

INTERNATIONAL STANDARD



BASIC EMC PUBLICATION

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



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BASIC EMC PUBLICATION

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

INTERNATIONAL
ELECTROTECHNICAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –**Part 4-6: Testing and measurement techniques –
Immunity to conducted disturbances, induced by radio-frequency fields**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 61000-4-6:2013. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

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;
- 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.

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

INTRODUCTION

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

Part 1: General

General considerations (introduction, fundamental principles)

Definitions, terminology

Part 2: Environment

Description of the environment

Classification of the environment

Compatibility levels

Part 3: Limits

Emission limits

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

Part 4: Testing and measurement techniques

Measurement techniques

Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines

Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

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

This part is an international standard which gives immunity requirements and test 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.

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 ~~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 document.

NOTE 2 Test methods are ~~defined~~ *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 ~~defined~~ *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 ~~defined~~ *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.

~~IEC 60050 (all parts), International Electrotechnical Vocabulary (IEV) (available at <<http://www.electropedia.org>>)~~

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 terms and definitions given in IEC 60050-161 as well as the following apply.~~

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>

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 ~~and equipment to verify the performance of the EUT~~

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

3.3

clamp injection

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

method of injecting signals onto cables using a clamp injection device

3.4

clamp injection device

clamp-on ~~“current” injecting device on a cable being~~ 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 ~~vectorial~~ **vectorial** sum of all currents flowing through these terminal(s) or screen (see also Figure 15a) and Figure 15b)).

3.6**coupling factor**

ratio ~~given~~ **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 ~~defined~~ **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

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

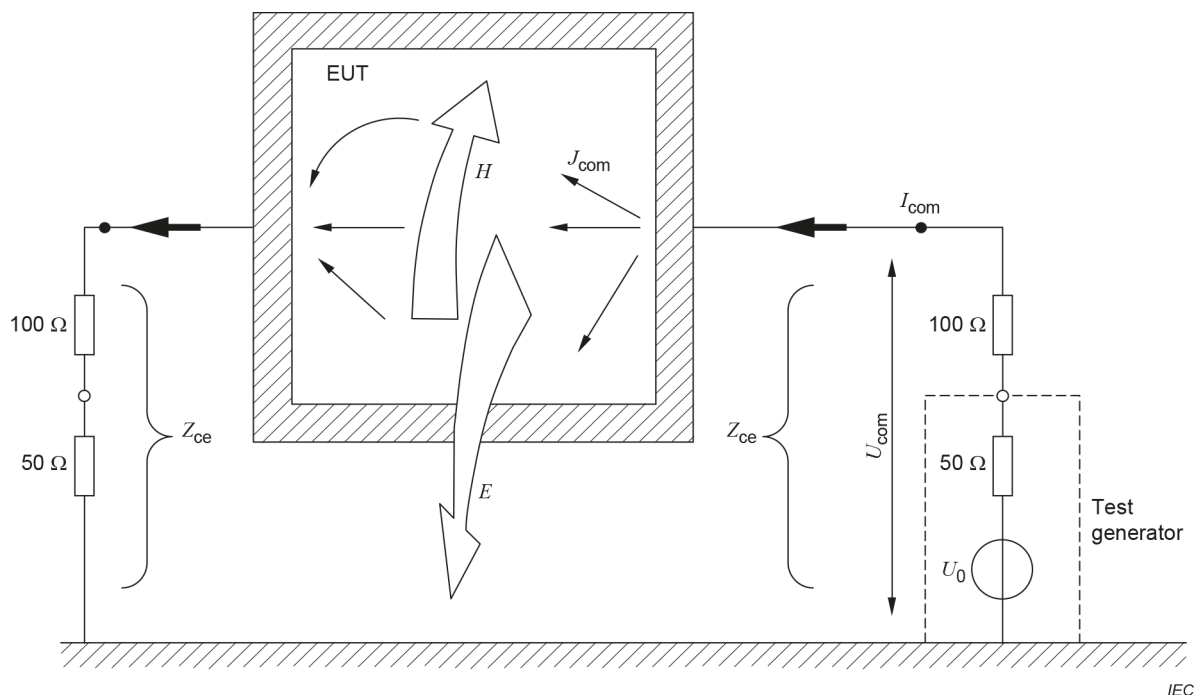
The source of disturbance covered by this document is basically an electromagnetic field, coming from intended RF transmitters, that ~~may~~ **can** act on the whole length of cables connected to installed equipment. The dimensions of the disturbed equipment, mostly a sub-part of a larger system, are 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 ($\lambda/4$, $\lambda/2$ 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~~ For the method described herein, the EUT is connected 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 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 ~~defined by their characteristics given~~ specified in 6.2. Any coupling and decoupling device fulfilling these characteristics can be used. The CDNs in ~~Annex~~ Annex C are only examples of commercially available networks.



Z_{ce} Common-mode impedance of the CDN, $Z_{ce} = 150\ \Omega$

U_0 Test generator source voltage (e.m.f.)

U_{com} Common-mode voltage between EUT and reference plane

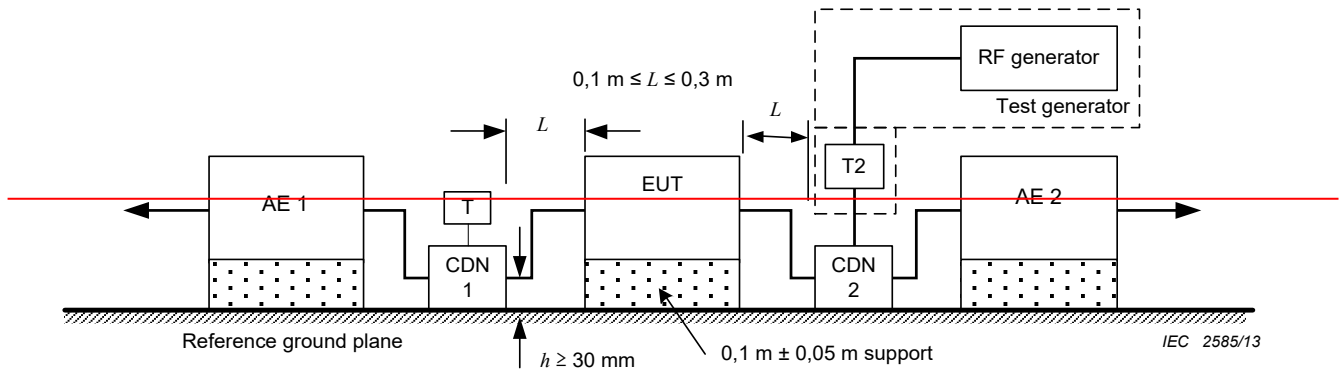
I_{com} Common-mode current through the EUT

J_{com} Current density on conducting surface or current on other conductors of the EUT

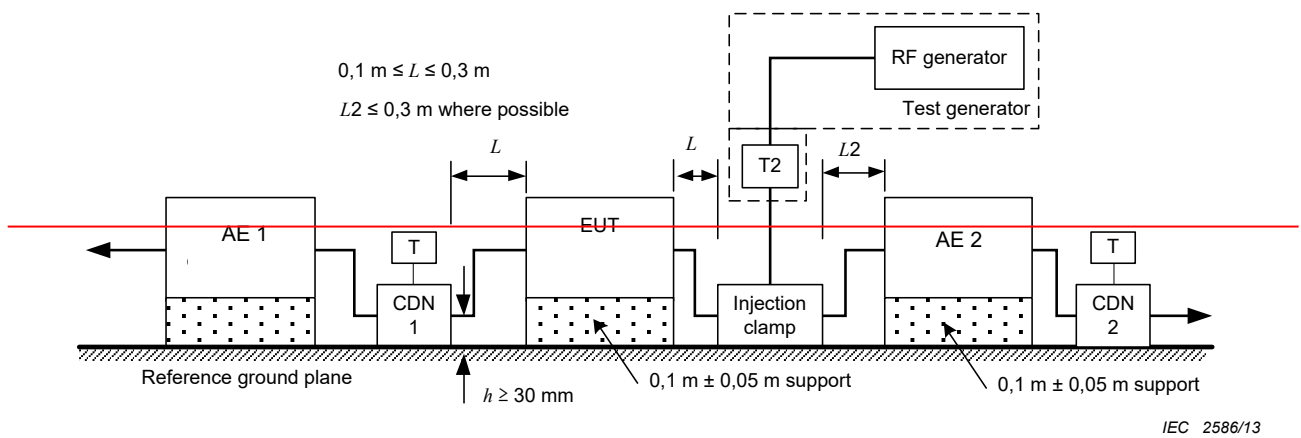
E, H Electric and magnetic fields

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

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



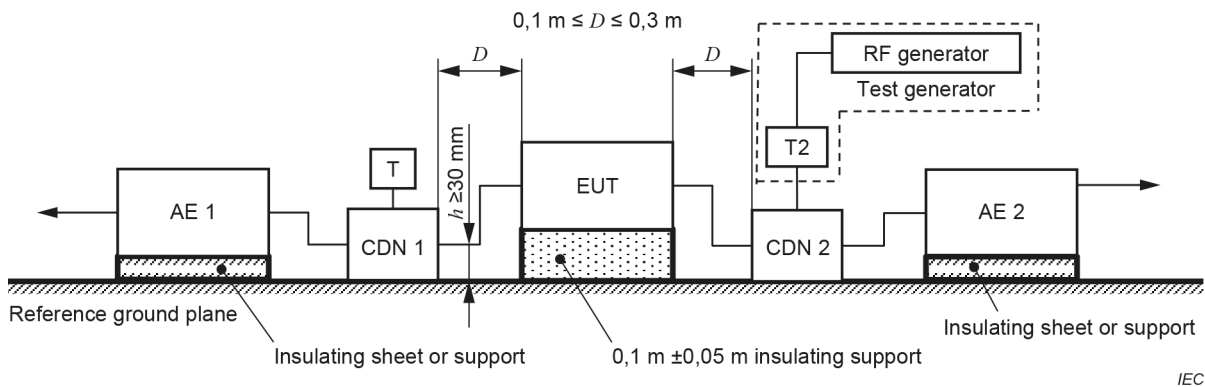
Schematic setup for immunity test used for CDN



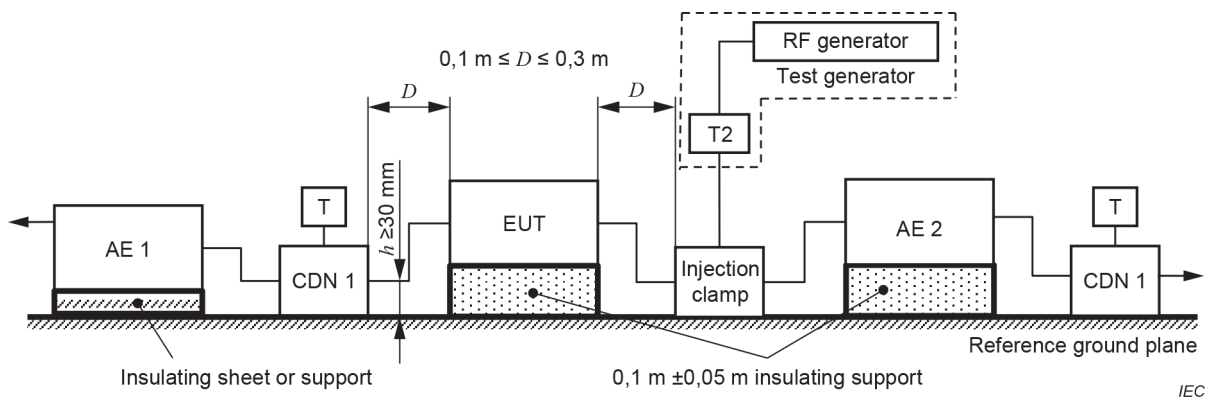
Schematic setup for immunity test used for injection clamp

- 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



a) Schematic setup for immunity test used for CDN



b) Schematic setup for immunity test used for injection clamp

- 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

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.

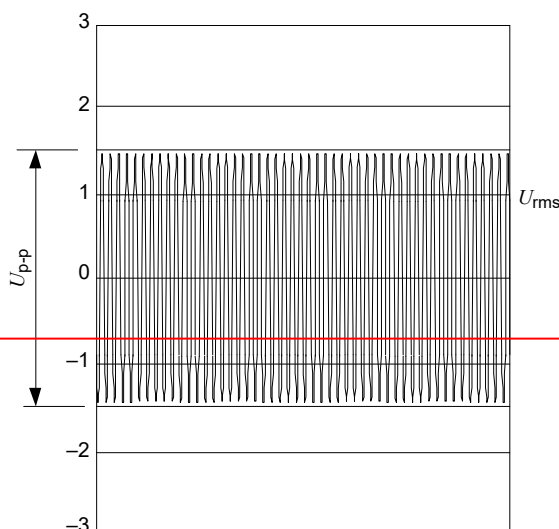
Table 1 – Test levels

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	
^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 defines 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.

