IEC 61000-4-6

Edition 5.0 2023-06

INTERNATIONAL STANDARD

colour inside

BASIC EMC PUBLICATION

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

IEC 61000-4-6:2023-06(en)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC 61000-4-6

Edition 5.0 2023-06

INTERNATIONAL STANDARD

colour inside

BASIC EMC PUBLICATION

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

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 33.100.20

ISBN 978-2-8322-7076-9

CONTENTS

FOREWORD 6
INTRODUCTION 8
1 Scope 9
2 Normative references 9
3 Terms and definitions 9
4 General 11
5 Test levels 13
6 Test equipment and level adjustment procedure 15
6.1 Test generator 15
6.2 Coupling and decoupling devices 16
6.2.1 General 16
6.2.2 Coupling/decoupling networks (CDNs) 18
6.2.3 Clamp injection devices 20
6.2.4 Direct injection devices 22
6.2.5 Decoupling networks 22
6.3 Verification of the common-mode impedance at the EUT port of coupling and decoupling devices 22
6.3.1 General 22
6.3.2 Insertion loss of the 150 Ω to 50 Ω adapters 23
6.4 Setting of the test generator 25
6.4.1 General 25
6.4.2 Setting of the output level at the EUT port of the coupling device 25
7 Test setup and injection methods 27
7.1 Test setup 27
7.2 EUT comprising a single unit 28
7.3 EUT comprising several units 30
7.4 Rules for selecting injection methods and test points 31
7.4.1 General 31
7.4.2 Injection method 31
7.4.3 Ports to be tested 32
7.5 CDN injection application 32
7.6 Clamp injection application 34
7.7 Direct injection application 36
8 Test procedure 36
9 Evaluation of the test results 37
10 Test report 38
Annex A (normative) EM and decoupling clamps 39
A.1 EM clamps 39
A.1.1 General 39
A.1.2 Specification of EM clamps 39
A.2 EM clamp characterization 41
A.2.1 Specification of the clamp test jig 41
A.2.2 Clamp characterization 42
A.3 Decoupling clamp characterization 47
A.3.1 General 47
A.3.2 Specification of decoupling clamps 47

A.3.3 Impedance 47
A.3.4 Decoupling factor 48
Annex B (informative) Selection criteria for the frequency range of application 50
Annex C (informative) Guidelines for selecting test levels 52
Annex D (informative) Information on coupling and decoupling networks 53
D.1 Basic features of the coupling and decoupling networks 53
D.2 Examples of coupling and decoupling networks 53
Annex E (informative) Information for the test generator specification 58
Annex F (informative) Test setup for large EUTs 59
F.1 General 59
F.2 Test setup for large EUTs 59
Annex G (informative) Measurement uncertainty of the voltage test level 62
G.1 General 62
G.2 General symbols 62
G.3 Uncertainty budgets for test methods 62
G.3.1 Definition of the measurand 62
G.3.2 MU contributors of the measurand 63
G.3.3 Input quantities and calculation examples for expanded uncertainty 64
G.4 Expression of the calculated measurement uncertainty and its application 71
Annex H (informative) Testing with multiple signals 73
H.1 General 73
H.2 Intermodulation 73
H.3 Power requirements 74
H.4 Level-setting requirements 75
H.5 Linearity check and harmonics checks of the test generator 75
H.6 EUT performance criteria with multiple signals 75
Annex I (informative) Port-to-port injection 76
I.1 General 76
I.2 Test setup for injection on identical ports 76
I.2.1 Selection of ports 76
I.2.2 Procedure for port-to-port injection 76
Annex J (informative) Amplifier compression and non-linearity 78
J.1 Objective of limiting amplifier distortion 78
J.2 Possible problems caused by harmonics and saturation 78
J.3 Limiting the harmonic content in the disturbance signal 78
J.4 Effect of linearity characteristic on the immunity test 79
J.4.1 General 79
J.4.2 Evaluation of the amplifier linearity characteristic 79
Bibliography 83

Figure 1 – Diagram showing EM fields near the EUT due to common-mode currents on its cables 12
Figure 2 – Schematic setup for immunity test to RF conducted disturbances 13
Figure 3 – Example of unmodulated and modulated RF signal 14
Figure 4 – Test generator setup 16
Figure 5 – Principle of coupling and decoupling – Symbols used for the indicated setup principles 17

