocket calculator with an a.c./d.c. adapter option, should be tested on the mains side of the adapter from 150 kHz upwards. The pocket calculator should be covered by the artificial hand.
- A hand-held battery-supplied multimeter which can have connections to ground should be tested on its cables from 150 kHz upwards. The multimeter should be covered by the artificial hand.
- A double insulated (mains) compact disc player which can be connected to an audio receiver, connected to insulated loudspeaker boxes, but also having an antenna input terminal which can be connected to ground should be tested on both mains supply and audio cable(s) from 150 kHz upwards.
- A burglar alarm having various insulated sensors distributed through a building, of which the maximum length of cable may extend 200 m (manufacturer's specification) should be tested on these cables from 150 kHz upwards.

Figure B.1 – Start frequency as function of cable length and equipment size

Annex C
(informative)

Guide for selecting test levels

The test levels should be selected in accordance with the electromagnetic radiation environment to which the EUT and cables may be exposed when finally installed. The consequences of failure should be kept in mind in selecting the test level to be used. A higher level should be considered if the consequences of failure are large.

If the EUT is to be installed at a few sites only, then inspection of the local RF sources enables a calculation of field strengths likely to be encountered. If the powers of the sources are not known it may be possible to measure the actual field strength at the location(s) concerned.

For equipment intended for operation in a variety of locations, the following guidelines may be followed in selecting the test level to be used.

The following classes are related to the levels listed in Clause 5; they are considered as general guidelines for the selection of the appropriate levels:

- Class 1: Low-level electromagnetic radiation environment. Typical level where radio/ television stations are located at a distance of more than 1 km and typical level for low-power transceivers.
- Class 2: Moderate electromagnetic radiation environment. Low-power portable transceivers (typically less than 1 W rating) are in use, but with restrictions on use in close proximity to the equipment. A typical commercial environment.
- Class 3: Severe electromagnetic radiation environment. Portable transceivers (2 W and more) are in use relatively close to the equipment but at a distance not less than 1 m. High-powered broadcast transmitters are in close proximity to the equipment and ISM equipment may be located close by. A typical industrial environment.
- Class X: X is an open level which may be negotiated and specified in the dedicated equipment specifications or equipment standards.

The test levels described are typical values which are rarely exceeded in the locations described. At some locations these values are exceeded, e.g. in the proximity of high-power transmitters or ISM equipment located in the same building. In such cases, it may be preferable to shield the room or building, and filter the signal and power wires to the equipment, rather than specifying all equipment to be immune to such levels.

Annex D
(informative)

Information on coupling and decoupling networks

D.1 Basic features of the coupling and decoupling networks

The CDN should provide:

– coupling of the disturbing signal to the EUT;
– stable impedance, seen from the EUT, independent of the AE common mode impedance;
– decoupling of the AE from the disturbing signal to prevent interference of the AE;
– transparency to the wanted signal.

The required parameters for the CDNs in the frequency range 150 kHz to 80 MHz are given in 6.2.1 and examples are given in D.2.

In the Figures D.1 to D.7, the common mode impedance, Z_{ce}, is formed by the sum of the internal resistance of the test generator (50 Ω) and the parallel combination of the resistors from the conductors of the cable under test (100 Ω). With the use of a suitable inductor L ($|\omega L| >> 150\ \Omega$), the decoupling elements, C_2, should not influence Z_{ce}.

The centre of the EUT port on the CDN should be located 30 mm above the reference ground plane. The cable between the CDN and the EUT can then represent a transmission line with a characteristic impedance of about 150 Ω if located at 30 mm above the reference ground plane.

The impedance of capacitors C_1, providing d.c. and LF separation of the test generator and the individual wires of the CDN, should be much less than 150 Ω in the frequency range of interest.

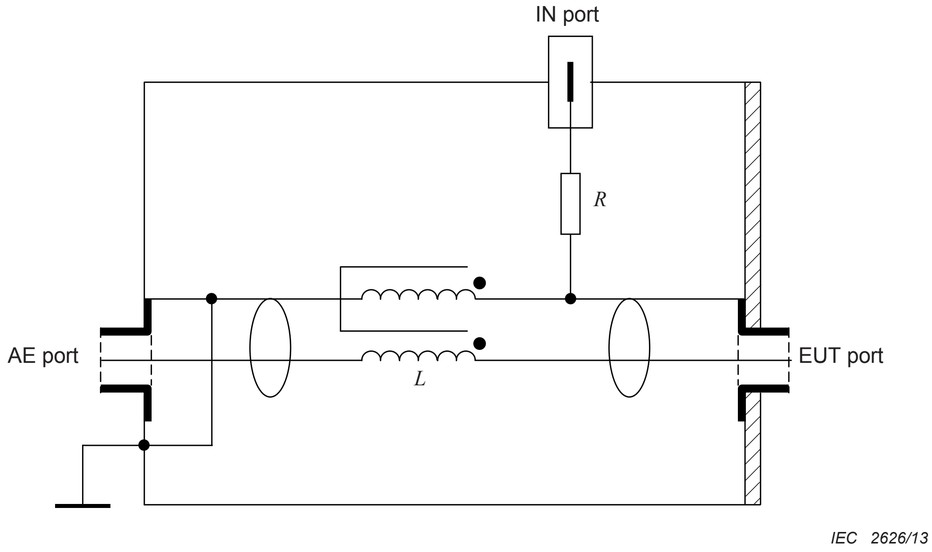
The AE is decoupled by a common mode inductor L, and by the capacitors C_2 for unscreened cables or by a common mode inductor L only. For screened cables, the capacitors C_2 are not needed as the screen will be connected to the reference ground plane at the AE side.

It is essential for unscreened cable that the value of C_2 is chosen such that the wanted signal is not unduly affected. It is not permissible for CDN parameters to be unduly affected by the wanted signal, e.g. in CDN-M1, saturation of the ferrite(s).

Warning: Since C_1 and C_2 bridge live parts in the mains CDNs, suitable Y capacitors shall be used. Due to the high leakage current, the CDN shall have an earth terminal which shall be connected to the reference ground plane under all test conditions, and the reference ground plane shall be appropriately connected to the protective earth.

D.2 Examples of coupling and decoupling networks

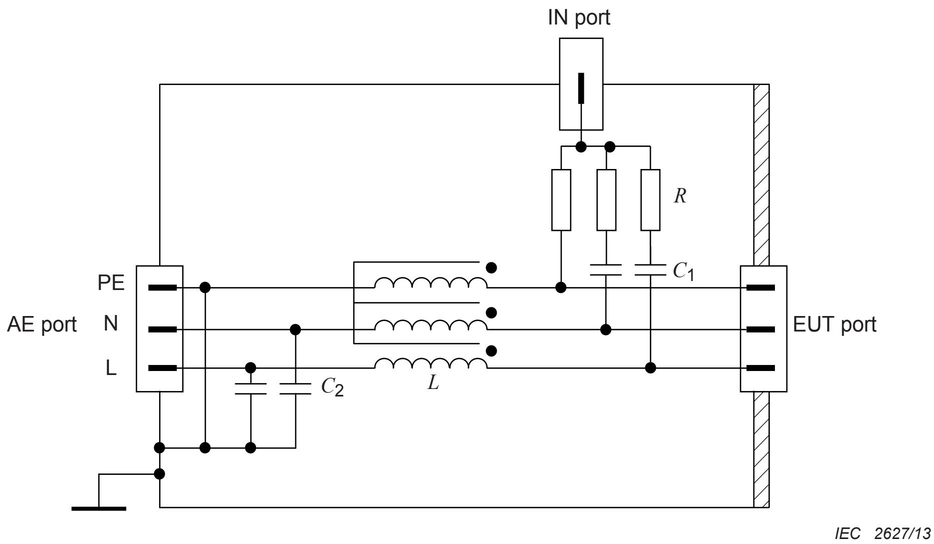
A number of possibilities are given in Figures D.1 to D.7 because it is impossible to cover all functional requirements with one CDN.



R = 100 Ω

$L \geq$ 280 µH at 150 kHz

Figure D.1 – Example of a simplified diagram for the circuit of CDN-S1 used with screened cables (see 6.2.2.5)

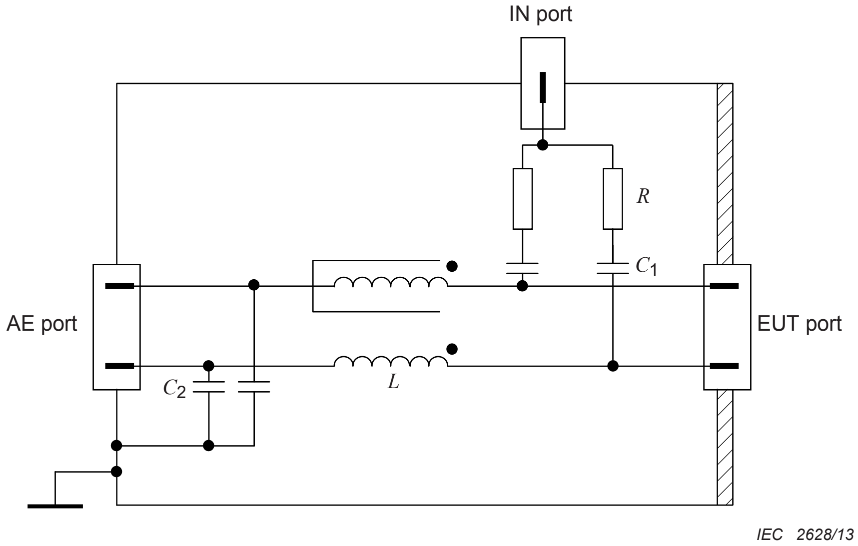


CDN-M3, C_1 (typical) = 10 nF, C_2 (typical) = 47 nF, R = 300 Ω, $L \geq$ 280 µH at 150 kHz

CDN-M2, C_1 (typical) = 10 nF, C_2 (typical) = 47 nF, R = 200 Ω, $L \geq$ 280 µH at 150 kHz

CDN-M1, C_1 (typical) = 22 nF, C_2 (typical) = 47 nF, R = 100 Ω, $L \geq$ 280 µH at 150 kHz

Figure D.2 – Example of simplified diagram for the circuit of CDN-M1/-M2/-M3 used with unscreened supply (mains) lines (see 6.2.2.2)



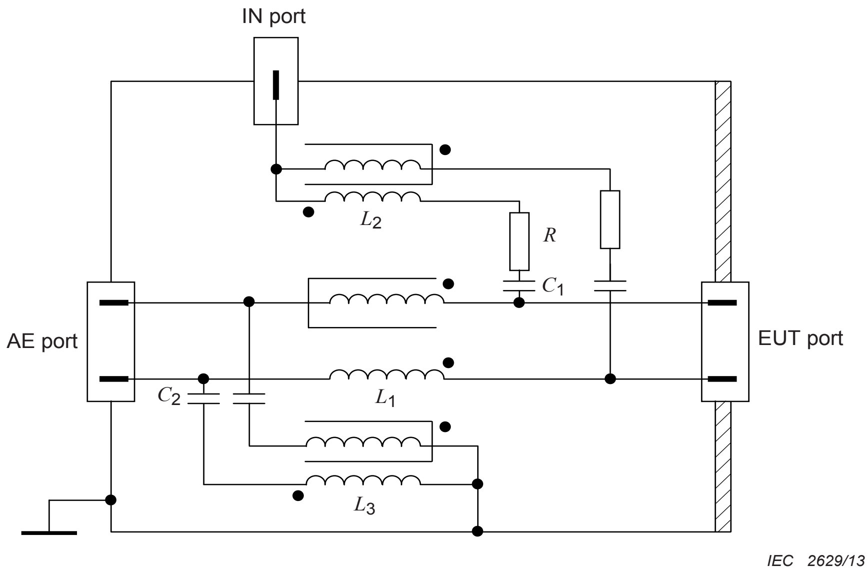
C_1 (typical) = 10 nF

C_2 (typical) = 47 nF

R = 200 Ω

$L \geq$ 280 μH at 150 kHz

Figure D.3 – Example of a simplified diagram for the circuit of CDN-AF2 used with unscreened unbalanced lines (see 6.2.2.4)



