



BSI Standards Publication

Electromagnetic compatibility (EMC)

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

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 It supersedes BS EN 61000-4-6:2009 which will be withdrawn on 27 November 2016.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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**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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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- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2016-11-27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.

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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.

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

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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_{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

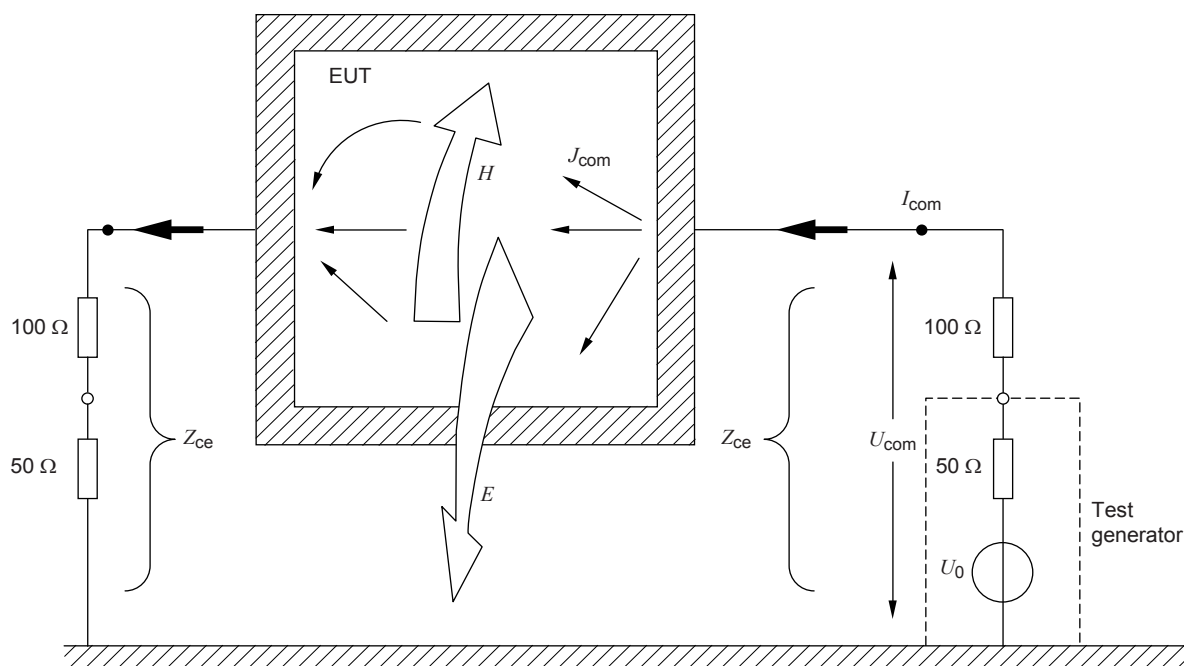
The source of disturbance covered by this part of IEC 61000 is basically an electromagnetic field, coming from intended RF transmitters, that may act on the whole length of cables connected to installed equipment. The dimensions of the disturbed equipment, mostly a sub-part of a larger system, are assumed 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 $150\ \Omega$ with respect to a reference ground plane. Where possible the EUT is tested by connecting it between two $150\ \Omega$ 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.

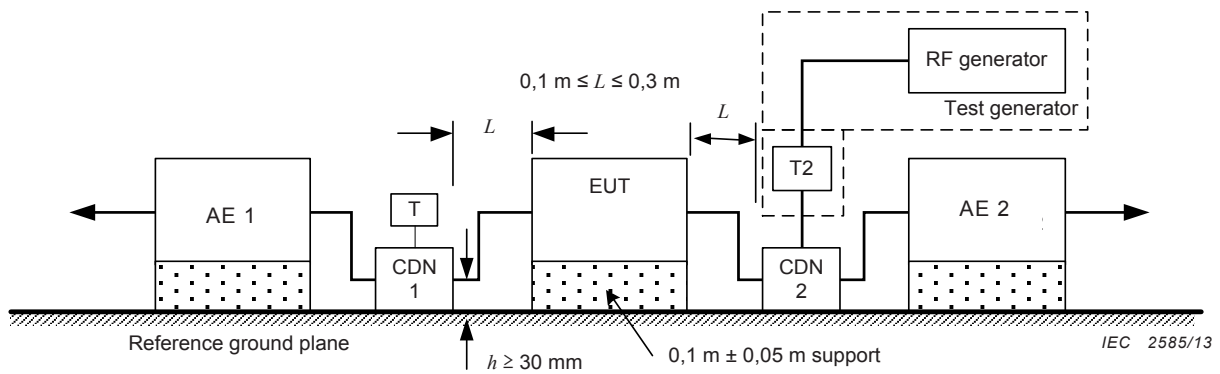
Coupling and decoupling devices are defined by their characteristics given in 6.2.1. Any coupling and decoupling device fulfilling these characteristics can be used. The CDNs in Annex D are only examples of commercially available networks.