Figure 6 – Principle of coupling and decoupling – Principle of direct injection to screened cables 17
Figure 7 – Principle of coupling and decoupling – Principle of coupling to unscreened cables according to the CDN method 18
Figure 8 – Principle of coupling and decoupling – Principle of decoupling 18
Figure 9 – Example of circuit for evaluating the transmission loss of the current clamp level-setting 21
Figure 10 – Example of circuit for level-setting setup in a 150 Ω test jig 21
Figure 11 – Example of the setup geometry to verify the impedance characteristics of the coupling and decoupling devices 23
Figure 12 – Setup principle to verify Z_{ce} of the coupling and decoupling device 24
Figure 13 – Setup principle for measuring the insertion loss of two 150 Ω to 50 Ω adapters 24
Figure 14 – Circuit and construction of the 150 Ω to 50 Ω adapter 24
Figure 15 – Definition of a common-mode point for unscreened and screened cables 26
Figure 16 – Setup for level-setting at the EUT port of the coupling/decoupling devices 27
Figure 17 – Example of test setup with a single unit EUT with only one CDN for injection (top view) 28
Figure 18 – Example of test setup with a single unit EUT (top view) using multiple CDNs 29
Figure 19 – Example of a test setup with a multi-unit EUT (top view) 30
Figure 20 – Rules for selecting the injection method 31
Figure 21 – Immunity test for two-port EUT (when only one CDN can be used) 34
Figure 22 – General principle of a test setup using clamp injection devices 35
Figure 23 – Example of the test unit locations on the ground plane when using injection clamps (top view) 36
Figure A.1 – Example: Construction details of the EM clamp 40
Figure A.2 – Example: Concept of the EM clamp 41
Figure A.3 – Dimension of a reference plane 42
Figure A.4 – Test jig 42
Figure A.5 – Test jig with inserted clamp 42
Figure A.6 – Impedance / decoupling factor measurement setup 43
Figure A.7 – Typical examples for clamp impedance, three typical clamps 45
Figure A.8 – Typical examples for decoupling factors, three typical clamps 45
Figure A.9 – Normalization setup for coupling factor measurement 46
Figure A.10 – S_{21} coupling factor measurement setup 46
Figure A.11 – Typical examples for coupling factor, three typical clamps 47
Figure A.12 – Decoupling clamp characterization measurement setup 48
Figure A.13 – Typical examples for the decoupling clamp impedance 48
Figure A.14 – Typical examples for decoupling factors 49
Figure B.1 – Start frequency as function of cable length and equipment size 51
Figure D.1 – Example of a simplified diagram for the circuit of CDN-S1 used with screened cables (see 6.2.2.5) 54
Figure D.2 – Example of simplified diagram for the circuit of CDN-M1, CDN-M2 and CDN-M3 used with unscreened supply (mains) lines (see 6.2.2.2) 54

Figure D.3 – Example of a simplified diagram for the circuit of CDN-AF2 used with unscreened unbalanced lines (see 6.2.2.4) 55
Figure D.4 – Example of a simplified diagram for the circuit of CDN-T2, used with an unscreened balanced pair (see 6.2.2.3) 55
Figure D.5 – Example of a simplified diagram of the circuit of CDN-T4 used with unscreened balanced pairs (see 6.2.2.3) 56
Figure D.6 – Example of a simplified diagram of the circuit of CDN AF8 used with unscreened unbalanced lines (see 6.2.2.4) 56
Figure D.7 – Example of a simplified diagram of the circuit of CDN-T8 used with unscreened balanced pairs (see 6.2.2.3) 57
Figure F.1 – Example of large EUT test setup with elevated horizontal reference ground plane 60
Figure F.2 – Example of large EUT test setup with vertical reference ground plane 61
Figure G.1 – Example of influences upon voltage test level using CDN 63
Figure G.2 – Example of influences upon voltage test level using EM clamp 63
Figure G.3 – Example of influences upon voltage test level using current clamp 63
Figure G.4 – Example of influences upon voltage test level using direct injection 64
Figure G.5 – Circuit for level-setting setup of CDN 65
Figure H.1 – Test frequencies f_1 and f_2 and intermodulation frequencies of the second and third order 73
Figure I.1 – Example of setup, port-to-port injection 77
Figure J.1 – Amplifier linearity measurement setup 80
Figure J.2 – Linearity characteristic 81
Figure J.3 – Measurement setup for modulation depth 81
Figure J.4 – Spectrum of AM modulated signal 82