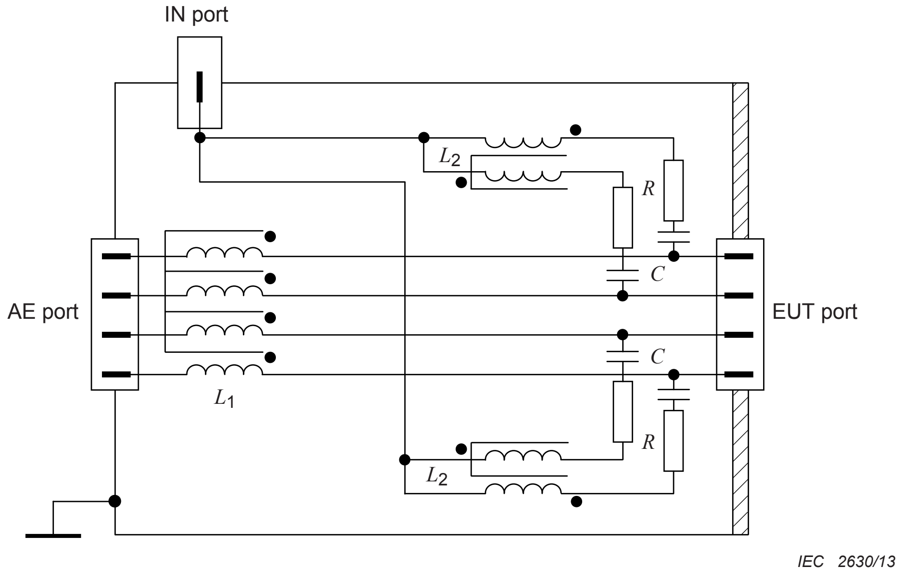
C_1 (typical) = 10 nF,

C_2 (typical) = 47 nF, R = 200 Ω

$L_1 \geq$ 280 μH at 150 kHz

$L_2 = L_3$ = 6 mH (when C_2 and L_3 are not used, $L_1 \geq$ 30 mH)

Figure D.4 – Example of a simplified diagram for the circuit of a CDN-T2, used with an unscreened balanced pair (see 6.2.2.3)



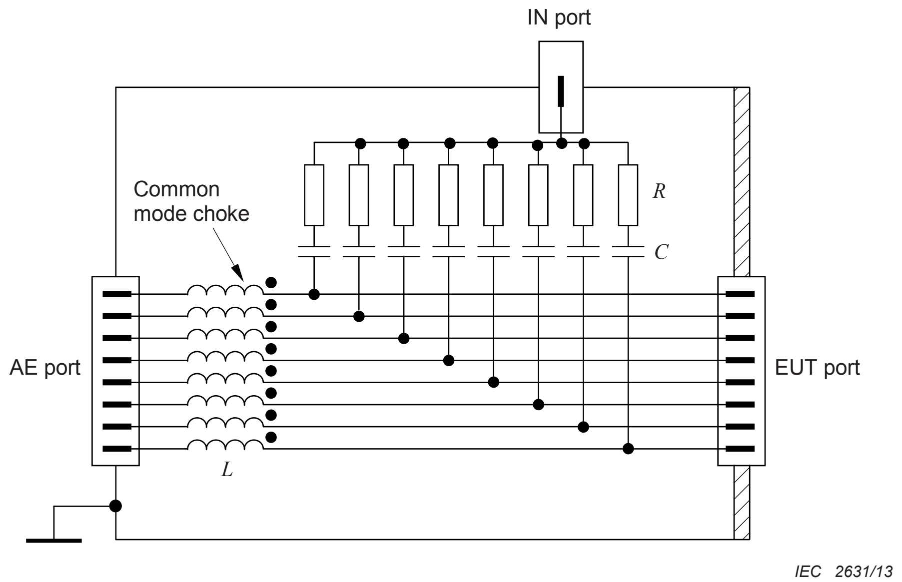
C (typical) = 5,6 nF

R = 400 Ω

L_1 >> 280 µH at 150 kHz

L_2 = 6 mH

Figure D.5 – Example of a simplified diagram of the circuit of a CDN-T4 used with unscreened balanced pairs (see 6.2.2.3)

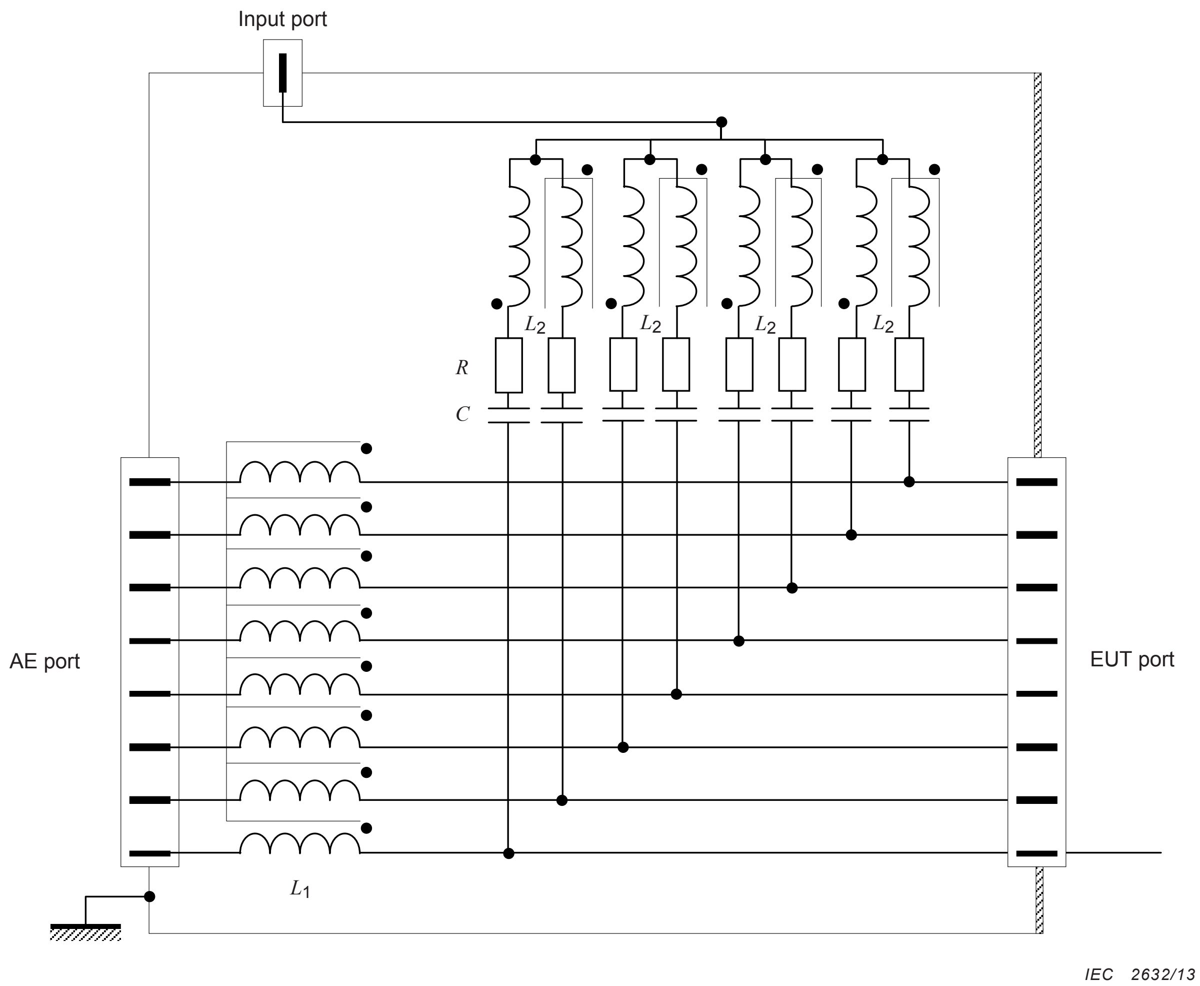


C (typical) = 2,2 nF

R = 800 Ω

L >> 280 µH at 150 kHz

Figure D.6 – Example of a simplified diagram of the circuit of a CDN AF8 used with unscreened unbalanced lines (see 6.2.2.4)



C (typical) = 2,2 nF

R = 800 Ω

L_1>> 280 µH at 150 kHz

L_2 >> 6 mH at 150 kHz

Figure D.7 – Example of a simplified diagram of the circuit of a CDN-T8 used with unscreened balanced pairs (see 6.2.2.3)

Annex E
(informative)

Information for the test generator specification

The available output power of the power amplifier, PA (Figure 3), is determined by taking into account the attenuator T2 (6 dB), the amplitude modulation depth (80 %) (see Figure 2), and the minimum coupling factor of the CDN or clamp used.

Table E.1 – Required power amplifier output power to obtain a test level of 10 V

Injection device	**Minimum coupling factor ± 1,5 dB** dB	**Required power at output of PA** W
CDN	0	7
Current clamp winding (ratio 5:1)	–14	176
EM clamp	–6	28

NOTE The coupling factor is defined in 3.6. It can be measured by using the output level setting circuit (see Figure 9c)). The coupling factor is the ratio between the output voltage U_{mr}, obtained when using a coupling and decoupling device in series with a 150 Ω to 50 Ω adapter and the output voltage when using two 150 Ω to 50 Ω adapters in series.

Annex F
(informative)

Test setup for large EUTs

F.1 General

The test setup as described in the main body of this standard (see Clause 7) is not fully sufficient to cover the needs of some large EUTs with cables entering or exiting the EUT at heights greater than 1 m. As the upper frequency of the test signal is 80 MHz, EUT size may be considerable compared to the wavelength, and resonance effects may be present with cables that are connected to such EUTs.

In this case, Annex F provides an alternative test method applicable to large EUTs that places the coupling device near to the cable entry, resulting in a small loop area with reduced resonance effects.

Examples of large EUTs to which Annex F may apply include, but are not limited to, the following:

– rack-mounted telecommunication switching systems;
– electrical machinery;
– rack-mounted switch and control gear.

F.2 Test setup for large EUTs

Examples of the test setup for large EUTs are given in Figures F.1 and F.2.

The elevated reference ground plane shown in Figure F.1 is the reference ground plane for this test setup. The purpose of the elevated reference ground plane is to reduce the length of cable between the EUT and CDN, thereby controlling or reducing the effects of resonances in the cables.

The size of the elevated reference ground plane shall be large enough to extend a minimum of 0,2 m beyond all CDNs used in the test. The length of cable under test between the EUT and CDN shall be a maximum of 0,3 m.

The elevated reference ground plane shall be placed at a height above the main ground plane so as to allow cables from the EUT to pass to the CDNs in a horizontal alignment.

The elevated reference ground plane shall be electrically connected to earth for safety reasons. This connection is not significant from an RF point of view in case that more than one CDN is used for the setup.

NOTE 1 The physical construction of the elevated reference ground plane and its support structure to ensure a mechanically safe condition are important.

The equipment to be tested should be placed on an insulating support of 0,1 m ± 0,05 m height above the ground plane. In case the equipment is delivered on a transport pallet, and if due to its excessive weight or size it cannot be safely removed from its transport pallet, then the EUT may be left on its pallet for testing even if its height exceeds 0,1 m ± 0,05 m. In case the equipment, because of size or weight, cannot be elevated 0,1 m ± 0,05 m, thinner insulation may be used provided the EUT is electrically isolated from the ground plane. Any variation from the standard method of testing shall be recorded in the test report.