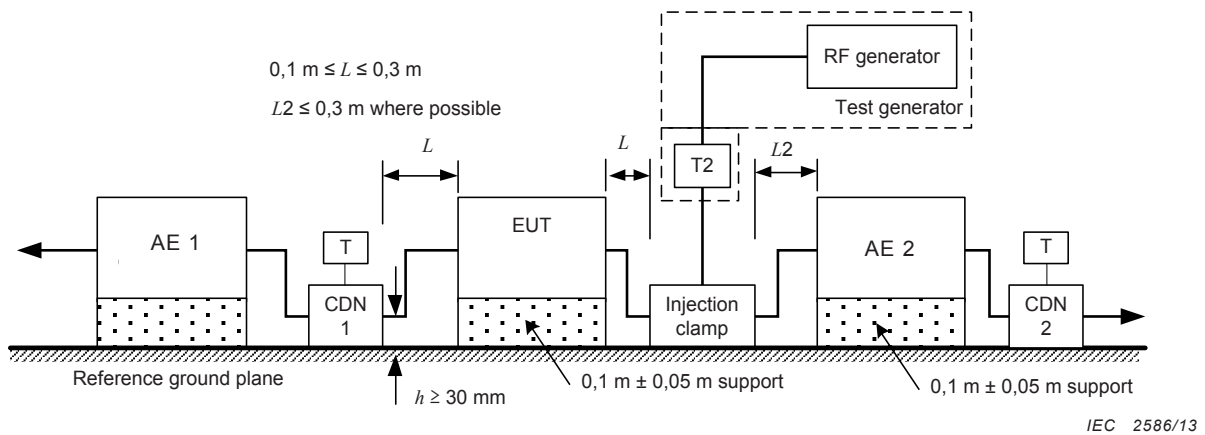
Z_{ce}	Common mode impedance of the CDN system, $Z_{ce^e} = 150 \, \Omega$
U_0	Test generator source voltage (e.m.f.)
U_{com}	Common mode voltage between EUT and reference plane
I_{com}	Common mode current through the EUT
J_{com}	Current density on conducting surface or current on other conductors of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

