BRITISH STANDARD

BS EN 61000-4-6:1996
IEC 61000-4-6:1996

Incorporating Amendments Nos. 1 and 2 and Corrigendum No. 1

Electromagnetic compatibility (EMC) —

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

The European Standard EN 61000-4-6:1996, with the incorporation of amendment A1:2001, has the status of a British Standard

ICS 33.100

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by Technical Committee GEL/210, Electromagnetic compatibility, to Subcommittee GEL/210/10, EMC High-frequency disturbances, upon which the following bodies were represented:

Association of Consulting Scientists
Association of Manufacturers of Domestic Electrical Appliances
British Telecommunications plc
BSI Staff
Electrical Installation Equipment Manufacturers' Association (BEAMA Ltd.)
EMC Test Laboratories Association
ERA Technology Ltd.
Federation of the Electronics Industry
GAMBICA (BEAMA Ltd.)
Lighting Industry Federation Ltd.
Professional Lighting and Sound Association
Power Supply Manufacturers' Association [PSMA (BEAMA Ltd.)]
Radiocommunications Agency
Co-opted members

This British Standard, having been prepared under the direction of the Electrotechnical Sector Board, was published under the authority of the Standards Board and comes into effect on 15 December 1996

The following BSI references relate to the work on this standard:
Committee reference GEL/210/10
Draft for comment 90/27512 DC

ISBN 0 580 26353 3

Amendments issued since publication

Amd. No.	Date	Comments
9500	May 1997	Correction of note to Figure D.1
13165	11 October 2001	See national foreword
13608 Corrigendum No.1	18 December 2001	See national foreword

Contents

National foreword

This British Standard has been prepared by Subcommittee GEL/210/10 and is the English language version of EN 61000-4-6:1996 *Electromagnetic compatibility (EMC) — Part 4-6: Testing and measurement techniques — Immunity to conducted disturbances, induced by radio-frequency fields,* including amendment A1:2001, published by the European Committee for Electrotechnical Standardization (CENELEC). It is identical with IEC 61000-4-6:1996, including amendment 1:2000, published by the International Electrotechnical Commission (IEC).

Annex B, Annex C, Annex D and Annex E are for information only.

The start and finish of text introduced or altered by amendment is indicated in the text by tags [A1⟩ ⟨A1]. Tags indicating changes to IEC text carry the number of the IEC amendment. For example, text altered by IEC amendment 1 is indicated by [A1⟩ ⟨A1].

National corrigendum December 2001 corrects the date of the CENELEC amendment A1 in the national foreword, the header of Table 2, 6.2.1, 6.4.1 (equations), 7.1.2, the note to Figure 7e and D.2.

IEC 61000 has been designated a Basic EMC publication for use in the preparation of dedicated product, product family and generic EMC standards.

IEC 61000 will be published in separate Parts in accordance with the following structure.

— *Part 1: General;*

— *Part 2: Environment;*

— *Part 3: Limits;*

— *Part 4: Testing and measurement techniques;*

— *Part 5: Installation and mitigation guidelines;*

— *Part 6: Generic standards;*

— *Part 9: Miscellaneous.*

From 1 January 1997, all IEC publications have the number 60000 added to the old number. For instance, IEC 27-1 has been renumbered as IEC 60027-1. For a period of time during the change over from one numbering system to the other, publications may contain identifiers from both systems.

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Find" facility of the BSI Standards Electronic Catalogue.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 39 and a back cover.

BSI copyright notice displayed in this document indicates when the document was last issued.

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 61000-4-6

July 1996

+ A1

February 2001

ICS 29.020

Descriptors: Electromagnetic compatibility, electric equipment, electronic equipment, radio disturbances

English version

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

(includes amendment A1:2001)
(IEC 61000-4-6:1996 + A1:2000)

Compatibilité électromagnétique (CEM) —
Partie 4-6: Techniques d'essai et de mesure —
Immunité aux perturbations conduites, induites par les champs radioélectriques
(inclut l'amendement A1:2001)
(CEI 61000-4-6:1996 + A1:2000)

Elektromagnetische Verträglichkeit (EMV) —
Teil 4-6: Prüf- und Meßverfahren —
Leitungsgeführte Störgrößen, induziert durch hochfrequente Felder
(enthält Änderung A1:2001)
(IEC 61000-4-6:1996 + A1:2000)

This European Standard was approved by CENELEC on 1996-07-02. Amendment A1 was approved by CENELEC on 2000-12-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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

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

CENELEC members are the national electrotechnical committees of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B-1050 Brussels

Ref. No. EN 61000-4-6:1996 + A1:2001 E

Foreword

The text of document 65A/165/FDIS-77B/144/FDIS, future edition 1 of IEC 1000-4-6, prepared by SC 65A, System aspects, of IEC TC 65, Industrial-process measurement and control and by SC 77B, High-frequency phenomena, of IEC TC 77, Electromagnetic compatibility, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61000-4-6 on 1996-07-02.

The following dates were fixed:

— latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop) 1997-04-01
— latest date by which the national standards conflicting with the EN have to be withdrawn	(dow) 1997-04-01

Annexes designated "normative" are part of the body of the standard. Annexes designated "informative" are given for information only. In this standard, Annex A and Annex ZA are normative and Annex B, Annex C, Annex D and Annex E are informative. Annex ZA has been added by CENELEC.

Foreword to amendment A1

The text of document 77B/291/FDIS, future amendment 1 to IEC 61000-4-6:1996, prepared by SC 77B, High-frequency phenomena, of IEC TC 77, Electromagnetic compatibility, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as amendment A1 to EN 61000-4-6:1996 on 2000-12-01.

The following dates were fixed:

— latest date by which the amendment has to be implemented at national level by publication of an identical national standard or by endorsement	(dop) 2001-09-01
— latest date by which the national standards conflicting with the amendment have to be withdrawn	(dow) 2003-12-01

Contents

blank

1 Scope

This section of International Standard IEC 1000-4 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 9 kHz up to 80 MHz. Equipment not having at least one conducting cable (such as mains supply, signal line or earth connection), which can couple the equipment to the disturbing RF fields is excluded.

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

This standard does not intend to specify the tests to be applied to particular apparatus or systems. Its main aim is to give a general basic reference to all concerned product committees of the IEC. The product committees (or users and manufacturers of equipment) remain responsible for the appropriate choice of the test and the severity level to be applied to their equipment.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this section of IEC 1000-4. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this section of IEC 1000-4 are encouraged to investigate the possibility of applying the most recent edition of the normative documents indicated below. Members of IEC and ISO maintain registers of valid International Standards.

IEC 50(131):1978, *International Electrotechnical Vocabulary (IEV) — Chapter 131: Electric and magnetic circuits.*

IEC 50(161):1990, *International Electrotechnical Vocabulary (IEV) — Chapter 161: Electro-magnetic compatibility.*

IEC 1000-4-3:1995, *Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 3: Radiated, radio frequency, electromagnetic field immunity test.*

CISPR 16-1:1993, *Specification for radio disturbance and immunity measuring apparatus and methods — Part 1: Radio disturbance and immunity measuring apparatus.*

CISPR 20:1990, *Limits and methods of measurement of immunity characteristics of sound and television broadcast receivers and associated equipment.*

3 General

The source of disturbance covered by this section of IEC 1000-4 is basically an electromagnetic field, coming from intended RF transmitters, that may act on the whole length of cables connected to an 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 involved. The in-going and out-going leads: e.g. mains, communication lines, interface cables, behave as passive receiving antenna networks because they can be several wavelengths long.

Between those cable networks, the susceptible equipment is exposed to currents flowing "through" the equipment. Cable systems connected to an equipment are assumed to be in resonant mode ($\lambda/4$, $\lambda/2$ open or folded dipoles) and as such are represented by coupling and decoupling devices having a common-mode impedance of 150 Ω with respect to a ground reference plane.

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 set-up as shown in Figure 2a.

The use of coupling and decoupling devices to apply the disturbing signal to one cable at the time, while keeping all other cables non-excited, see Figure 2b, can only approximate the real situation where disturbing sources act on all cables simultaneously, with a range of different amplitudes and phases.

Coupling and decoupling devices are defined by their characteristics given in 6.2. Any coupling and decoupling device fulfilling these characteristics can be used. The coupling and decoupling networks in Annex D are only examples of commercially available networks.

4 Definitions

For the purpose of this section of IEC 1000-4, the following definitions, together with those in IEC 50 (161) apply.

4.1
artificial hand
an electrical network simulating the impedance of the human body under average operational conditions between a hand-held electrical appliance and earth
[IEV 161-04-27]

NOTE The construction should be in accordance with IEC CISPR 16-1.

4.2
auxiliary equipment (AE)
equipment necessary to provide the EUT with the signals required for normal operation and equipment to verify the performance of the equipment under test

4.3
clamp injection
clamp injection is obtained by means of a clamp-on "current" injecting device on the cable

— current clamp: A transformer, the secondary winding of which consists of the cable into which the injection is made.
— electromagnetic clamp (EM-clamp): Injection device with combined capacitive and inductive coupling.

4.4
common-mode impedance
the ratio of the common-mode voltage and the common-mode current at a certain port

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

4.5
coupling factor
the ratio given by the open-circuit voltage (e.m.f.) obtained at the EUT port of the coupling (and decoupling) device divided by the open-circuit voltage obtained at the output of the test generator

4.6
coupling network
electrical circuit for transferring energy from one circuit to another with a defined impedance

NOTE Coupling and decoupling devices can be integrated into one box [coupling and decoupling networks (CDN)] or they can be in separate networks (commonly clamp injection).

4.7
decoupling network
electrical circuit for preventing test signals applied to the EUT from affecting other devices, equipment or systems that are not under test

4.8
EUT
equipment under test

4.9
test generator
a generator (RF generator, modulation source, attenuators, broadband power amplifier and filters) capable of generating the required signal (see Figure 3)

4.10
electromotive force (e.m.f.)
the voltage at the terminals of the ideal voltage source in the representation of an active element
[IEV 131-01-38]

4.11
measurement result, U_{mr}
voltage reading of the measurement equipment

4.12
voltage standing wave ratio (VSWR)
the ratio of a maximum to an adjacent minimum voltage magnitude along the line

5 Test levels

No tests are required for induced disturbances caused by electromagnetic fields coming from intentional RF transmitters in the frequency range 9 kHz to 150 kHz.

Table 1 — Test levels

Frequency range 150 kHz – 80 MHz		
Level	Voltage level (e.m.f.)	
	U_0[dB(µV)]	U_0[V]
1	120	1
2	130	3
3	140	10
X[a]	special	
[a] X is an open level.		

The open-circuit test levels (e.m.f.) of the unmodulated disturbing signal, expressed in r.m.s., are given in Table 1. The test levels are set at the EUT port of the coupling and decoupling devices, see 6.4.1. For testing of 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 4. Guidance for selecting test levels is given in Annex C.

NOTE 1 IEC 1000-4-3 also defines test methods for establishing the immunity of electrical and electronic equipment against radiated electromagnetic energy. It covers frequencies above 80 MHz. Product committees may decide to choose a lower or higher transition frequency than 80 MHz (see Annex B).

NOTE 2 Product committees may select alternative modulation schemes.

6 Test equipment

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 required point. A typical arrangement comprises the following items which may be separate or integrated into one or more test instruments (see 4.9 and Figure 3).

— RF signal 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 either an automated sweep capability $\leq 1,5 \times 10^{-3}$ decade/s and/or manual control, or in the case of RF synthesizers, they shall be programmable with frequency-dependent step sizes and dwell times;

— attenuator T1 (typically 0 dB ... 40 dB) of adequate frequency rating to control the disturbing test source output level. T1 may be included in the RF generator;

— RF switch, S1, by which the disturbing test signal can be switched on and off when measuring the immunity of the EUT. S1 may be included in the RF generator and is optional;

— broadband power amplifier(s) PA may be necessary to amplify the signal if the output power of the RF generator is insufficient;

— low-pass filters (LPF), and/or high-pass filters (HPF) may be necessary to avoid interference with some types of EUT, for example RF receivers caused by (sub-) harmonics. When required they shall be inserted in between the broadband power amplifier, PA, and the attenuator T2;

— attenuator, T2, (fixed ≥ 6 dB, Zo = 50 Ω), with sufficient power ratings. T2 is provided to reduce the mismatch from the power amplifier to the network and shall be located as close as possible to the coupling device.

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

Characteristics of the test generator without modulation are given in Table 2.

Table 2 — Characteristics of the test generator

Output impedance	50 Ω, VSWR ≤ 1,2
Harmonics and distortion	more than 15 dB below carrier level
Amplitude modulation	internal or external, 80 % ± 5 % in depth by a 1 kHz ± 10 % sine wave
Output level	sufficiently high to cover test level (see also Annex E)

6.2 Coupling and decoupling devices

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.