The AE may be located on the elevated reference ground plane but does not need to be located on it provided the AE is connected to the EUT via a CDN. When direct injection is used, the AE may be located off of the elevated reference ground plane provided proper decoupling is used. In the case where clamp injection is used instead of injection via a CDN, the AE shall be located on the elevated reference ground plane.

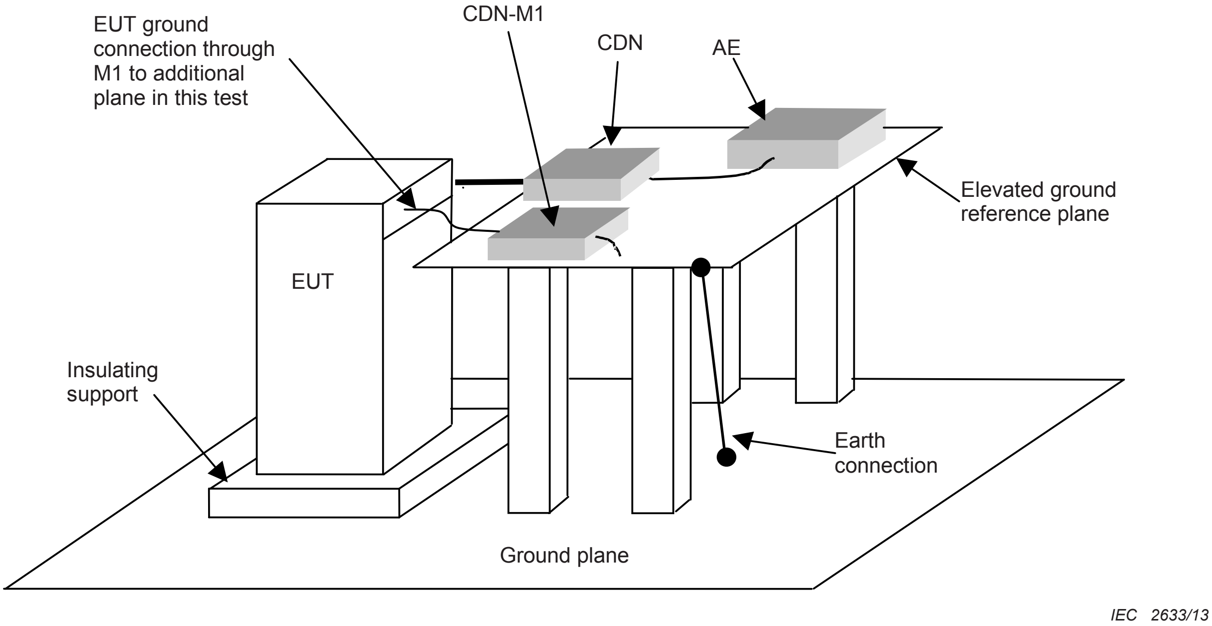


Figure F.1 – Example of large EUT test setup with elevated horizontal reference ground plane

The vertical reference ground plane shown in Figure F.2 is the reference ground plane for this test setup. The purpose of the vertical reference ground plane is to reduce the length of cable between the EUT and CDN, thereby controlling or reducing the effects of resonances in the cables.

NOTE 2 The vertical reference ground plane may be more applicable than the horizontal elevated reference ground plane in cases where cables enter/exit the EUT at multiple heights or where only one CDN is applied.

The vertical reference ground plane shall be electrically connected to earth for safety reasons. This connection is not significant from an RF point of view.

The size of the vertical reference ground plane shall be large enough to extend a minimum of 0,2 m beyond all CDNs used in the test. In case of EUT having only one line, the vertical reference ground plane shall extend to the floor and bonded to the floor with low inductivity. The length of cable under test between the EUT and CDN shall be a maximum of 0,3 m. The distance between the EUT and the vertical reference ground plane shall be such that the 0,3 m cable length requirement can be satisfied. A wall of a shielded room can be used as the vertical reference ground plane.

The CDNs shall be mounted to the vertical reference ground plane at a height that allows cables from the EUT to pass to the CDNs in a horizontal alignment.

The statements given for the test setup using a horizontal elevated reference ground plane (i.e., insulating support and location of AE) apply for the test setup using a vertical reference ground plane accordingly.

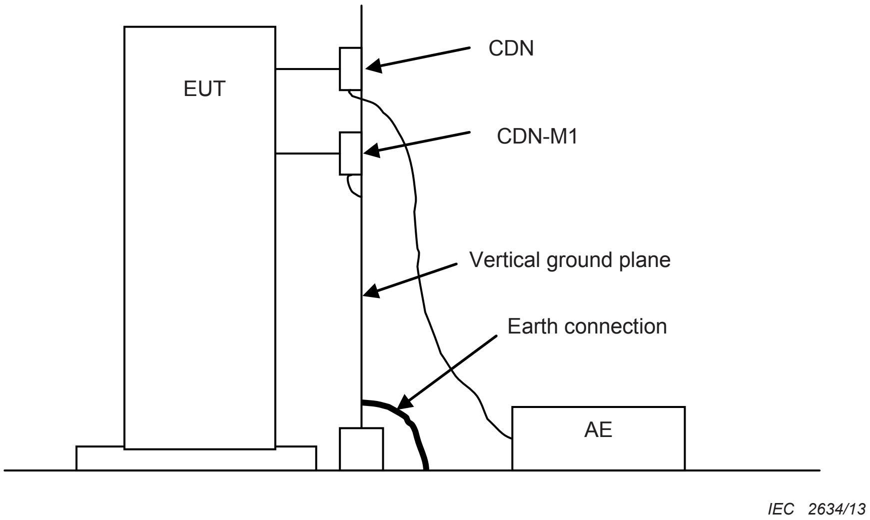


Figure F.2 – Example of large EUT test setup with vertical reference ground plane

Annex G
(informative)

Measurement uncertainty of the voltage test level

G.1 General

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

Annex G 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 voltage test level setting procedure described in 6.4. Other parameters of the disturbance quantity (e.g. modulation frequency, modulation depth, etc.) may be of equal importance and should also be considered by the test laboratory as appropriate. The methodology shown in Annex G is considered to be applicable to all parameters of the disturbance quantity.

The subject of Annex G is the evaluation of MU of the voltage level set in the case of 150 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 out of the scope of Annex G.

G.2 General symbols

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

X_i input quantity

x_i estimate of X_i

$u(x_i)$ standard uncertainty of x_i

c_i sensitivity coefficient

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

$u_c(y)$ (combined) standard uncertainty of y

$U(y)$ expanded uncertainty of y

k coverage factor

δX_i correction for the influence quantity X_i

G.3 Uncertainty budgets for test methods

G.3.1 Definition of the measurand

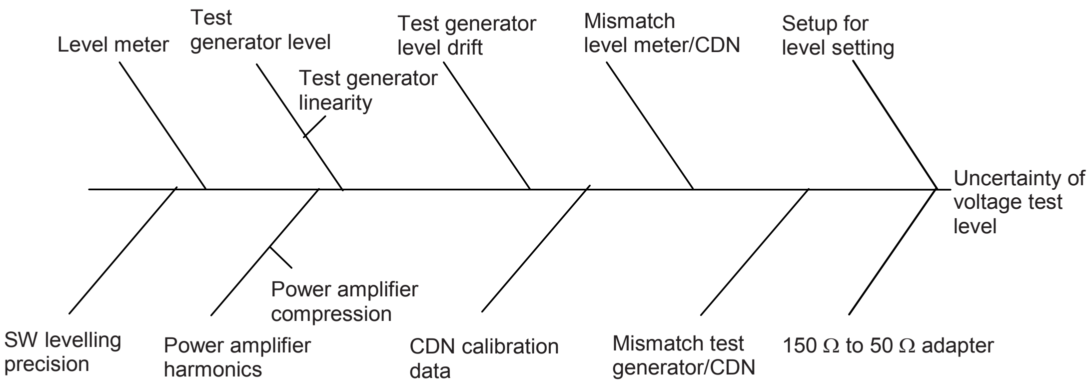
The measurand is the open circuit test level U_0 as defined in Clause 5.

NOTE U_0 is the voltage supplied through a coupling device to a 150 Ω load at a specific frequency comprised between 150 kHz and 80 MHz. For the purpose of measurement uncertainties it is expressed in dB(μV).

1 Numbers in square brackets refer to the reference documents at the end of Annex G.

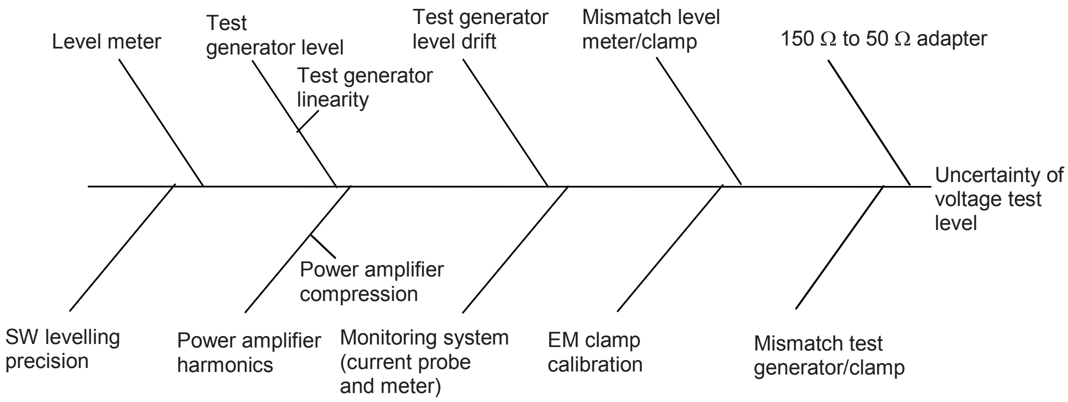
G.3.2 MU contributors of the measurand

The following influence diagrams (Figures G.1 to G.4) give examples of influence quantities upon voltage test level. It should be understood that the diagrams are not exhaustive. The most important contributors from the influence diagrams have been selected for the uncertainty budget calculation examples shown in Tables G.1 to G.8. At least these contributors listed in Tables G.1 to G.8 shall be used for the calculation of MU in order to obtain comparable budgets for 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.