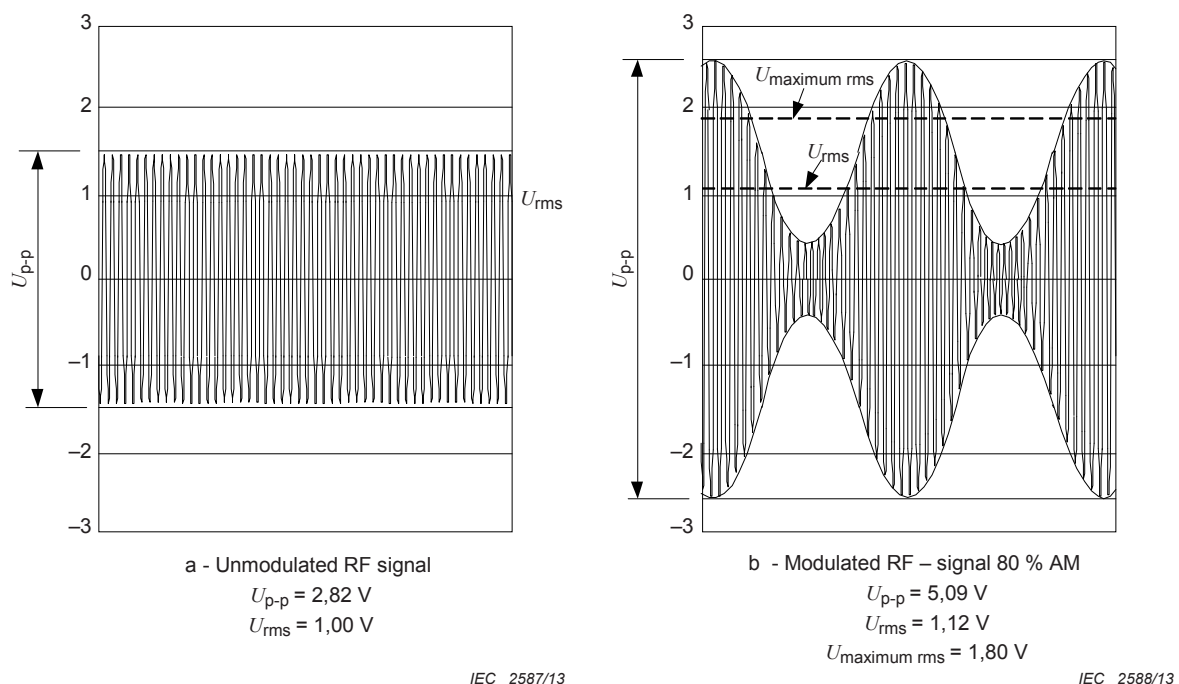


Figure 2 – Open circuit waveforms at the EUT port of a coupling device for test level 1

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):

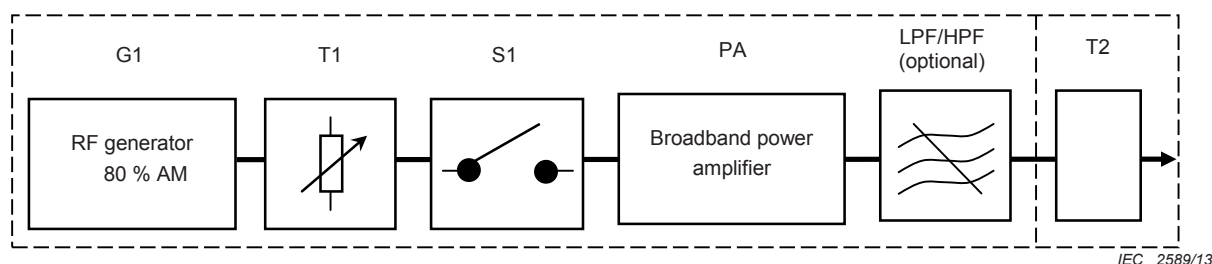
- RF generator(s), G1, capable of covering the frequency band of interest and of being amplitude modulated by a 1 kHz sine wave with a modulation depth of 80 %. They shall have manual control (e.g. frequency, amplitude, modulation index) or in the case of RF synthesizers, they shall be programmable with 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, $m = \left(\begin{matrix} +5 \\ 80 \\ -20 \end{matrix} \right) \% ,$ with $m = 100 \times \frac{U_{pp,max} - U_{pp,min}}{U_{pp,max} + U_{pp,min}}$ 1 kHz $\pm$ 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.

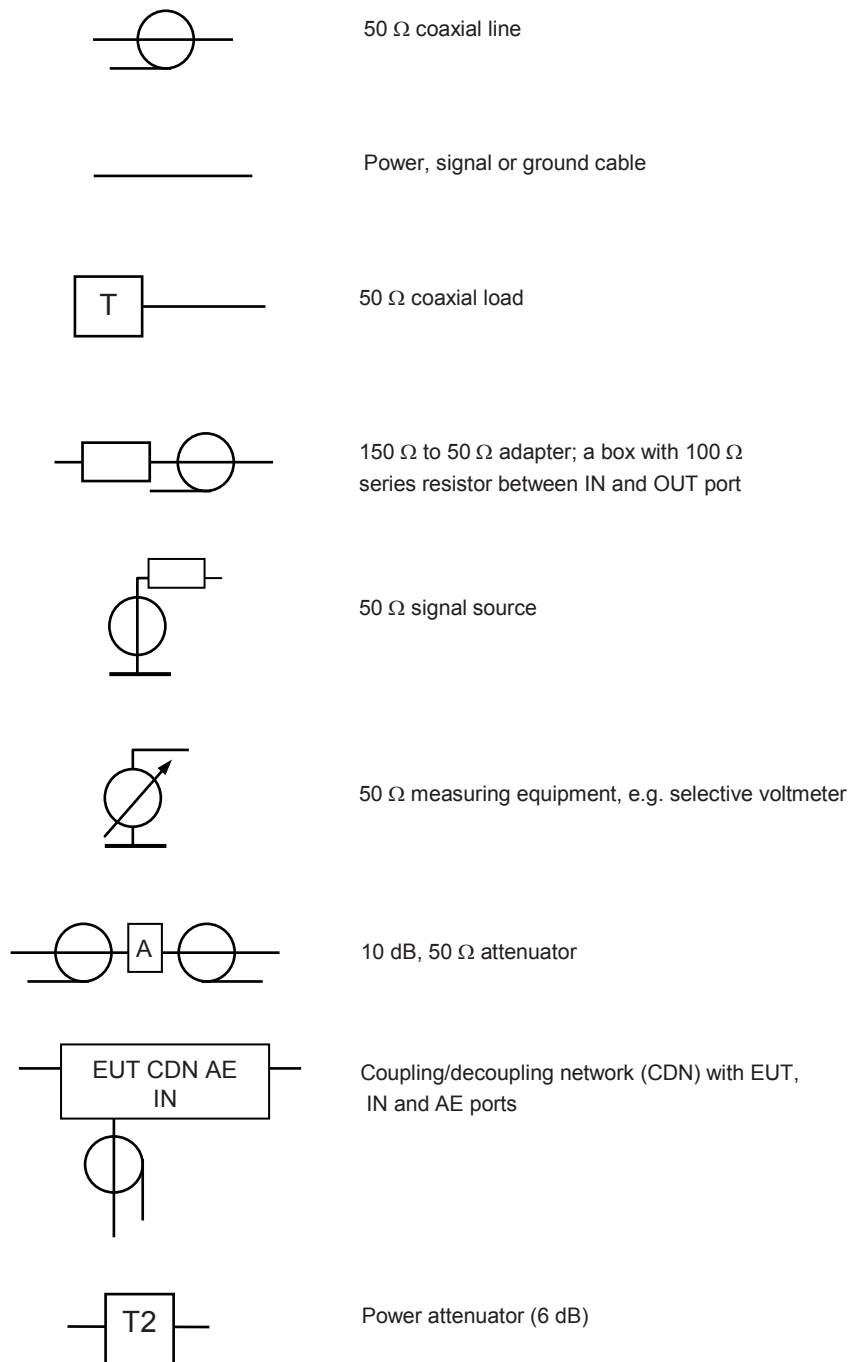
NOTE 1 A CDN may not be applicable if the internal signal attenuation has an unacceptable influence on the intended signal.

