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Electromagnetic compatibility (EMC)

Part 4.6: Testing and measurement techniques — Immunity to conducted disturbances, induced by radio-frequency fields

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Electromagnetic compatibility (EMC)

Part 4.6: Testing and measurement techniques — Immunity to conducted disturbances, induced by radio-frequency fields

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Preface

This Standard was prepared by the Joint Standards Australia/ Standards New Zealand Committee TE-003 Electromagnetic Compatibility, to supersede AS IEC 61000.4.6:2017, *Electromagnetic compatibility (EMC), Part 4.6: Testing and measurement techniques — Immunity to conducted disturbances, induced by radio-frequency fields* in Australia and AS/NZS IEC 61000.4.6:2013, *Electromagnetic compatibility (EMC), Part 4.6: Testing and measurement techniques — Immunity to conducted disturbances, induced by radio-frequency fields* in New Zealand.

The objective of this document 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 in this document describes a consistent method to assess the immunity of an equipment or system against a specified phenomenon.

Equipment not having at least one conducting wire 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 document.

This document is identical with, and has been reproduced from, IEC 61000-4-6:2023, *Electromagnetic compatibility (EMC) — Part 4-6: Testing and measurement techniques — Immunity to conducted disturbances, induced by radio-frequency fields*.

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FOREWORD

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IEC 61000-4-6 has been prepared by subcommittee 77B: High frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility. It is an International Standard.

It forms Part 4-6 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107.

This fifth edition cancels and replaces the fourth edition published in 2013. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) selection of injection devices revised;

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b) need of AE impedance check for clamp injection removed and Annex H deleted;

c) saturation check revised;

d) new Annex H on testing with multiple signals;

e) level-setting only with feedback loop.

The text of this International Standard is based on the following documents:

Draft	Report on voting
77B/863/FDIS	77B/865/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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

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

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

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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.

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Australian/New Zealand Standard

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.

NOTE 1 Product committees might decide to use the methods described in this document also for frequencies up to 230 MHz (see Annex B) although the methods and test instrumentation are intended to be used in the frequency range up to 80 MHz.

Equipment not having at least one conducting wire 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 document.

NOTE 2 Test methods are specified 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 specified are structured for the primary objective of establishing adequate repeatability of results at various facilities for quantitative analysis of effects.

The object of this document 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 in this document describes a consistent method to assess the immunity of an equipment or system against a specified phenomenon.

NOTE 3 As described in IEC Guide 107, this document 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 are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

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3.1
artificial hand
AH
electrical network simulating the impedance of the human body under average operational conditions between a hand-held electrical appliance and earth

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

[SOURCE: IEC 60050-161:1990, 161-04-27, modified - the note has been added.]

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

Note 1 to entry: Auxiliary equipment can be useful for monitoring the EUT.

3.3
clamp injection
method of injecting signals onto cables using a clamp injection device

3.4
clamp injection device
clamp-on signal injecting device that is 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 vectoral sum of all currents flowing through these terminal(s) or screen (see also Figure 15a) and Figure 15b)).

3.6
coupling factor
ratio determined 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
coupling device
electrical circuit or device for transferring energy from one circuit to another with a specified 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

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3.9
decoupling network
decoupling device
electrical circuit or device 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

SEE: Figure 4.

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 document is basically an electromagnetic field, coming from intended RF transmitters, that can 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 (λ/4, λ/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. For the method described herein, the EUT is connected 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 1.

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 2), 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 specified in 6.2. Any coupling and decoupling device fulfilling these characteristics can be used. The CDNs in Annex C are only examples of commercially available networks.

