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INTERNATIONAL STANDARD

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BASIC EMC PUBLICATION

PUBLICATION FONDAMENTALE EN CEM

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

**Compatibilité électromagnétique (CEM) –
Partie 4-6: Techniques d'essai et de mesure – Immunité aux perturbations conduites, induites par les champs radioélectriques**

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FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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

This standard forms part 4-6 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107, *Electromagnetic compatibility – Guide to the drafting of electromagnetic compatibility publications*.

This third edition of IEC 61000-4-6 cancels and replaces the second edition published in 2003, Amendment 1 (2004) and Amendment 2 (2006).This edition constitutes a technical revision.

The document 77B/571/FDIS, circulated to the National Committees as Amendment 3, led to the publication of the new edition.

The text of this standard is based on the second edition, its Amendment 1, Amendment 2 and on the following documents:

FDIS	Report on voting
77B/571/FDIS	77B/577/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of the base publication and its amendments will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

INTRODUCTION

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

Part 1: General

General considerations (introduction, fundamental principles)

Definitions, terminology

Part 2: Environment

Description of the environment

Classification of the environment

Compatibility levels

Part 3: Limits

Emission limits

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

Part 4: Testing and measurement techniques

Measurement techniques

Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines

Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

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

This part is an international standard which gives immunity requirements and test procedure related to conducted disturbances induced by radio-frequency fields.

ELECTROMAGNETIC COMPATIBILITY (EMC) –

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

1 Scope and object

This part of IEC 61000 relates to the conducted immunity requirements of electrical and electronic equipment to electromagnetic disturbances coming from intended radio-frequency (RF) transmitters in the frequency range 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 1 Test methods are defined in this part 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 quantitative analysis of effects.

The object of this standard is to establish a common reference for evaluating the functional immunity of electrical and electronic equipment when subjected to conducted disturbances induced by radio-frequency fields. The test method documented in this part of IEC 61000 describes a consistent method to assess the immunity of an equipment or system against a defined phenomenon.

NOTE 2 As described in IEC Guide 107, this standard is a basic EMC publication for use by product committees of the IEC. As also stated in Guide 107, the IEC product committees are responsible for determining whether this immunity test standard should be applied or not, and if applied, they are responsible for determining the appropriate test levels and performance criteria. TC 77 and its sub-committees are prepared to co-operate with product committees in the evaluation of the value of particular immunity tests for their products.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-161, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

3 Terms and definitions

For the purposes of this part of IEC 61000, the terms and definitions given in IEC 60050-161 as well as the following definitions apply.

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

[IEV 161-04-27]

NOTE The construction should be in accordance with CISPR 16-1-2.

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

3.3
clamp injection
clamp injection is obtained by means of a clamp-on “current” injecting device on the cable:

– **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

3.4
common-mode impedance
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 Figures 8a and 8b).

3.5
coupling factor
ratio given by the open-circuit voltage (e.m.f.) obtained at the EUT port of the coupling (and decoupling) device divided by the open-circuit voltage obtained at the output of the test generator

3.6
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 network (CDN)) or they can be in separate networks.

3.7
coupling/decoupling network
CDN
electrical circuit incorporating the functions of both the coupling and decoupling networks

3.8
decoupling network
electrical circuit for preventing test signals applied to the EUT from affecting other devices, equipment or systems that are not under test

3.9
test generator
generator (RF generator, modulation source, attenuators, broadband power amplifier and filters) capable of generating the required test signal (see Figure 3)

3.10
electromotive force
e.m.f.
voltage at the terminals of the ideal voltage source in the representation of an active element

[IEV 131-01-38:1978]

3.11
measurement result
$\boldsymbol{U_{mr}}$
voltage reading of the measurement equipment

3.12
voltage standing wave ratio
VSWR
ratio of a maximum to an adjacent minimum voltage magnitude along the line

4 General

The source of disturbance covered by this part of IEC 61000 is basically an electromagnetic field, coming from intended RF transmitters, that may act on the whole length of cables connected to installed equipment. The dimensions of the disturbed equipment, mostly a sub-part of a larger system, are assumed to be small compared with the wavelengths involved. The in-going and outgoing leads (e.g. mains, communication lines, interface cables) behave as passive receiving antenna networks because of their length, which can be several wavelengths.