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

Parameter	Frequency band	
	0,15 MHz to 24 MHz	24 MHz to 80 MHz
$ Z_{ce} $	$150 \Omega \pm 20 \Omega$	$150 \Omega \begin{smallmatrix} +60\Omega \\ -45\Omega \end{smallmatrix}$

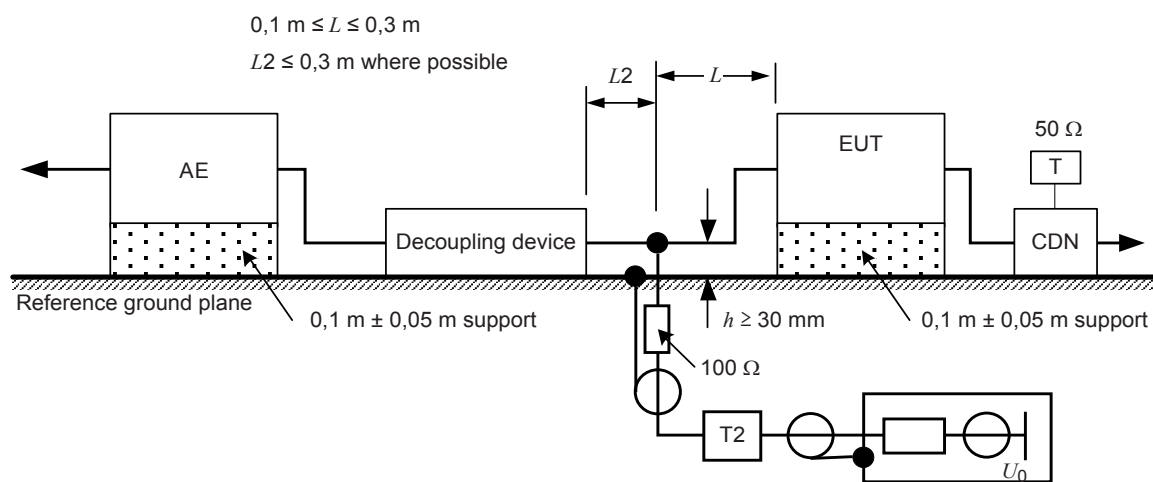
NOTE 2 Neither the argument of Z_{ce} nor the decoupling factor between the EUT port and the AE port are specified separately. These factors are embodied in the requirement that the tolerance of $|Z_{ce}|$ shall be met with the AE port open or short-circuited to the reference ground plane.

NOTE 3 Details for clamps are given in Annex A.