IEC 2635/13

Figure G.1 – Example of influences upon voltage test level using CDN



IEC 2636/13

Figure G.2 – Example of influences upon voltage test level using EM clamp

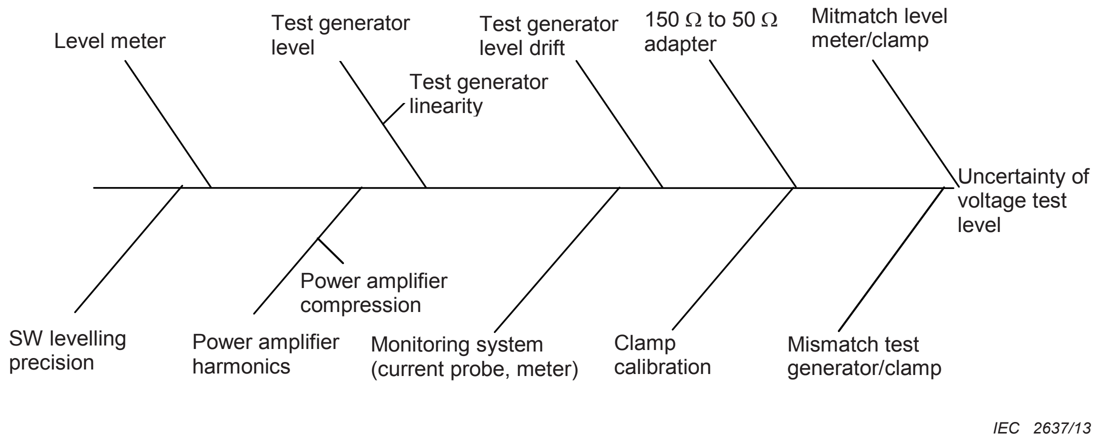


Figure G.3 – Example of influences upon voltage test level using current clamp

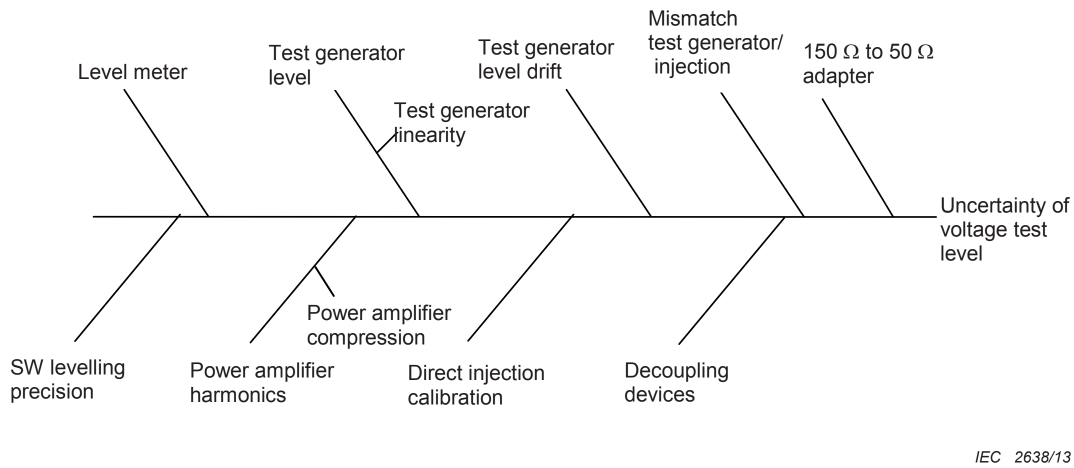


Figure G.4 – Example of influences upon voltage test level using direct injection

G.3.3 Input quantities and calculation examples for expanded uncertainty

The examples below assume the same instrumentation used in the test level setting procedure is used for generating the voltage test level (the measurement setup for the test level setting is that depicted in Figure 9c) and Figure G.5), except for the measuring instrument, which is absent during the test. However, the uncertainty contributions that would exist, if different instrumentation is used, are shown in Tables G.1 to G.8 but their values are set to zero (see notes below Tables G.1 to G.8).

Therefore, it has to be recognized that the contributions which apply for the level setting process and for the test may not be the same. This leads to (slightly) different uncertainty budgets for each process.

Tables G.1 to G.8 give examples of an uncertainty budget for voltage level setting. Each uncertainty budget consists of two parts, the uncertainty for level setting and the uncertainty for test. The level setting process determines the relation between U_x and U_mr. (See Figure G.1.) During the test process, U_x is reproduced.

Model function for CDN voltage level setting process (all quantities in logarithmic units):

$$U_0 = U_\mathrm{LMc} + 15{,}6\ \mathrm{dB} + \delta LM_\mathrm{c} + \delta RCAL + \delta SETUP + \delta SW_\mathrm{c} + \delta ML$$

Explanation of contributions:

U_{LMc} Voltage indication U_{mr} from the power meter directly in or converted to dB(µV).

NOTE 1 The other symbols are included in the explanation of terms below.

Model function for CDN test process (all quantities in logarithmic units):

$$U_0 = U_x + 20 \log (6/5) + \delta LMC_t + \delta CAL + \delta SW_t$$

$$U_x = U_{LMc} + 20\log(5)$$

NOTE 2 The symbols are included in the explanation of terms below.

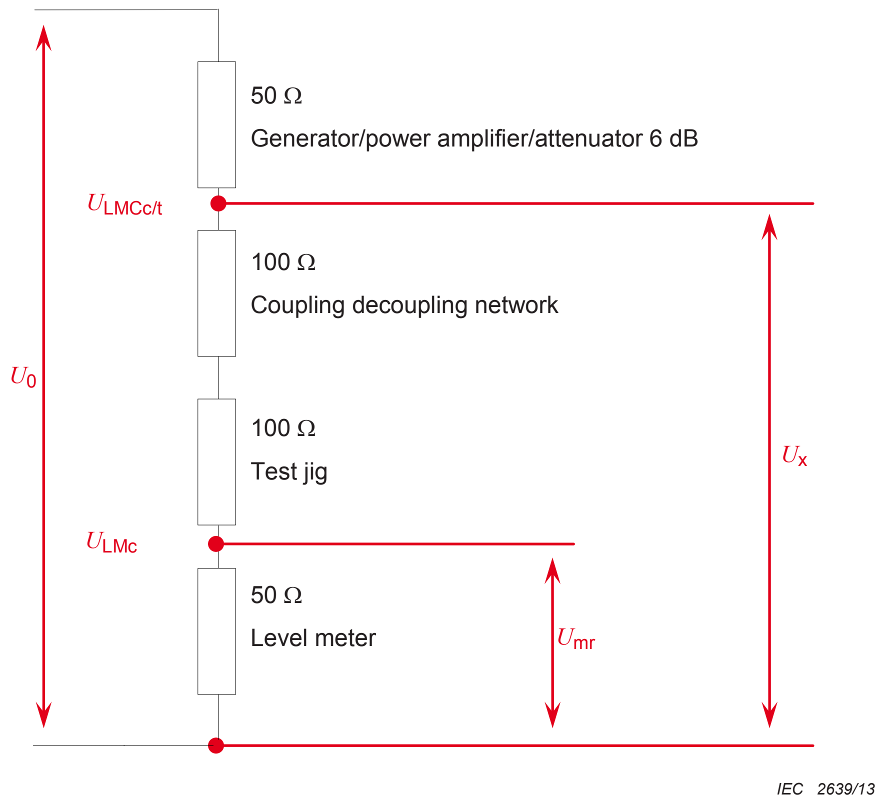


Figure G.5 – Circuit for level setting setup

Table G.1 – CDN level setting process

Symbol	Uncertainty Source X_i	$U(x_i)$	Unit	Distribution	Divisor	$u(x_i)$	Unit	c_i	$u_i(y)$	Unit	$u_i(y)^2$
$\delta RCAL$	150 Ω - 50 Ω adapter, deviation	0,3	dB	rectangular	1,73	0,17	dB	1	0,17	dB	0,03
	150 Ω - 50 Ω adapter, calibration	0,2	dB	normal k=2	2	0,10	dB	1	0,10	dB	0,01
$\delta SETUP$	Setup for level setting	0,35	dB	normal k=1	1	0,35	dB	1	0,35	dB	0,12
δLM_c	Level meter	0,5	dB	rectangular	1,73	0,29	dB	1	0,29	dB	0,08
δSW_c	SW levelling precision	0,3	dB	rectangular	1,73	0,17	dB	1	0,17	dB	0,03
δLMC_c (1,2)	Level meter in control loop	0	dB	rectangular	1,73	0,00	dB	1	0,00	dB	0,00
δTG_c (1,2)	Test generator	0	dB	rectangular	1,73	0,00	dB	1	0,00	dB	0,00
δMT_c (3)	Mismatch test generator/CDN	0	dB	U-shaped	1,41	0,00	dB	1	0,00	dB	0,00
δML	Mismatch level meter/CDN	0,5	dB	U-shaped	1,41	0,35	dB	1	0,35	dB	0,13
				$\Sigma u_i(y)^2$							0,40
				Combined uncertainty $u(y) = \sqrt{\Sigma u_i(y)^2}$							0,63
				Expanded uncertainty (CAL) $U = u(y) \times k$, k = 2							**1,27** dB

Table G.2 – CDN test process

Symbol	Uncertainty Source X_i	$U(x_i)$	Unit	Distribution	Divisor	$u(x_i)$	Unit	c_i	$u_i(y)$	Unit	$u_i(y)^2$
δCAL	Calibration	1,27	dB	normal k=2	2	0,63	dB	1	0,63	dB	0,40
δLMCt (1,2)	Level meter in control loop	0,3	dB	rectangular	1,73	0,17	dB	1	0,17	dB	0,03
δTGt (1,2)	Test generator	0	dB	rectangular	1,73	0,00	dB	1	0,00	dB	0,00
δMTt (3)	Mismatch test generator/CDN	0	dB	U-shaped	1,41	0,00	dB	1	0,00	dB	0,00
δSWt	SW levelling precision	0,3	dB	rectangular	1,73	0,17	dB	1	0,17	dB	0,03
				$\Sigma u_i(y)^2$							0,46
				Combined uncertainty $u(y) = \sqrt{\Sigma u_i(y)^2}$							0,68
				Expanded uncertainty $U = u(y) \times k$, k = 2							**1,36** dB

NOTE 3 Either LMC or the test generator (TG) contributions enter into Tables G.1 and G.2 for level setting and/or test, depending on whether a control loop for the signal generator and amplifier output level is used or not. In this example, the test generator does not contribute to the uncertainty budget because it is part of the control loop. The contribution from the control loop is established by the level meter (see also Note 4). However, the test generator is included in Tables G.1 and G.2 to remind the test labs that they can consider this item depending on the labs' particular test setup. In this case a more detailed analysis of the TG contribution is needed, see explanation of terms.

NOTE 4 If the same equipment is used for level setting and testing, then only the contributions of repeatability and linearity enter into Table G.2 for the test process. The contribution for the level setting can be neglected.

NOTE 5 If the same circuit is used for level setting and testing, then these contributions do not enter into the Tables G.1 and G.2.

Explanation of terms:

RCAL – is the uncertainty of the 150 Ω to 50 Ω adapter. This contribution can normally be obtained from the calibration report. Alternatively, the insertion loss can be measured using a network analyzer (see Figure 8c)). The maximum deviation from the specified loss (9,5 dB) and its calibration uncertainty should be included in Tables G.1 and G.2. It is recommended that 0,5 dB be used if the calibration certificate states only the compliance to the tolerance.

NOTE 6 Deviations can be corrected in the software. In this case, the maximum deviation can be reduced to the interpolation uncertainty and calibration uncertainty.

NOTE 7 The impedance of the 150 Ω to 50 Ω adapter can also be measured directly, for example, using a network analyzer or taken from the calibration certificate. In this case, the deviation from 100 Ω and the calibration uncertainty can be inserted in the Tables G.1 and G.2. The sensitivity coefficient c_i for this contribution is changed accordingly.

SETUP – is a combination of uncertainties introduced by the setup for level setting, i.e., calibration fixture, the connection between the CDN and the CDN adapter and the reference ground plane impacts, for example, contact to the reference ground plane. This contribution can be derived from reproducibility tests with changing conditions or estimated on the basis of experience as shown in the example.

LM_{c} – is the uncertainty of the level meter, i.e., the voltmeter or power meter used for measurement of the level at the output of the CDN. It is taken from the manufacturer's specifications in the example but could be determined from other sources as well.

SW_{c} – is the uncertainty derived from the discrete level step size of the signal generator and software windows for level setting during the level setting process. The software window can usually be adjusted by the test lab.

LMC_{c} – is the uncertainty of the level meter, i.e., the voltmeter or power meter used for the control loop for the signal generator and amplifier output level. It can be taken from the manufacturer's specifications or determined from other sources.

TG_{c} – is the uncertainty of the test generator including frequency generator, power amplifier and attenuator. It can be taken from the manufacturer's specifications or determined from other sources.

NOTE 8 The uncertainty of the individual components of the test generator (for example, signal generator, power amplifier stability, power amplifier rapid gain variation, attenuator, etc.) can be assessed separately, especially where a control loop is not used in the test setup.

MT_{c} – is a combination of the mismatches between the amplifier, the attenuator and the CDN.

ML – is the mismatch between the CDN and the level meter.

CAL– is the expanded uncertainty of the test voltage level in the level setting process.

LMC_{t} – is the uncertainty of the level meter, for example, the voltmeter, used at the output of the power amplifier taken from the manufacturer's specification. Alternatively, a power meter can be used in order to obtain a lower uncertainty.