The coupling and decoupling devices can be combined into one box (so called: coupling/decoupling network; CDN) or can consist of several parts. The main coupling and decoupling device parameter, the common-mode impedance seen at the EUT-port, is specified in Table 3.

Rules for selecting the appropriate injection method are given below and in 7.1.

Table 3 — Main coupling and decoupling device parameter

	Frequency band	
Parameter	0,15 MHz – 26 MHz	26 MHz – 80 MHz
$\lvert Z_{ce} \rvert$	1 50 Ω ± 20 Ω	$150\ \Omega\ ^{+60}_{-45}\ \Omega$

NOTE 1 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 ground reference plane.

NOTE 2 When clamp injection methods are used, without complying with the common-mode impedance requirements for the auxiliary equipment, the requirements of Z_{ce} may not be met. However, the injection clamps can provide acceptable test results when the guidance of 7.3 is followed.

6.2.1 *Direct injection*

The disturbing signal, coming from the test generator is injected on to screened and coaxial cables via a 100 Ω resistor. In between the auxiliary equipment (AE) and the injection point, a decoupling circuit (see 6.2.4) shall be inserted as close as possible to the injection point (see Figure 5b). For certain simple screened cable configurations, the decoupling circuit together with the 100 Ω resistor may be combined into one box. (See Annex D, Figure D.1.)

6.2.2 *Coupling and decoupling networks (CDNs)*

These networks comprise the coupling and decoupling circuits in one box and can be used for specific unscreened cables e.g. CDN-M1, CDN-M2, CDN-M3, CDN-T2, CDN-T4, CDN-AF-2, see Annex D. Typical concepts of the coupling and the decoupling networks are given in Figure 5c and Figure 5d. The networks shall not unduly affect the functional signals. Constraints on such effects may be specified in the product standards.

6.2.2.1 *Coupling and decoupling networks for power supply lines*

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

The disturbing signal shall be coupled to the supply lines, using type CDN-M1 (single wire), CDN-M2 (two wires) or CDN-M3 (three wires), or equivalent networks (see Annex D.) Similar networks can be defined for a 3-phase mains system. The coupling circuit is given in Figure 5c.

All power supply lines from the EUT to the AE shall be coiled to form current compensated chokes to prevent saturation.

If in real installations the supply wires are individually routed, separate coupling and decoupling networks CDN-M1 shall be used and all input ports shall be treated separately.

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

— through the CDN-M1 when the characteristics or specification of the EUT permit. In this case, the (power) supply shall be provided through the CDN-M3 network;

— when the characteristics or specification of the EUT do not permit to have a CDN-M1 network in series with the earth terminal for RF or other reasons, the earth terminal shall be directly connected to the ground reference 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.

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

6.2.2.2 *Coupling and decoupling 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 coupling and decoupling network. Figure D.4, Figure D.5 and Figure D.6 in Annex D show these possibilities.

— CDN-T2 for a cable with 1 symmetrical pair (2 wires).

— CDN-T4 for a cable with 2 symmetrical pairs (4 wires).

— CDN-T8 for a cable with 4 symmetrical pairs (8 wires).

NOTE Other CDN-Tx-networks can be used, if they are suitable for the intended frequency range and satisfy the requirements of 6.2. For example, the ratio of conversion from differential mode to common mode 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 applied.

For balanced multi-pair cables, clamp injection is more appropriate.

6.2.2.3 *Coupling and decoupling for unscreened non-balanced lines*

For coupling and decoupling disturbing signals to an unscreened cable with non-balanced lines, the coupling and decoupling network described in Figure D.3 of Annex D may be used.

— CDN-AF2 for a cable with 2 wires.

For non-balanced multi-wire cables, clamp injection is more appropriate.

6.2.3 *Clamp injection*

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 auxiliary equipment. As such, the auxiliary equipment becomes part of the coupling and decoupling devices (see Figure 6). Subclause 7.2 gives instructions for proper application.

When an EM-clamp or a current clamp is used without fulfilling the constraints given in 7.2, the procedure defined in 7.3 shall be followed. In this procedure, the induced voltage is set in the same way as described in 6.4.1. In addition, the resulting current shall be monitored and corrected for.

6.2.3.1 *Current clamp*

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

NOTE 1 When using a current clamp, care should be taken that the higher harmonics generated by the power amplifier (PA) do not appear at higher 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.

6.2.3.2 EM–clamp

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

6.2.4 *Decoupling network*

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 26 MHz and ≥ 150 Ω above 26 MHz. The inductance can be achieved either by having a number of windings on ferrite toroids (see Figure 5d) or by using a number of ferrite toroids over the cable (usually as a clamp-on tube).

These decoupling networks shall be used on the lines under test by direct injection.

Furthermore, the decoupling networks shall be used on all cables not subjected to the test, but connected to the EUT and/or AEs.

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

Coupling and decoupling devices are characterized by the common-mode impedance seen at the EUT port, $|Z_{ce}|$. Its correct value ensures the reproducibility of the test results.

The coupling and decoupling devices and the impedance reference plane (Figure 7a) shall be placed on a ground reference plane of which the size exceeds the projected geometry of the set-up on all sides by at least 0,2 m.

A network analyzer or impedance meter shall be used with a 50 Ω reference impedance. The network analyzer shall be calibrated (with open circuit, short circuit and a 50 Ω load) at the impedance reference plane. It is necessary to make a short connection (L ≤ 30 mm) between the impedance reference connection and the EUT port terminals. The principle of Figure 7b and the geometry of Figure 7a shall be used to verify $|Z_{ce}|$.

The coupling and decoupling networks shall meet the impedance requirements of Table 3 in 6.2 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 7b. This requirement ensures sufficient attenuation and makes the set-up of the auxiliary equipment, e.g. open or short circuited, inputs insignificant.

If clamp injection or direct injection is used, it is unrealistic to verify the common-mode impedance for each AE set-up connected to the EUT. Normally, it is sufficient to follow the procedure as given in 7.2. In all other cases the procedure defined in 7.3 shall be used.

6.3.1 *Insertion loss of the 150 Ω to 50 Ω adaptors*

Two 150 Ω to 50 Ω adaptors of identical construction as shown in Figure 7d and Figure 7e are required. The adaptors shall be placed on a ground reference plane, the size of which exceeds the projected geometry of this set-up on all sides by at least 0,2 m. The insertion loss is measured according to the principle of Figure 7c. Its value shall be in the range of 9,5 ± 0,5 dB (theoretical value 9,5 dB caused by the additional series impedance when measured in a 50 Ω system. If necessary, the cable attenuation of the test set-up shall be compensated for. Precision attenuators at the inputs and outputs of receivers and generators are recommended.

6.4 Setting of the test generator

For the correct setting of the unmodulated test level the procedure in 6.4.1 shall be applied. It is assumed that the test generator, the coupling and decoupling devices and the 150 Ω to 50 Ω adaptor comply with the requirements of 6.1, 6.2 and 6.3.1.

WARNING. During the setting of the test generator, all connections to the EUT and AE port of the coupling and decoupling devices other than those required (see Figure 8), shall be disconnected either to avoid short-circuit conditions or to avoid destruction of the measurement equipment.

The output level of the test generator shall be set (see 6.4.1) with an unmodulated carrier. After the correct settings have been made, the modulation shall be switched on and checked using an RF oscilloscope.

During the tests the modulation shall remain switched on.

6.4.1 *Setting of the output level at the EUT port of the coupling device*

The test generator shall be connected to the RF input port of the coupling device. The EUT port of the coupling device shall be connected in common-mode through the 150 Ω to 50 Ω adaptor to a measuring equipment having a 50 Ω input impedance. The AE port shall be loaded in common-mode with a 150 Ω to 50 Ω adaptor, terminated with 50 Ω. The set-up is given in Figure 8 for all coupling and decoupling devices.

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

Using the above-mentioned set-up, the test generator shall be adjusted to yield the following reading on the measuring equipment.

— $U_{mr} = U_o/6 \pm 25$ %, in linear quantities, or

— $U_{mr} = U_o - 15{,}6$ dB ± 2 dB in logarithmic quantities.

The setting has to be performed for each individual coupling and decoupling device. The control parameters of the test generator setting (software parameters, attenuator setting, etc.) shall be recorded and used for testing.

NOTE 1 U_o is the test voltage specified in Table 1 and U_{mr} is the measured voltage as defined in 4.11 and Figure 8. To minimize testing errors, the output level of the test generator is set by setting U_{mr} with 150 Ω loads and not by setting U_o.

NOTE 2 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 adaptor terminated by the 50 Ω measuring equipment.

When the level setting for current clamps is carried out in a 50 Ω test environment (see Annex A), the voltage, U_{mr}, appearing across the 50 Ω load shall be 6 dB less than the test level required. In this case, the measured voltages or resulting currents in the 50 Ω test jig are equal to:

$U_{mr} = (U_o/2) \pm 25$ %, in linear quantities

or

$U_{mr} = U_o - 6$ dB ± 2 dB in logarithmic quantities

or

$$I_{(50\ \Omega\ \text{test jig})} = U_{o\ (\text{current clamp})} / (50\ \Omega + 50\ \Omega_{(\text{measurement receiver})})$$

$$I\ [\text{dB}\ (\mu\text{A})] = U_o\ [\text{dB}\ (\mu\text{V})] - 40\ [\text{dB}(\Omega)]$$

7 Test set-up for table-top and floor-standing equipment

The equipment to be tested is placed on an insulating support of 0,1 m height above a ground reference plane. All relevant cables shall be provided with the appropriate coupling and decoupling devices at a distance between 0,1 m and 0,3 m from the projected geometry of the EUT on the ground reference plane, see Figure 9 and Figure 10. Subclauses 7.1 to 7.5 give more detailed information.

7.1 Rules for selecting injection methods and test points

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

7.1.1 *Injection method*

Figure 1 gives rules for selecting the injection method.

All cables, selected for testing, shall be terminated functionally as close as possible to the real installation conditions. CDNs not listed in this standard, but meeting the requirements of this standard, may also be used.

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

If a product committee decides that a certain kind of coupling and decoupling device is more appropriate for cables connected to that 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.

7.1.2 *Test points*

In order to avoid unnecessary testing, the following guidance should be applied.

In general, it is sufficient that only a limited number, n (with $2 \leq n \leq 5$) of current distributions through the EUT are excited.

Testing shall be carried out using the most sensitive cable configuration. All other cables connected to the EUT shall either be disconnected (when functionally allowed) or provided with decoupling networks only.

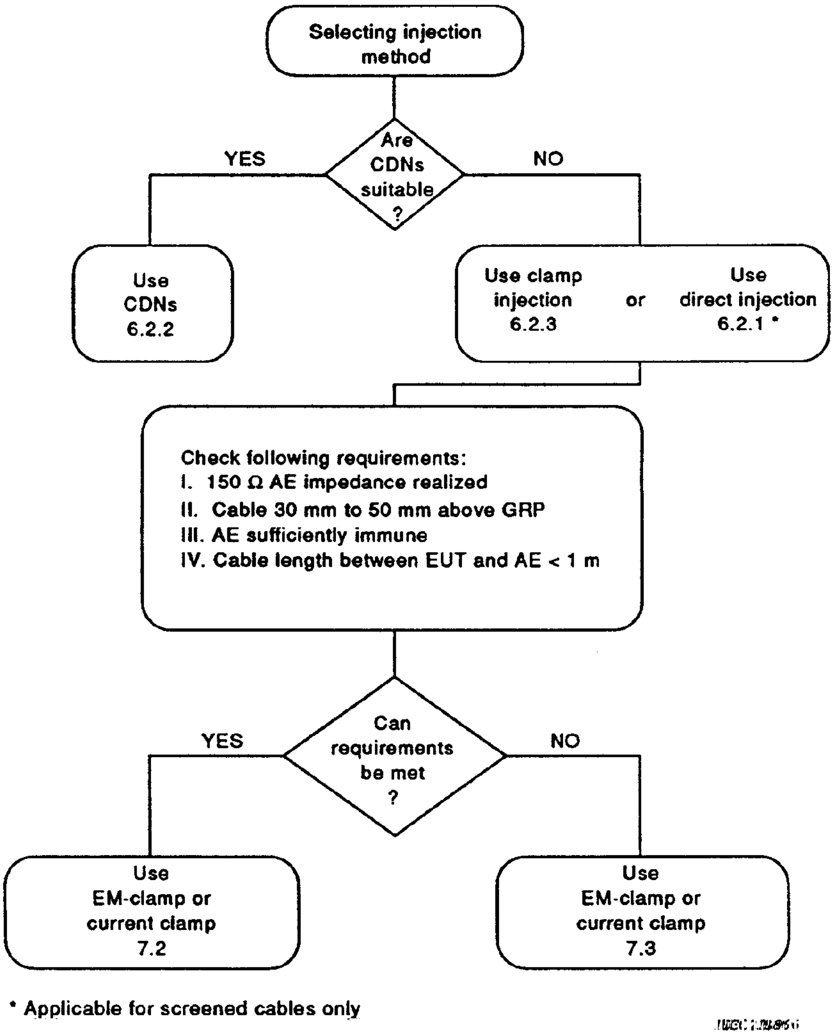


Figure 1 — Rules for selecting the injection method

7.2 Procedure for clamp injection application

When using clamp injection, the AE set-up shall present the common-mode impedance as required in 6.2 as closely as possible. Each AE used with clamp injection shall represent the functional installation conditions as closely as possible. To approximate the required common-mode impedance the following measures need to be taken.