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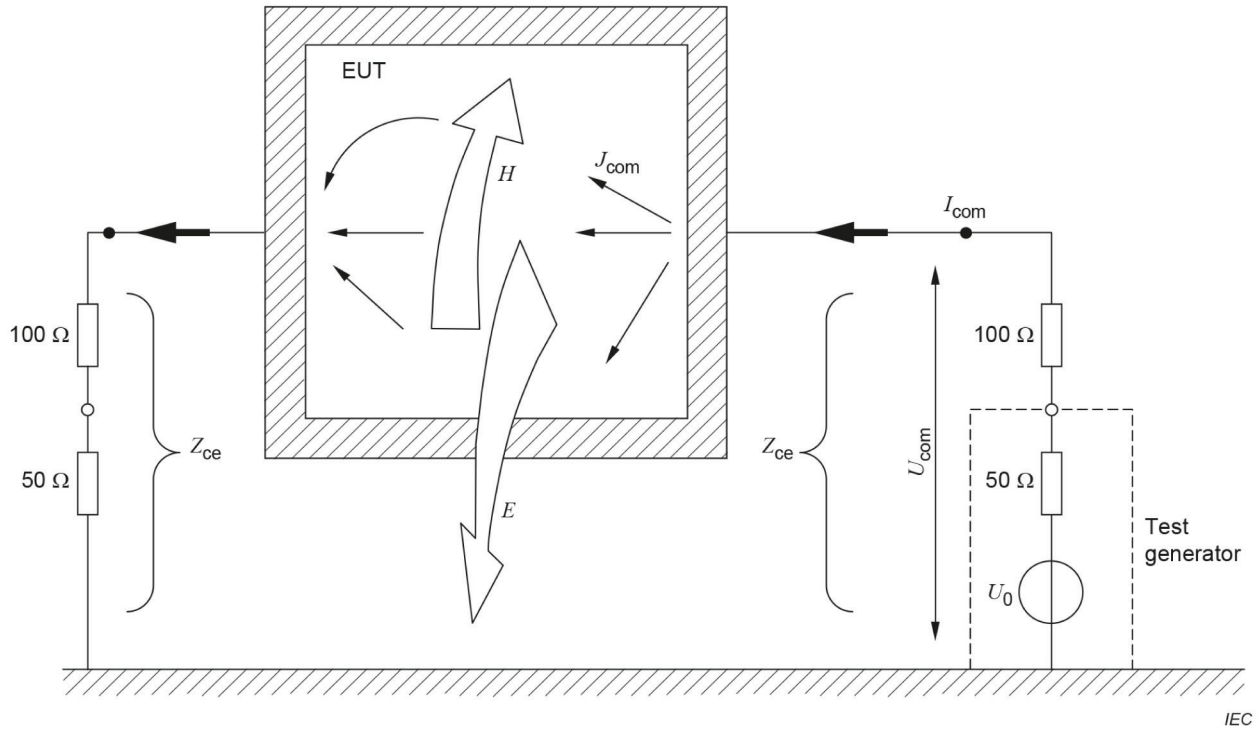
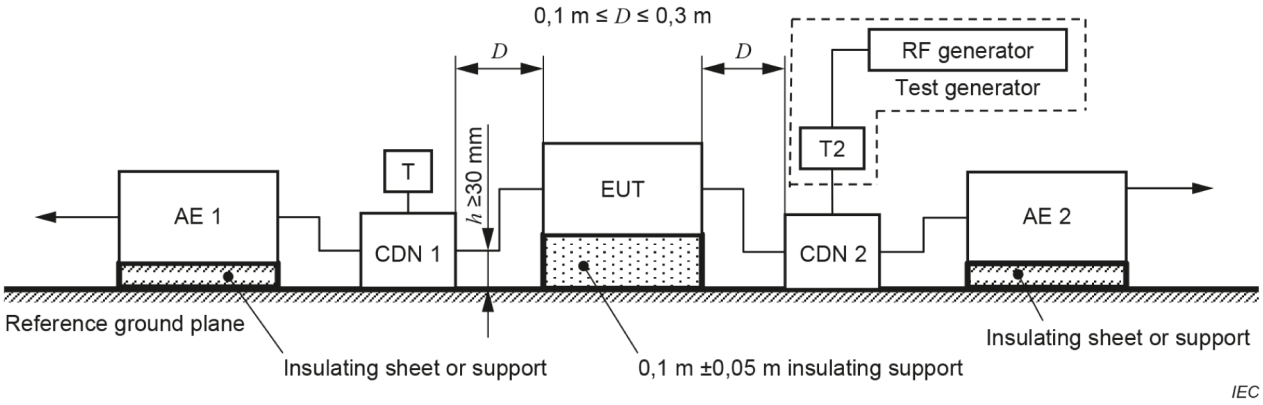


Z_{ce} Common-mode impedance of the CDN, Z_{ce} = 150 Ω
U_0 Test generator source voltage (e.m.f.)
U_{com} Common-mode voltage between EUT and reference plane
I_{com} Common-mode current through the EUT
J_{com} Current density on conducting surface or current on other conductors of the EUT
E, H Electric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

Figure 1 — Diagram showing EM fields near the EUT due to common-mode currents on its cables



a) — Schematic setup for immunity test used for CDN

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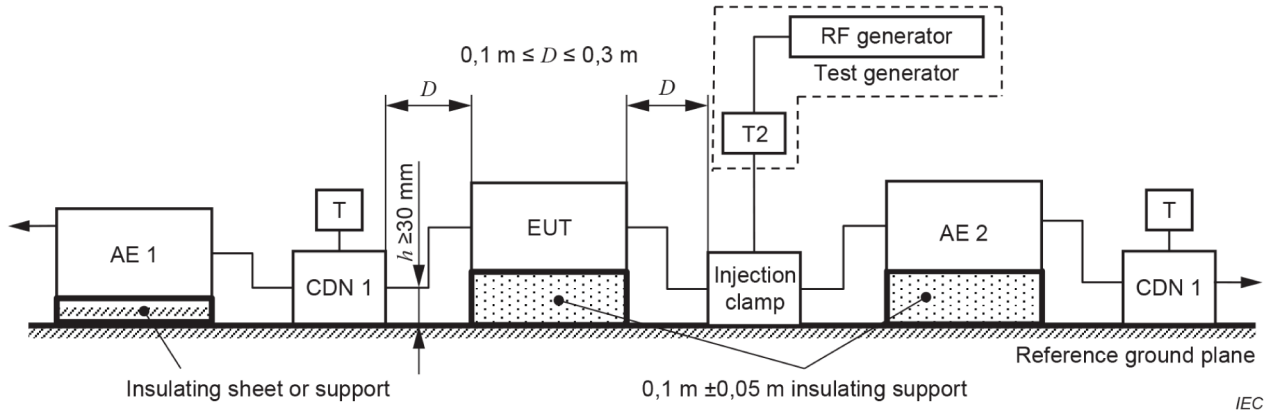