Between those cable networks, the susceptible equipment is exposed to currents flowing “through" the equipment. Cable systems connected to an equipment are assumed to be in resonant mode (λ/4, λ/2 open or folded dipoles) and as such are represented by coupling and decoupling devices having a common-mode impedance of 150 Ω with respect to a ground reference plane. Where possible the EUT is tested by connecting it between two 150 Ω common-mode impedance connections: one providing an RF source and the other providing a return path for the current.

This test method subjects the EUT to a source of disturbance comprising electric and magnetic fields, simulating those coming from intentional RF transmitters. These disturbing fields (E and H) are approximated by the electric and magnetic near-fields resulting from the voltages and currents caused by the test 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.

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 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 61000-4-3 also defines test methods for establishing the immunity of electrical and electronic equipment against radiated electromagnetic energy. It covers frequencies above 80 MHz. Product committees 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 3.9 and Figure 3):

– RF generator(s), G1, capable of covering the frequency band of interest and of being amplitude modulated by a 1 kHz sine wave with a modulation depth of 80 %. They shall have manual control (e.g., frequency, amplitude, modulation index) or in the case of RF synthesizers, they shall be programmable with frequency-dependent step sizes and dwell times;

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

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

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

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

– attenuator, T2, (fixed ≥ 6 dB, Z_o = 50 Ω), with sufficient power ratings. T2 is provided to reduce the mismatch from the power amplifier 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 with and without modulation are given in Table 2.

Table 2 – Characteristics of the test generator

Output impedance	50 Ω
Harmonics and distortion	any spurious spectral line shall be at least 15 dB below the carrier level
Amplitude modulation	internal or external, 80 % ± 5 % in depth 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 and for preventing applied test signals from affecting other devices, equipment and systems that are not under test.

The coupling and decoupling devices can be combined into one box (a 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.

The preferred coupling and decoupling devices are the CDNs, for reasons of test reproducibility and protection of the AE. However, if they are not suitable or available, other injection methods can be used. Rules for selecting the appropriate injection method are given below and in 7.1.

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

Parameter	**Frequency band**	
	0,15 MHz – 26 MHz	26 MHz – 80 MHz
$\lvert Z_{ce} \rvert$	150 Ω ± 20 Ω	150 Ω + 60 Ω – 45 Ω

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 7.4 is followed.

6.2.1 Coupling/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 Figures 5c and 5d. The networks shall not unduly affect the functional signals. Constraints on such effects may be specified in the product standards.

6.2.1.1 CDNs for power supply lines

Coupling/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.

The performance of the CDN shall not be unduly degraded by saturation of the magnetic material due to current taken by the EUT. Wherever possible, the network construction should ensure that the magnetising effect of the forward current is cancelled by that due to the return current.

If in real installations the supply wires are individually routed, separate CDN-M1 coupling and decoupling networks 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 the presence of a CDN-M1 network in series with the earth terminal for RF or other reasons, the earth terminal shall be directly connected to the 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 from the CDN to the ground reference plane are obligatory (in some cases, these connections may be provided by the construction of the CDN).

6.2.1.2 CDNs for unscreened balanced lines

For coupling and decoupling disturbing signals to an unscreened cable with balanced lines, a CDN-T2, CDN-T4 or CDN-T8 shall be used as coupling and decoupling network. Figures D.4, D.5 and 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 may be used if they are suitable for the intended frequency range and satisfy the requirements of 6.2. For example, the differential to common mode conversion loss of the CDNs should have a larger value than the specified conversion ratio of the cable to be installed or equipment connected to the installed cable. If different conversion ratios are specified for cable and equipment then the smaller value applies. Often, clamp injection needs to be applied to multi-pair balanced cables because suitable CDNs might not be available.

6.2.1.3 Coupling and decoupling for unscreened non-balanced lines

For coupling and decoupling disturbing signals to an unscreened cable with non-balanced lines, a coupling and decoupling network as described in Figure D.3 for a single pair may be used.

NOTE If no suitable CDN is available, clamp injection should be used.

6.2.2 Clamp injection devices

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 7.3 gives instructions for proper application.

When an EM clamp or a current clamp is used without fulfilling the constraints given in 7.3, the procedure defined in 7.4 shall be followed. The induced voltage is set in the same way as described in 6.4.1. In addition, the resulting current shall be monitored and corrected for. In this procedure, a lower common mode impedance may be used, but the common mode current is limited to the value which would flow from a 150 Ω source.