

Electromagnetic compatibility (EMC) —

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

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- British Telecommunications plc
- BSI Staff
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- 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.)]
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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**.

The content of CENELEC Interpretation Sheet 1 (July 2004) has been incorporated by amendment into Clause 5.

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.*

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Partie 4-6: Techniques d'essai et de mesure —
Immunité aux perturbations conduites, induites par
les champs radioélectriques
(inclut l'amendement A1:2001)
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Teil 4-6: Prüf- und Meßverfahren —
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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.

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- 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.

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Foreword to Interpretation Sheet 1

This Interpretation Sheet to the European Standard EN 61000-4-6:1996 was prepared by the Interpretation Panel of the Technical Committee CENELEC TC 210, Electromagnetic compatibility (EMC). The text of the draft was submitted to the Unique Acceptance Procedure and was approved by CENELEC on 2004-04-17.

Contents

	Page
Foreword	2
1 Scope	5
2 Normative references	5
3 General	5
4 Definitions	6
5 Test levels	7
6 Test equipment	7
7 Test set-up for table-top and floor-standing equipment	11
8 Test procedure	14
A1 9 Evaluation of test results	15
10 Test report	15 A1
Annex A (normative) Additional information regarding clamp injection	27
Annex B (informative) Selection criteria for the frequency range of application	32
Annex C (informative) Guide for selecting test levels	34
Annex D (informative) Information of coupling and decoupling networks	34
Annex E (informative) Information for the test generator specification	38
Annex ZA (normative) Normative references to international publications with their corresponding European publications	39
Figure 1 — Rules for selecting the injection method	12
Figure 2 — Immunity test to RF conducted disturbances	16
Figure 3 — Test generator set-up	17
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)	18
Figure 5 — Principles of coupling and decoupling	19
Figure 6 — Principle of coupling and decoupling according to the clamp injection method	21
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	22
Figure 8 — Set-up for level setting	24
Figure 9 — Example of test set-up with a single-unit system for class II safety equipment	25
Figure 10 — Example of a test set-up with a multi-unit system, considered as a single EUT for class II safety equipment	26

	Page
Figure A.1 — Circuit for level setting set-up in a 50 Ω test jig	28
Figure A.2 — The 50 Ω test jig construction	28
Figure A.3 — Construction details of the EM-clamp	29
Figure A.4 — Concept of the EM-clamp (ElectroMagnetic clamp)	30
Figure A.5 — Coupling factor of the EM-clamp	30
Figure A.6 — General principle of a test set-up using injection clamps	31
Figure A.7 — Example of the test unit locations on the ground plane when using injection clamps (top view)	31
Figure B.1 — Start frequency as function of cable length and equipment size	33
Figure D.1 — Example of a simplified diagram for the circuit of CDN-S1 used with screened cables	35
Figure D.2 — Example of a simplified diagram for the circuit of CDN-M1/-M2/-M3 used with unscreened supply (mains) lines	36
Figure D.3 — Example of a simplified diagram for the circuit of CDN-AF2 used with unscreened non-balanced lines	36
Figure D.4 — Example of a simplified diagram for the circuit of CDN-T2, used with an unscreened balanced pair	37
Figure D.5 — Example of a simplified diagram of the circuit of CDN-T4 used with unscreened balanced pairs	37
Figure D.6 — Example of a simplified diagram of the circuit of CDN-T8 used with unscreened balanced pairs	38
Table 1 — Test levels	7
Table 2 — Characteristics of the test generator	8
Table 3 — Main coupling and decoupling device parameter	8
Table E.1 — Required power amplifier output power to obtain a test level of 10 $V_{e.m.f.}$	38

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.)	
	$U_0[\text{dB}(\mu\text{V})]$	$U_0[\text{V}]$
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.

Interpretation statement

The test levels are to be applied as stated in Table 1, or as defined in the product standard, without any increase to take into account uncertainties in the setting of the output level at the EUT port of the coupling device. The test generator shall be adjusted to produce the nominal value of U_{mr} as defined in 6.4.1 of the standard. (See national foreword).

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, $Z_0 = 50 \Omega$), 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 $\leq 1,2$
Harmonics and distortion	more than 15 dB below carrier level
Amplitude modulation	internal or external, 80 % $\pm$ 5 % in depth by a 1 kHz $\pm$ 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

Parameter	Frequency band	
	0,15 MHz – 26 MHz	26 MHz – 80 MHz
$ Z_{ce} $	150 $\Omega \pm 20 \Omega$	150 $\Omega \begin{smallmatrix} +60 \\ -45 \end{smallmatrix} \Omega$

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 $|Z_{ce}|$ 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 ≥ 16 A) and/or complex supply systems (multi-phase or various parallel supply voltages) other injection methods may be selected.

The disturbing signal shall be coupled to the supply lines, using type CDN-M1 (single wire), CDN-M2 (two wires) or CDN-M3 (three wires), or equivalent networks (see Annex D.) Similar networks can be defined for a 3-phase mains system. The coupling circuit is given in Figure 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 $280\ \mu\text{H}$ is required at 150 kHz. The reactance shall remain high, $\geq 260\ \Omega$ up to 26 MHz and $\geq 150\ \Omega$ 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, $|Z_{\text{ce}}|$. 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 $50\ \Omega$ reference impedance. The network analyzer shall be calibrated (with open circuit, short circuit and a $50\ \Omega$ load) at the impedance reference plane. It is necessary to make a short connection ($L \leq 30\ \text{mm}$) 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 $|Z_{\text{ce}}|$.

The coupling and decoupling networks shall meet the impedance requirements of Table 3 in 6.2 while the input port is terminated with a $50\ \Omega$ load and the AE-port is sequentially loaded in common-mode with a short-circuit and an open-circuit condition as shown in Figure 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 $9,5 \pm 0,5\ \text{dB}$ (theoretical value 9,5 dB caused by the additional series impedance when measured in a $50\ \Omega$ 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.