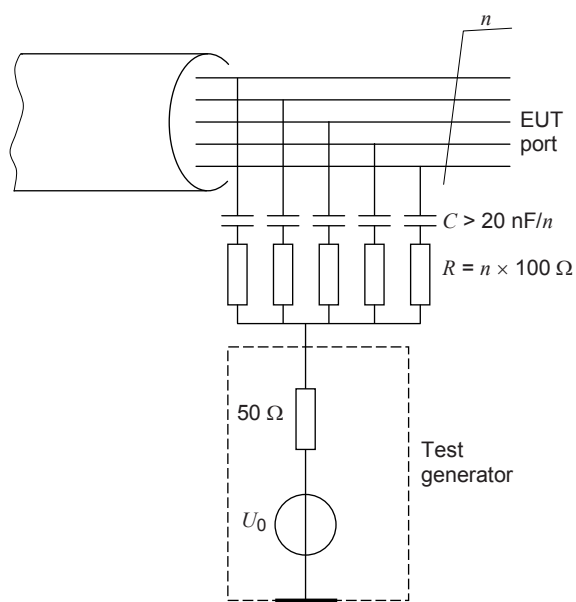
IEC 2590/13

a) List of symbols used for the indicated setup principles



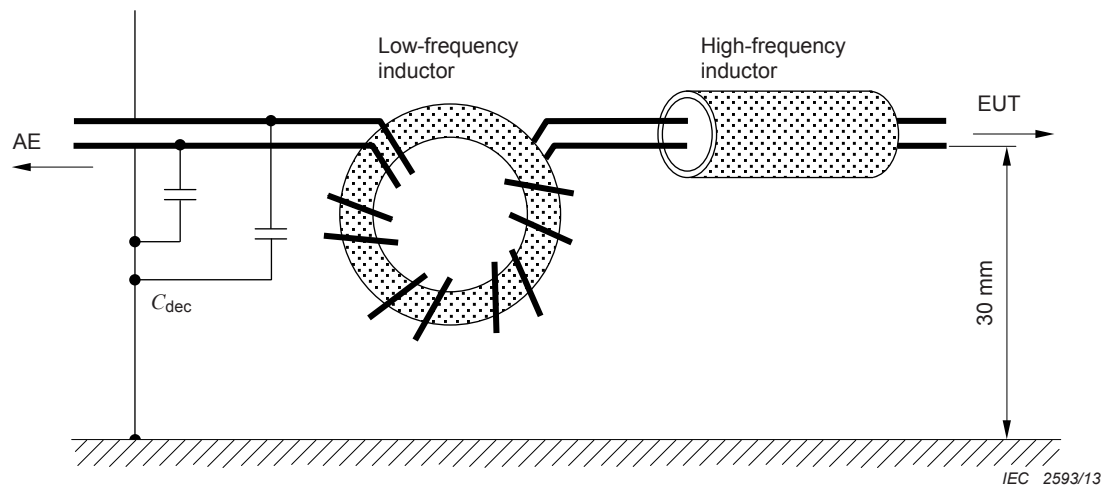
IEC 2591/13

b) Principle of direct injection to screened cables



IEC 2592/13

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



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

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

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

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 $\geq 16 \text{ A}$) 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

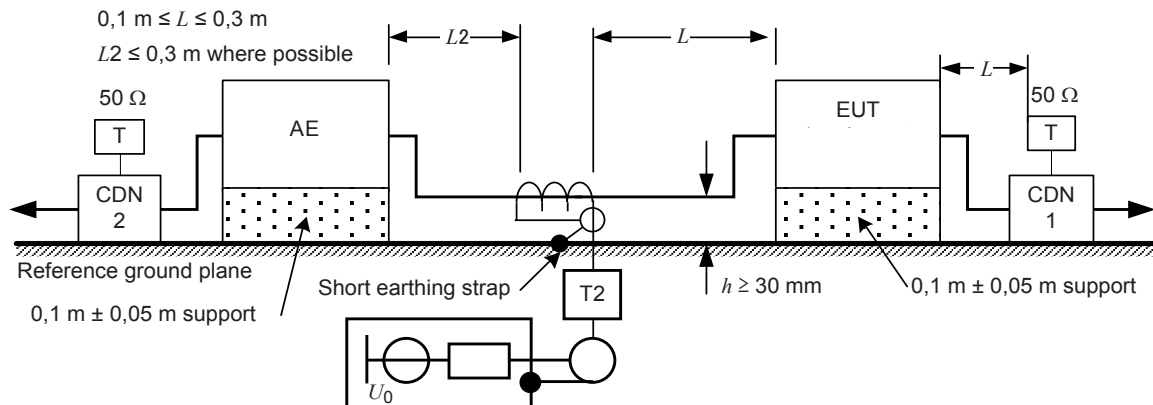
With clamp injection devices, the coupling and decoupling functions are separated. Coupling is provided by the clamp-on device while the common mode impedance and the decoupling functions are established at the AE. As such, the AE becomes part of the coupling and decoupling devices (see Figure 5). It 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.