T: Termination 50 Ω

T2: Attenuator (6 dB)

CDN: Coupling and decoupling network

Injection clamp: Current clamp or EM clamp

Insulating sheet or support: A non-conductive coating, foot, roller and/or caster may be used as an alternative to an insulating support. The height shall be as specified. The height of the insulating sheet or support under a decoupled AE need not be specified

b) — Schematic setup for immunity test used for injection clamp

Figure 2 — Schematic setup for immunity test to RF conducted disturbances

5 Test levels

According to this document, 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 RMS (root mean square), are specified 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	

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Table 1 *(continued)*

Frequency range 150 kHz to 80 MHz		
Level	**Voltage level (e.m.f.)**	
	U_0 **V**	U_0 **dB(μV)**
[a] "X" can be any level, above, below or 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 3. Annex C provides guidance for selecting test levels.

NOTE 1 IEC 61000-4-3 also specifies 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.

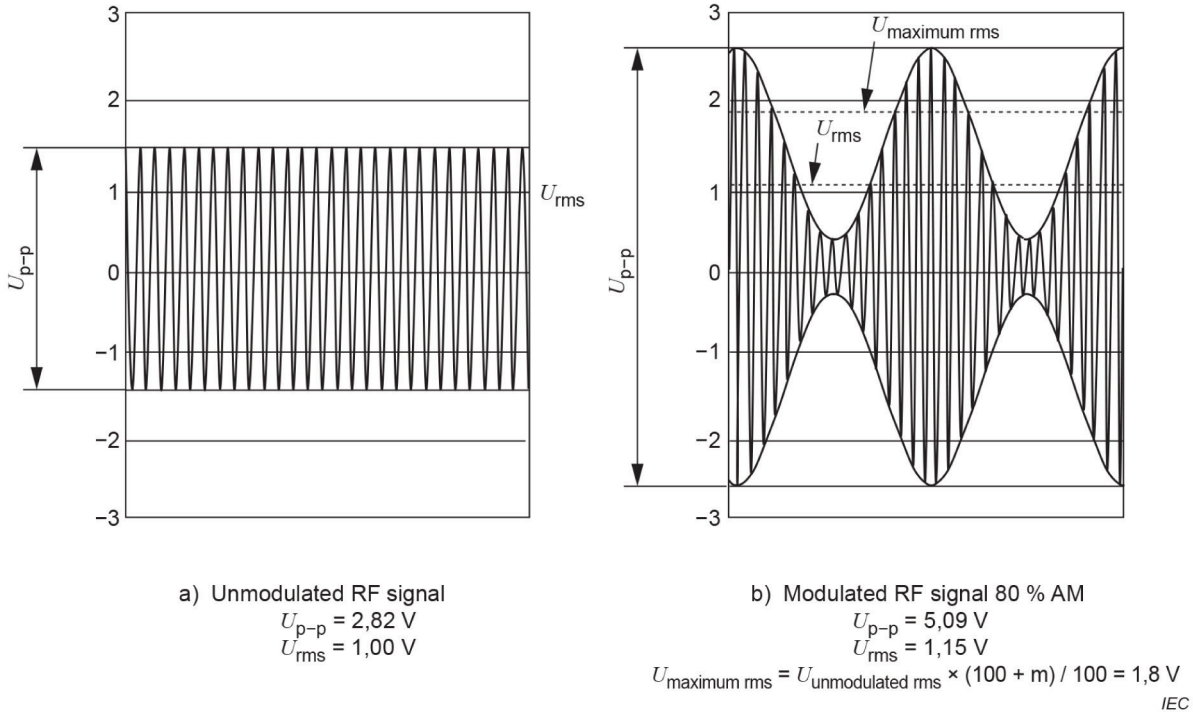

Figure 3 — Example of unmodulated and modulated RF signal

6 Test equipment and level adjustment procedure

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 can be separate or integrated into one or more test instruments (see 3.10, Figure 4, and Figure 5):

- 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

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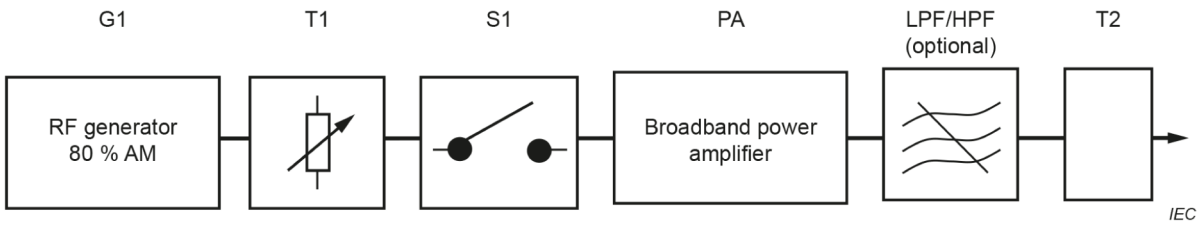
control (e.g. frequency, amplitude, modulation index) or in the case of RF synthesizers, they shall be programmable with frequency-dependent step sizes and dwell times;

- attenuator T1, (typically 0 dB to 40 dB) of adequate frequency rating to control the disturbing test source output level. T1 can 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 can be included in the RF generator and is optional;
- broadband power amplifier(s), PA, might be necessary to amplify the signal if the output power of the RF generator is insufficient;
- low-pass filters (LPFs) or high-pass filters (HPFs), or both, can be used to avoid interference caused by (higher order or sub-) harmonics with some types of EUT, for example RF receivers. When required, they shall be inserted between the broadband power amplifier PA and the attenuator T2;
- attenuator T2, fixed attenuation (6 dB ± 0,5 dB), with sufficient power ratings. T2 is provided to reduce the VSWR at the output of the power amplifier. Larger attenuation values may be used.