TG_{t} – is the uncertainty of the test generator including the frequency generator, the power amplifier and the attenuator. It can be taken from the manufacturer's specifications or determined from other sources.

NOTE 9 The uncertainty of the individual components of the test generator (for example, signal generator, power amplifier stability, power amplifier rapid gain variation, attenuator, etc.) can be assessed separately, especially where a control loop is not used in the test setup.

MT_{t} – is a combination of the mismatches between the amplifier, the attenuator and the CDN. This contribution can be neglected if the same setup, i.e., the attenuator and cables, is used for level setting and test.

SW_{t} – is the uncertainty derived from the discrete level step size of the signal generator and software windows for level setting during the test process. The software window can usually be adjusted by the test laboratory.

Model function for EM clamp voltage level setting process (all quantities in logarithmic units):

$$U_0 = U_{\mathrm{LMc}} + 15{,}6\ \mathrm{dB} + \delta LM_{\mathrm{c}} + \delta RCAL + \delta SETUP + \delta SW_{\mathrm{c}} + \delta ML$$

Explanation of contributions

U_{LMc} voltage indication U_{mr} from the power meter directly in or converted to dB(μV)

NOTE 10 The other symbols are included in the explanation of terms below.

Model function for EM clamp test process (all quantities in logarithmic units):

$$U_0 = U_{\mathrm{x}} + 20\log(6/5) + \delta LMC_{\mathrm{t}} + \delta CAL + \delta SW_{\mathrm{t}} + \delta AETERM$$

$$U_x = U_{LMc} + 20\log (5)$$

NOTE 11 The symbols are included in the explanation of terms below.

Table G.3 – EM clamp level setting process

Symbol	Uncertainty Source X_i	$U(x_i)$	Unit	Distribution	Divisor	$u(x_i)$	Unit	c_i	$u_i(y)$	Unit	$u_i(y)^2$
$\delta RCAL$	150 Ω - 50 Ω adapter, deviation	0,3	dB	rectangular	1,73	0,17	dB	1	0,17	dB	0,03
	150 Ω - 50 Ω adapter, calibration	0,2	dB	normal k=2	2	0,10	dB	1	0,10	dB	0,01
$\delta SETUP$	Setup for level setting	0,35	dB	normal k=1	1	0,35	dB	1	0,35	dB	0,12
δLM_c	Level meter	0,5	dB	rectangular	1,73	0,29	dB	1	0,29	dB	0,08
δSW_c	SW levelling precision	0,3	dB	rectangular	1,73	0,17	dB	1	0,17	dB	0,03
δLMC_c (8,9)	Level meter in control loop	0	dB	rectangular	1,73	0,00	dB	1	0,00	dB	0,00
δTG_c (8,9)	Test generator	0	dB	rectangular	1,73	0,00	dB	1	0,00	dB	0,00
δMT_c (10)	Mismatch test generator/clamp	0	dB	U-shaped	1,41	0,00	dB	1	0,00	dB	0,00
δML	Mismatch level meter/clamp	0,5	dB	U-shaped	1,41	0,35	dB	1	0,35	dB	0,13
				$\Sigma u_i(y)^2$							0,40
				Combined uncertainty $u(y) = \sqrt{\Sigma u_i(y)^2}$							0,63
				Expanded uncertainty (CAL) $U = u(y) \times k$, k = 2							**1,27** dB

Table G.4 – EM clamp test process

Symbol	Uncertainty Source X_i	$U(x_i)$	Unit	Distribution	Divisor	$u(x_i)$	Unit	c_i	$u_i(y)$	Unit	$u_i(y)^2$
δCAL	Calibration	1,27	dB	normal k=2	2	0,63	dB	1	0,63	dB	0,40
δLMC_t(8,9)	Level meter in control loop	0,3	dB	rectangular	1,73	0,17	dB	1	0,17	dB	0,03
δTG_t (8,9)	Test generator	0	dB	rectangular	1,73	0,00	dB	1	0,00	dB	0,00
δMT_t (10)	Mismatch test generator/clamp	0	dB	U-shaped	1,41	0,00	dB	1	0,00	dB	0,00
δSW_t	SW levelling precision	0,3	dB	rectangular	1,73	0,17	dB	1	0,17	dB	0,03
$\delta AETERM$	AE termination	2,5	dB	rectangular	1,73	1,45	dB	1	1,45	dB	2,09
				$\Sigma u_i(y)^2$							2,55
				Combined uncertainty $u(y) = \sqrt{\Sigma u_i(y)^2}$							1,60
				Expanded uncertainty $U=u(y) \times k$, k = 2							**3,19** dB

NOTE 12 Either LMC or the test generator (TG) contributions enter into Tables G.3 and G.4 for level setting and/or test, depending on whether a control loop for the signal generator and amplifier output level is used or not. In this example, the test generator does not contribute to the uncertainty budget because it is part of the control loop. The contribution from the control loop is established by the level meter (see also Note 13). However, the test generator is included in Tables G.3 and G.4 to remind the test labs that they can consider this item depending on the labs' particular test setup. In this case a more detailed analysis of the TG contribution is needed. See explanation of terms.

NOTE 13 If the same equipment is used for level setting and testing, then only the contributions of repeatability and linearity enter into Table 4 for the test process. The contribution for the level setting can be neglected.

NOTE 14 If the same circuit is used for level adjustment and testing, then these contributions do not enter into Tables G.3 and G.4.

Explanation of terms:

Several items apply in principle as in the previous example (CDN method). These items are not explained here; the previous example should be consulted.

NOTE 15 Uncertainty related to 7.4.1, where a monitoring probe is used and current limitation is applied, is not considered in Annex G. In this case, the value of U_0 is no longer the same as that determined in the level setting procedure, but it is reduced to an unknown value. Therefore, no uncertainty can be assigned to U_0 in this case.

AETERM – is the effect of the AE impedance, which should be maintained at 150 Ω. Deviations from this value have significant influence especially in the lower frequency range (below 10 MHz), where the directivity of the EM clamp is weak. In this case, the contribution of *AETERM* to the uncertainty budget may be larger than the numerical value used in the examples here. A lower value may be used for frequencies above 10 MHz.

This contribution can be investigated experimentally using a network analyzer. The coupling factor of the clamp can be measured for a 150 Ω AE impedance and compared to different AE impedances.

Model function for current clamp voltage level setting process (all quantities in logarithmic units):

$$U_0 = U_{\mathrm{LMc}} + 15{,}6\ \mathrm{dB} + \delta LM_{\mathrm{c}} + \delta RCAL + \delta JIG + \delta SW_{\mathrm{c}} + \delta ML$$

Explanation of contributions:

U_{LMc} voltage indication U_{mr} from the power meter directly in or converted to dB(μV)

NOTE 16 The other symbols are included in the explanation of terms below.

Model function for current clamp test process (all quantities in logarithmic units):

$$U_0 = U_{\mathrm{x}} + 20\log(6/5) + \delta LMC_{\mathrm{t}} + \delta CAL + \delta SW_{\mathrm{t}} + \delta AETERM$$

$$U_{\mathrm{x}} = U_{\mathrm{LMc}} + 20\log(5)$$

NOTE 17 The symbols are included in the explanation of terms below.

Table G.5 – Current clamp level setting process

Symbol	Uncertainty Source X_i	$U(x_i)$	Unit	Distribution	Divisor	$u(x_i)$	Unit	c_i	$u_i(y)$	Unit	$u_i(y)^2$
$\delta RCAL$	150 Ω - 50 Ω adapter, deviation	0,3	dB	rectangular	1,73	0,17	dB	1	0,17	dB	0,03
	150 Ω - 50 Ω adapter, calibration	0,2	dB	normal k=2	2	0,10	dB	1	0,10	dB	0,01
δJIG	Test jig	0,5	dB	normal k=1	1	0,50	dB	1	0,50	dB	0,25
δLM_{c}	Level meter	0,5	dB	rectangular	1,73	0,29	dB	1	0,29	dB	0,08
δSW_{c}	SW levelling precision	0,3	dB	rectangular	1,73	0,17	dB	1	0,17	dB	0,03
δLMC_{c} (12,13)	Level meter in control loop	0	dB	rectangular	1,73	0,00	dB	1	0,00	dB	0,00
δTG_{c} (12,13)	Test generator	0	dB	rectangular	1,73	0,00	dB	1	0,00	dB	0,00
δMT_{c} (14)	Mismatch test generator/clamp	0	dB	U-shaped	1,41	0,00	dB	1	0,00	dB	0,00
δML	Mismatch level meter/clamp	0,5	dB	U-shaped	1,41	0,35	dB	1	0,35	dB	0,13
				$\Sigma u_i(y)^2$							0,53
				Combined uncertainty $u(y) = \sqrt{\Sigma u_i(y)^2}$							0,73
				Expanded Uncertainty *(CAL)* $U = u(y) \times k$, k = 2							**1,46** dB

Table G.6 – Current clamp test process

Symbol	Uncertainty Source X_i	$U(x_i)$	Unit	Distribution	Divisor	$u(x_i)$	Unit	c_i	$u_i(y)$	Unit	$u_i(y)^2$
δCAL	Calibration	1,46	dB	normal k=2	2	0,73	dB	1	0,73	dB	0,53
δLMC_t (12,13)	Level meter in control loop	0,3	dB	rectangular	1,73	0,17	dB	1	0,17	dB	0,03
δTG_t (12,13)	Test generator	0	dB	rectangular	1,73	0,00	dB	1	0,00	dB	0,00
δMT_t (14)	Mismatch Test generator/clamp	0	dB	U-shaped	1,41	0,00	dB	1	0,00	dB	0,00
δSW_t	SW levelling precision	0,3	dB	rectangular	1,73	0,17	dB	1	0,17	dB	0,03
$\delta AETERM$	AE termination	2,5	dB	rectangular	1,73	1,45	dB	1	1,45	dB	2,09
				$\Sigma u_i(y)^2$							2,68
				Combined uncertainty $u(y) = \sqrt{\Sigma u_i(y)^2}$							1,64
				Expanded uncertainty $U = u(y) \times k$, k = 2							**3,27 dB**

NOTE 18 Either LMC or the test generator (TG) contributions enter into Tables G.5 and G.6 for level setting and/or test, depending on whether a control loop for the signal generator and amplifier output level is used or not. In this example, the test generator does not contribute to the uncertainty budget because it is part of the control loop. The contribution from the control loop is established by the level meter (see also Note 19). However, the test generator is included in Tables G.5 and G.6 to remind the test labs that they can consider this item depending on the labs' particular test setup. In this case, a more detailed analysis of the TG contribution is needed. See explanation of terms.

NOTE 19 If the same equipment is used for level setting and testing, then only the contributions of repeatability and linearity enter into Table G.6 for the test process. The contribution for the level setting can be neglected.

NOTE 20 If the same circuit is used for level setting and testing, then these contributions do not enter into Tables G.5 and G.6.

Explanation of terms:

Several items apply in principle as in the previous examples (for example, CDN method). These items are not explained here; one of the previous examples should be consulted.

NOTE 21 Uncertainty related to 7.4.1 where a monitoring probe is used and current limitation is applied is not considered in Annex G. In this case the value of U_0 is no longer the same as that determined in the level setting procedure, but it is reduced to an unknown value. Therefore, no uncertainty can be assigned to U_0 in this case.

JIG – is a combination of uncertainties due to the test jig. This contribution can be derived from reproducibility tests with changing conditions or estimated based on experience as done in the example.

Model function for direct injection voltage level setting process (all quantities in logarithmic units):

$$U_0 = U_{\mathrm{LMc}} + 15{,}6\ \mathrm{dB} + \delta LM_{\mathrm{c}} + \delta RCAL + \delta SETUP + \delta SW_{\mathrm{c}} + \delta ML$$

Explanation of contributions:

U_{LMc} voltage indication U_{mr} from the power meter directly in or converted to dB(μV)

NOTE 22 The other symbols are included in the explanation of terms below.