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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 $50\ \Omega$ 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.

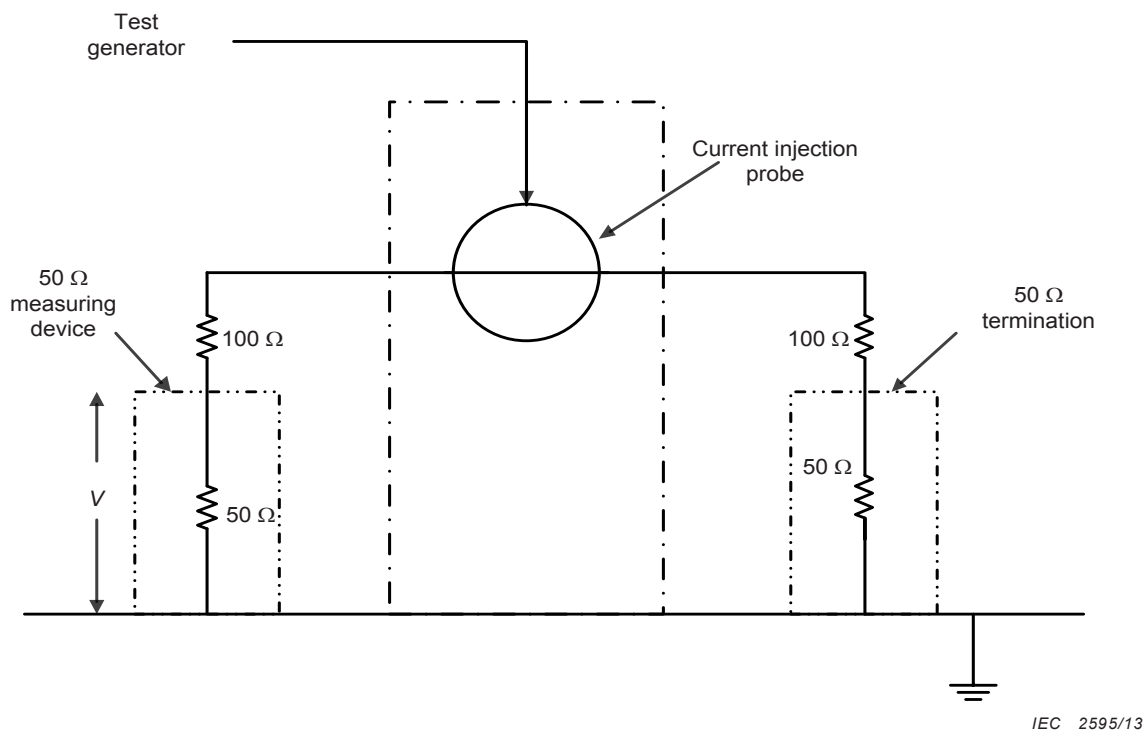
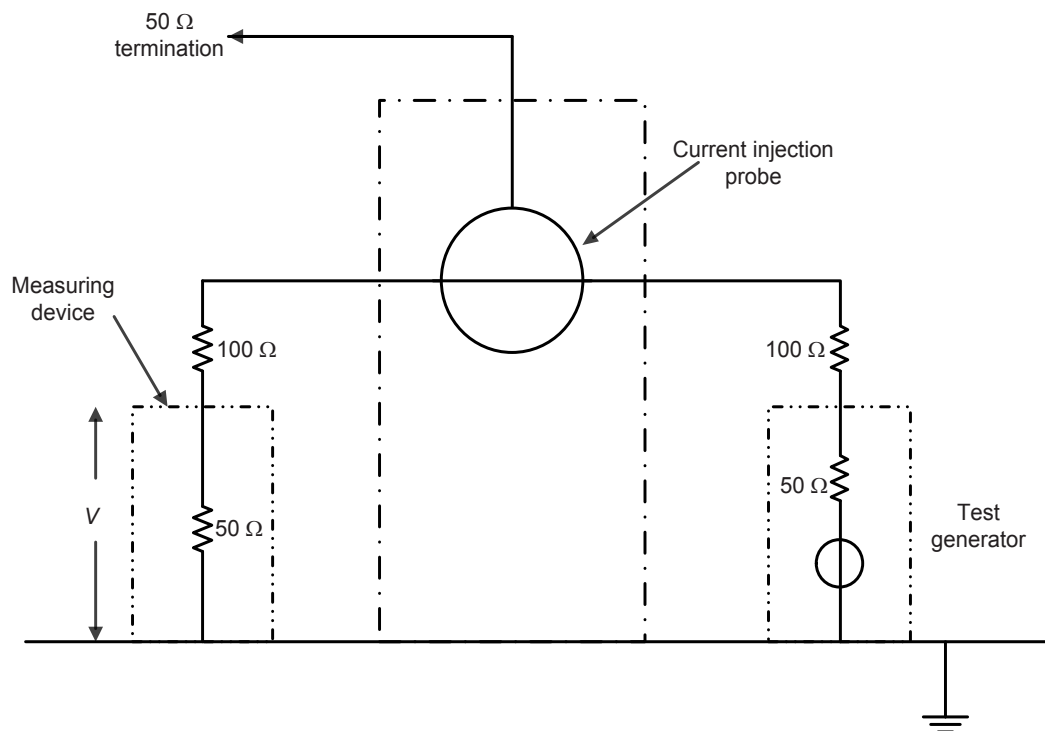