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

Table 2 — Characteristics of the test generator

Nominal output impedance	50 Ω
Harmonics and distortion	Within 150 kHz and 80 MHz, any spurious signal shall be at least 15 dB below the carrier level, measured directly at the output of the test generator.
Amplitude modulation	Internal or external, $m = \left(80 \begin{smallmatrix}+5\\-20\end{smallmatrix}\right)\%$, with $m = 100 \times \frac{U_{pp,max} - U_{pp,min}}{U_{pp,max} + U_{pp,min}}$ 1 kHz ± 0,1 kHz sine wave
Output level	Sufficiently high to cover test level (see also Annex E).
NOTE 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

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PA	Broadband power amplifier
T2	Attenuator (see 6.1)
LPF/HPF	Low pass filter and/or high pass filter (optional)
S1	RF switch

Figure 4 — 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 (e.g. CDN) or can consist of several parts (e.g. current clamp and decoupling clamp).

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, for example the attenuation of the CDN adversely affects the intentional operation of the EUT, or not available on the market, other injection methods can be used. Rules for selecting the appropriate injection method are specified in 7.4. Other injection methods, due to their electrical properties, are unlikely to meet the parameters of Table 3.

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	$150\ ^{+60}_{-45}$ 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		

NOTE Details regarding clamps are specified in Annex A.

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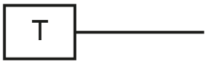
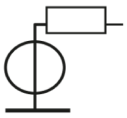
50 Ω coaxial line

Power, signal or ground cable



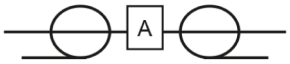
50 Ω coaxial load

150 Ω to 50 Ω adapter; a box with 100 Ω series resistor between IN and OUT port

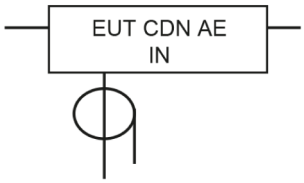


50 Ω signal source

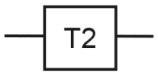
50 Ω measuring equipment, e.g. voltmeter



10 dB, 50 Ω attenuator



Coupling/decoupling network (CDN) with EUT, IN and AE ports



Attenuator (see 6.1)

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Figure 5 — Principle of coupling and decoupling - Symbols used for the indicated setup principles

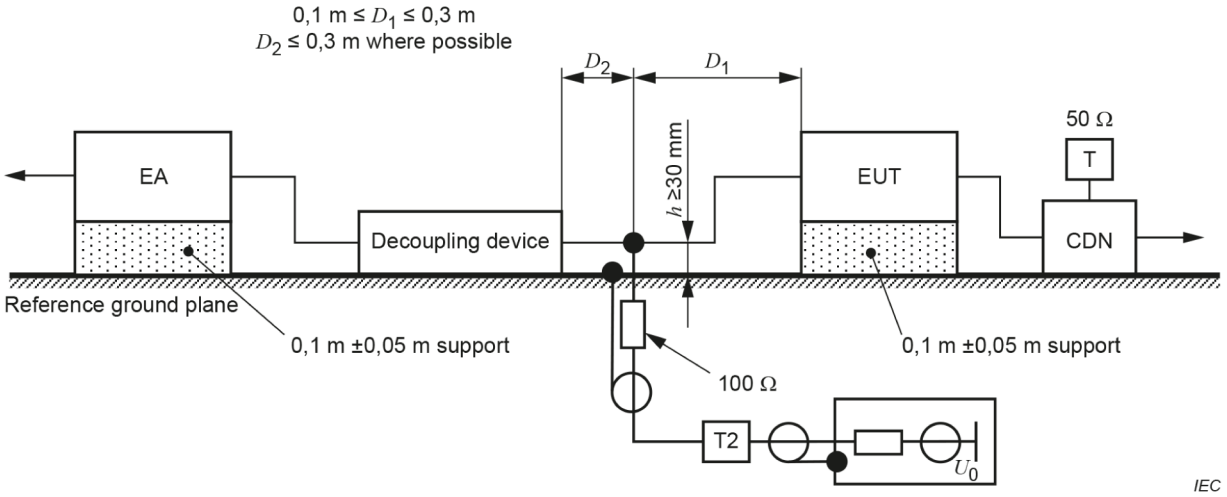

Figure 6 — Principle of coupling and decoupling - Principle of direct injection to screened cables