Model function for direct injection test process (all quantities in logarithmic units):

$$U_0 = U_{\mathrm{x}} + 20 \log (6/5) + \delta LMC_{\mathrm{t}} + \delta CAL + \delta SW_{\mathrm{t}} + \delta DD$$

$$U_{\mathrm{x}} = U_{\mathrm{LMc}} + 20 \log (5)$$

NOTE 23 The symbols are included in the explanation of terms below.

Table G.7 – Direct injection level setting process

Symbol	Uncertainty Source X_i	$U(x_i)$	Unit	Distribution	Divisor	$u(x_i)$	Unit	c_i	$u_i(y)$	Unit	$u_i(y)^2$
$\delta RCAL$	150 Ω - 50 Ω adapter, deviation	0,3	dB	rectangular	1,73	0,17	dB	1	0,17	dB	0,03
	150 Ω - 50 Ω adapter, calibration	0,2	dB	normal k=2	2	0,10	dB	1	0,10	dB	0,01
$\delta SETUP$	Set-up for level setting	0,5	dB	normal k=1	1	0,50	dB	1	0,50	dB	0,25
δLM_c	Level meter	0,5	dB	rectangular	1,73	0,29	dB	1	0,29	dB	0,08
δSW_c	SW levelling precision	0,3	dB	rectangular	1,73	0,17	dB	1	0,17	dB	0,03
δLMC_c (16,17)	Level meter in control loop	0	dB	rectangular	1,73	0,00	dB	1	0,00	dB	0,00
δTG_c (16,17)	Test generator	0	dB	rectangular	1,73	0,00	dB	1	0,00	dB	0,00
δMT_c (18)	Mismatch test generator/CDN	0	dB	U-shaped	1,41	0,00	dB	1	0,00	dB	0,00
δML	Mismatch level meter/CDN	0,5	dB	U-shaped	1,41	0,35	dB	1	0,35	dB	0,13
				$\Sigma u_i(y)^2$							0,53
				Combined uncertainty $u(y) = \sqrt{\Sigma u_i(y)^2}$							0,73
				Expanded uncertainty (CAL) $U=u(y) \times k$, k = 2							**1,46** dB

Table G.8 – Direct injection test process

Symbol	Uncertainty Source X_i	$U(x_i)$	Unit	Distribution	Divisor	$u(x_i)$	Unit	c_i	$u_i(y)$	Unit	$u_i(y)^2$
δCAL	Calibration	1,46	dB	normal k=2	2	0,73	dB	1	0,73	dB	0,53
δLMC_t (16,17)	Level meter in control loop	0,3	dB	rectangular	1,73	0,17	dB	1	0,17	dB	0,03
δTG_t (16,17)	Test generator	0	dB	rectangular	1,73	0,00	dB	1	0,00	dB	0,00
δMT_t (18)	Mismatch test generator/clamp	0	dB	U-shaped	1,41	0,00	dB	1	0,00	dB	0,00
δSW_t	SW levelling precision	0,3	dB	rectangular	1,73	0,17	dB	1	0,17	dB	0,03
δDD	Decoupling devices	2,3	dB	rectangular	1,73	1,33	dB	1	1,33	dB	1,77
				$\Sigma u_i(y)^2$							2,36
				Combined uncertainty $u(y) = \sqrt{\Sigma u_i(y)^2}$							1,54
				Expanded uncertainty $U=u(y) \times k$, k = 2							**3,07** dB

NOTE 24 Either LMC or TG contributions enter into Tables G.7 and G.8 for level setting and/or test, depending on whether a control loop for the signal generator and amplifier output level is used or not. In this example, the test generator does not contribute to the uncertainty budget because it is part of the control loop. The contribution from the control loop is established by the level meter (see also Note 25). However, the test generator is included in Tables G.7 and G.8 to remind the test labs that they can consider this item depending on the labs' particular test setup. In this case a more detailed analysis of the TG contribution is needed. See explanation of terms.

NOTE 25 If the same equipment is used for level setting and testing, then only the contributions of repeatability and linearity enter into Table G.8 for the test process. The contribution for the level setting can be neglected.

NOTE 26 If the same circuit is used for level setting and testing, then these contributions do not enter into the Tables G.7 and G.8.

Explanation of terms:

Several items apply in principle as in the previous examples (for example, CDN method). These items are not explained here; one of the previous examples should be consulted.

DD – is a combined uncertainty of the decoupling devices and the AE termination. Good decoupling gives less effect due to the AE termination, poor decoupling gives a strong effect. This contribution can be calculated from the impedance of the decoupling element.

G.4 Expression of the calculated measurement uncertainty and its application

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

The voltage test level shall be reported in terms of the best estimate of the voltage and its expanded uncertainty. The best estimate shall be the average of the voltage U_0 over the relevant frequency range.

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

In logarithmic units:

U_0 = 129,5 dB(μV) ± 1,36 dB (example for CDN injection)

This corresponds in linear scale to:

U_0 = 3 V + (17 %) – (14,5 %)

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. It is also not intended to be used in the assessment of the voltage tolerance requirement, as defined in 6.4.

G.5 Bibliography

[1] IEC/TR 61000-1-6:2012, *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,* *www.ukas.com*

[3] ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM: 1995)*

Annex H
(informative)

Measurement of AE impedance

H.1 General

Annex H gives information on how to measure the common mode impedance of a general AE as used together with an EUT. The details regarding the setup for EUT testing are described in the main body of the standard. If a dedicated AE unit is always used together with the EUT, it is also used during the testing. In the latter case, the AE is viewed as being a part of the EUT, and it is exempt from the impedance requirements below.

Annex H shows examples on how the AE impedance is measured, and further provides guidance on how the AE common mode impedance can be approximated to the ideal impedance of 150 Ω.

H.2 Common mode impedance

H.2.1 Impedance requirements

In accordance with the test setups described in Clauses 6 and 7, the AE impedance should preferably meet the impedance requirements given in Table 3 (repeated in Table H.1 for convenience).

Table H.1 – Impedance requirements for the AE

	Frequency band	
Parameter	0,15 MHz to 24 MHz	24 MHz to 80 MHz
$\lvert Z_{ce} \rvert$	150 Ω ± 20 Ω	$150\ \Omega\ {}^{+60\Omega}_{-45\Omega}$
NOTE When testing in accordance with 7.7 the AE impedance is likely to be lower than that specified in the table. Please see the text in 7.7 regarding current monitoring during clamp injection for additional information		

H.2.2 Measurement setup using an impedance analyzer

The AE impedance is measured using the setup shown in Figure 8b) of the present standard. All wires of the AE cable are connected together to provide a low impedance at high frequencies (<< 150 Ω at > 150 kHz), and are connected to the impedance network analyzer. Note that the AE shall be functional and connected to the mains supply and other AE (if any) during the measurement. The AE may not be able to perform normal operation on the cable, where the impedance analyzer is connected.

NOTE Care needs to be taken that the AE and the impedance analyzer are not damaged by potential high voltages/currents when wires of the AE cable are connected together. The connections can be made via capacitors of at least 20 nF.

H.2.3 Measurement using level calibration setup

The AE impedance can also be measured using the level setting setup shown in Figure 9c). In this case, the AE is connected in parallel with a suitable CDN and the 100 Ω calibration resistance in series with 50 Ω voltmeter impedance.

See H.2.2 regarding the practical setup and AE operation during the measurements.

The impedance of the AE is derived from the change of the voltage division ratio from the test level U_0 due to the loading from the AE. The voltage limits as read from the 50 Ω voltmeter are given in Table H.2. See Figure H.1.

Table H.2 – Derived voltage division ratios for AE impedance measurements

	Frequency band	
Parameter	0,15 MHz to 24 MHz	24 MHz to 80 MHz
$\|Z_{ce}\|$	150 Ω ± 20 Ω	$150\ \Omega\ ^{+60\Omega}_{-45\Omega}$
Ideal ($\|Z_{ce}\|$ = 150 Ω)	0,111 × U_0 (-19,1 dB)	0,111 × U_0 (-19,1 dB)
Upper voltage limit	0,116 × U_0 (-18,7 dB)	0,123 × U_0 (-18,2 dB)
Lower voltage limit	0,106 × U_0 (-19,5 dB)	0,097 × U_0 (-20,2 dB)
NOTE The nominal values in Table H.2 do not consider measurement uncertainty and all impedances are assumed to be pure resistances. They are a guidance, not a requirement.		

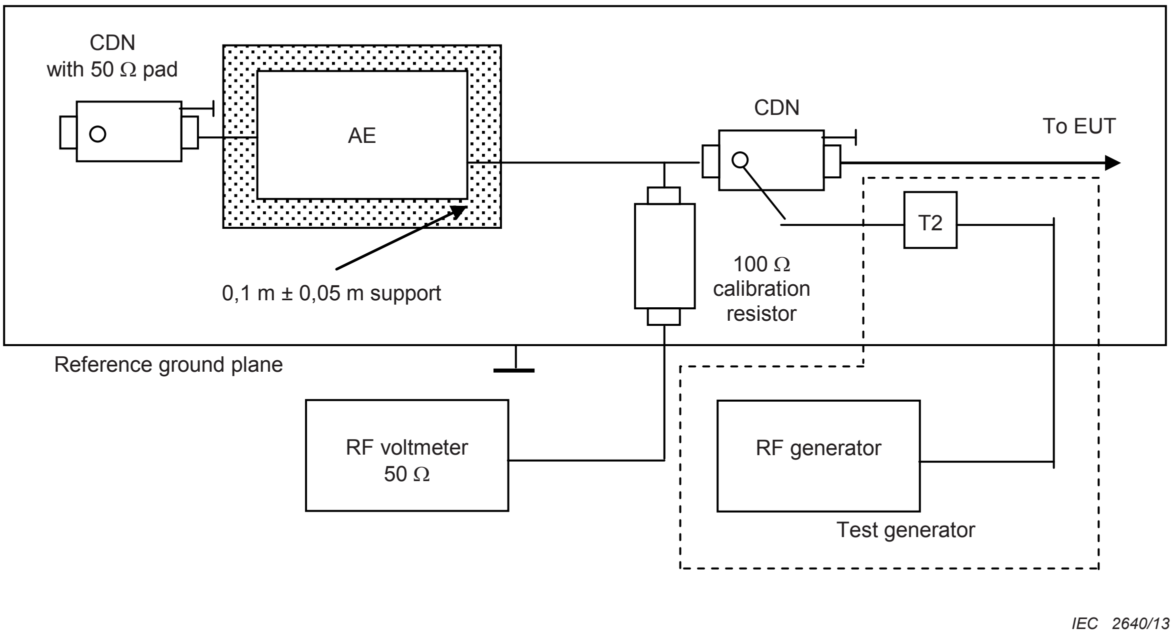


Figure H.1 – Impedance measurement using a voltmeter

H.2.4 Measurement using current probe setup

The AE impedance can also be measured using the current monitoring probe mentioned in 7.7. In this case, the AE is connected in parallel with a suitable CDN and the current flowing from the injection CDN is monitored and compared with the current expected from an ideal 150 Ω AE impedance.

The AE impedance is measured using the setup shown in Figure H.2. Note that the AE shall be functional and connected to the mains supply and other AE (if any) during the measurement. The AE may not be able to perform normal operation on the signal cable, as the CDN may affect the functional signal transmission between AE and EUT.

The impedance of the AE is derived from the change of the voltage division ratio from the test level U_0 due to the loading from the AE. The voltage limits as read from the 50 Ω voltmeter are given in Table H.3. Note that the figures are given for an ideal current probe having a transducer factor of 0 dB(V/A). If the probe transducer factor differs from 0 dB(V/A), the voltage reading shall be corrected for the actual transducer factor.