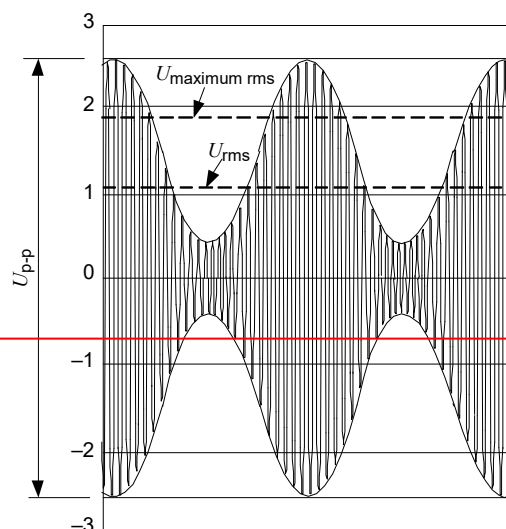


a - Unmodulated RF signal

$$U_{p-p} = 2,82 \text{ V}$$

$$U_{rms} = 1,00 \text{ V}$$

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b - Modulated RF – signal 80 % AM

$$U_{p-p} = 5,09 \text{ V}$$

$$U_{rms} = 1,12 \text{ V}$$

$$U_{maximum \text{ rms}} = 1,80 \text{ V}$$

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

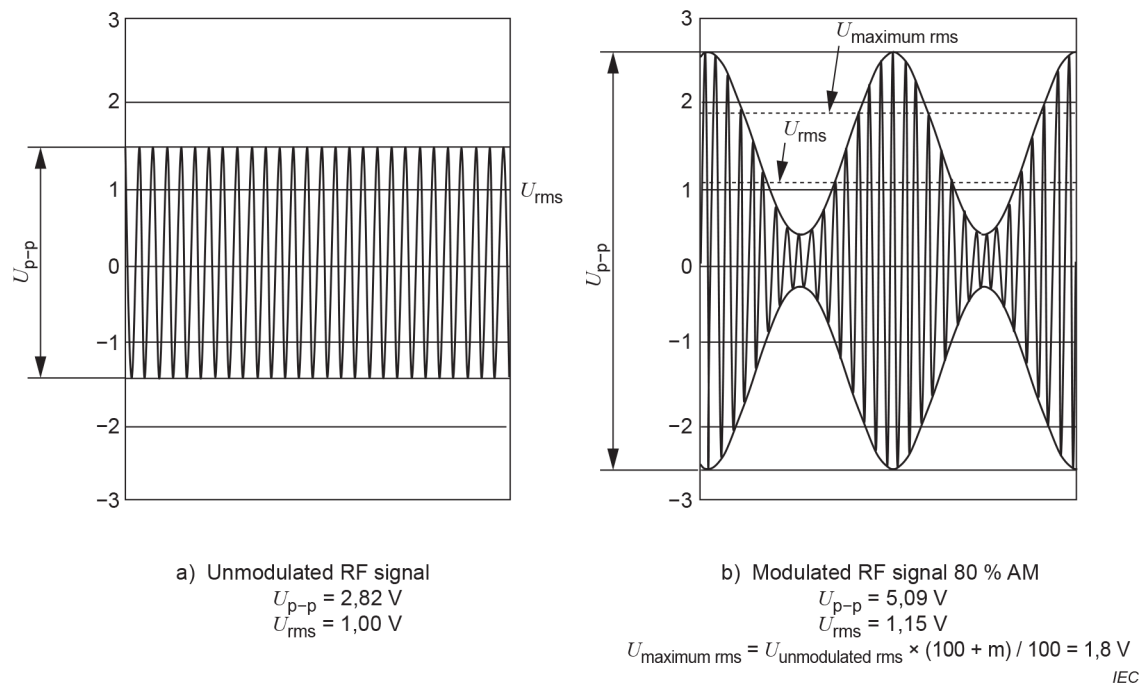


Figure 3 – Example of unmodulated and modulated RF signal

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 ~~may~~ 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 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 ~~may~~ 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 ~~may~~ can be included in the RF generator and is optional;
- broadband power amplifier(s), PA, ~~may~~ 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, ~~may~~ can be ~~necessary~~ 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 ≥ 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.~~

- attenuator T2, fixed attenuation ($6 \text{ dB} \pm 0,5 \text{ dB}$), 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 , VSWR<1,5 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 at the EUT port of the coupling device. The -15 dBc can also be measured directly at the output of the amplifier 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 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.	

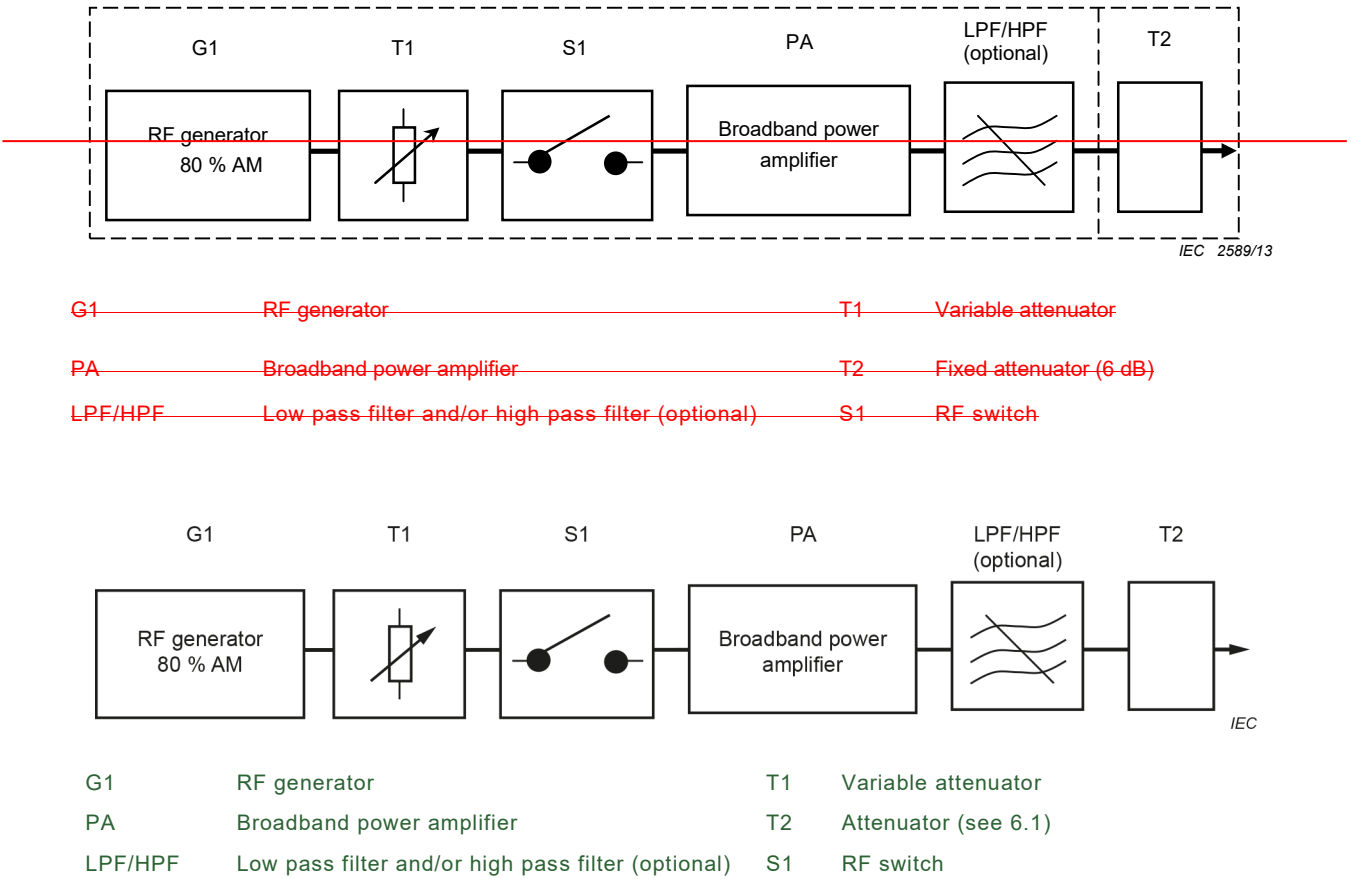


Figure 4 – Test generator setup

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 (~~a CDN or an EM clamp~~ e.g. CDN) or can consist of several parts (e.g. current clamp and decoupling clamp).

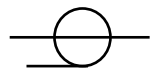
The preferred coupling and decoupling devices are the CDNs, for reasons of test reproducibility and protection of the AE. The main coupling and decoupling device parameter, the common mode impedance seen at the EUT port, is specified in Table 3. If CDNs are not applicable, for example the attenuation 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.

~~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} $	$150 \Omega \pm 20 \Omega$	$150^{+60}_{-45} \Omega$
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		

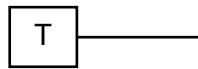
NOTE Details regarding clamps are specified in Annex A.



50 Ω coaxial line



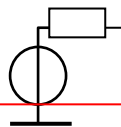
Power, signal or ground cable



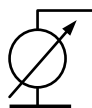
50 Ω coaxial load



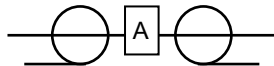
150 Ω to 50 Ω adapter; a box with 100 Ω series resistor between IN and OUT port



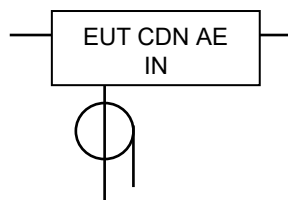
50 Ω signal source



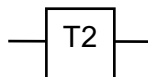
50 Ω measuring equipment, e.g. selective voltmeter



10 dB, 50 Ω attenuator



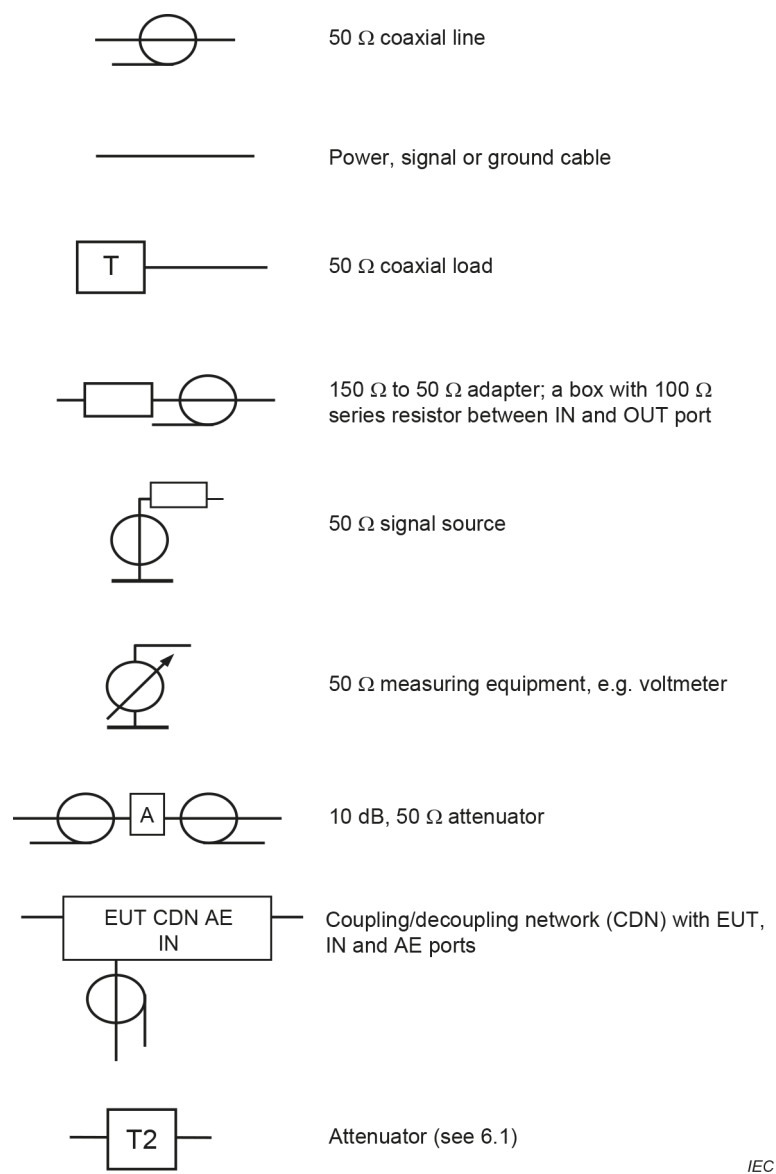
Coupling/decoupling network (CDN) with EUT, IN and AE ports