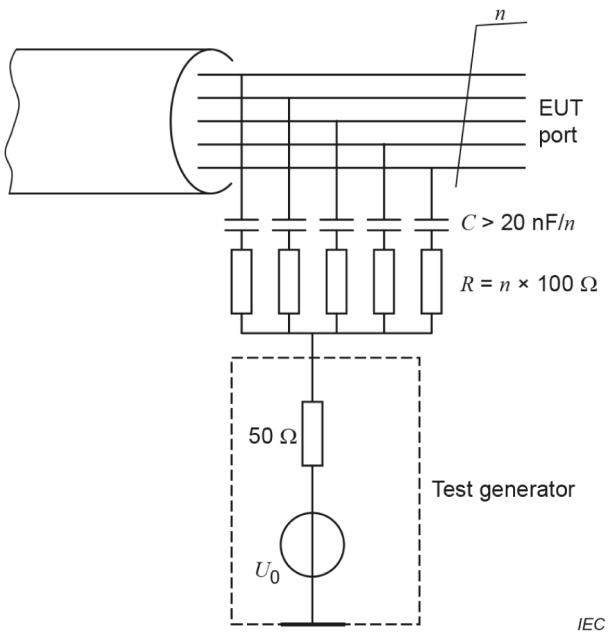

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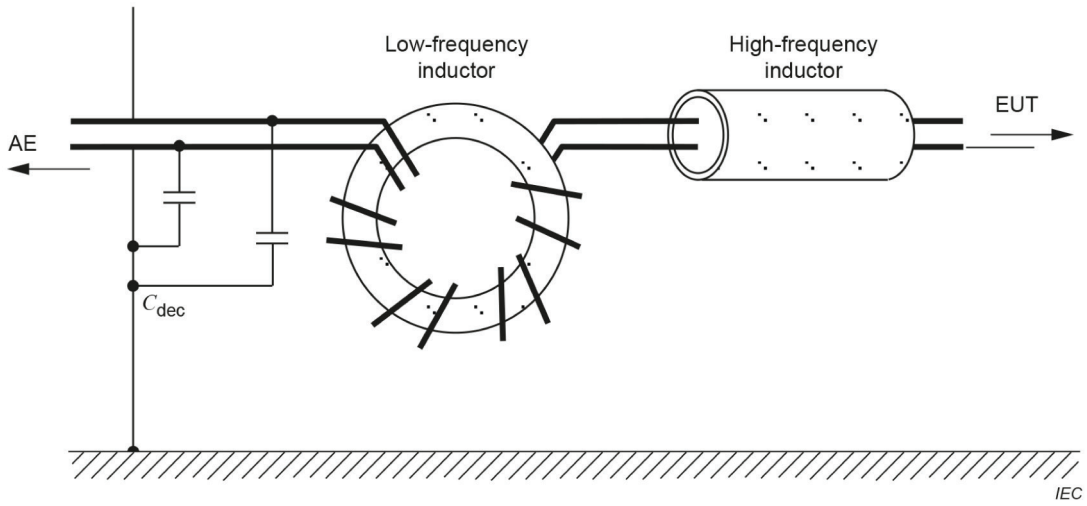
Figure 7 — Principle of coupling and decoupling - Principle of coupling to unscreened cables according to the CDN method



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

Figure 8 — Principle of coupling and decoupling - Principle of 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 shown in Figure 7 and Figure 8. Table 4 summarizes the usage of the different types of CDNs as specified in Annex D. The CDNs selected shall not unduly affect the functional signals. Constraints on such effects may be specified in the product standards.

Guidance is given in 6.2.2.2 to 6.2.2.5 for the selection of CDNs. CDNs shall be selected to match the number of wires in the EUT port to be tested, for example for a port with three data lines a CDN-AF3 shall be used.

NOTE Attention is drawn to potential non-linear behaviour of CDNs containing non-linear devices (e.g. clipping devices).

Table 4 — Usage of CDNs

Line type	Examples	CDN type
Power supply (AC and DC) and earth connection	AC mains, DC 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 Figure D.4, Figure D.5, Figure D.7 and Annex H)

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Table 4 *(continued)*

Line type	Examples	CDN type
Unscreened unbalanced lines	Any line not belonging to other groups	CDN-AFx or CDN-Mx (see Figure D.3 and Figure 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) 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 specified for a three-phase mains system. The coupling circuit is shown in Figure 7.

NOTE The performance of the CDN can be degraded by saturation of the magnetic material due to current drawn by the EUT, especially when using CDN-M1. This can be avoided if the magnetizing effect of the forward current is cancelled by that due to the return current.

WARNING — The capacitors used within the CDNs bridge live parts. As a result, high leakage currents can occur and safety connections from the CDN to the reference ground plane are mandatory (in some cases, these connections might 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. Figure D.4, Figure D.5 and Figure D.7 show these possibilities:

- CDN-T2 for a cable with one symmetrical pair (two wires);
- CDN-T4 for a cable with two symmetrical pairs (four wires);
- CDN-T8 for a cable with four symmetrical pairs (eight wires).

The number of symmetrical pairs is determined by the cable connected to the port.

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 if suitable CDNs are not available.

6.2.2.4 CDNs for unscreened unbalanced lines

For coupling and decoupling disturbing signals to an unscreened cable with unbalanced lines, an AFx or Mx CDN shall be used. Figure D.3 is an example for a two-wire CDN (AF2) and Figure D.6 for an eight-wire CDN (AF8).

If no CDN for the unscreened unbalanced line is applicable, follow the decision chart in Figure 20.

6.2.2.5 CDNs for screened cables

For coupling and decoupling disturbing signals to a screened cable, an Sx-type CDN shall be 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 to appropriate ground (e.g. metallic housing, large ground structure on a

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printed circuit board) at both ends of the cable. If this condition is not met, the cable shall 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. 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 The EM clamp provides some decoupling above 10 MHz (see Annex A).