Figure 6 – Example of circuit for level setting setup in a $150\ \Omega$ test jig



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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, $\geq 260 \Omega$ up to 24 MHz and $\geq 150 \Omega$ 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.

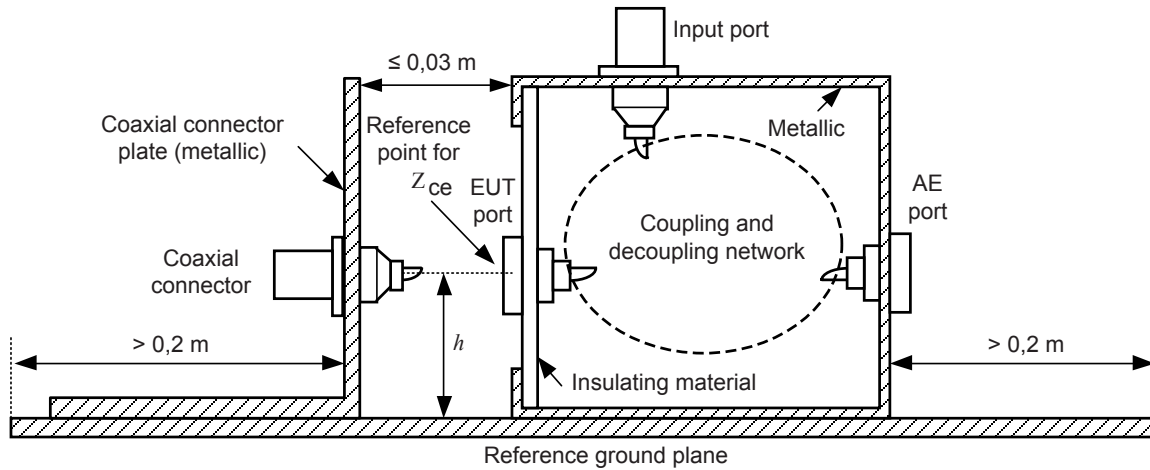
The CDNs shall meet the impedance requirements of Table 3 while the input port is terminated with a $50\ \Omega$ load and the AE port is sequentially loaded in common mode with a short-circuit and an open circuit condition as shown in Figure 8b). This requirement ensures sufficient attenuation and makes 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 $150\ \Omega$ to $50\ \Omega$ adapters

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

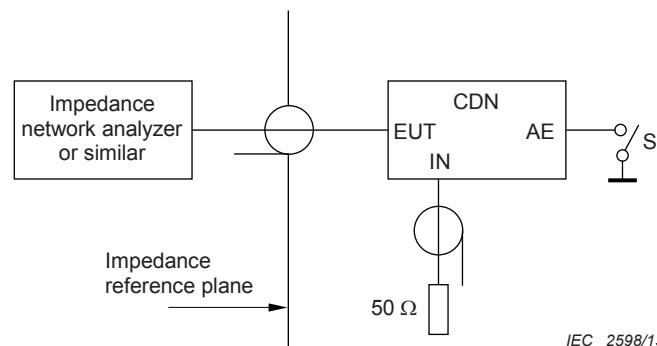
The adapters shall be placed on a reference ground plane, the size of which exceeds the projected geometry of this setup on all sides by at least 0,2 m. The insertion loss is measured according to the principle of Figure 8c). Its value shall be in the range of $(9,5 \pm 0,5)$ dB (theoretical value 9,5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



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- 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.