— Each AE, used with clamp injection, shall be placed on an insulating support 0,1 m above the ground reference plane.

— All cables connected to each AE, other than those being connected to the EUT, shall be provided with decoupling networks, see 6.2.4. These decoupling networks shall be applied no further than 0,3 m from the AE. The cable(s) between the AE and the decoupling network(s) or in between the AE and the injection clamp shall not be bundled nor wrapped and shall be kept between 30 mm and 50 mm above the ground reference plane (Figure 6).

— The cable length between the AE and the clamp injection device shall be as short as possible ($\leq$ 0,3 m) to improve reproducibility at higher frequencies ($\geq$ 30 MHz). When using the EM-clamp, this is of less importance as the common-mode impedance is mainly determined by the EM-clamp at frequencies above 10 MHz (wavelength 30 m or less).

— At each AE the decoupling network installed on the cable, closest to the one(s) being connected to the EUT, shall be replaced by a CDN which is terminated at its input port with 50 Ω (see Annex A, Figure A.7). This CDN represents the 150 Ω loading of the AE to the ground reference plane. In the case where the AE is provided with a (separate) earth terminal, this earth terminal shall be connected through a CDN-M1 network, terminated with 50 Ω at the input port, to the ground reference plane while keeping decoupling networks on all other cables.

In all other cases the procedure given in 7.3 should be followed.

7.3 Procedure for clamp injection when the common-mode impedance requirements cannot be met

When using clamp injection and the common-mode impedance requirements cannot be met at the AE side, it is necessary that the common-mode impedance of the AE is less than or equal to the common-mode impedance of the EUT port being tested. If not, measures shall be taken, e.g. by using decoupling capacitors at the AE port, to satisfy this condition. In this procedure, only the relevant differences with 7.2 are given.

— Each AE and EUT used with clamp injection shall represent the functional installation conditions as close as possible e.g. either the EUT shall be connected to the ground reference plane or placed on an insulating support (see Figure A.6 and Figure A.7).

— By means of an extra current probe (having low insertion loss), inserted in between the injection clamp and the EUT, the current resulting from the induced voltage (set according to 6.4.1) shall be monitored. If the current exceeds the nominal circuit value I_{max} given below, the test generator level shall be reduced until the measured current is equal to the I_{max} value:

$I_{max} = U_o/150\ \Omega$.

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

To ensure reproducibility, the test set-up shall be fully described in the test report.

7.4 EUT comprising a single unit

The EUT shall be placed on an insulating support, 0,1 m above the ground reference plane. For table-top equipment, the ground reference plane may be placed on a table (see Figure 9).

On all cables to be tested, coupling and decoupling devices shall be inserted. The coupling and decoupling devices shall be placed on the ground reference plane, making direct contact with it at about 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 nor wrapped. Their height above the ground reference plane shall be between 30 mm and 50 mm.

If the EUT is provided with other earth terminals, they shall, when allowed, be connected to the ground reference plane through the coupling and decoupling network CDN-M1, see 6.2.2.1 (i.e. the AE port of the CDN-M1 is then connected to the ground reference 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 ground reference plane.

Auxiliary equipment (AE) required for the defined operation of the EUT according to the specifications of the product committee, e.g. communication equipment, modem, printer, sensor, etc., as well as auxiliary equipment necessary for ensuring any data transfer and assessment of the functions, shall be connected to the EUT through coupling and decoupling devices. However, as far as possible the number of cables to be tested should be limited by restricting attention to the representative functions. See 7.1 for detailed information.

7.5 EUT comprising several units

Equipment comprising several units which are interconnected together (see Figure 10), shall be tested using one of the following methods.

Preferred method: Each sub-unit shall be treated and tested separately as an EUT, see 7.4, considering all others as AE. Coupling and decoupling devices shall be placed on the cables (according to 7.1) of the sub-units considered as the EUT. All sub-units shall be tested in turn.

Alternative method: Sub-units that are always connected together by short cables, i.e. ≤ 1 m, and that are part of the equipment to be tested, can be considered as one EUT. No conducted immunity test shall be performed on their interconnecting cables, these cables being regarded as internal cables of the system.

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 0,1 m above the ground reference plane. The interconnecting cables of these units shall also be placed on the insulating support. Coupling and decoupling devices shall be placed on all other cables of the EUT, e.g. on cables to the mains supply and auxiliary equipment (see 7.1).

8 Test procedure

The EUT shall be tested within its intended operating and climatic conditions. The temperature and relative humidity should be recorded in the test report.

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

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

The test shall be performed with the test generator connected to each of the coupling and decoupling devices in turn while the other non-excited RF input ports of the coupling devices are terminated by a 50 Ω load resistor.

Filters shall be used to prevent (higher order or sub-) harmonics from disturbing the EUT. A 100 kHz high-pass filter (HPF), may be required after the test generator. The band stop characteristics of the low-pass filters (LPF) shall be sufficient to suppress the harmonics so that they do not affect the results. These filters shall be inserted after the test generator before setting the test level (see 6.4.1).

The frequency range is swept from 150 kHz to 80 MHz, using the signal levels established during the setting process, and with the disturbance signal 80 % amplitude modulated with a 1 kHz sine wave, pausing to adjust the RF signal level or to switch coupling devices as necessary. The rate of sweep shall not exceed $1,5 \times 10^{3}$ decades/s. Where the frequency is swept incrementally, the step size shall not exceed 1 % of the start and thereafter 1 % of the preceding frequency value.

The dwell time at each frequency shall not be less than the time necessary for the EUT to be exercised, and able to respond. Sensitive frequencies e.g. clock frequency(ies) and harmonics or frequencies of dominant interest shall be analyzed separately.

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

The use of special exercising program is recommended.

Testing shall be performed according to a test plan, which shall be included in the test report.

The test report shall include:

— the size of the EUT;

— representative operating conditions of the EUT;

— whether the EUT is tested as a single or multiple unit;

— the type of the test facility used and the positions of the EUT(s), AE(s) and coupling and decoupling devices;

— the coupling and decoupling devices used and their coupling factors;

— the frequency range of application of the test;

— the rate of sweep of frequency, dwell time and frequency steps;

— the test level to be applied;

— the type(s) of interconnecting cables to be used and the interface port (of the EUT) to which these were connected;

— the performance criteria that have been applied;

— a description of the EUT exercising method.

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

The test documentation shall include the test conditions, a statement of calibration, and the test results.

[A1)

9 Evaluation of test results

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

a) normal performance within limits specified by the manufacturer, requestor or purchaser;

b) temporary loss of function or degradation of performance which ceases after the disturbance ceases, and from which the equipment under test recovers its normal performance, without operator intervention;

c) temporary loss of function or degradation of performance, the correction of which requires operator intervention;

d) loss of function or degradation of performance which is not recoverable, owing to damage to hardware or software, or loss of data.

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

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

10 Test report

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

— the items specified in the test plan required by clause 8 of this standard;

— identification of the EUT and any associated equipment, for example, brand name, product type, serial number;

— identification of the test equipment, for example, brand name, product type, serial number;

— any special environmental conditions in which the test was performed, for example, shielded enclosure;

— any specific conditions necessary to enable the test to be performed;

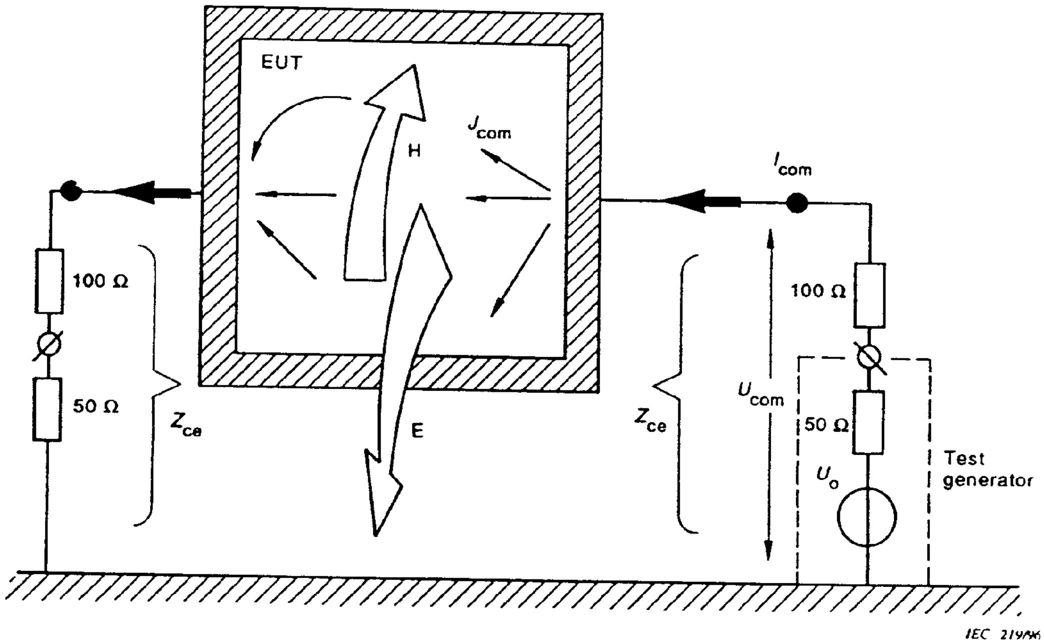
— performance level defined by the manufacturer, requestor or purchaser; (A1]

[A1]
— performance criterion specified in the generic, product or product-family standard;

— any effects on the EUT observed during or after the application of the test disturbance, and the duration for which these effects persist;

— the rationale for the pass/fail decision (based on the performance criterion specified in the generic, product or product-family standard, or agreed between the manufacturer and the purchaser);

— any specific conditions of use, for example cable length or type, shielding or grounding, or EUT operating conditions, which are required to achieve compliance. [A1]



Z_{ce} Common-mode EUT point impedance of the coupling and decoupling network system, Z_{ce} = 150 Ω

NOTE – The 100 Ω resistors are included in the coupling and decoupling networks. The left input is terminated by a (passive) 50 Ω load and the right input is loaded by the test generator.

U_o Test generator output voltage (e.m.f.)