Power attenuator (6 dB)

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a) List of symbols used for the indicated setup principles



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

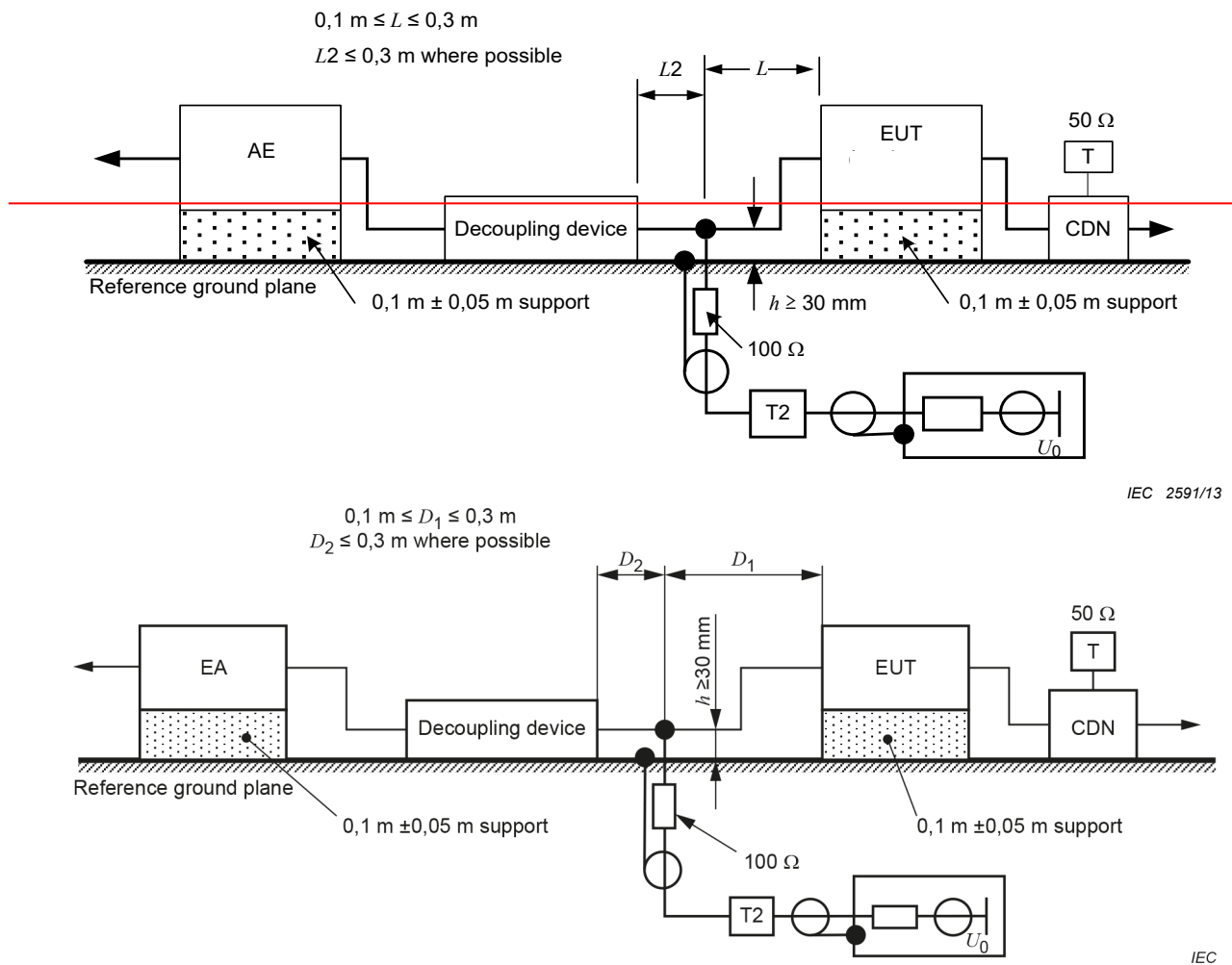


**Figure 6 – Principle of coupling and decoupling –
 Principle of direct injection to screened cables**

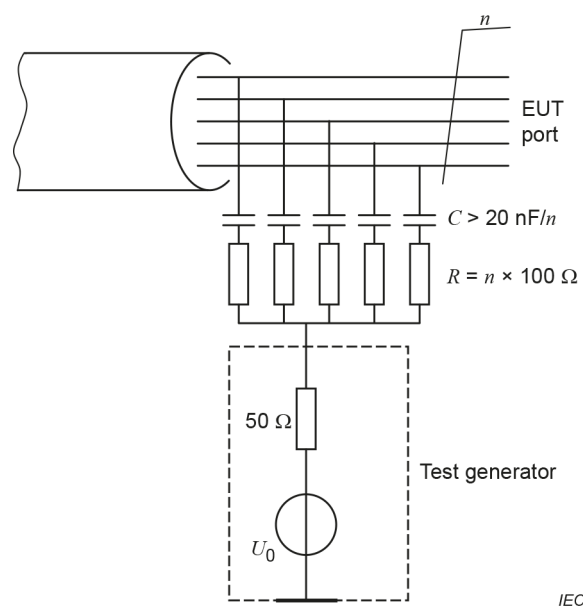
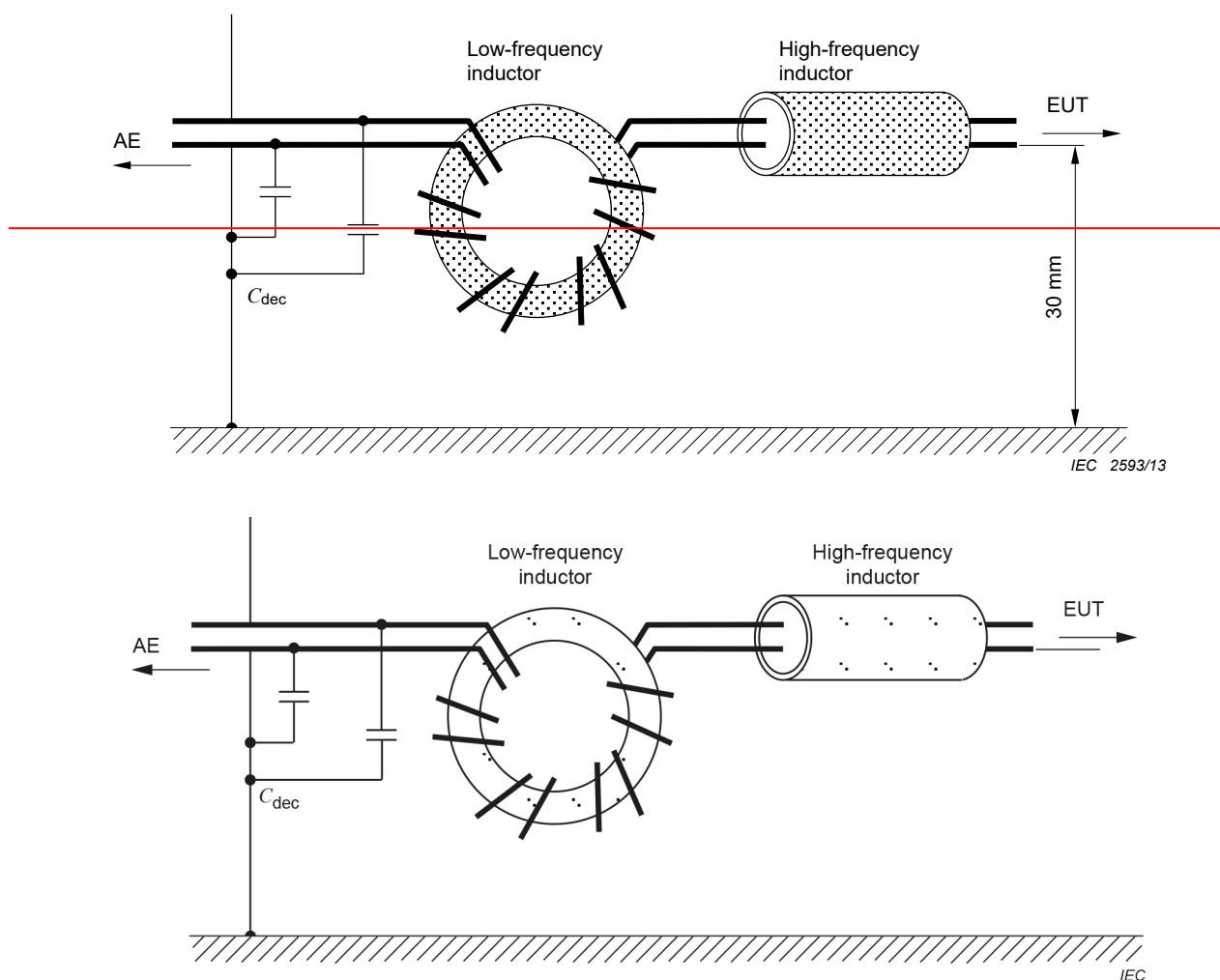


Figure 7 – Principle of coupling and decoupling –
Principle of coupling to unscreened cables according to the CDN method



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, $\mu_R = 700$

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 ~~(see advice given in Figure 12)~~. 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)
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) ~~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~~ specified for a three-phase mains system. The coupling circuit is shown in Figure 7.

~~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.~~

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 ~~may~~ can occur and safety connections from the CDN to the reference ground plane are mandatory (in some cases, these connections ~~may~~ 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 ~~because~~ if suitable CDNs ~~might~~ are 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.~~

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 ~~is~~ 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 printed circuit board) at both ends of the cable. If this condition is not met, the cable ~~should~~ shall be treated as an unscreened cable.

6.2.3 Clamp injection devices

6.2.3.1 General

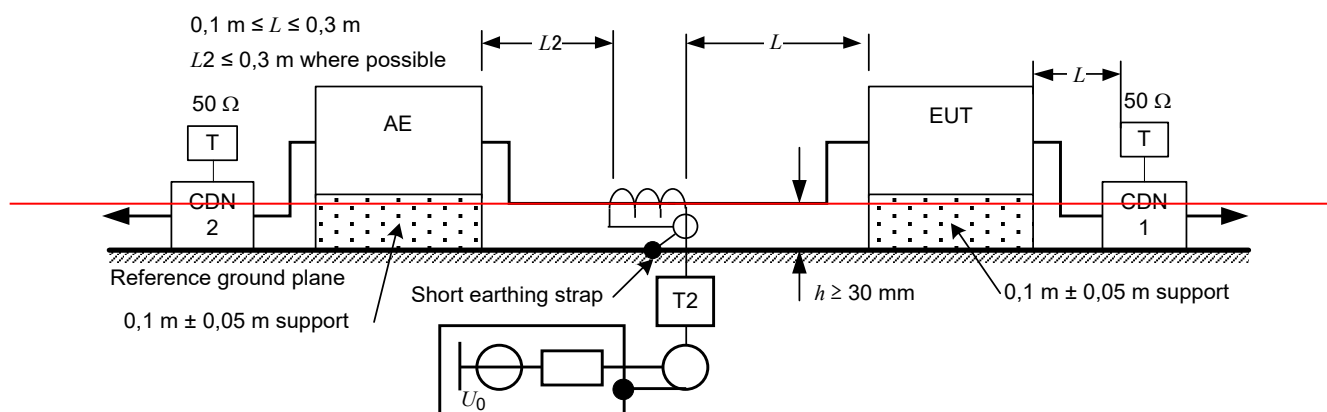
With clamp injection devices, the coupling and decoupling functions are separated. Coupling is provided by the clamp-on device, while the common-mode impedance and the decoupling functions are established at the AE. As such, the AE becomes part of the coupling and decoupling devices ~~(see Figure 5). 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_{ee} 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 specified 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 $150\ \Omega$ established by the AE. In this case, the test generator's output impedance ($50\ \Omega$) is transformed into $2\ \Omega$. 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 4.6 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.~~

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.

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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 terminal voltage is

port by a $50\ \Omega$ 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 $150\ \Omega$ established by the AE. In this case, the test generator's output impedance ($50\ \Omega$) is transformed into $2\ \Omega$. 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.