Instructions for proper application are specified in 7.6.

6.2.3.2 Current clamp

This device establishes an inductive coupling to the cable connected to the EUT.

The current clamp shall not induce significant attenuation. The increase of the transmission loss of the test jig when inserting the current clamp shall not exceed 1,6 dB. A circuit of the transmission loss verification setup is shown in Figure 10.

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 compared to the 1,6 dB requirement above.

NOTE 2 For example, with a 5:1 turns 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 turns ratios can be used.

The signal level applied to the current injection clamp is set prior to the test. The test level-setting procedure is specified in 6.4.2 and Figure 10.

NOTE 3 The cable is generally positioned through the centre of the clamp to minimize capacitive coupling.

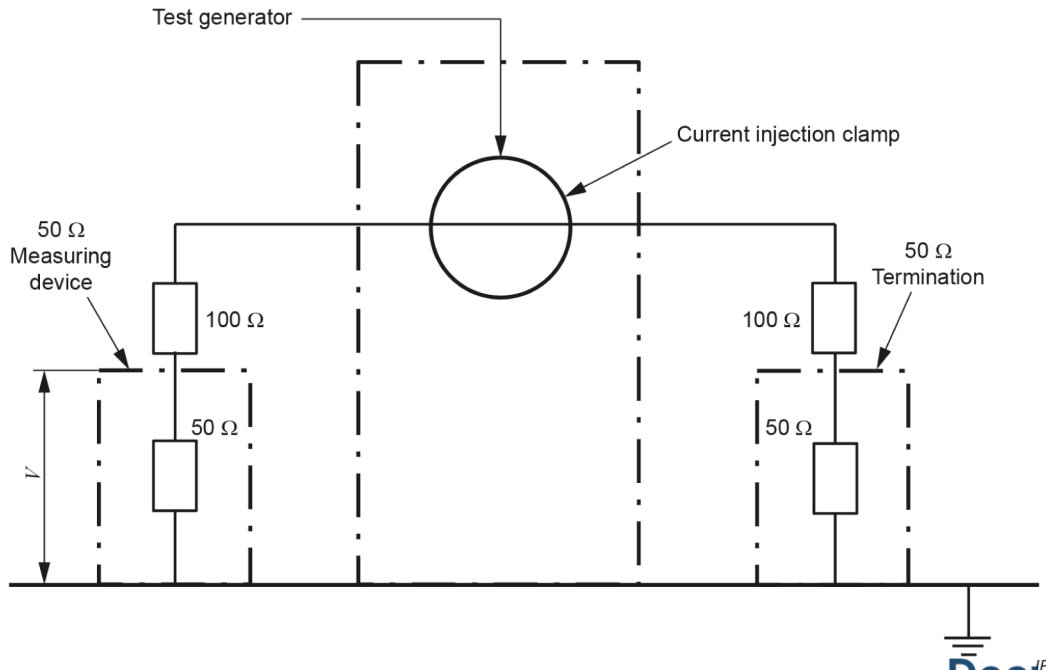

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Figure 9 — Example of circuit for level-setting setup in a 150 Ω test jig

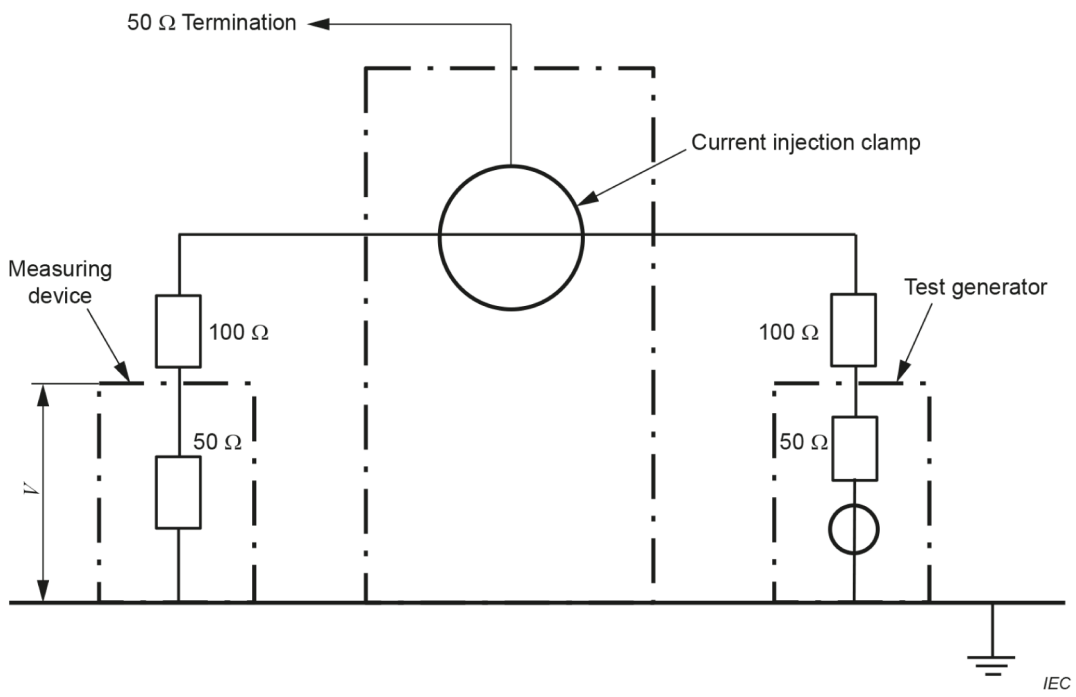

Figure 10 — Example of circuit for evaluating the transmission loss of the current clamp level-setting

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 Clause A.2 and Clause A.3.