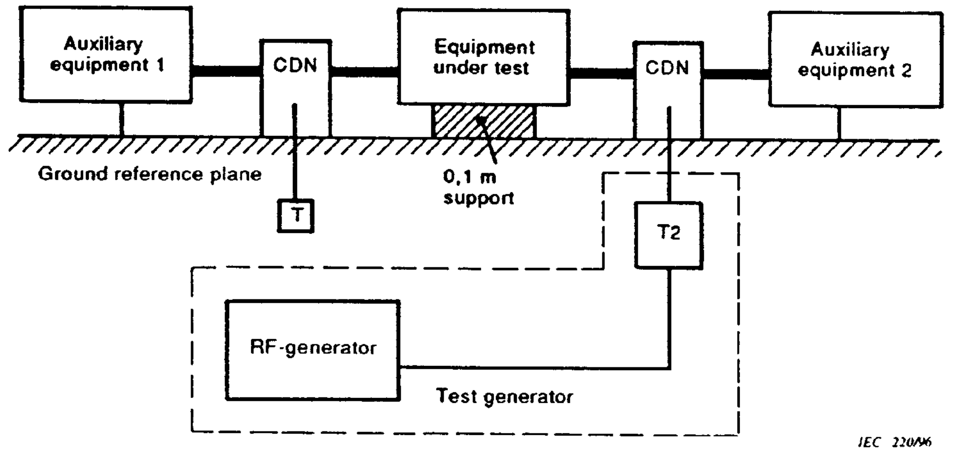
U_{com} Common-mode voltage between EUT and reference plane

I_{com} Common-mode current through the EUT

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

E, H Electric and magnetic fields

Figure 2a — Diagram to show EM fields near the EUT due to common-mode currents on its cables



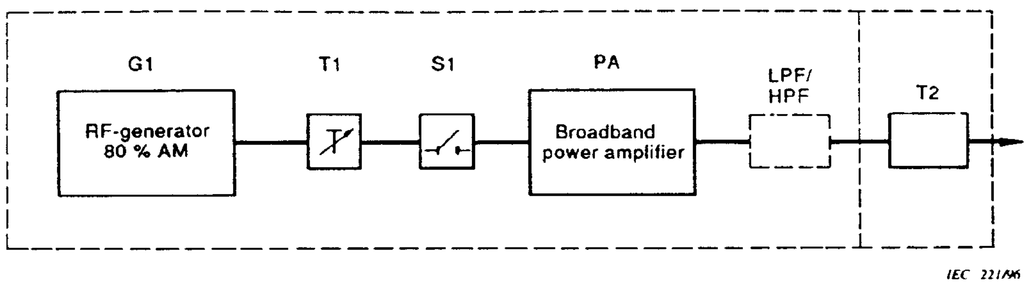
T Termination 50 Ω

T_2 Power attenuator (6 dB)

CDN Coupling and decoupling network

Figure 2b — Schematic set-up for immunity test to RF conducted disturbances

Figure 2 — Immunity test to RF conducted disturbances



G1 RF generator

PA Broadband power amplifier

LPF/HPF Low-pass filter and/or high-pass filter

T1 Variable attenuator

T2 Fixed attenuator (6 dB)

S1 RF switch

Figure 3 — Test generator set-up

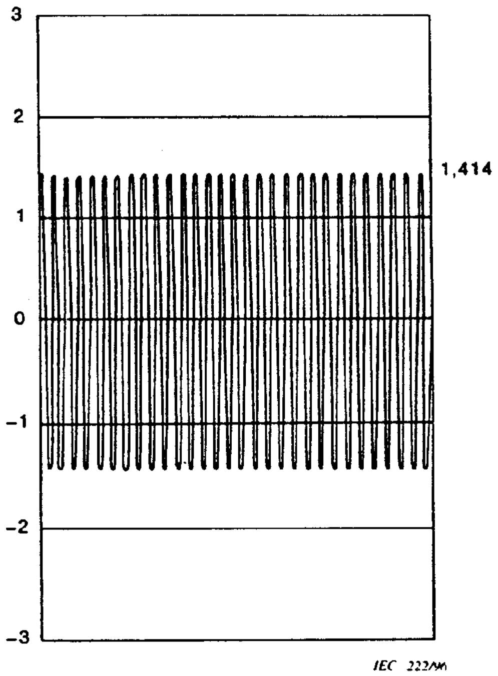


Figure 4a — Unmodulated RF signal
U_{pp} = 2,82 V, U_{rms} = 1,00 V

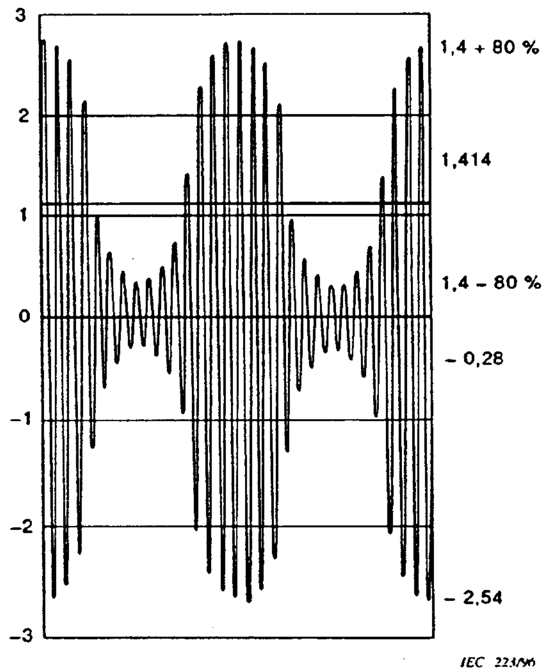


Figure 4b — Modulated RF signal 80 % AM
U_{pp} = 5,09 V, U_{rms} = 1,12 V

Figure 4 — Definition of the wave shapes occurring at the output of the EUT port of a coupling device (e.m.f. of test level 1)

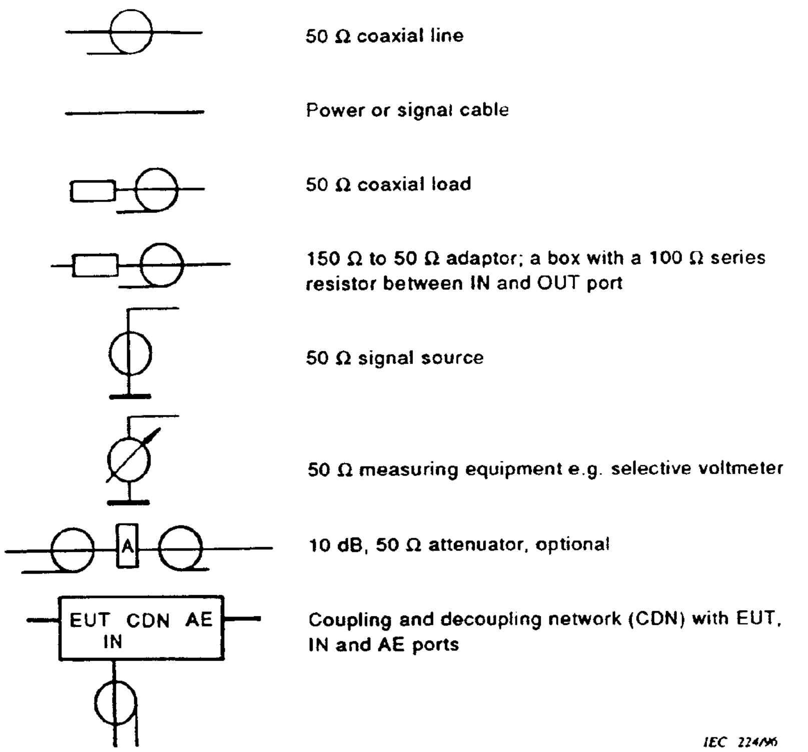


Figure 5a — List of symbols used for the following set-up principles

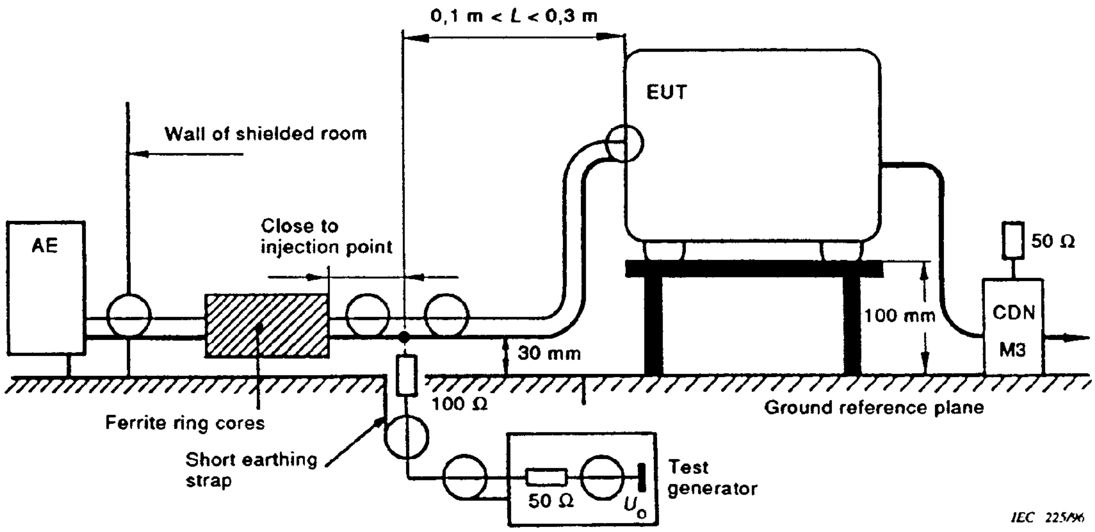


Figure 5b — Principle of direct coupling to screened cables

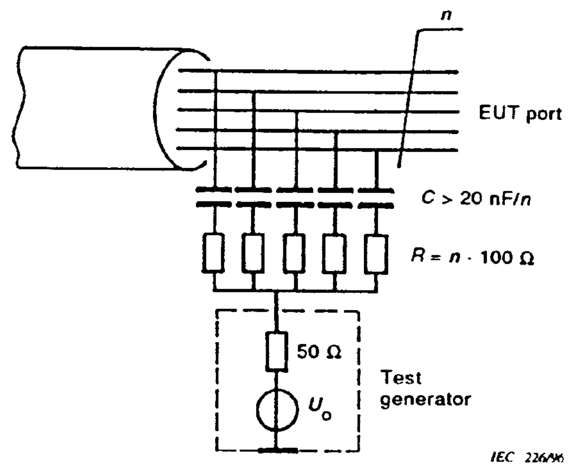
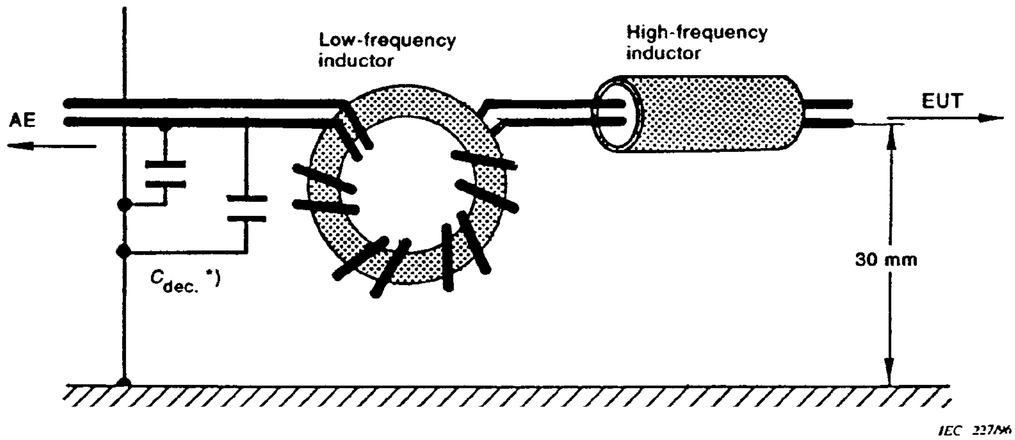


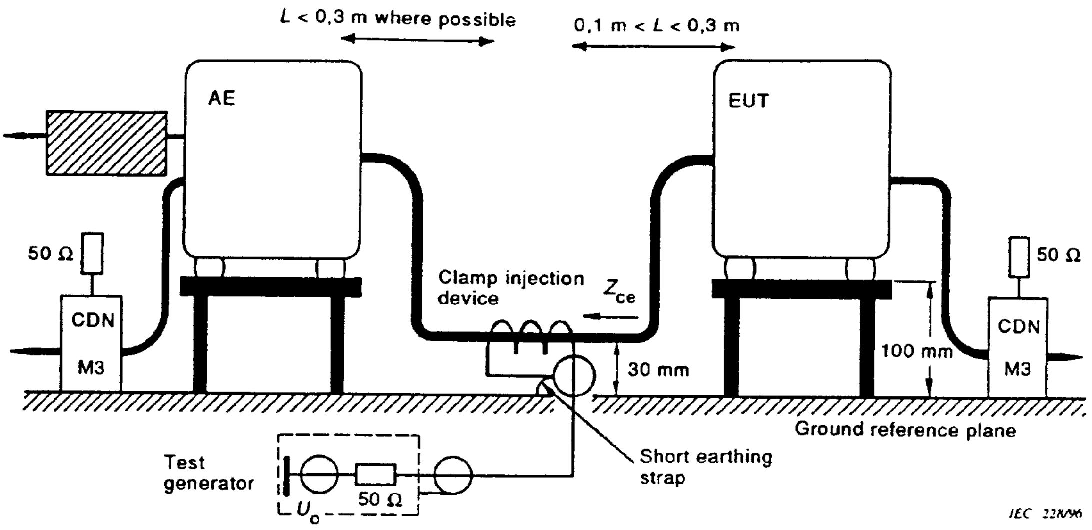
Figure 5c — Principle of coupling to unscreened (supply) cables



Example: Typically C_{dec} = 47 nF (only on unscreened cables), $L_{(150\ kHz)}$ ≥280 μH.
Low frequency inductor: 17 turns on a ferrite toroid material: NiZn, μ_R = 1 200;
High frequency inductor: 2-4 ferrite toroids (forming a tube), material: NiZn, μ_R = 700

Figure 5d — Principle of decoupling

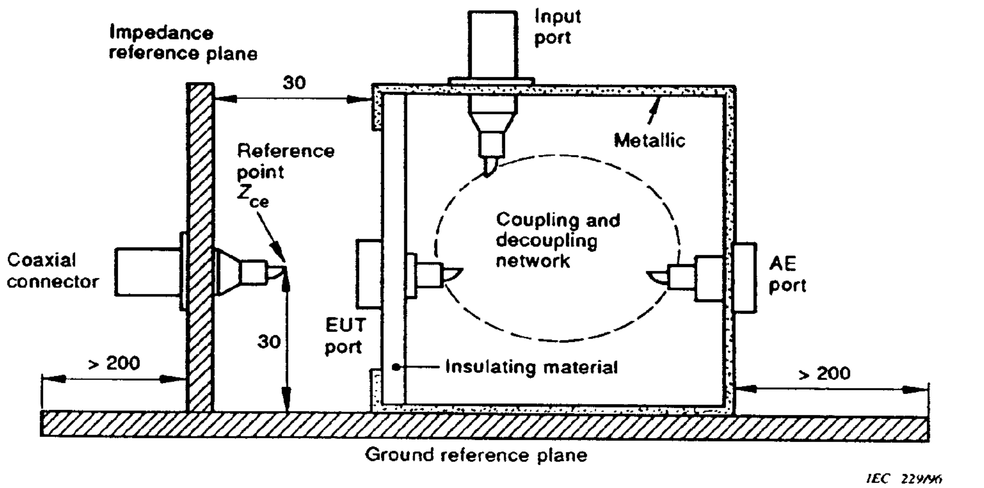
Figure 5 — Principles of coupling and decoupling



NOTE – 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 7.2).