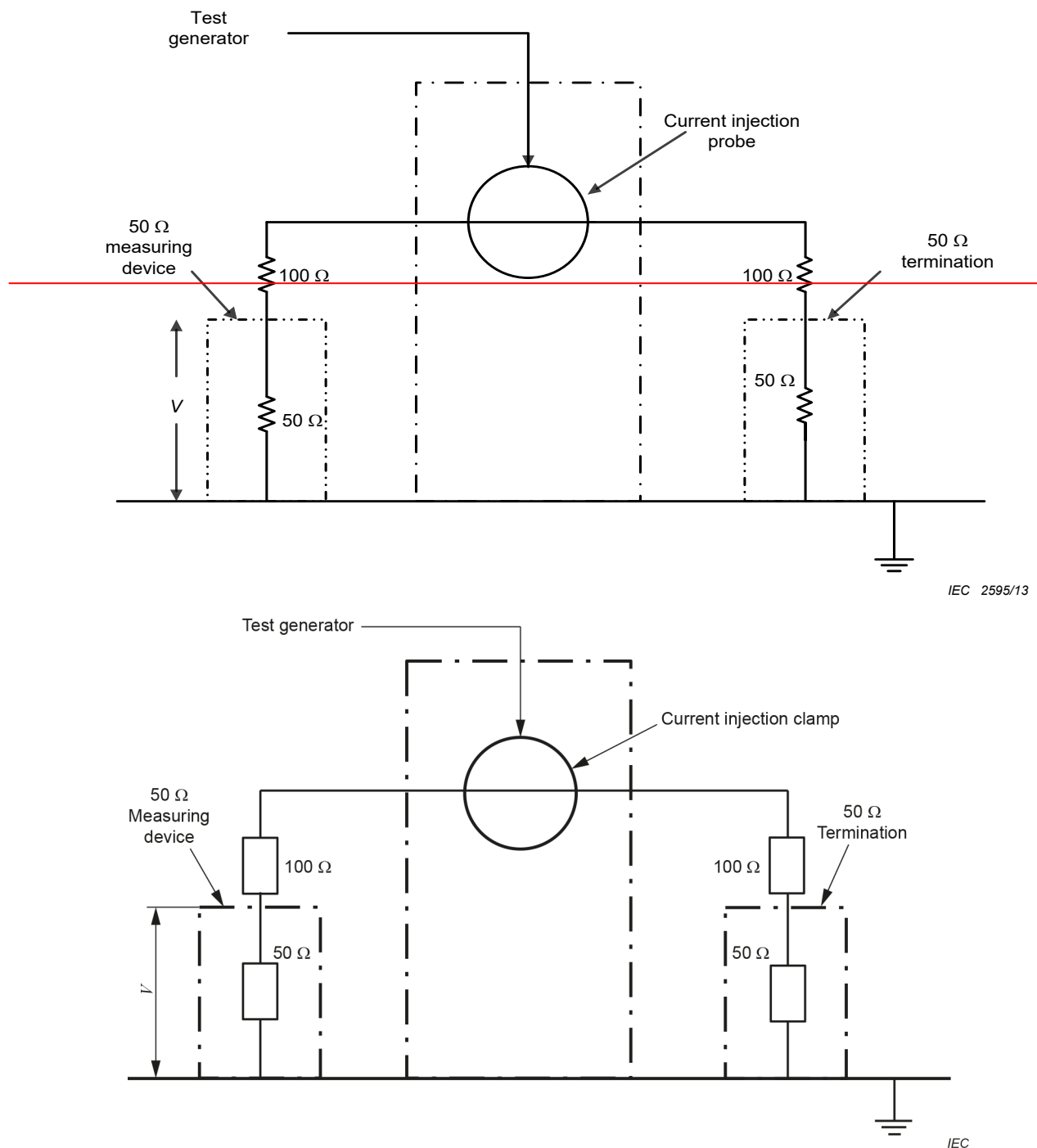


Figure 9 – Example of circuit for level-setting setup in a $150\ \Omega$ test jig

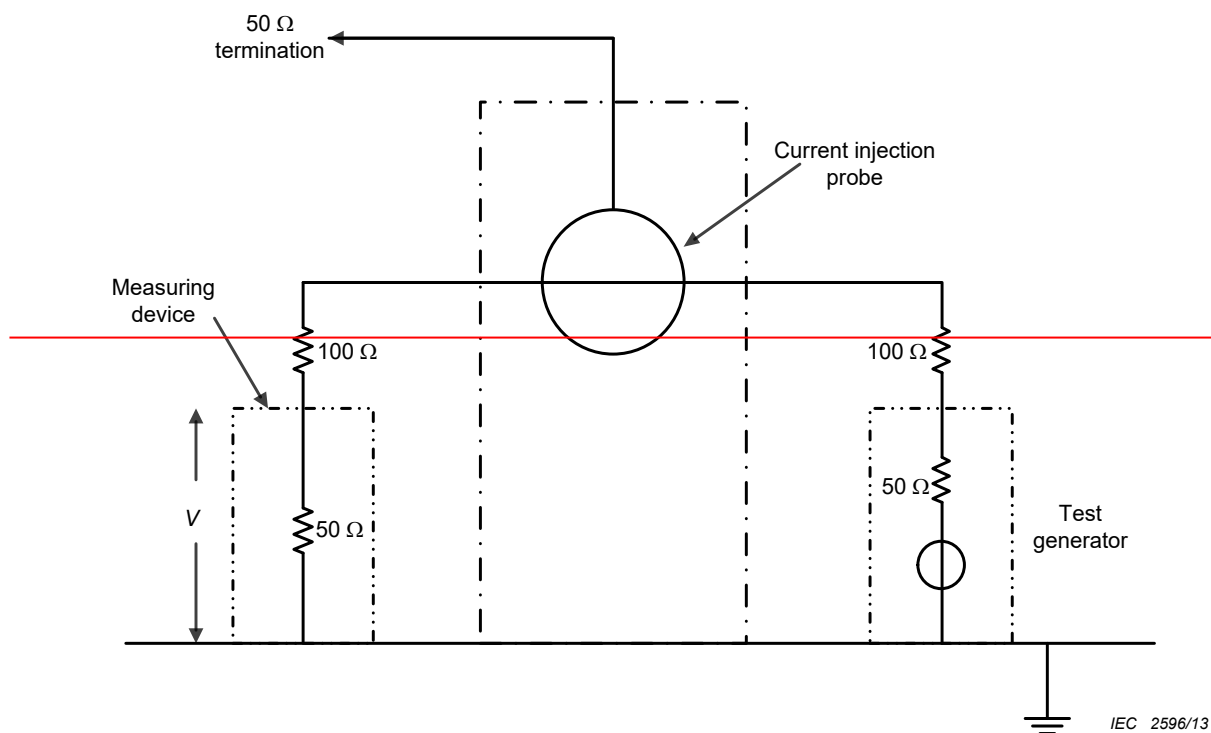
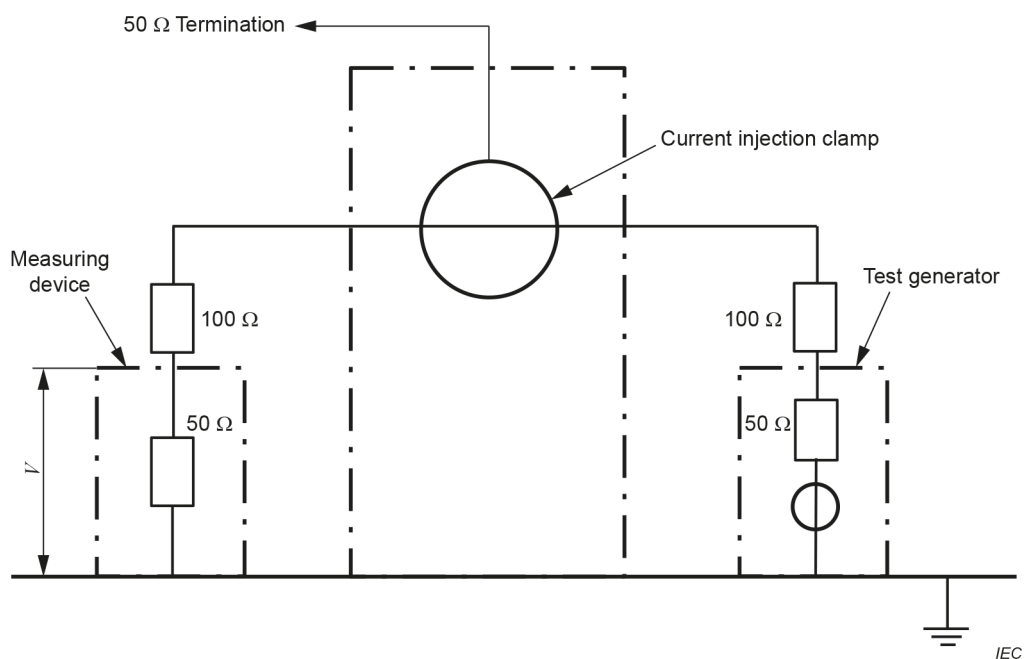


Figure 10 – Example of circuit for evaluating the ~~performance~~ transmission loss of the current clamp ~~level-setting~~

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

~~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.~~

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, ~~a proper caution should be exercised to~~ ensure a good ~~connection-producing~~ 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, $\geq 260 \Omega$ 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 8) 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.~~ Decoupling clamps are specified in Clause A.3.

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 ~~and/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, $|Z_{\text{ce}}|$. 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.

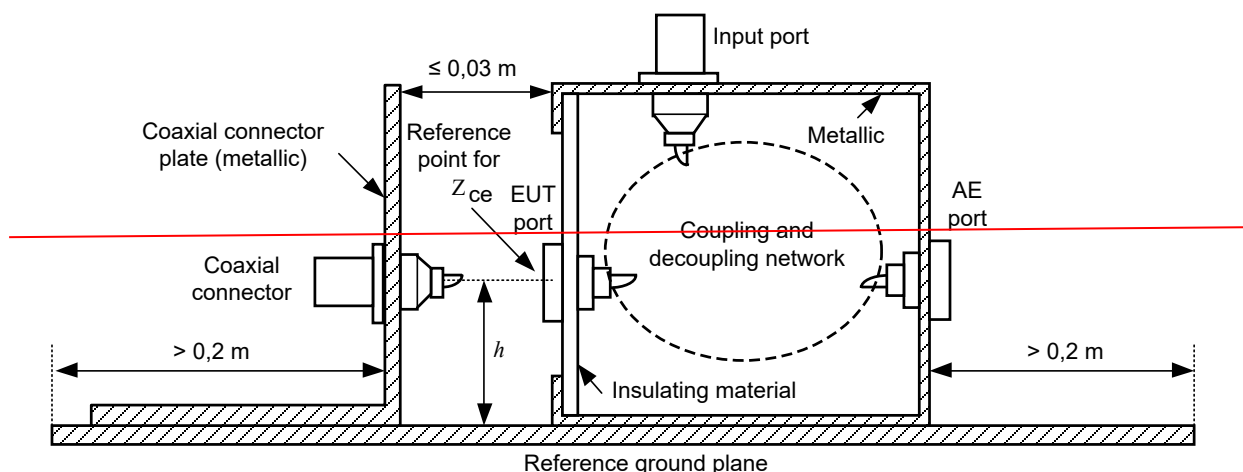
The CDNs shall meet the impedance requirements of Table 3 while the input port is terminated with a 50 Ω load and the AE port is sequentially loaded in common mode with a short-circuit and an open circuit condition as shown in Figure 12. This requirement ensures sufficient attenuation and makes the setup 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. ~~In all other cases the procedure defined in 7.7 shall be used.~~ 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).