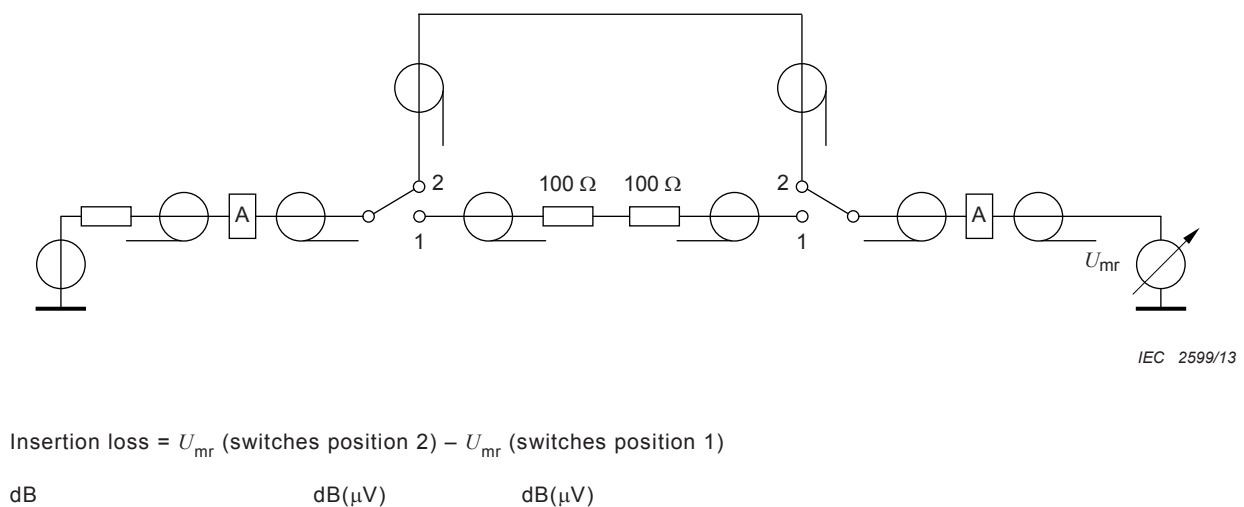
a) Example of the setup geometry to verify the impedance characteristics of the coupling and decoupling devices



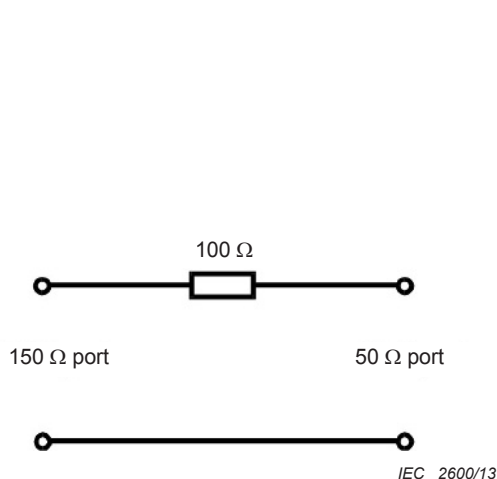
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The impedance requirement shall be met with the open and closed switch S (see 6.3).

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

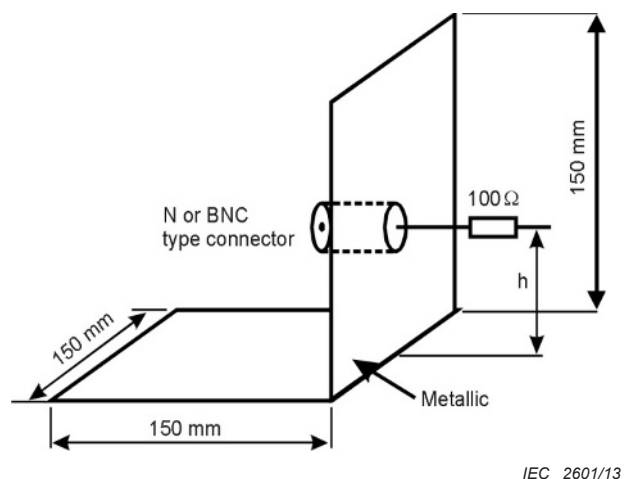


c) Setup principle for measuring the insertion loss of two 150 Ω to 50 Ω adapters



NOTE Low inductance resistor:
Power rating $\geq 2,5$ 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.