Unterminated CDNs are equivalent to decoupling networks.

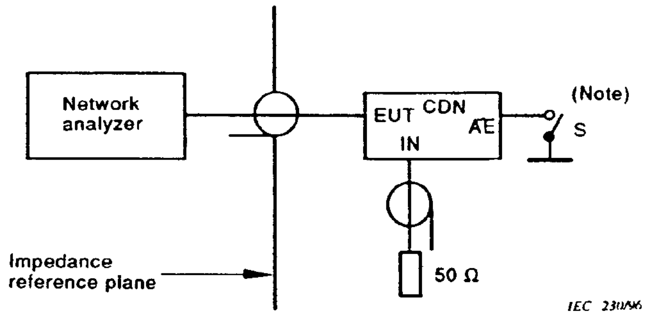
Figure 6 — Principle of coupling and decoupling according to the clamp injection method



Dimensions in millimetres

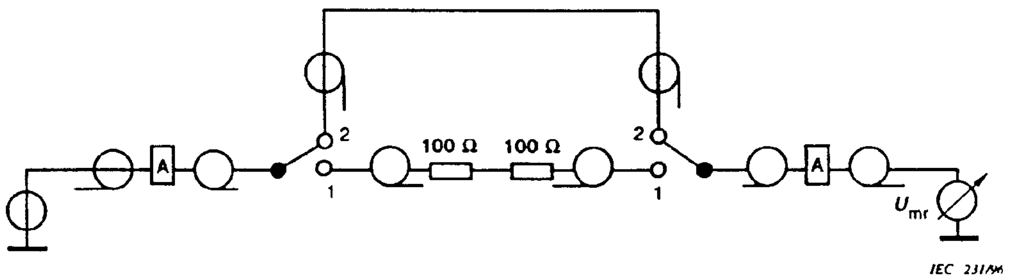
- Ground reference plane: shall exceed the projection of the coupling and decoupling devices and other components by at least 0,2 m.
- Impedance reference plane (with BNC connector): 0,1 m × 0,1 m.
- Both planes shall be made out of copper, brass or aluminum and must have good RF contact.

Figure 7a — Example of the set-up geometry to verify the impedance characteristics of the coupling and decoupling devices



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

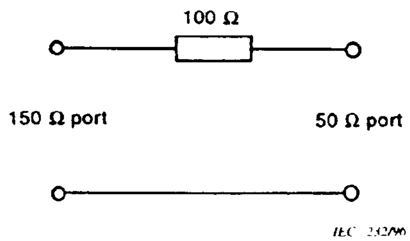
Figure 7b — Set-up principle to verify Z_{ce} of the coupling and decoupling devices



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

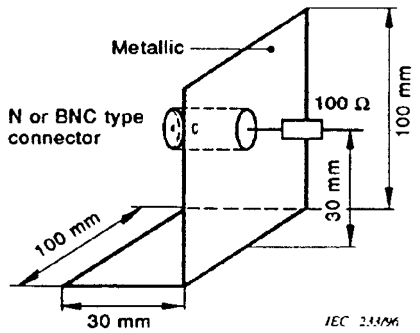
dB dB (µV) dB (µV)

Figure 7c — Set-up principle for measuring the insertion loss of two 150 Ω to 50 Ω adaptors



NOTE– Low inductance resistor: P ≥ 2,5 W

Figure 7d — Circuit of the 150 Ω to 50Ω adaptor



NOTE – Identical with Figure 7a (impedance reference plane), but with 100 Ω low inductance resistor added.

Figure 7e — Construction diagram of the 150 Ω to 50 Ω adaptor

Figure 7 — Details of set-ups and components to verify the essential characteristics of coupling and decoupling devices and the 150 Ω to 50 Ω adaptors

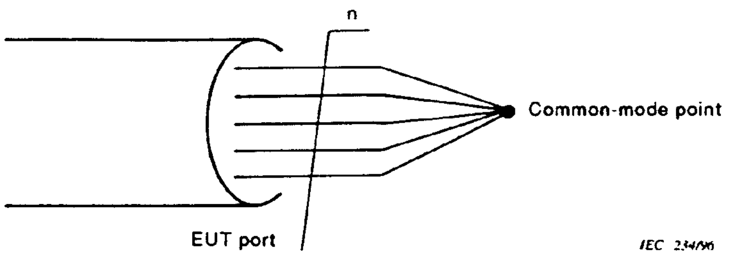


Figure 8a — Definition of a common-mode point with unscreened cables

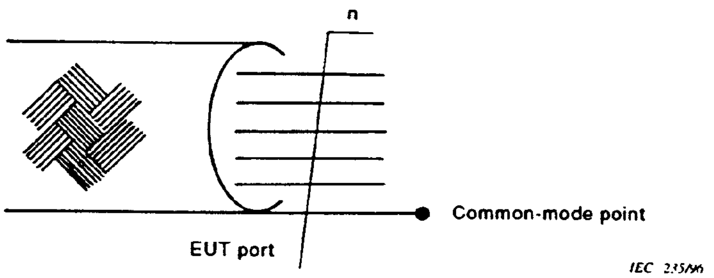
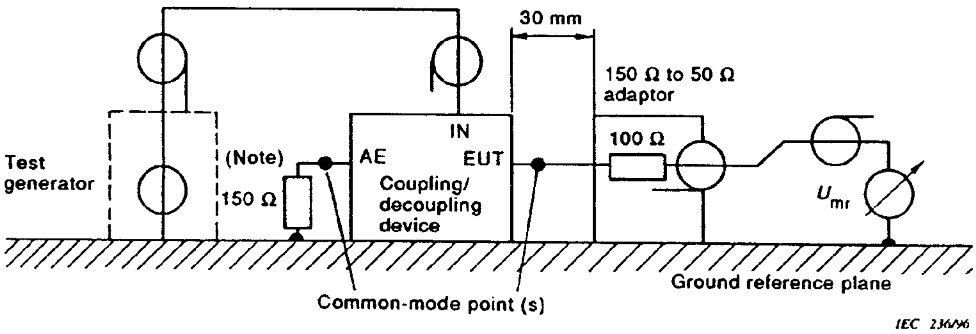


Figure 8b — Definition of a common-mode point with screened cables



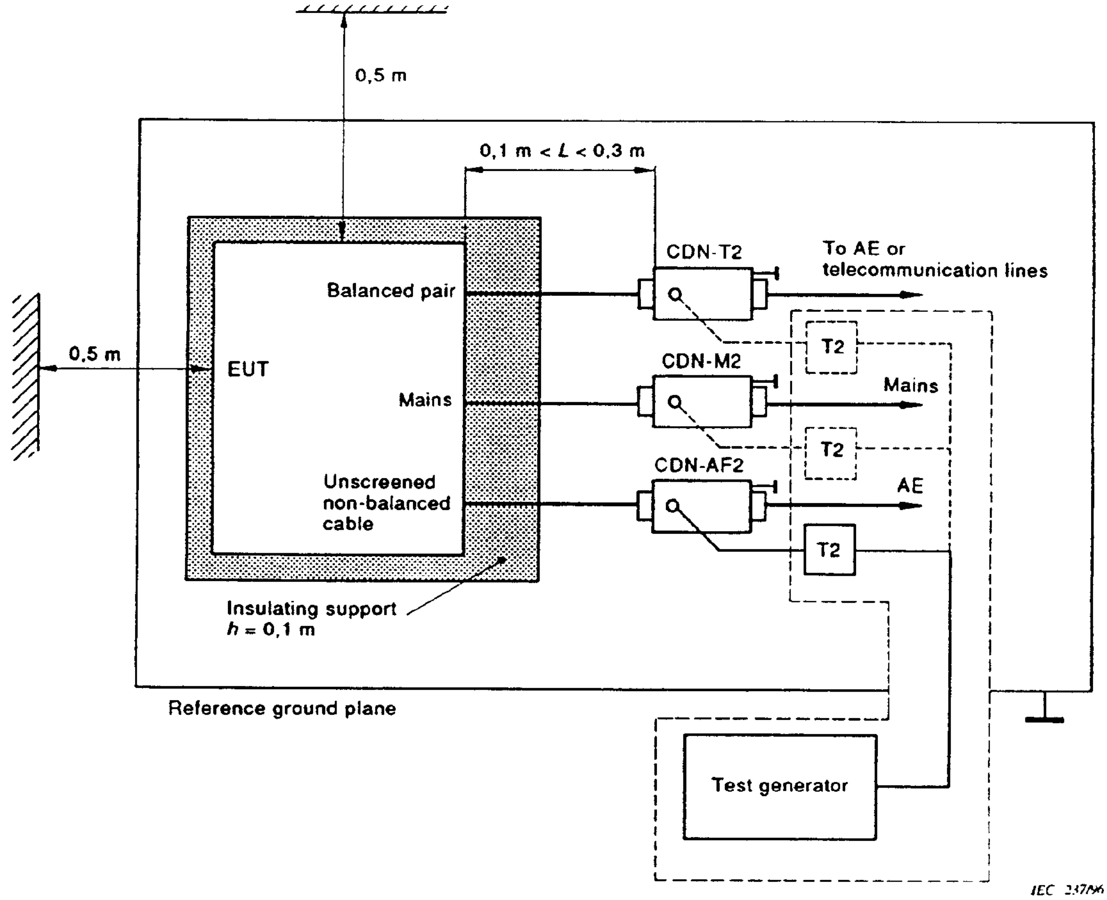
Examples of coupling and decoupling devices:

- coupling and decoupling networks (CDNs)
- direct injection network (with decoupling)
- clamp injection device (current clamp or EM-clamp)

NOTE – The 150 Ω loading, e.g. a 150 Ω to 50 Ω adaptor terminated with a 50 Ω load, at the AE-port shall only be applied to unscreened cables (screened cables have their screen connected to the ground reference plane at the AE-side)

Figure 8c — Set-up for level setting at the EUT port of coupling and decoupling devices