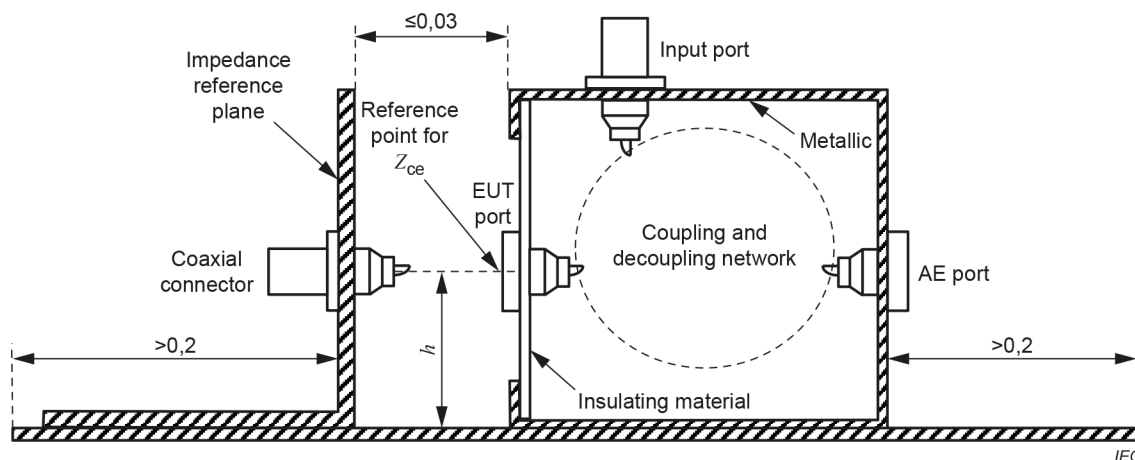
The adapters shall be placed on a reference ground plane, the size of which exceeds the projected geometry of this setup on all sides by at least 0,2 m. The insertion loss is measured according to the principle of Figure 13. Its value shall be in the range of $(9,5 \pm 0,5)$ dB (theoretical value of 9,5 dB caused by the additional series impedance when measured in a 50 Ω system). Attenuators with suitable VSWR (suggested: $VSWR \leq 1,2$) 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.~~

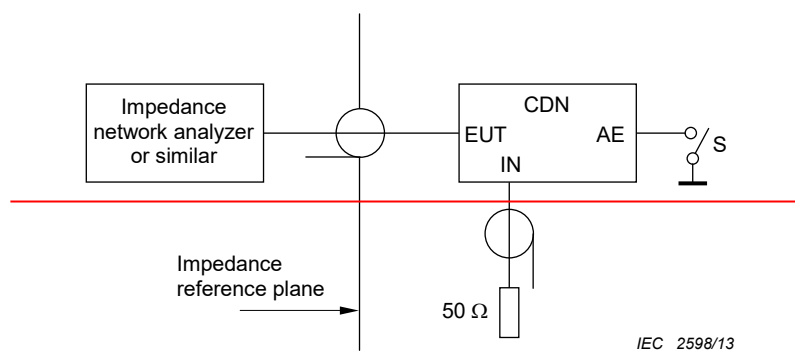
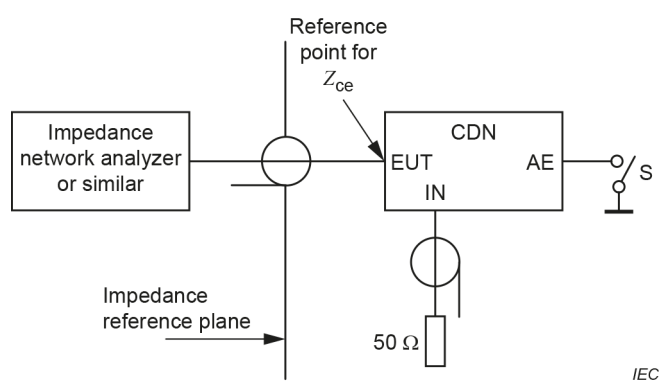
Dimensions in meters



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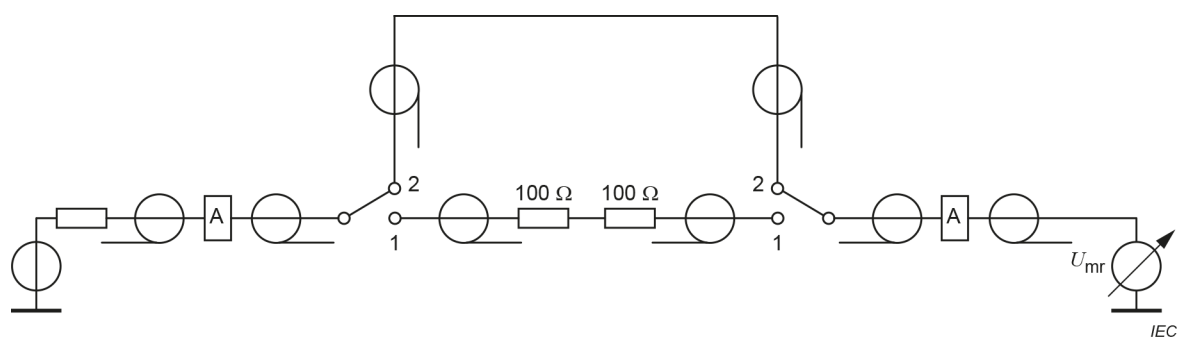
- The reference ground plane shall exceed the projection of the coupling and decoupling devices and other components by at least 0,2 m.
- The coaxial connector shall be connected horizontally to the EUT port.
- The height h of the EUT port depends on the individual CDN, which can vary from 0,03 m to 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-a) 11 – 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).

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



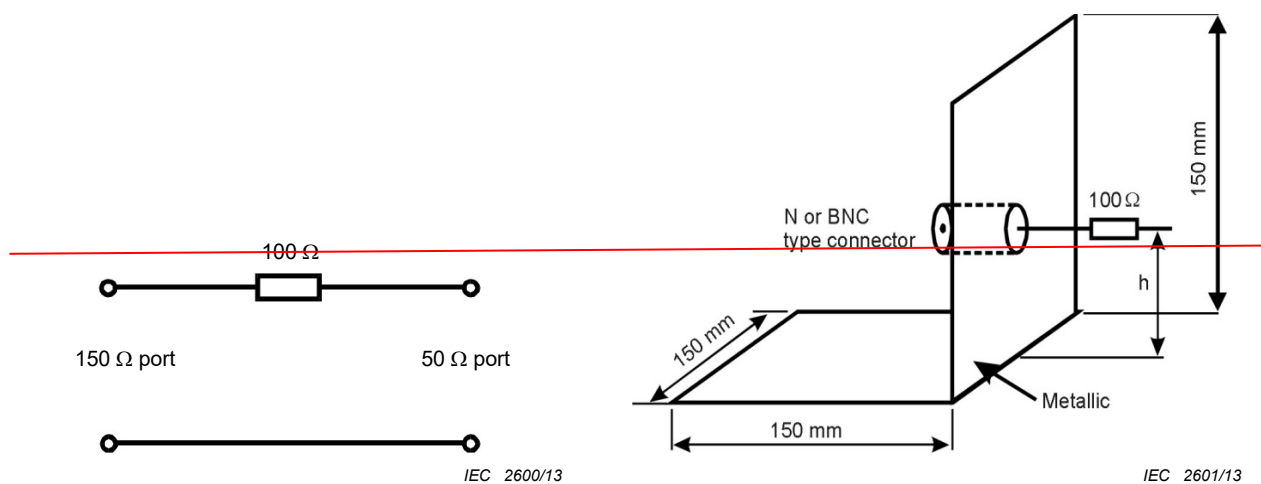
$$\text{Insertion loss} = U_{mr} (\text{switches position 2}) - U_{mr} (\text{switches position 1})$$

dB

dB(μV)

dB(μV)

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



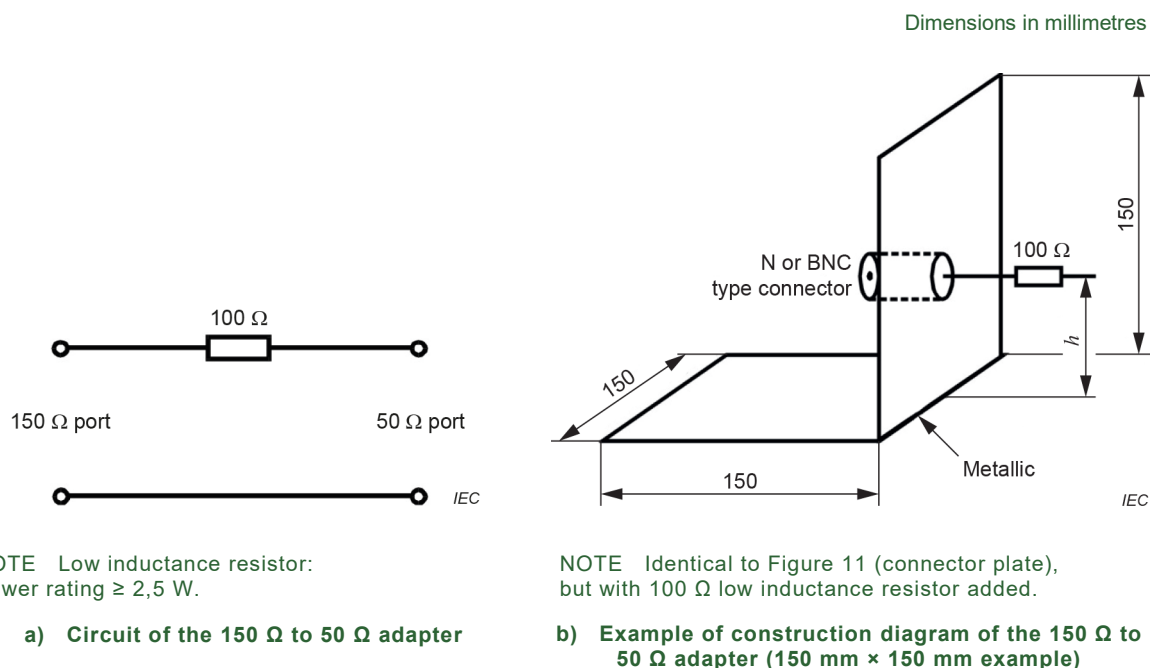
NOTE Low inductance resistor:
Power rating $\geq 2,5$ W

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 $\times$ 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



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

a) Circuit of the 150 Ω to 50 Ω adapter

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 $\times$ 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.

~~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 (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 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~~ 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.

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

- ~~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_{mf} 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 $P_{for,inc}$ or the voltage at the output port of the 150 Ω to 50 Ω adapter $U_{mf,inc}$;~~

~~3) calculate the difference $P_{for,inc} - P_{for}$ or $U_{mf,inc} - U_{mf}$ (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.~~

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 $P_{for, required}$ 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 $P_{\text{formax, inc}}$;
- iv) if the difference $P_{\text{formax, inc}} - P_{\text{formax}}$ 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 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.

Alternatively, the saturation verification procedure specified above may be directly included in the level-setting process of each CDN.

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

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

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

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

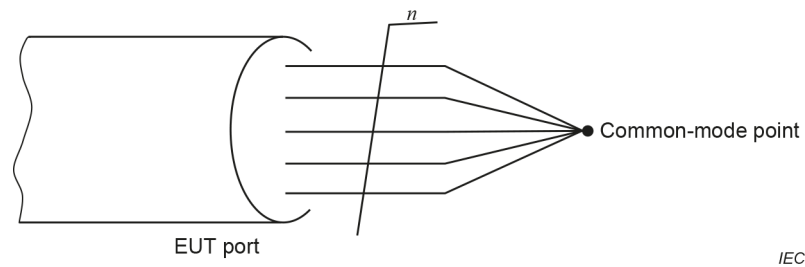
NOTE 32 U_0 is the test voltage specified in Table 1 and U_{mr} is the measured voltage as defined in 3.12 and shown in Figure 16. To minimize testing errors, the output level of the test generator is set by setting U_{mr} with 150 Ω loads (for instance with the 150 Ω to 50 Ω adapter and 50 Ω termination) and not by setting U_0 .

NOTE 43 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.

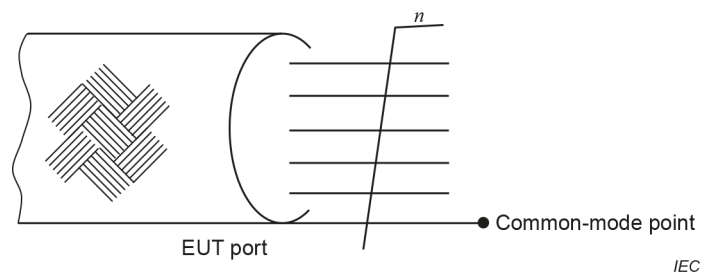
~~NOTE 5—In case of test instrumentation without amplifier output power control, the procedure is repeated for each coupling device and each target test level. For test systems with amplifier output power control or by following the procedure for amplifier linearity given in Annex K, the procedure of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

It is intended that the test generator setting process should be carried out at least annually and when significant changes are made to the test generator or its relevant equipment (RF generator, amplifier, CDN, coupling device, etc.), or both.