Table H.3 – Derived voltage ratios for AE impedance measurements

	Frequency band	
Parameter	0,15 MHz to 24 MHz	24 MHz to 80 MHz
$\|Z_{ce}\|$	150 Ω ± 20 Ω	$150\ \Omega\ ^{+60\Omega}_{-45\Omega}$
Ideal ($\|Z_{ce}\|$ = 150 Ω) (assuming 0 dB probe transducer factor)	0,003 333 × U_0 (-49,5 dB)	0,003 333 × U_0 (-49,5 dB)
Upper current limit (assuming 0 dB probe transducer factor)	0,003 571 × U_0 (-48,9 dB)	0,003 922 × U_0 (-48,1 dB)
Lower current limit (assuming 0 dB probe transducer factor)	0,003 125 × U_0 (-50,1 dB)	0,002 778 × U_0 (-51,1 dB)
NOTE The nominal values in Table H.3 do not consider measurement uncertainty and all impedances are assumed to be pure resistances. They are a guidance, not a requirement.		

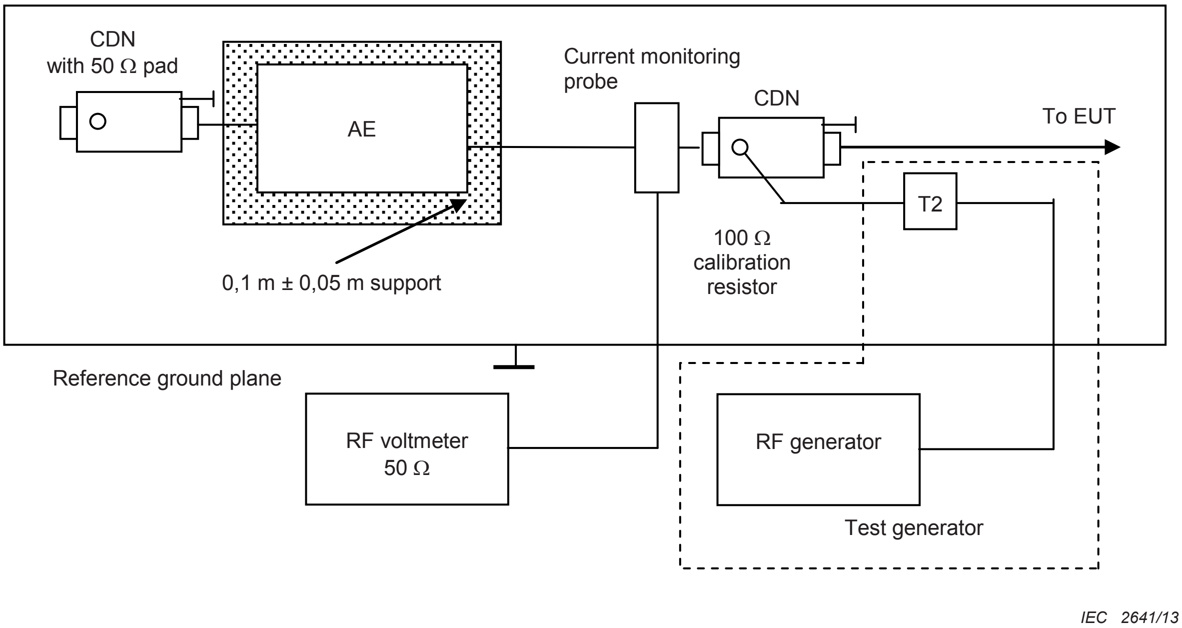


Figure H.2 – Impedance measurement using a current probe

H.3 Guidance on providing an ideal AE impedance

The goal of using a general AE, and in that case to achieve an ideal AE common mode impedance of 150 Ω, is to get reproducibility of the EUT testing.

When no CDN is applicable, then the AE should have a 150 Ω common mode impedance in order to obtain reproducible and correct results. This may be achieved, when the AE cables connected to the EUT have the following properties:

- either screened cable, the screen being connected to the metal chassis of the AE (or to its PCB ground plane);

- or non screened cable, but with some wires connected or having high capacitive coupling to the chassis or to the PCB ground plane.

The following suggestions are made for establishing the 150 Ω impedance using an AE having a metal chassis:

- connect the chassis of the AE to the reference ground plane via 150 Ω;
- use a low capacitance (< 100 pF) mains isolation transformer to supply the AE with power. The protective earth lead shall not be connected directly to the earth. For safety reasons a RF choke > 280 μH may be used. The same procedure applies if a d.c. supply (with galvanic isolation) is required or a battery supply is used;
- use as few external cables as possible;
- bundle AE cables close to the AE, and place the AE on 300 mm insulation, to reduce the coupling to the reference ground plane;
- use fibre optic signal converters for connection to other AE.

The following suggestions are made for establishing the 150 Ω impedance using an AE where the chassis is constructed from non conducting material:

- connect the shield of a screened cable to the reference ground plane via 150 Ω, or connect the PCB ground plane to the reference ground plane via 150 Ω;
- connect all wires of the AE cable together to a common point via capacitors, and connect that point to the reference ground plane via 150 Ω. Care should be taken that the AE is not damaged by potential high voltages/currents when wires of the AE cable are connected together. The connections can be made via capacitors of at least 20 nF.

If despite the above measures $Z_{AE} \leq 150\ \Omega$ cannot be approached, then try to reduce Z_{AE} by applying additional terminated CDNs to the AE if possible. See also the note in Table H.1.

Annex I
(informative)

Port to port injection

I.1 General

Experience shows that some specific EUTs may react in a more sensitive way to RF signals, when injection is done on one port and another identical port is terminated. Product committees may decide to use the method described in Annex I instead of the procedure of the main part of this standard.

Annex I gives information on the testing of ports, of which there are several identical ones on an EUT. Annex I introduces an injection method, where the RF signal is injected on one of these identical ports, and where the termination impedance is placed on another of these ports, instead of on the port chosen in accordance with 7.5.

The testing is performed in supplement to the test cases specified by 7.5, in order to evaluate the immunity of the EUT to RF signals induced on one port and flowing to another, identical port.

Examples of identical ports can be, but are not limited to: local area network (Ethernet etc), Pt100 temperature inputs, analog inputs/outputs, digital inputs/outputs, tachometer counter inputs.

I.2 Test setup for injection on identical ports

I.2.1 Selection of ports

Injection is performed between 2 identical port types. The 2 ports chosen for testing are two ports physically placed as close together as possible. Several groups of identical sets of ports may be present on the EUT, and in such case sets of each type of port are selected for testing.

NOTE A product committee can specify that testing is only required for specific cable or interface types, or that testing is required only for ports having cables exceeding a certain length. Annex I applies only to such ports that are chosen for testing.

I.2.2 Procedure for port to port injection

One port is chosen as the injection port. The other port is chosen as the termination port, where the 50 Ω termination is connected on the CDN. See Figure I.1.

In accordance with the main body of this standard, all other EUT ports are equipped with CDNs used as decoupling devices, where the 50 Ω termination is not connected, as specified in the main body of this standard.

If more types of ports are available on the test object, the testing is repeated on a set of these remaining port types also.

If the testing on the identical ports cannot be performed using CDNs, the general rules provided in Clause 7 are applied to the injection on the identical ports. Figure 12 provides guidance for the selection of injection method.

The testing on the ports and the treatment of the test results are performed just as described in the main body of this standard.

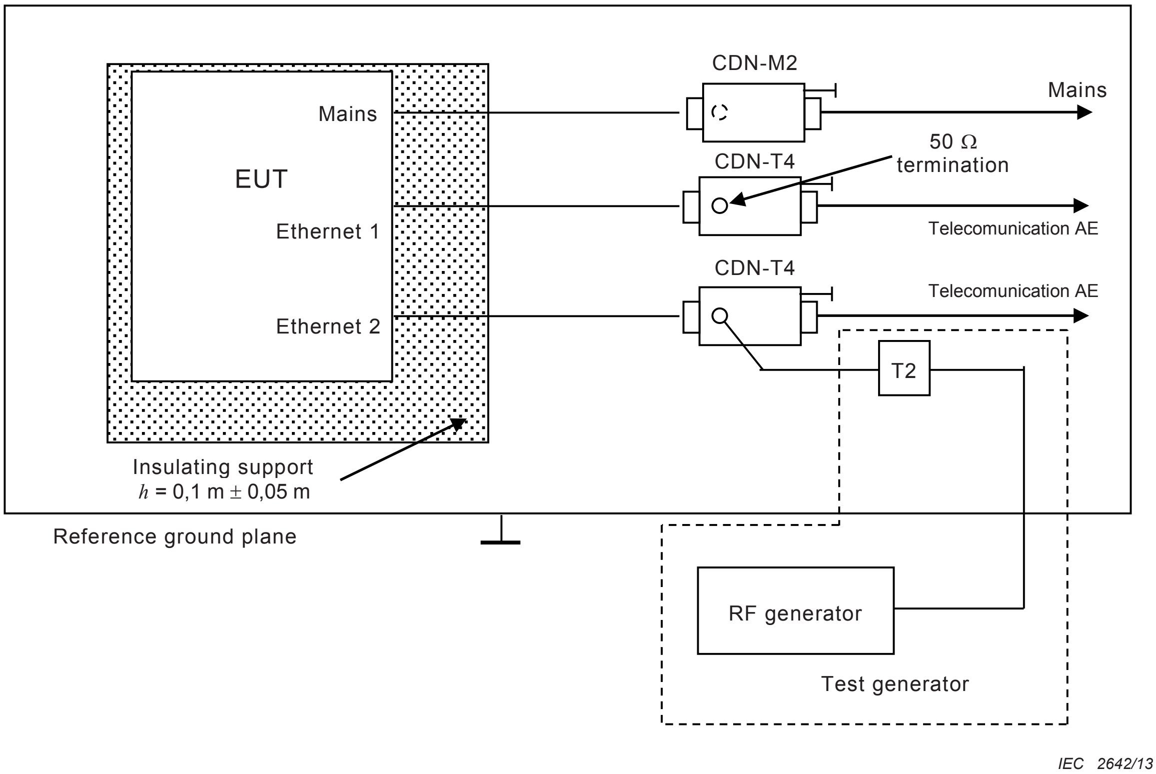


Figure I.1 – Example of setup, port to port injection

Annex J
(informative)

Amplifier compression and non-linearity

J.1 Objective of limiting amplifier distortion

Amplifier non-linearity can contribute to the uncertainty of the disturbance signal applied to the EUT. The goal is to keep amplifier non-linearity low enough that it does not dominate the uncertainty. Annex J is provided to assist test laboratories in understanding and limiting amplifier distortion.

J.2 Possible problems caused by harmonics and saturation

Operating an amplifier in saturation may result in the following scenarios:

a) The harmonics may contribute significantly to the measured values taken during test level calibration as the power meter will measure the total power of both the fundamental and its harmonics. For example, assume that the second and third harmonics are 15 dB below the fundamental frequency at the EM clamp input terminal and all other harmonics can be ignored. Further assume that the effective EM clamp factor is 5 dB lower at the frequency of the third harmonic than at the fundamental frequency. The voltage level of the fundamental frequency will be only 10 dB larger than the level of the third harmonic. If a total amplitude of 10 V is measured, the fundamental frequency may only contribute 9,5 V. This may be acceptable error, when it is smaller than the EM clamp calibration uncertainty. A frequency selective device such as a spectrum analyzer would not have this measurement error.

b) Harmonics may cause an EUT failure where the EUT is robust at the intended fundamental frequency but not robust at the harmonic frequency. The false failure would be recorded incorrectly and may lead to an incorrect redesign.

c) Harmonics may also affect the test result, even if they are very well suppressed in special situations. For example, if a 60 MHz receiver is tested, even very weak harmonics of a 20 MHz signal may overload the receiver input. A similar scenario may also occur if the signal generator output has non-harmonically related signals. Special low pass or notch filters could be used to protect sensitive EUTs.

d) Saturation may be present without measurable harmonics. This occurs if the amplifier has a low pass output filter which suppresses the harmonics and/or internal circuitry and combining technology may work to suppress the harmonics at the band edges. This situation may also lead to incorrect results.
   1) If this occurs during calibration, wrong calibration data will be derived as the assumption of linearity is used in the algorithm described in 6.4.2.
   2) During a test, this type of saturation will lead to an incorrect modulation index and harmonics of the modulation frequency (usually 1 kHz).