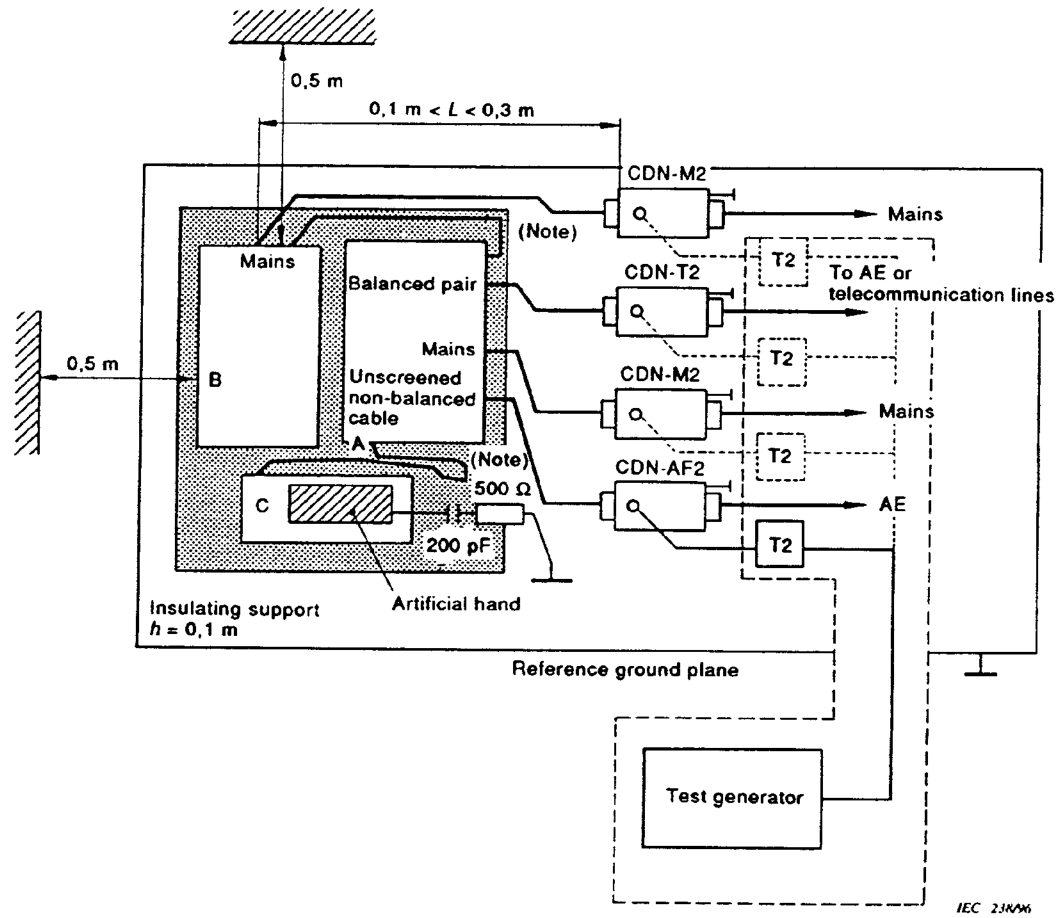
Figure 8 — Set-up for level setting (see 6.4.1)



NOTE – The EUT clearance from any metallic obstacles shall be at least 0,5 m.

All non-excited input ports of the CDNs shall be terminated by 50 Ω loads.

Figure 9 — Example of test set-up with a single-unit system for class II safety equipment (see IEC 536)



NOTE – The EUT clearance from any metallic obstacles shall be at least 0,5 m.

All non-excited input ports of the CDNs shall be terminated by 50 Ω loads.
Interconnecting cables (≤1 m) belonging to the EUT shall remain on the insulating support.

Figure 10 — Example of a test set-up with a multi-unit system, considered as a single EUT for class II safety equipment (see IEC 536)

Annex A (normative) Additional information regarding clamp injection

The alternative method, that is applicable to most cables and the equipment, uses the EM-clamp or current clamp in accordance with 7.2 and 7.3.

A.1 Current injection clamp

The current injection clamp is mainly used for injecting RF voltages on to individual wires or whole cable looms between two units.

The required performance of the current clamp is that the transmission loss of the test jig shall not exceed 1 dB when tested in a 50 Ω system with a current clamp installed and terminated at its input port by a 50 Ω load. A circuit of the level setting set-up is given in Figure A.1 and a drawing of the test jig is given in Figure A.2.

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 8. When the level setting is not carried out in a 150 Ω impedance environment but in a 50 Ω test jig, the following procedure shall be followed.

— The screen of the cable connected to the input port of the injection clamp shall also be connected to the test jig's reference plane by a low impedance connection.

— The test jig shall be terminated at one end with a 50 Ω coaxial load and at the other end with a power attenuator with a VSWR less than 1,2 over the frequency range of interest. The power attenuator shall be connected to the 50 Ω input of an RF voltmeter or an RF spectrum analyzer.

— The output level of the generator shall be increased until the voltage level measured on a RF voltmeter or spectrum analyzer reaches the test level required minus 6 dB, see 6.4.1. The output level of the generator shall be recorded at each step frequency, see Figure A.1.

A.2 EM clamp

The construction and concept of the EM-clamp are given in Figure A.3 and Figure A.4.

The EM-clamp (in contrast to the conventional current injection clamp) has a directivity ≥ 10 dB, above 10 MHz, so that a dedicated impedance between the common-mode point of the AE and the ground reference plane is no longer required. Above 10 MHz, the behaviour of the EM-clamp is similar to that of a CDN.

The level setting procedure for the EM-clamp shall be carried out according to 6.4.1 in a 150 Ω environment as indicated in Figure 8.

A.3 Test set-up

To undertake the test, the clamp(s) shall be placed on the cable to be tested. The clamp shall be supplied with the test generator level previously established during the level setting procedure.

During a test, the ground connection shall be made from the screen of the input port of the current injection clamp or the earth bar of the EM clamp, to the ground reference plane (see Figure A.6 and Figure A.7).

When, during testing, the monitored current, both with the EM-clamp and with the current clamp, exceeds the nominal circuit current value (see 7.3), the test generator output level shall be reduced until the current equals this nominal circuit current level. The reduced test generator output value level shall be recorded in the test report.

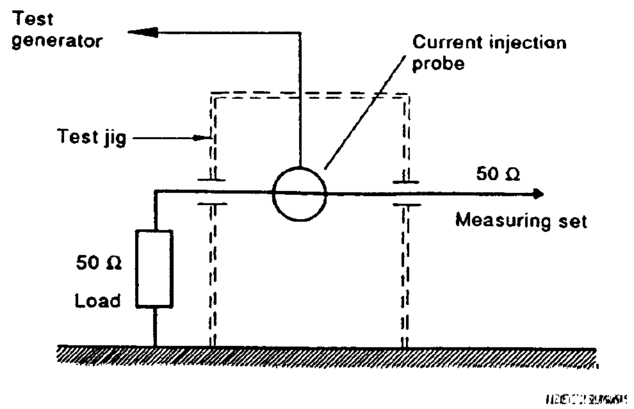
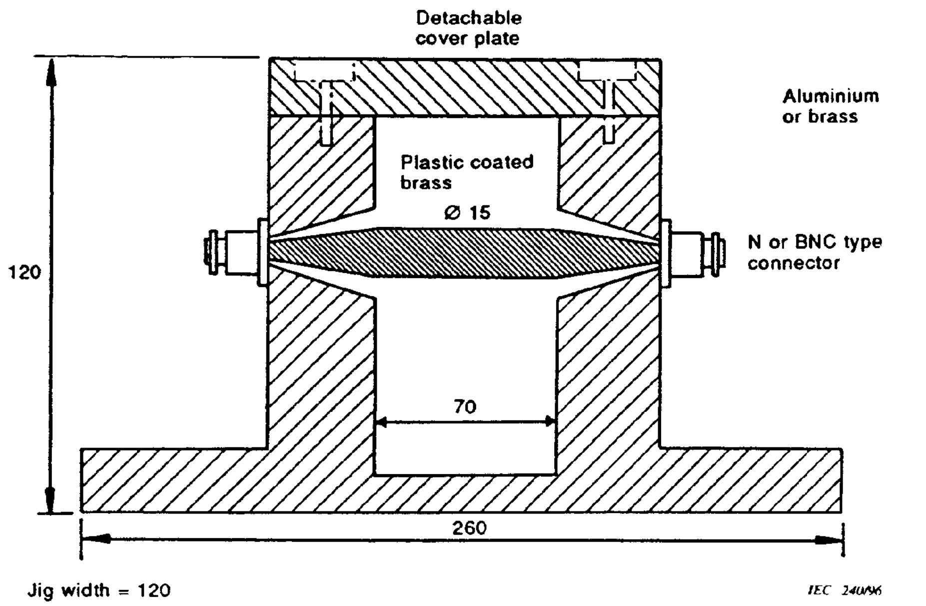


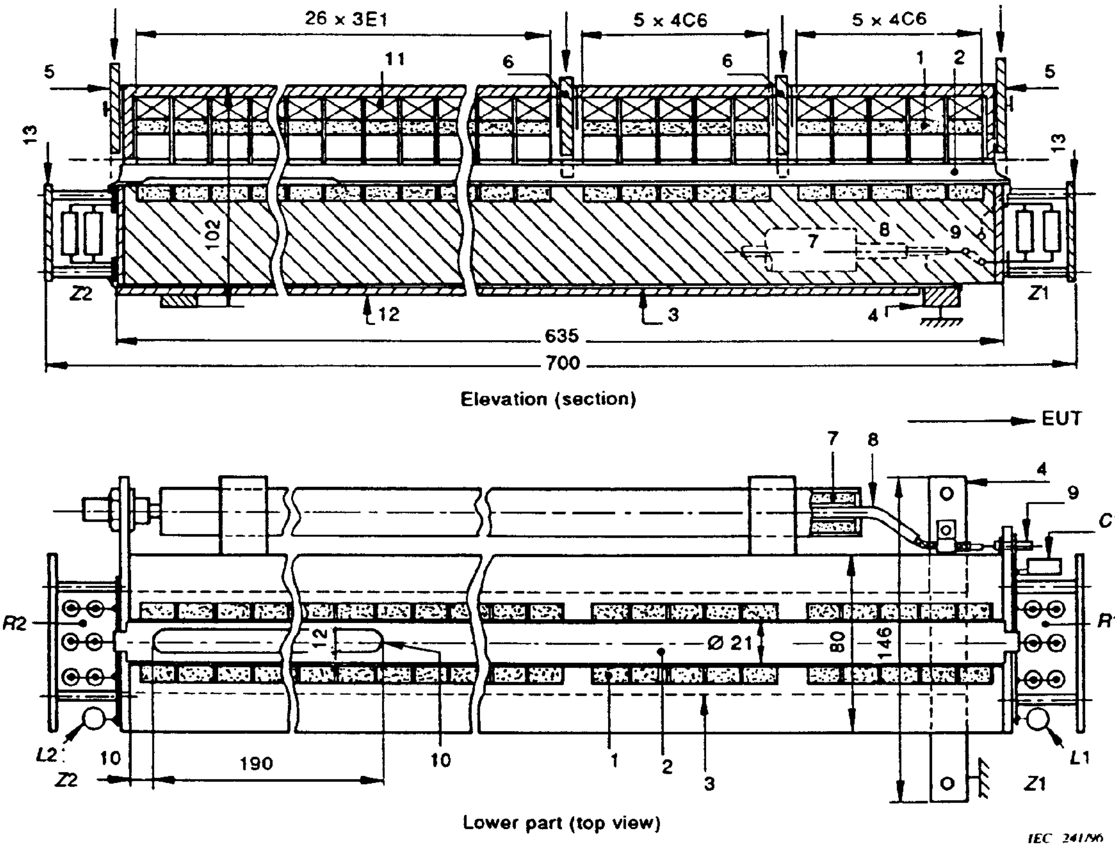
Figure A.1 — Circuit for level setting set-up in a 50 Ω test jig



Dimensions in millimetres

Figure A.2 — The 50 Ω test jig construction

EM clamp 0,15-230MHz

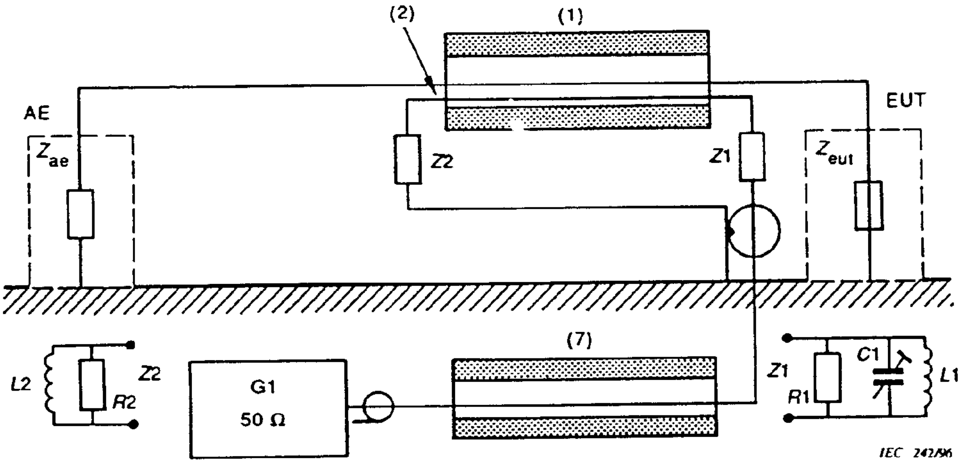


Dimensions in millimetres

Parts list:

1	Ferrite ring cores ϕ 36 × ϕ 23 × 15 mm 10 rings, type 4C65, NiZn, μ ≈ 100 26 rings, type 3C11, MnZn, μ ≈ 4 300
2	Semi-cylinder of copper foil glued to the groove
3	Lower conductor plate
4	Earth bar
5/6	Devices for pressing the cable under test into the groove Parts from insulating material with pressure springs (not shown)
7	Ferrite tube, 4C65
8	Coaxial cable, 50 Ω, with BNC connector
9	Switch for the disconnection of Z1
10	Slot for part No. 2
11	Elastic fixing of ferrite (upper semi-ring)
12	Lower insulating plate
13	Protection plate for Z1, Z2
EUT:	Equipment under test
Z1:	Series impedance: C_1: 20-100 pF, L1: 0,15 μH, R1: 50 Ω/ 12 W
Z2:	Series impedance: L_2: 0,8 μH, R2: 50 Ω/ 12 W

Figure A.3 — Construction details of the EM-clamp

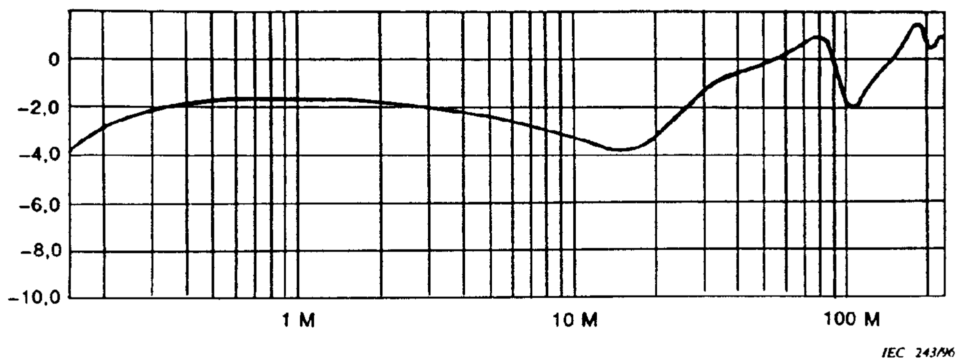


1	Ferrite tube (clamp) length 0,6 m, ϕ 20 mm, consisting of 10 rings, 4C65 (μ ≈ 100) at the EUT side and 26 rings 3C11 (μ ≈ 4 300) at AE side
2	Semi-cylinder of copper foil
7	Ferrite tube (μ ≈ 100) included in the EM-clamp construction
Z1, Z2	built in to optimize the frequency response and directivity
G1	Test generator

Principle of the EM-clamp:

- magnetic coupling by the ferrite tube (item 1)
- electric coupling by close proximity between EUT-cable and copper foil (item 2)

Figure A.4 — Concept of the EM-clamp (ElectroMagnetic clamp)



Typical characteristics of a commercially available construction of the EM-clamp:

- Operating frequency range: 0,15 MHz to 230 MHz
- Frequency response of the coupling factor of the EM-clamp.
- Max. e.m.f. rating according to table 1:
  0,15 MHz to 100 MHz; 140 V max. 15 V min.
  100 MHz to 230 MHz; 140 V max. 5 V min.
- Directivity and decoupling EUT/AE ≥10 dB beyond 10 MHz

Figure A.5 — Coupling factor of the EM-clamp

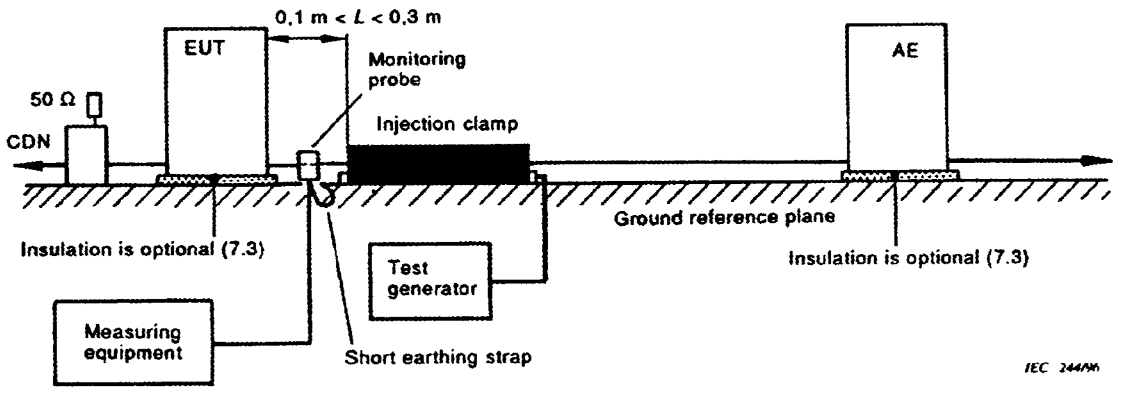
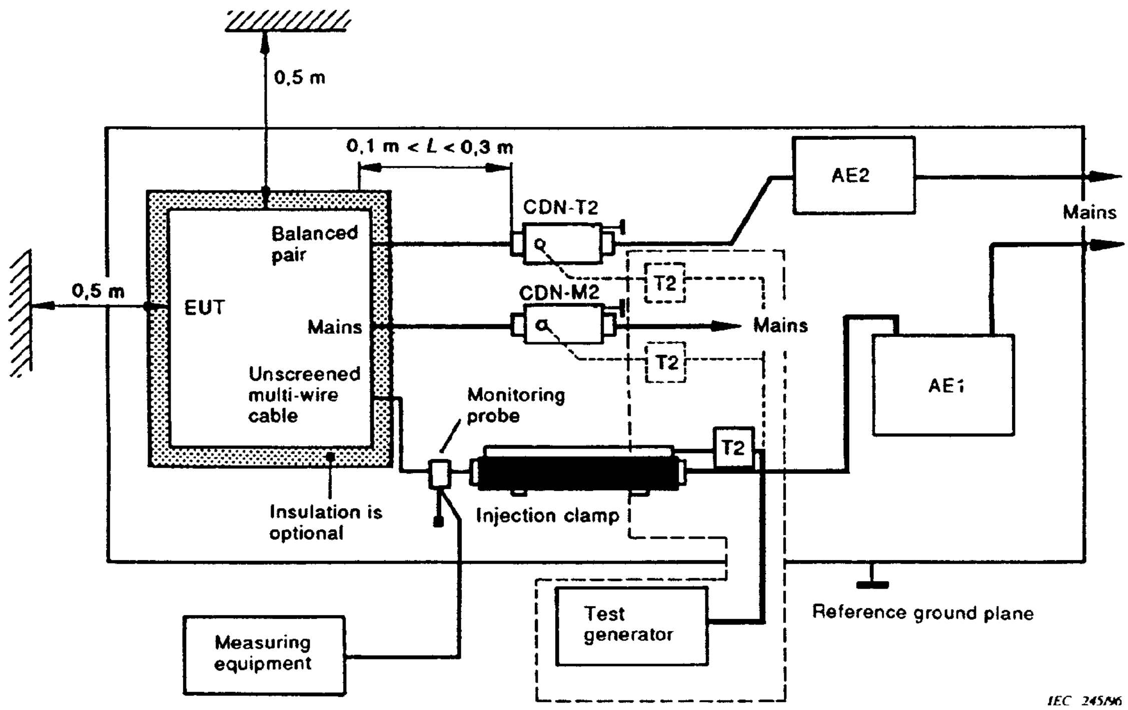


Figure A.6 — General principle of a test set-up using injection clamps



NOTE – The EUT clearance from any metallic obstacles shall be at least 0,5 m.

All non-excited input ports of the CDNs shall be terminated by 50 Ω loads.

Figure A.7 — Example of the test unit locations on the ground plane when using injection clamps (top view)

Annex B (informative)
Selection criteria for the frequency range of application

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

In general, the stop frequency will be 80 MHz. In some cases, where small-sized equipment is considered (dimension < $\lambda/4$), dedicated product standards may prescribe that the stop frequency is extended up to a maximum of 230 MHz. The coupling and decoupling device parameters (second column, Table 3) are then required to be extended from 80 MHz up to 230 MHz. When using this test method up to higher frequencies, results are influenced by: the size of equipment, the type(s) of interconnecting cables used, and the availability of special CDNs, etc. Further guidance for proper application should be supplied in the dedicated product standards.

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

Three different situations are considered.

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

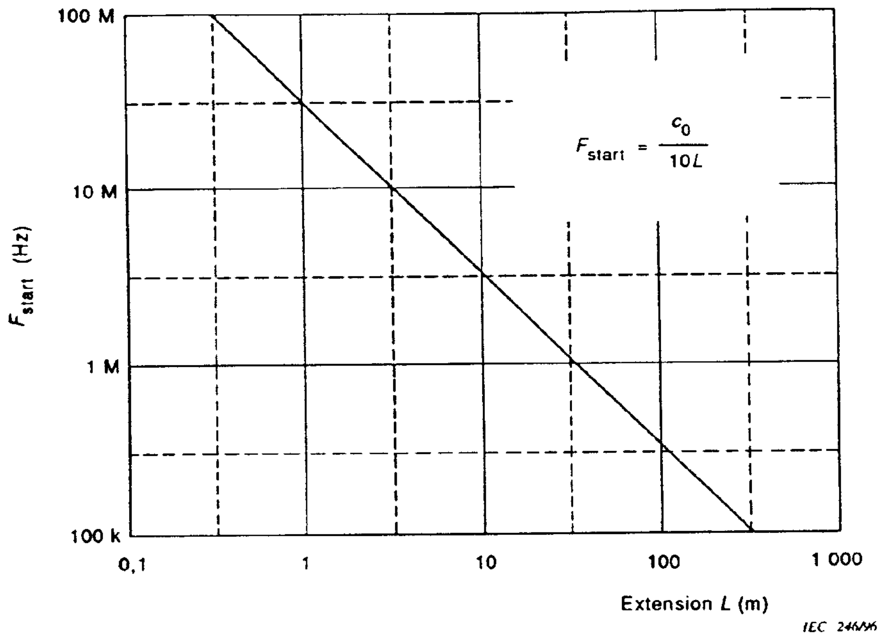
For battery-powered equipment (dimension $\geq \lambda/4$), its size, including the maximum length of the cables connected, determine the start frequency, Figure B.1.

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

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

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

The start frequency is 150 kHz.



c_0 = 3×10^8 m/s

L = cable length + equipment size

Examples:

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

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

Annex C (informative)
Guide for selecting test levels

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

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

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

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

— Class 1: Low-level electromagnetic radiation environment. Typical level where radio/television stations are located at a distance of more than 1 km and typical level for low-power transceivers.

— Class 2: Moderate electromagnetic radiation environment. Low-power portable transceivers (typically less than 1 W rating) are in use, but with restrictions on use in close proximity to the equipment. A typical commercial environment.

— Class 3: Severe electromagnetic radiation environment. Portable transceivers (2 W and more) are in use relatively close to the equipment but at a distance not less than 1 m. High-powered broadcast transmitters are in close proximity to the equipment and ISM equipment may be located close by. A typical industrial environment.

— Class X: X is an open level which may be negotiated and specified in the dedicated equipment specifications or equipment standards.

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

Annex D (informative)
Information on coupling and decoupling networks

D.1 Basic features of the coupling and decoupling networks

The coupling and decoupling network should provide:

— coupling of the disturbing signal to the EUT;

— stable impedance, seen from the EUT, independent of the AE common-mode impedance;

— decoupling of the AE from the disturbing signal to prevent interference of the AE;

— transparency to the wanted signal.

Typical parameters for the coupling and decoupling networks in the frequency range 150 kHz to 80 MHz are given in 6.2 and examples are given in D.2.

In the figures in D.2, the common-mode impedance, Z_{ce}, is formed by the internal impedance of the test generator (50 Ω) and the n.100 Ω resistors in series with each of the excited lines, representing a series equivalent value of 100 Ω (Figure 5c). With the use of a suitable inductor $L(|\omega L| >> 150\ \Omega)$, the decoupling elements, C_2, should not influence Z_{ce}.

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

The impedance of capacitors C_1, providing DC- and LF-separation of the test generator and the individual wires of the coupling and decoupling network, should be much less than 150 Ω in the frequency range of interest.