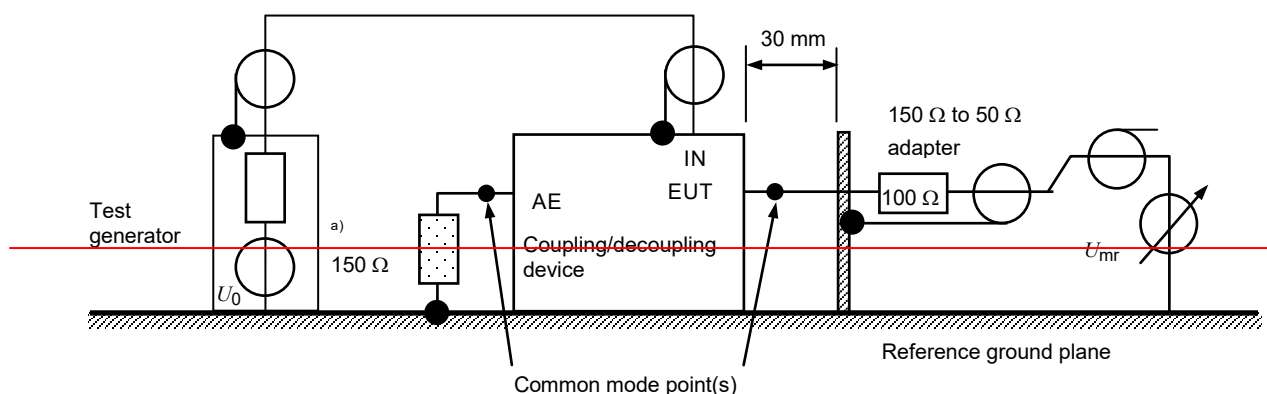


a) Definition of a common-mode point with unscreened cables containing n wires



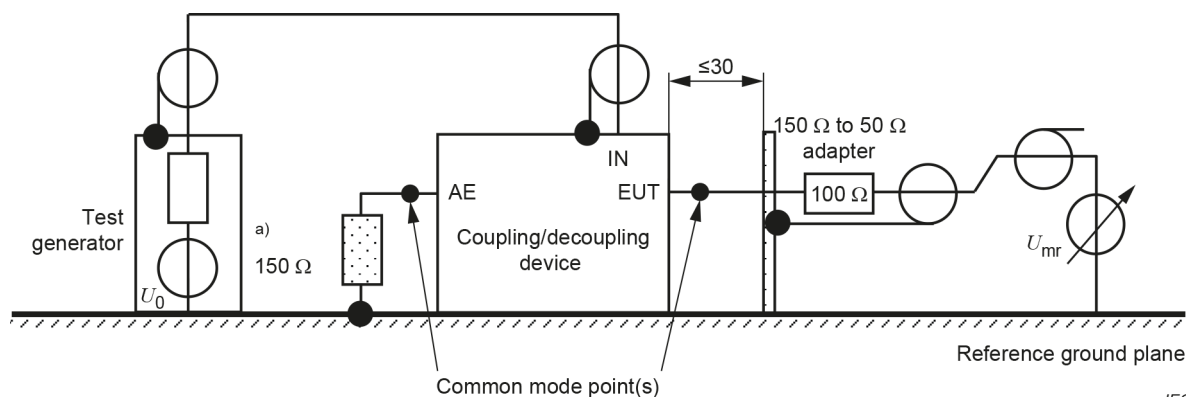
b) Definition of a common-mode point with screened cables containing n wires

Figure 15 – Definition of a common-mode point for unscreened and screened cables



IEC 2604/13

Dimensions in millimetres



IEC

Coupling/decoupling devices:

- CDNs;
- direct injection network (with decoupling);
- clamp injection device (e.g. EM clamp, current clamp with decoupling device).

- a) The 150 Ω loading, for example 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 16 – Setup for level-setting at the EUT port of the coupling/decoupling devices

7 Test setup and injection methods

7.1 Test setup

The equipment to be tested is placed on an insulating support of $0,1 \text{ m} \pm 0,05 \text{ m}$ height above a reference ground plane. A non-conductive roller/caster in the range of $0,1 \text{ m} \pm 0,05 \text{ m}$ 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.~~

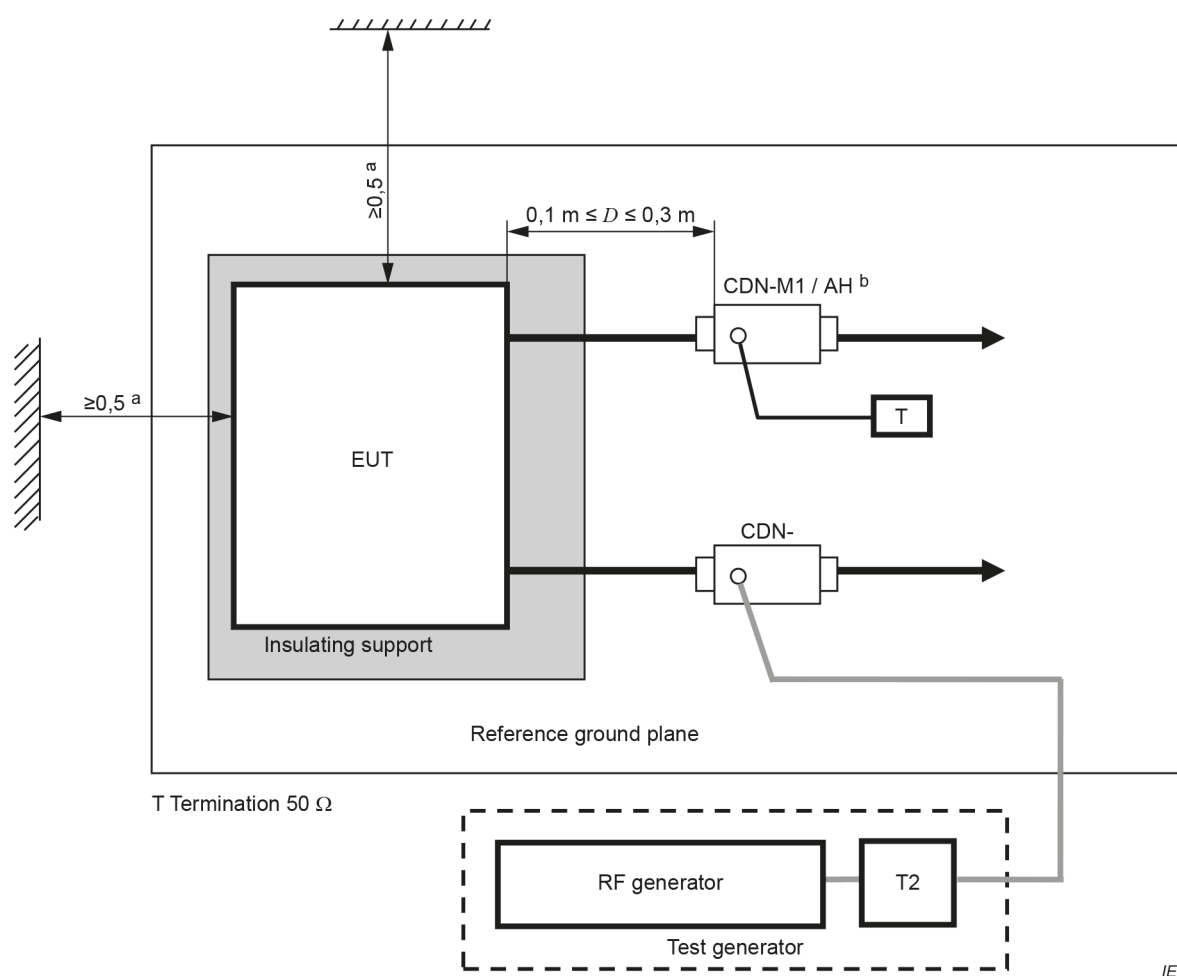
Grounding of the equipment shall be consistent with the EUT's installation instructions.

Where coupling ~~and/or~~ or decoupling devices, ~~or both~~, are required, they shall be located between 0,1 m and 0,3 m from the EUT (this distance is denoted ~~D~~ in this document). This distance is to be measured horizontally from the projection of the EUT onto the reference ground plane to the coupling ~~and/or~~ or decoupling device, ~~or both~~. See Figure 18, Figure 19 and Figure 22. Subclauses 7.2 to 7.7 provide more detailed information. Annex F shows a test setup example of a large EUT.

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

If the EUT is provided with a human interface device (i.e. keyboard, or any hand-held accessory), then the artificial hand shall be placed on this human interface device or wrapped around the accessory and connected to the reference ground plane. Details on construction, application and use of the artificial hand can be found in CISPR 16-1-2.

Dimensions in metres



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

^b The CDN not used for injection shall be terminated with 50 Ω, providing only a single return path. An artificial hand (AH) can also be used, depending on the kind of EUT.

Figure 17 – Example of test setup with a single unit EUT with only one CDN for injection (top view)

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 18).

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.~~

Custom length of cables can be necessary, i.e. shortened or modified to a length to fulfill the setup requirements.

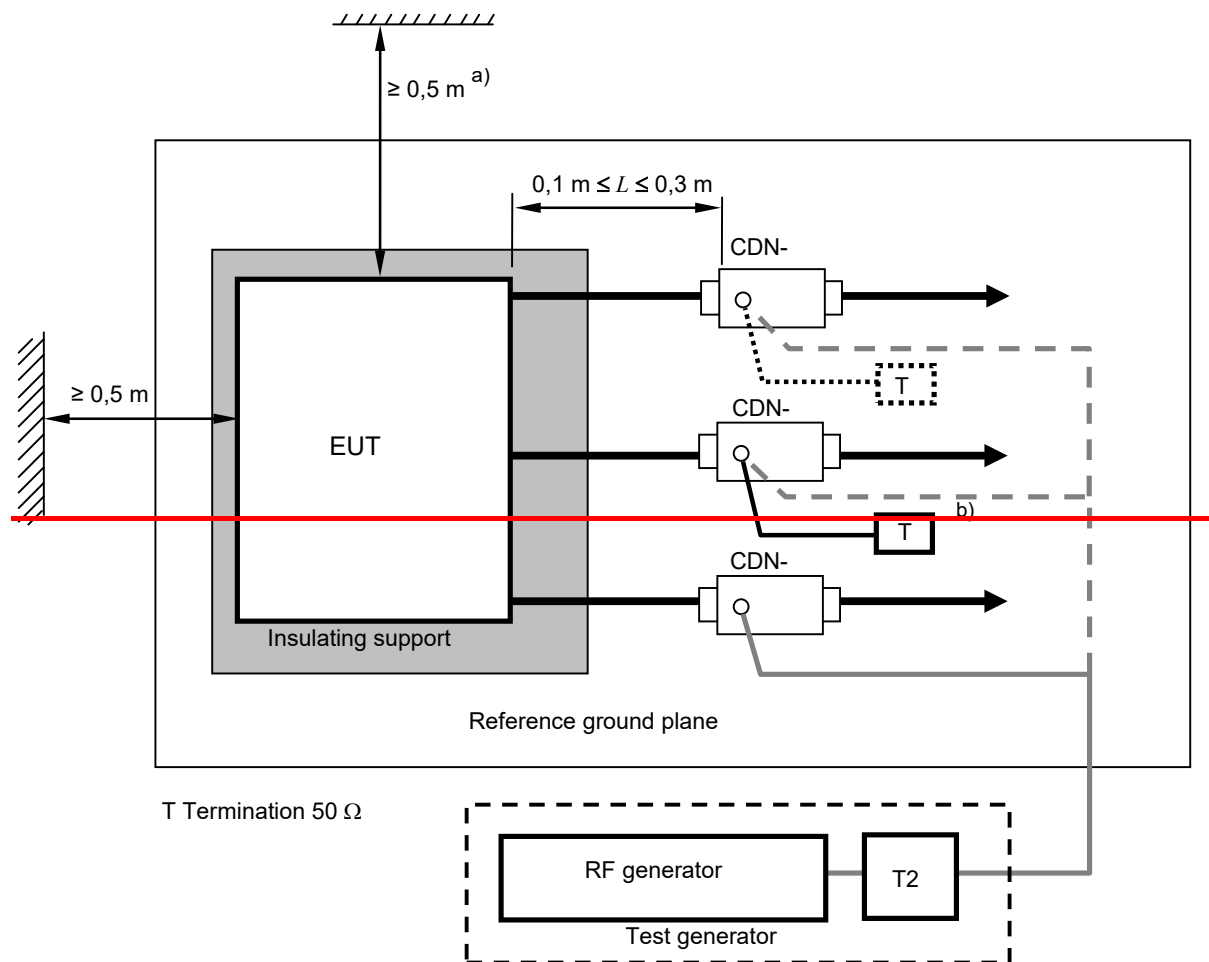
The preferred length of cable between EUT and CDN is less than 0,3 m. In case the cables cannot be shortened to this length, the setup shall be stretched out up to a cable length of maximum 2 m to allow a straight layout of the cable. In case of cable lengths exceeding 2 m, the excess cable length shall be laid out in serpentines if the cable is flexible enough to do so. The excess length of the cable shall be kept at least 30 mm above the reference ground plane, and not bundled or wrapped.