From the examples given above, it is clear that a numerical limit for amplifier distortion cannot be given, as the effect of distortion depends heavily on the type of EUT tested.

J.3 Limiting the harmonic content in the disturbance signal

The harmonic content of the disturbance signal can be limited with the use of an adjustable/tracking/tuneable low-pass filter at the output of the amplifier.

For all frequencies where harmonics are produced at the output of the amplifier, the harmonics in the amplifier output signal should be 15 dB less than the fundamental. This is considered adequate, with the exception of the scenario discussed in J.2, item c).

This would limit the disturbance voltage level error to 10 %. For example, a 10 V signal measured broadband would be caused by 9 V from the fundamental and 4,5 V from the harmonics. This may be a situation which is acceptable for calibration uncertainty.

For amplifiers containing a fixed low-pass filter in their output, the upper fundamental frequency concerned is about 1/3 of the maximum specified frequency of the amplifier.

For situations in which a low pass filter suppresses harmonics of a saturated amplifier, the 2 dB compression point of the amplifier should not be exceeded under any conditions (for example worst frequency, maximum disturbance voltage level with modulation). At the 2 dB compression point, the peak amplitude (in voltage) would be reduced by 20 %. This would cause a reduction of the 80 % amplitude modulation index down to 64 %, in other words, a 20 % reduction of a voltage rectified within the EUT.

J.4 Effect of linearity characteristic on the immunity test

J.4.1 General

Issues which affect the result of the immunity test are the linearity characteristic of the amplifier, harmonics and saturation of the amplifier.

It is assumed in the CDN and/or clamp level setting procedure described in 6.4.2 that the amplifier used shall generate a linear output in proportion to the input signal.

Amplifier linearity should be verified, thus assuring that the amplifier used generates the correct disturbance voltage level at the calibration voltage level or at lower calculated levels.

Amplifier linearity also has an effect on the amplitude modulation (AM) depth. Therefore, the AM depth should also be verified.

J.4.2 Evaluation of the amplifier linearity characteristic

J.4.2.1 Evaluation level range

The linearity characteristic of the amplifier should be evaluated over the range of the amplifier that is used for testing. This shall include the minimum level, including the increase from modulation, to the maximum level, including the increase from modulation.

The maximum level is referred to as the maximum level of the CW signal to be measured increased by 5,1 dB to allow for the contribution of modulation.

When calculating different test disturbance voltage levels, based on a single coupling device level adjustment process, the evaluation range of linearity shall be the minimum to maximum amplifier output used for the test. For example, if a 1 V test is performed using the data obtained from a 10 V level adjustment process, the evaluation range of linearity is defined as the power amplifier outputs required to achieve a 1,8 V minimum to 18 V (e.m.f.).

Different coupling devices may require different amplifier output power to achieve the required disturbance level and this shall also be considered. For example, a current probe may require more power than a CDN to achieve a disturbance test level of 10 V.

NOTE The coupling devices calibration process described in 6.4.2 states that the test laboratory must confirm 2 dB of tolerance when maximum output power of the amplifier is increased by 5,1 dB. This process is applicable only to confirm the amplifier saturation status, not to evaluate the linearity characteristic discussed in Annex J.

J.4.2.2 Evaluation process

It is important to use actual load and environmental conditions, such as the coupling device and the test system used for the EUT test, for the evaluation of amplifier linearity. The test arrangement is shown in Figure J.1.

Amplifier linearity shall be evaluated at least at the minimum, middle and maximum frequency range available for the amplifier. For example, an amplifier with a frequency range of 0,15 MHz to 80 MHz shall be evaluated at 0,15 MHz, 40 MHz and 80 MHz.

NOTE Evaluation of test data taken on the amplifier can be used to justify the selection of different frequency points.

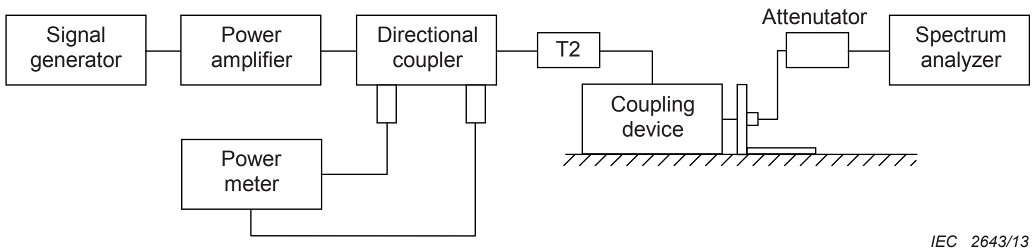


Figure J.1 – Amplifier linearity measurement setup

A linearity test shall be performed in accordance with the following procedure for each frequency as defined above.

1) Determine the signal generator setting necessary to generate both the minimum and maximum levels (see J.4.2.1) for the appropriate coupling device setup.
2) Set the signal generator to the minimum value determined in step 1), and record the output of the signal generator and the forward power of the amplifier.
3) Increase the setting of the signal generator by 1 dB and record the output of the signal generator and the forward power of the amplifier.
4) Repeat steps 2) and 3) until the maximum set value of the signal generator determined in step 1) is reached.
5) Repeat steps 1) to 4) for the remaining frequencies.

J.4.2.3 Linearity criteria

For the results obtained in J.4.2.2, the measured amplifier output shall increase by 1 dB (±1 dB) for each 1 dB increase in the signal generator output (that is, the tolerance of the power amplifier linearity is ±1 dB).

If the measured data obtained following the process defined in J.4.2.2 meets the ±1 dB specification, then the amplifier which the test laboratory uses satisfies the linearity criteria. If the data exceeds this linearity specification, then J.4.2.4 and J.4.2.5 shall also apply.

Figure J.2 shows an example defining the tolerance of +1 dB, -1 dB based on the amplifier output at a single frequency. The signal generator output in this example is varied between a minimum level of -30 dBm and a maximum level of 0 dBm. In this example the amplifier exceeds the tolerance.

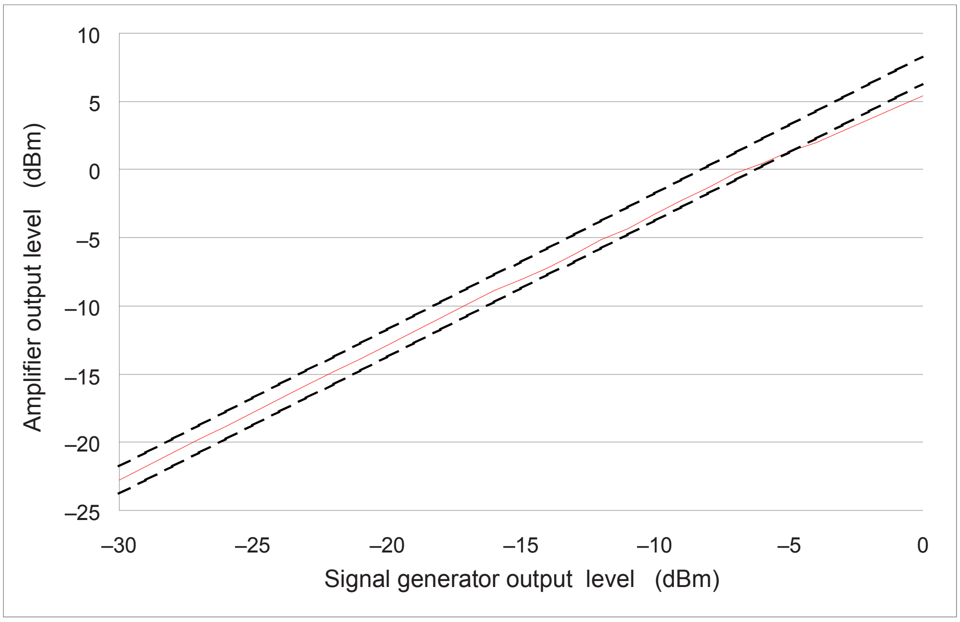


Figure J.2 – Linearity characteristic

J.4.2.4 Confirming AM modulation

When the evaluation result obtained according to J.4.2.3 exceeds ± 1 dB of the linearity criteria, the test laboratory needs to confirm AM modulation according to the following procedure. The test arrangement is shown in Figure J.3.

The test frequency shall be any failing frequencies established in J.4.2.3.

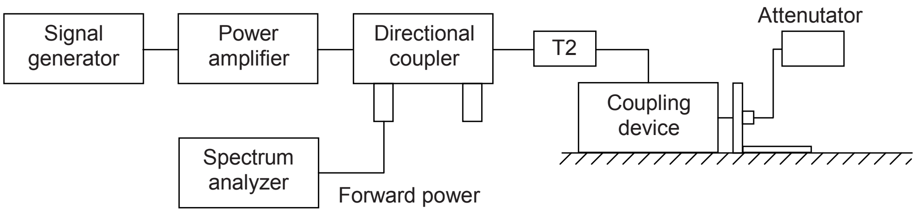


Figure J.3 – Measurement setup for modulation depth

1) Set the signal generator output to the maximum value determined in J.4.2.1 at the appropriate frequency and enable the AM modulation.
2) Set the center frequency of the spectrum analyzer shown in Figure J.3 to the signal output frequency defined in step 1).
3) Adjust the spectrum analyzer to show the carrier spectrum, the upper side band and lower side band spectrum on the screen. For example, resolution bandwidth = 100 Hz, span = 10 kHz.
4) Record the amplitude difference (L_{cs}) between the carrier level ($L_{carrier}$) and the upper or lower side band level ($L_{sideband}$). (Refer to Figure J.4.) $L_{cs} = L_{carrier} - L_{sideband}$

When L_{cs} is larger than 10 dB (m < 64 %) or L_{cs} is less than 6 dB, the results should be included in the test report.

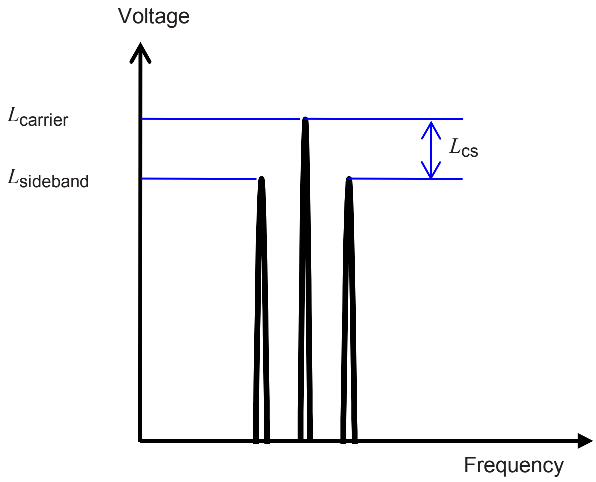


Figure J.4 – Spectrum of AM modulated signal

J.4.2.5 Immunity test when the amplifier linearity characteristic exceeds the criteria

When the evaluation result of J.4.2.3 does not fulfil the criteria for linearity by ± 1 dB, but fulfils the criteria of J.4.2.4, it is necessary to adjust the forward power during actual EUT test according to the following methods.

One method is to use a system with feedback, in which a power meter is used to monitor the output power from the test generator.

Another method is for systems without a feedback, where the forward power calibration needs to be done at each desired test level.

In both cases the requirements of 6.1 shall be met.

Bibliography

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

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

CISPR 16-1-4, *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 20, *Sound and television broadcast receivers and associated equipment – Immunity characteristics – Limits and methods of measurement*

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