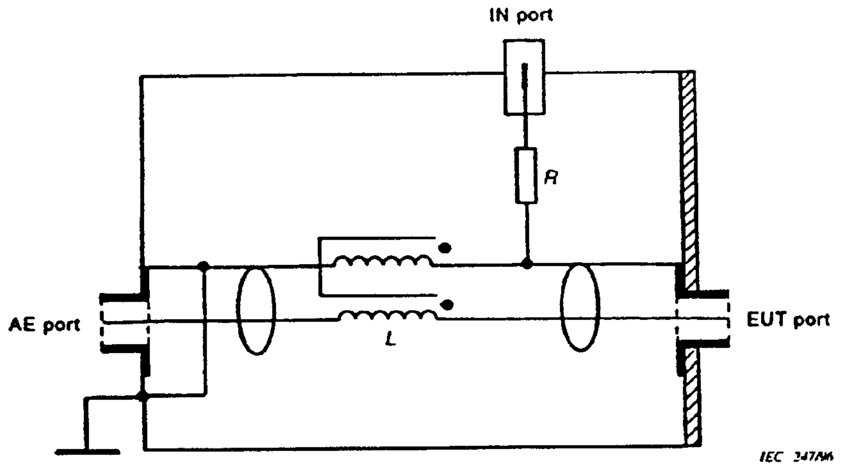
The AE is decoupled by a common-mode inductor L, and by the capacitors C_2 for unscreened cables or by a common-mode inductor L only. For screened cables, the capacitor C_2 is not needed as the screen will be connected to the ground reference plane at the AE-side.

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

WARNING. Since C_1 and C_2 bridge live parts in the mains coupling and decoupling networks, suitable Y-capacitors must be used. Due to the high leakage current, the CDN shall have an earth terminal which shall be connected to the ground reference plane under all test conditions.

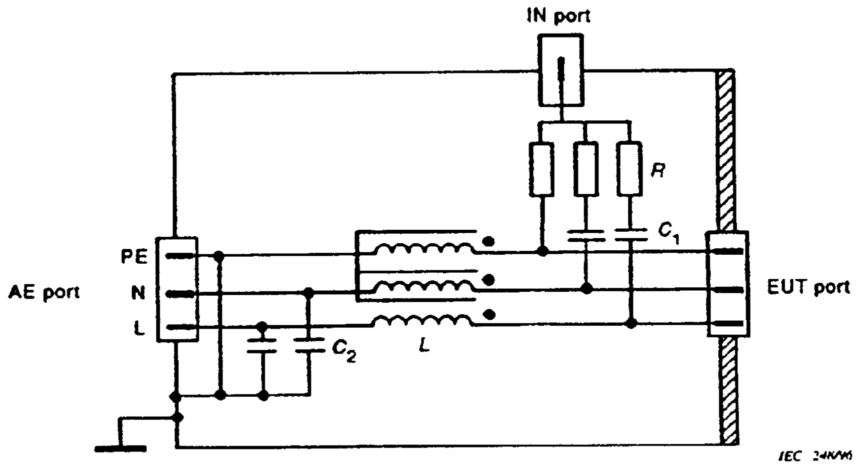
D.2 Examples of coupling and decoupling networks

A number of possibilities are given in Figure D.1 to Figure D.6 because it is impossible to cover all functional requirements with one coupling and decoupling network.



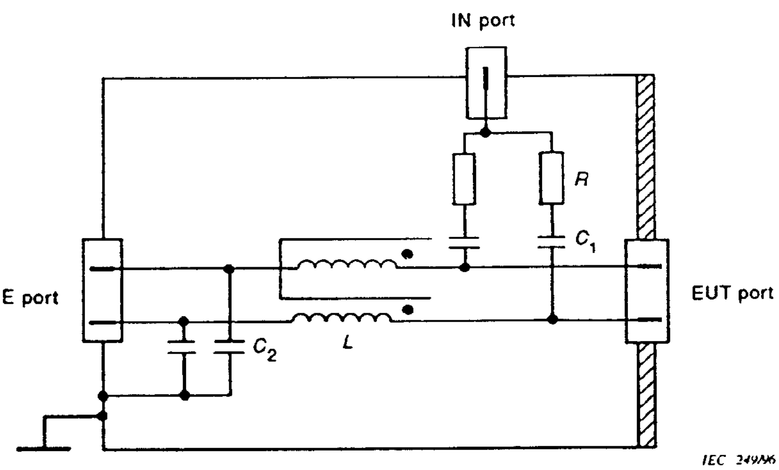
NOTE - R = 100 Ω
L ≥ 280 µH at 150 kHz.

Figure D.1 — Example of a simplified diagram for the circuit of CDN-S1 used with screened cables (see 6.2.1)



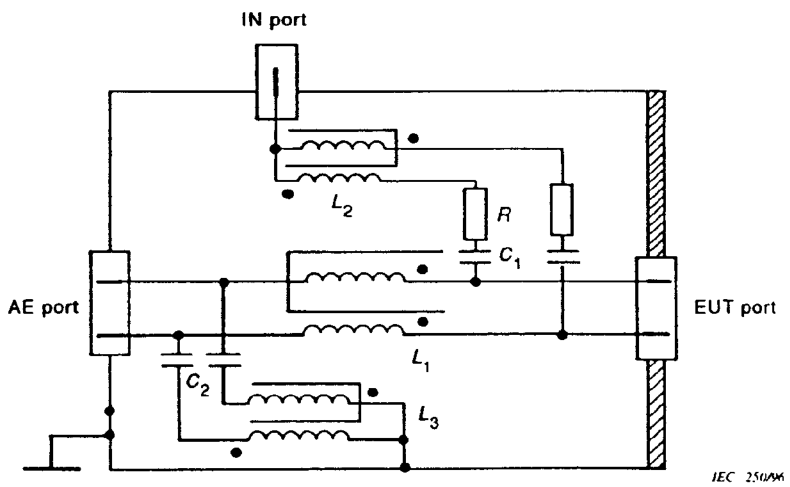
NOTE – CDN-M3, C_1 (typ) = 10 nF, C_2 (typ) = 47 nF, R = 300 Ω, $L \geq 280$ µH at 150 kHz.
CDN-M2, C_1 (typ) = 10 nF, C_2 (typ) = 47 nF, R = 200 Ω, $L \geq 280$ µH at 150 kHz.
CDN-M1, C_1 (typ) = 22 nF, C_2 (typ) = 47 nF, R = 100 Ω, $L \geq 280$ µH at 150 kHz.

Figure D.2 — Example of simplified diagram for the circuit of CDN-M1/-M2/-M3 used with unscreened supply (mains) lines (see 6.2.2.1)



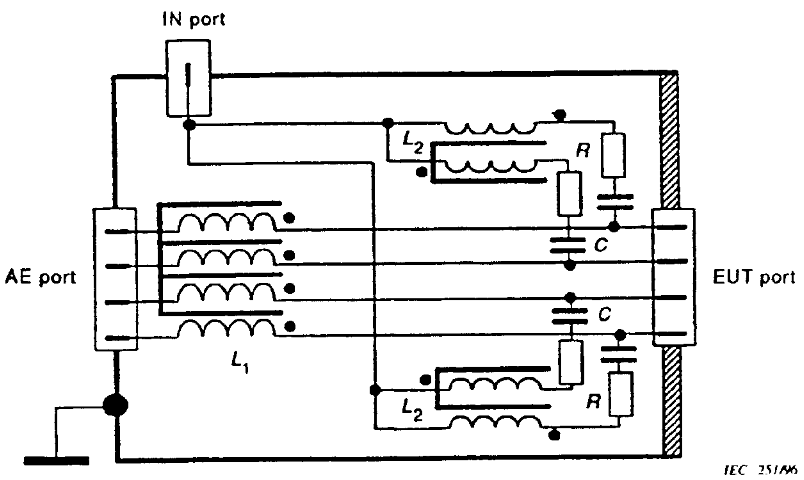
NOTE – C_1 (typ) = 10 nF
C_2 (typ) = 47 nF
R = 200 Ω
$L \geq 280$ µH at 150 kHz

Figure D.3 — Example of a simplified diagram for the circuit of CDN-AF2 used with unscreened non-balanced lines (see 6.2.2.3)



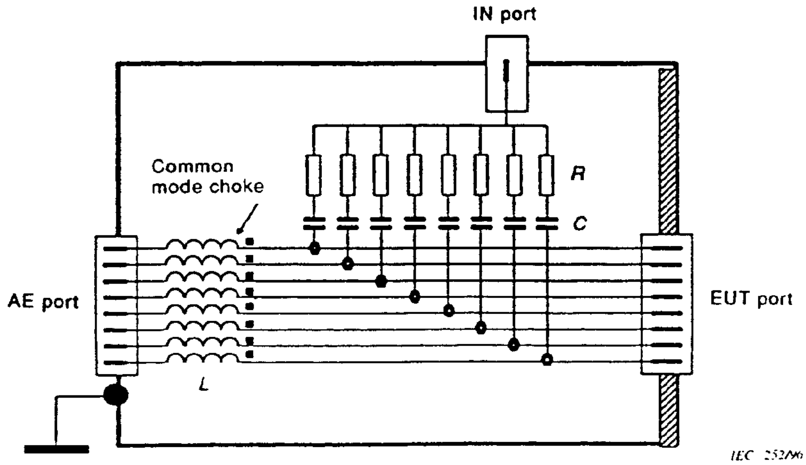
NOTE – C_1 (typ) = 10 nF,
C_2 (typ) = 47 nF, R = 200 Ω
L_1 ≥ 280 µH at 150 kHz
L_2 = L_3 = 6 mH (when C_2 and L_3 are not used, L_1 ≥ 30 mH)

Figure D.4 — Example of a simplified diagram for the circuit of a CDN-T2, used with an unscreened balanced pair (see 6.2.2.2)



NOTE – C(typ) = 5,6 nF
R = 400 Ω
L_1 >> 280 µH at 150 kHz
L_2 = 6 mH

Figure D.5 — Example of a simplified diagram of the circuit of a CDN-T4 used with unscreened balanced pairs (see 6.2.2.2)



NOTE – C(typ) = 2,2 nF
R = 800 Ω
L >> 280 µH at 150 kHz.

Figure D.6 — Example of a simplified diagram of the circuit of a CDN-T8 used with unscreened balanced pairs (see 6.2.2.2)

Annex E (informative)
Information for the test generator specification

The available output power of the power amplifier, PA, (Figure 3) is determined by taking into account the attenuator T_2 (6 dB), the amplitude modulation depth (80 %) (see Figure 4) and the minimum coupling factor of the CDN or clamp used.

Table E.1 — Required power amplifier output power to obtain a test level of 10 $V_{e.m.f.}$

Injection device	Minimum coupling factor ± 1,5 dB dB	Required power at output of PA W
CDN	0	7
Current clamp winding ratio 5:1	–14	176
EM-clamp	–6	28
NOTE The coupling factor is defined in 4.5. It can be measured by using the output level setting circuit, see Figure 8c. The coupling factor is the ratio between the output voltage U_{mr}, obtained when using a coupling and decoupling device in series with a 150 Ω to 50 Ω adaptor and the output voltage when using two 150 Ω to 50 Ω adaptors in series.		

Annex ZA (normative)
Normative references to international publications with their corresponding European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

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

Publication	Year	Title	EN/HD	Year
IEC 50(131)	1978	*International Electrotechnical Vocabulary (IEV) Chapter 131: Electric and magnetic circuits*	—	—
IEC 50(161)	1990	*Chapter 161: Electromagnetic compatibility*	—	—
IEC 1000-4-3	1995	*Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 3: Radiated, radio-frequency, electromagnetic field immunity test*	—	—
CISPR 16-1	1993	*Specification for radio disturbance and immunity measuring apparatus and methods — Part 1: Radio disturbance and immunity measuring apparatus*	—	—
CISPR 20	1990	*Limits and methods of measurement of immunity characteristics of sound and television broadcast receivers and associated equipment*	—[1]	—

[1] See EN 55020:1994, *Electromagnetic immunity of broadcast receivers and associated equipment.*

BSI —British Standards Institution

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level. It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover.
Tel: +44 (0)20 8996 9000. Fax: +44 (0)20 8996 7400.

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Buying standards

Orders for all BSI, international and foreign standards publications should be addressed to Customer Services. Tel: +44 (0)20 8996 9001.
Fax: +44 (0)20 8996 7001. Email: orders@bsi-global.com. Standards are also available from the BSI website at http://www.bsi-global.com.

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Library and its Technical Help to Exporters Service. Various BSI electronic information services are also available which give details on all its products and services. Contact the Information Centre.
Tel: +44 (0)20 8996 7111. Fax: +44 (0)20 8996 7048. Email: info@bsi-global.com.

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration.
Tel: +44 (0)20 8996 7002. Fax: +44 (0)20 8996 7001.
Email: membership@bsi-global.com.

Information regarding online access to British Standards via British Standards Online can be found at http://www.bsi-global.com/bsonline.

Further information about BSI is available on the BSI website at http://www.bsi-global.com.

Copyright

BSI
389 Chiswick High Road
W4 4AL
London