All deviations exceeding the preferred cable lengths of maximum 30 cm shall be stated in the test report.

If the EUT is provided with other earth terminals, ~~when allowed~~ in addition to the dedicated PE, they all shall be bonded together and then connected to the reference ground plane through CDN-M1 (unless this would significantly deviate from the intended installation in practice), see 6.2.2.2 and Figure 17 (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, for example 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, ~~or both~~. ~~As far as possible,~~ The number of cables to be tested ~~may~~ can be limited; however, ~~all types of physical ports should~~ at least one of each physical type port shall be submitted to injection.

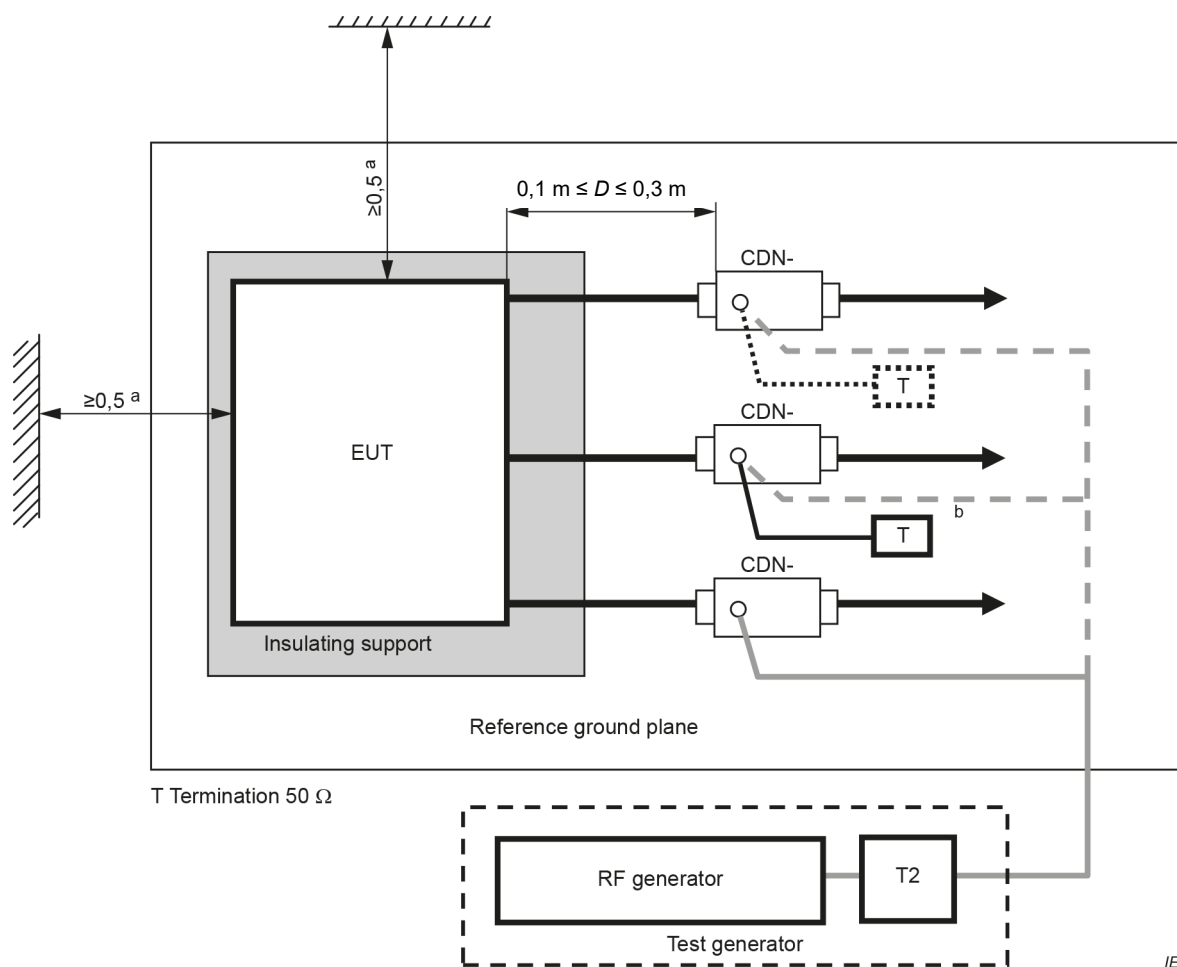


IEC 2605/13

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 50Ω , providing only a return path. All other CDNs shall be configured as decoupling networks.~~

Dimensions in metres



^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 single return path. All other CDNs shall be configured as decoupling networks.

Figure 18 – Example of test setup with a single unit EUT (top view) using multiple CDNs

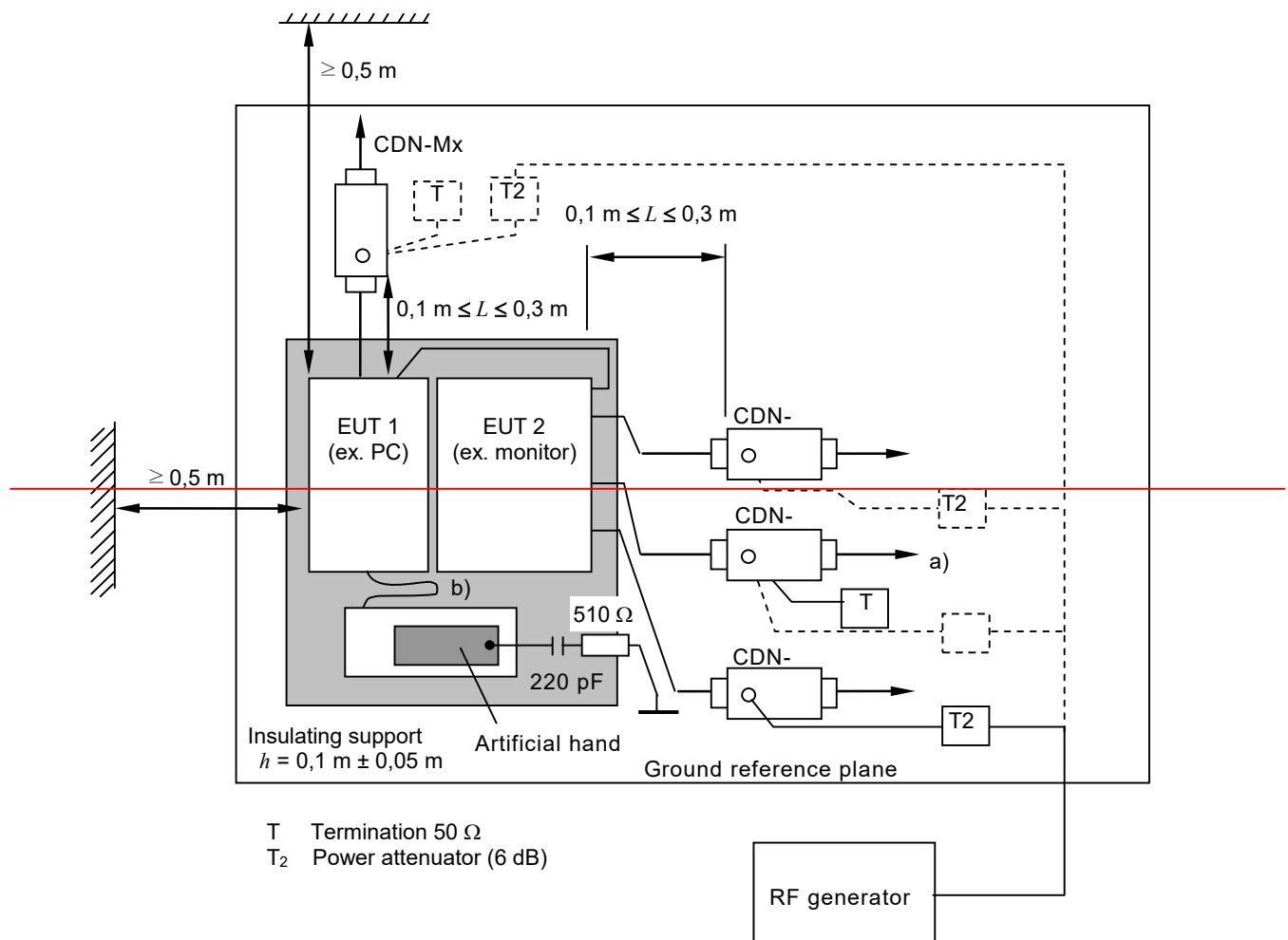
7.3 EUT comprising several units

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. $\leq 0,4$ 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 19.

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 7.7.

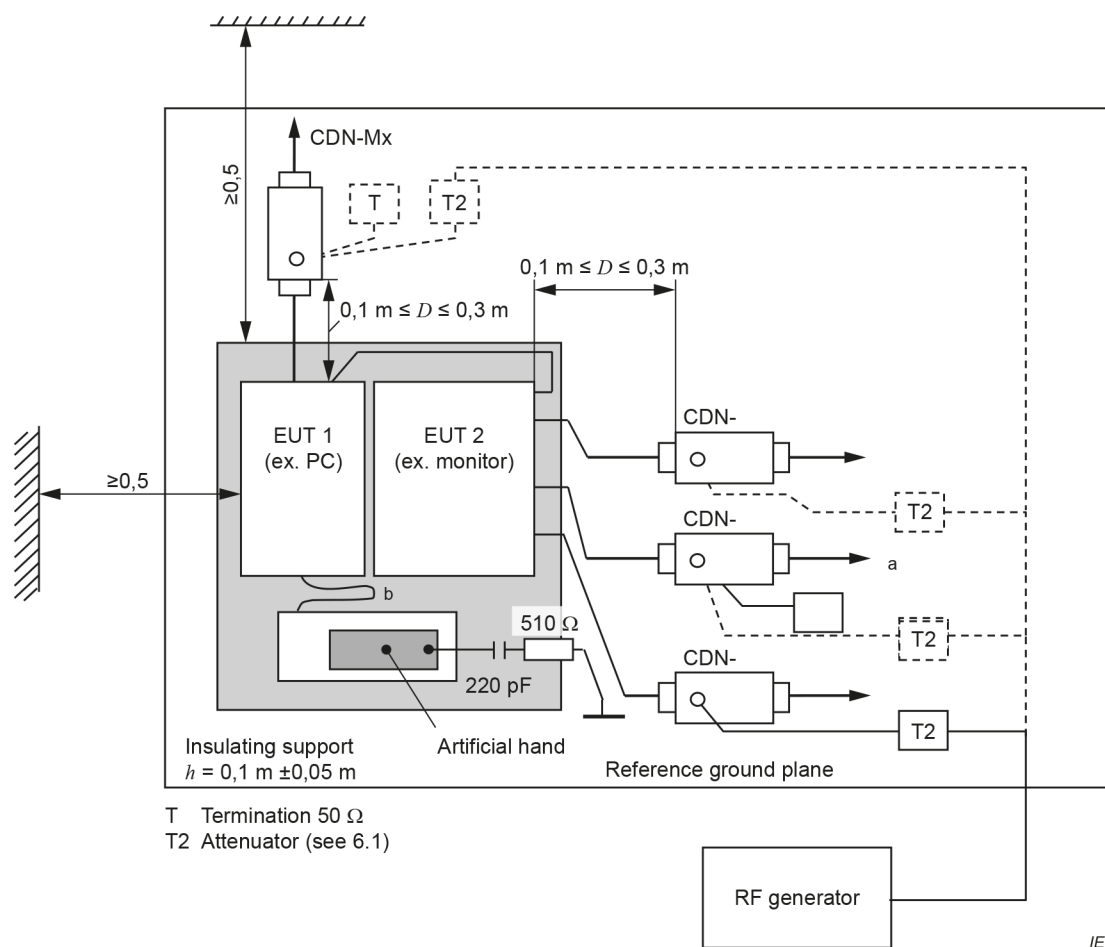
The EUT clearance from any metallic obstacles other than the test equipment shall be at least 0,5 m.



IEC 2606/13

- 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.~~

Dimensions in metres



- ^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 ($\leq 0,4$ m) belonging to the EUT shall remain on the insulating support.