6.2.4 Direct injection devices

Direct injection is only applicable to screened or coaxial cables. When using direct injection, the disturbing signal is injected onto the screen via a 100 Ω resistor (even if the screen is ungrounded or grounded at one end only). Between the AE and the injection point, a decoupling clamp as specified in Clause A.3 shall be inserted as close as possible to the injection point (see Figure 6). A ground connection shall be made from the screen of the direct injection device's input port to the reference ground plane.

If the screen is intended to be grounded at the AE side, a connection from the screen of the cable under test to the reference ground plane (RGP) should be made at the AE side of the decoupling element to improve decoupling and reproducibility unless this connection would significantly deviate from practical application (e.g. remote sensor with screened cable).

When making direct connection to foil screens, ensure a good contact for 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 8) or by using a number of ferrite toroids over the cable (usually as a clamp-on tube).

NOTE Decoupling clamps are specified in Clause A.3.

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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 document. When CDNs are used in this way, they shall meet the requirements of 6.2. The use of CDNs as decoupling devices is the preferred choice. If CDNs are not applicable, decoupling clamps as specified in Clause A.3 shall be used.

The decoupling networks shall be used on all cables not selected for the test, but connected to the EUT or AEs, or both. For exceptions, see 7.3. Although the preferred choice is to decouple each cable individually, more cables may be routed in the same decoupling clamp, if the dimension of the clamp allows that.

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.

NOTE The common-mode impedance of coupling and decoupling devices is calibrated using the setup shown in Figure 11 to Figure 14.

The coupling and decoupling devices and the impedance reference plane (Figure 11) 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 11. The magnitude of the common-mode impedance seen at the connector on the impedance reference 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 12. This requirement ensures sufficient attenuation and makes the setup of the AE, for example 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 specified in 7.6. For direct injection it is generally sufficient to follow the procedure specified in 7.7.

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 14a). The construction of the adapter is shown in Figure 14b).

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 13. Its value shall be in the range of (9,5 ± 0,5) dB (theoretical value of 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.

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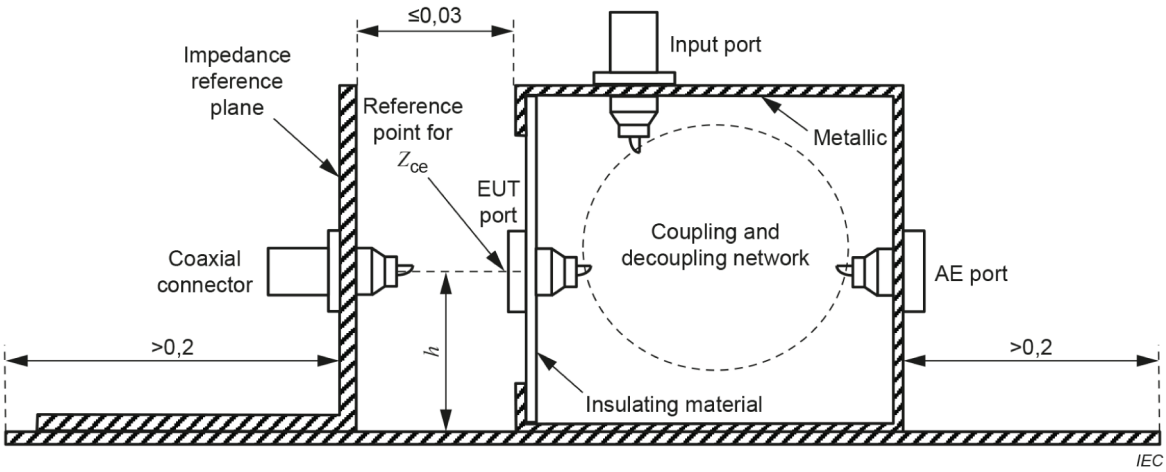
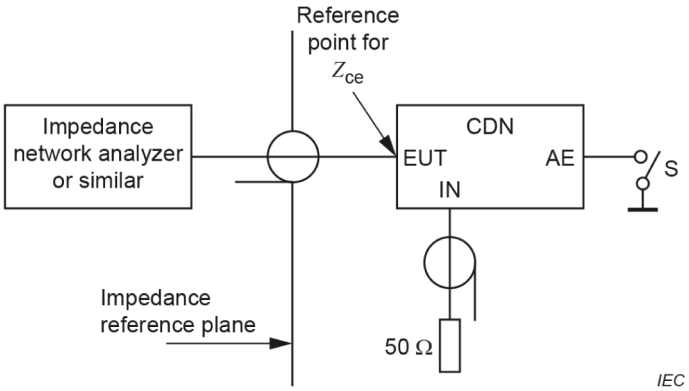
Dimensions in meters



- The reference ground plane shall exceed the projection of the coupling and decoupling devices and other components by at least 0,2 m.
- The coaxial connector shall be connected horizontally to the EUT port.
- The height *h* of the EUT port depends on the individual CDN, which can vary from 0,03 m to 0,10 m; particular large current CDNs have an EUT port located higher above the reference ground plane.
- The impedance reference plane (with the coaxial connector): 0,1 m × 0,1 m for *h* = 0,03 m and 0,15 m × 0,15 m for other values of *h*.
- The impedance reference plane and CDN shall have a good RF contact to the reference ground plane.