Figure 19 – Example of a test setup with a multi-unit EUT (top view)

7.4 Rules for selecting injection methods and test points

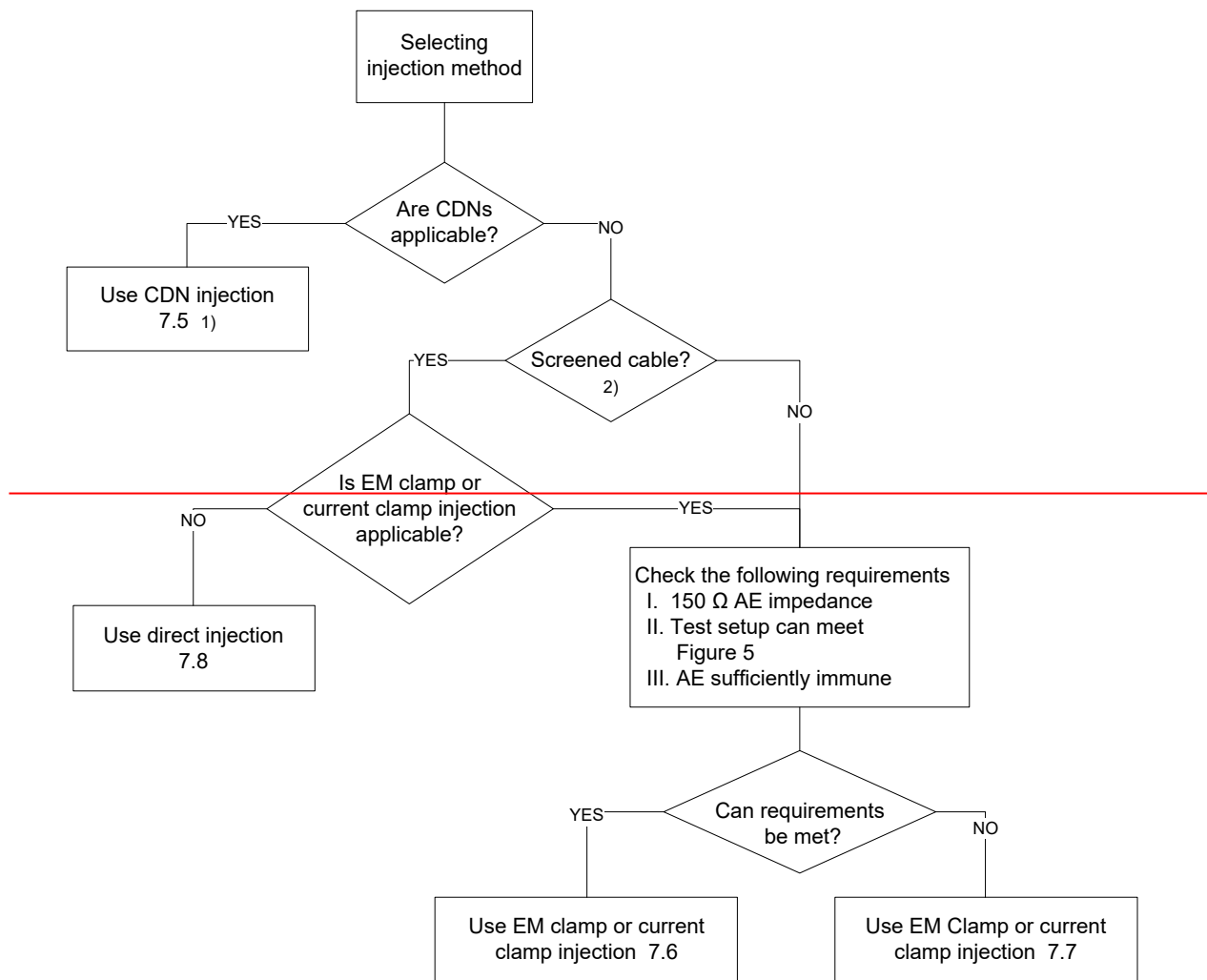
7.4.1 General

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, for example 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.~~

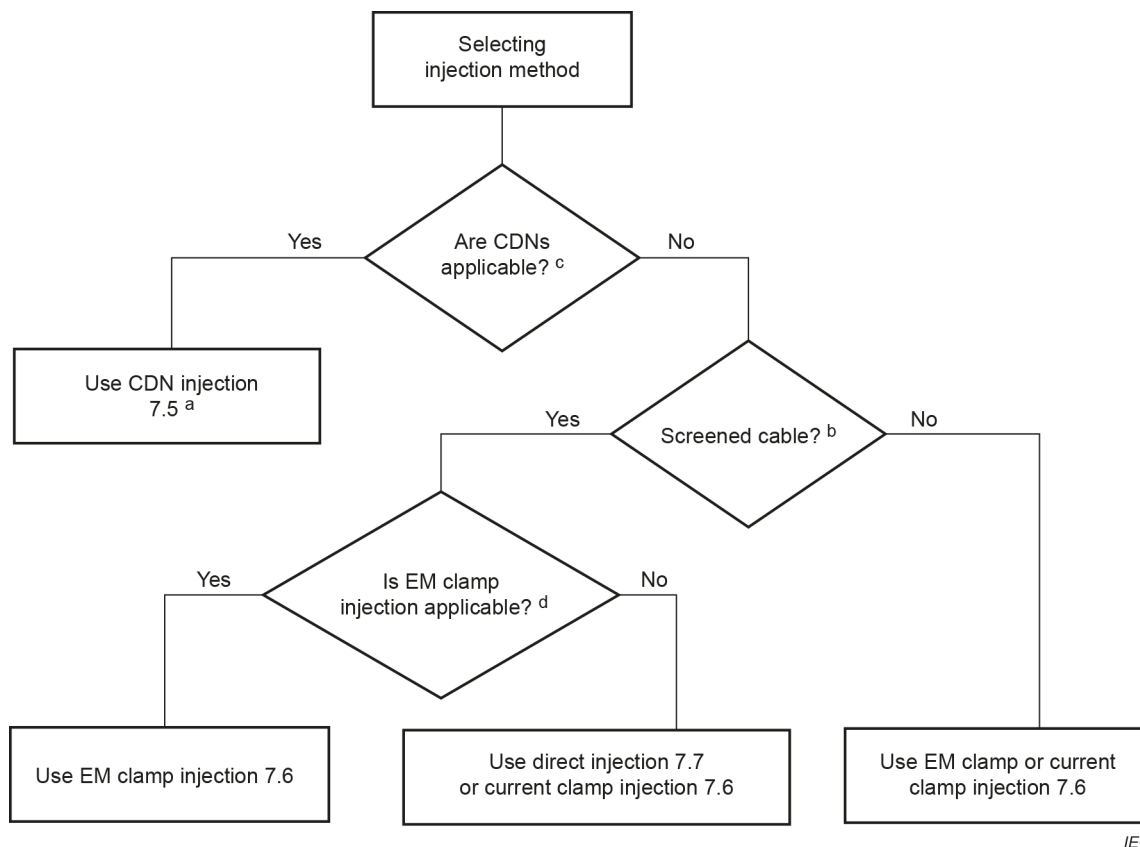
7.4.2 Injection method

Figure 20 gives rules for selecting the injection method.



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~~1) See Table 4.~~~~2) See 6.2.4.~~



IEC

^a See Table 4.

^b See 6.2.3.

^c See 6.2.1.

^d “Applicable” means that the EM clamp can technically accommodate the cable.

NOTE The decision path in the flowchart prefers test methods using a coupling device, for example CDN or EM clamp over direct injection, because the use of a coupling device is usually more prescriptive and leaves less room for individual setups, like direct injection.

Figure 20 – Rules for selecting the injection method

~~Where not specified herein,~~ Testing shall be performed with 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 document, but meeting the requirements of this document, may also be used.

Where 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, regardless of cable types present. If the bundle of cables is too large for testing as one cable, they should be separated by cable type or function (e.g. signal, mains, screened, etc.) and at least one cable of each type or function tested individually.

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.~~ In any one test, only two 150 Ω networks are required, one for signal injection, one for signal return path. It is not necessary to connect unterminated CDNs to all other EUT ports which are not yet undergoing RF test signal injection.

or return path. These other ports can instead be left open (unless the technical function of the EUT requires a treatment of these ports for operation) until they shall be used for injection of the test signal. At that time the suitable CDN can be connected and used for injection on each of such ports in turn. The ~~network~~ CDN 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~~ shall 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 21a)) then it is to be placed on an insulating support $0,1\text{ m} \pm 0,05\text{ m}$ 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 $150\ \Omega$ 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~~ AE's and EUT's installation requirements.
- c) One CDN shall be connected to the port intended to be tested and one CDN with $50\ \Omega$ 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 $150\ \Omega$ 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- S_n ($n = 1, 2, 3, \dots$): if the EUT has several CDN- S_n ports, the port which is closest to the port selected for injection (shortest geometrical distance) shall be used;
 - 4) CDN-M2 used for AC or DC 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 1 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.

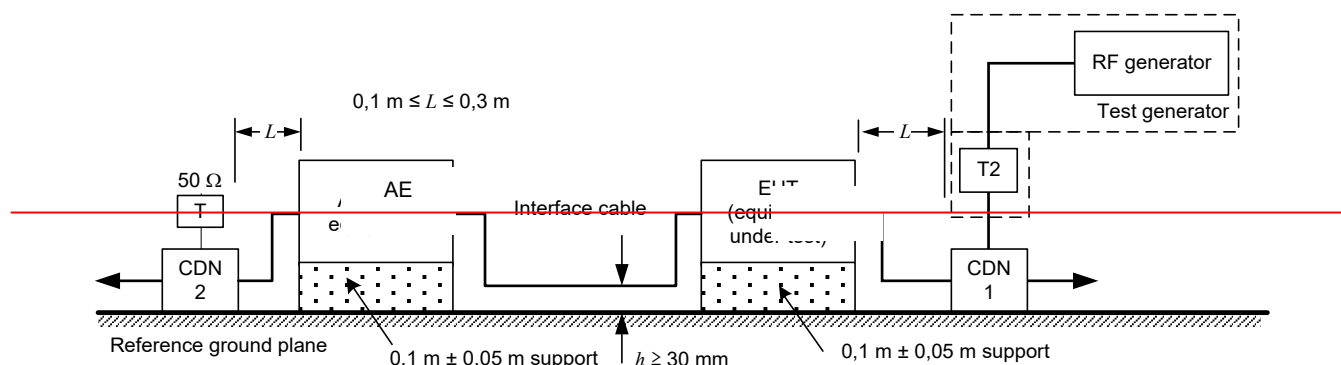
NOTE 2 The capacitive coupling path from the EUT to the reference ground plane provides the return path for the test signal.

- 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 $50\ \Omega$ in accordance with the above-mentioned priority. All other connections of the AE shall be decoupled (see Figure 21a)). If an AE connected to the EUT shows an error during the test, ~~a decoupling device (preferably a terminated EM clamp) should~~ may be connected between the EUT and AE (see Figure 21b)). The interface cable should have enough length to add the terminated EM clamp without changing the setup.
- 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~~ may be connected between EUT and AE, as mentioned above.

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:

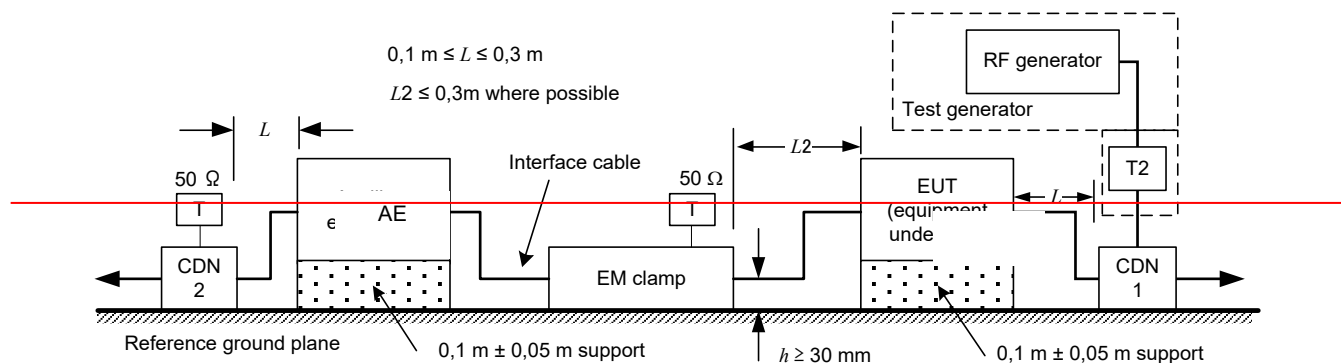
- through the CDN-M1 when the characteristics or specification of the EUT permit. In this case, the (power) supply shall be provided through an appropriate CDN-Mx type network;
- when the characteristics or specification of the EUT do not permit the presence of a CDN-M1 network in series with the earth terminal for RF or other reasons (for example, if this would significantly deviate from the intended installation in practice), 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 three-phase supply, a similar adjustment shall be done regarding the use of an appropriate CDN-Mx type network.



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~~The interface cable is set at 1 m if possible.~~

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



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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