Figure 11 — Example of the setup geometry to verify the impedance characteristics of the coupling and decoupling devices



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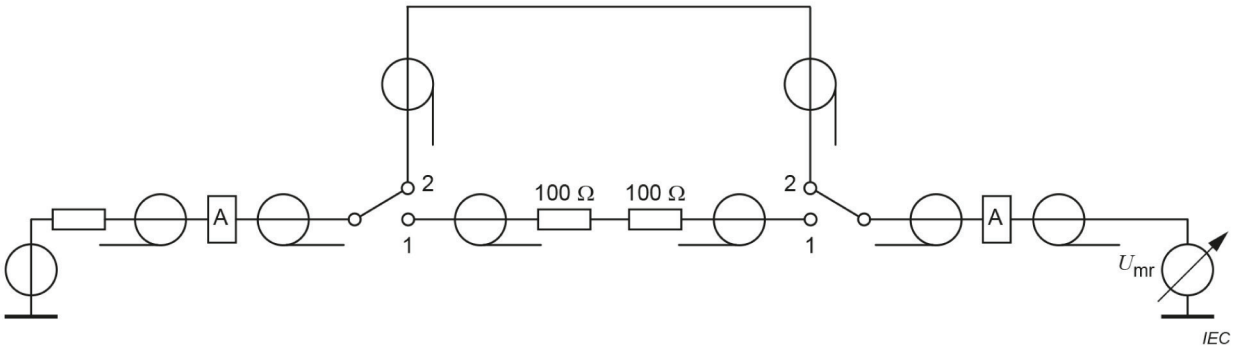
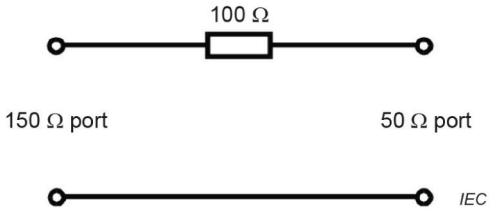
The impedance requirement shall be met with the open and closed switch S (see 6.3).

Figure 12 — Setup principle to verify Z_{ce} of the coupling and decoupling device



$$\underset{\text{dB}}{\text{Insertion loss}} = \underset{\text{dB}(\mu\text{V})}{U_{\text{mr}}(\text{switches position 2})} - \underset{\text{dB}(\mu\text{V})}{U_{\text{mr}}(\text{switches position 1})}$$

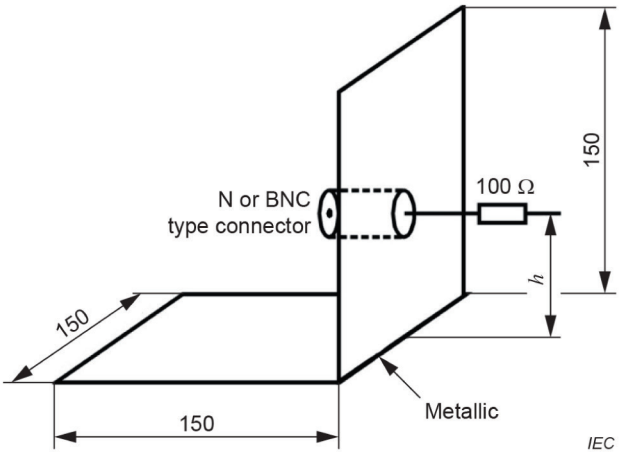
Figure 13 — Setup principle for measuring the insertion loss of two 150 Ω to 50 Ω adapters



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

a) — Circuit of the 150 Ω to 50 Ω adapter

Dimensions in millimetres



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NOTE Identical to Figure 11 (connector plate), but with 100 Ω low inductance resistor added.

b) — Example of construction diagram of the 150 Ω to 50 Ω adapter (150 mm × 150 mm example)

Figure 14 — Circuit and construction of the 150 Ω to 50 Ω adapter

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. 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).

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 (see Figure 15) 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 shown in Figure 16 for all coupling and decoupling devices.

NOTE 1 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 9.

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 starting at the lowest frequency:

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 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 exceeds the highest frequency (for example 80 MHz) in the range of the test. The stop frequency shall be included.

The laboratory shall ensure that the amplifier is not saturated. This should be demonstrated by applying the following procedure:

1) Determine, across all used coupling devices, the highest forward power P_{formax} required during the level-setting process at each frequency step.

2) For each frequency, repeat the following steps:

   i) set the output level of the power amplifier to P_{formax};

   ii) increase the control level of the RF signal generator by 5,1 dB;

   iii) record the new forward power $P_{formax,\,inc}$;

   iv) if the difference $P_{formax,inc}$ - P_{formax} is between 3,1 dB and 7,1 dB for all frequency steps, then the amplifier is in tolerance and the test system is sufficient for testing

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