Table 1 – Test levels 14
Table 2 – Characteristics of the test generator 15
Table 3 – Main parameter of the combination of the coupling and decoupling device 16
Table 4 – Usage of CDNs 19
Table B.1 – Main parameter of the combination of the coupling and decoupling device when the frequency range of the test is extended above 80 MHz 50
Table E.1 – Required power amplifier output power to obtain a test level of 10 V 58
Table G.1 – CDN level-setting process 65
Table G.2 – CDN test process 65
Table G.3 – EM clamp level-setting process 67
Table G.4 – EM clamp test process 68
Table G.5 – Current clamp level-setting process 69
Table G.6 – Current clamp test process 69
Table G.7 – Direct injection level-setting process 70
Table G.8 – Direct injection test process 71

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

ELECTROMAGNETIC COMPATIBILITY (EMC) –

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

FOREWORD

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

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

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

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

a) selection of injection devices revised;
b) need of AE impedance check for clamp injection removed and Annex H deleted;
c) saturation check revised;
d) new Annex H on testing with multiple signals;

e) level-setting only with feedback loop.

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

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

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

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

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

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

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

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

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

INTRODUCTION

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

Part 1: General

General considerations (introduction, fundamental principles)

Definitions, terminology

Part 2: Environment

Description of the environment

Classification of the environment

Compatibility levels

Part 3: Limits

Emission limits

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

Part 4: Testing and measurement techniques

Measurement techniques

Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines

Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

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

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

ELECTROMAGNETIC COMPATIBILITY (EMC) –

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

1 Scope

This part of IEC 61000 relates to the conducted immunity requirements of electrical and electronic equipment to electromagnetic disturbances coming from intended radio-frequency (RF) transmitters in the frequency range 150 kHz up to 80 MHz.

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

Equipment not having at least one conducting wire or cable (such as mains supply, signal line or earth connection) which can couple the equipment to the disturbing RF fields is excluded from the scope of this document.

NOTE 2 Test methods are specified in this part of IEC 61000 to assess the effect that conducted disturbing signals, induced by electromagnetic radiation, have on the equipment concerned. The simulation and measurement of these conducted disturbances are not adequately exact for the quantitative determination of effects. The test methods specified are structured for the primary objective of establishing adequate repeatability of results at various facilities for quantitative analysis of effects.

The object of this document is to establish a common reference for evaluating the functional immunity of electrical and electronic equipment when subjected to conducted disturbances induced by RF fields. The test method in this document describes a consistent method to assess the immunity of an equipment or system against a specified phenomenon.

NOTE 3 As described in IEC Guide 107, this document is a basic EMC publication for use by product committees of the IEC. As also stated in Guide 107, the IEC product committees are responsible for determining whether this immunity test standard should be applied or not, and if applied, they are responsible for determining the appropriate test levels and performance criteria.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

3 Terms and definitions

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

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

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

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

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

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

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

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

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

3.4
clamp injection device
clamp-on signal injecting device that is either a current clamp or an electromagnetic clamp

3.4.1
current clamp
transformer, the secondary winding of which consists of the cable into which the injection is made

3.4.2
electromagnetic clamp
EM clamp
injection device with combined capacitive and inductive coupling

3.5
common-mode impedance
ratio of the common-mode voltage and the common-mode current at a certain port

Note 1 to entry: This common-mode impedance can be determined by applying a unity common-mode voltage between the terminal(s) or screen of that port and a reference plane (point). The resulting common-mode current is then measured as the vectoral sum of all currents flowing through these terminal(s) or screen (see also Figure 15a) and Figure 15b)).

3.6
coupling factor
ratio determined by the open-circuit voltage (e.m.f.) obtained at the EUT port of the coupling (and decoupling) device divided by the open-circuit voltage obtained at the output of the test generator

3.7
coupling network
coupling device
electrical circuit or device for transferring energy from one circuit to another with a specified impedance

Note 1 to entry: Coupling and decoupling devices can be integrated into one box (coupling and decoupling network (CDN)) or they can be in separate networks.

3.8
coupling/decoupling network
CDN
electrical circuit incorporating the functions of both the coupling and decoupling networks

3.9
decoupling network
decoupling device
electrical circuit or device for preventing test signals applied to the EUT from affecting other devices, equipment or systems that are not under test

3.10
test generator
generator (RF generator, modulation source, attenuators, broadband power amplifier and filters) capable of generating the required test signal

SEE: Figure 4.

3.11
electromotive force
e.m.f.
voltage at the terminals of the ideal voltage source in the representation of an active element

3.12
measurement result
U_{mr}
voltage reading of the measurement equipment

3.13
voltage standing wave ratio
VSWR
ratio of a maximum to an adjacent minimum voltage magnitude along the line

4 General

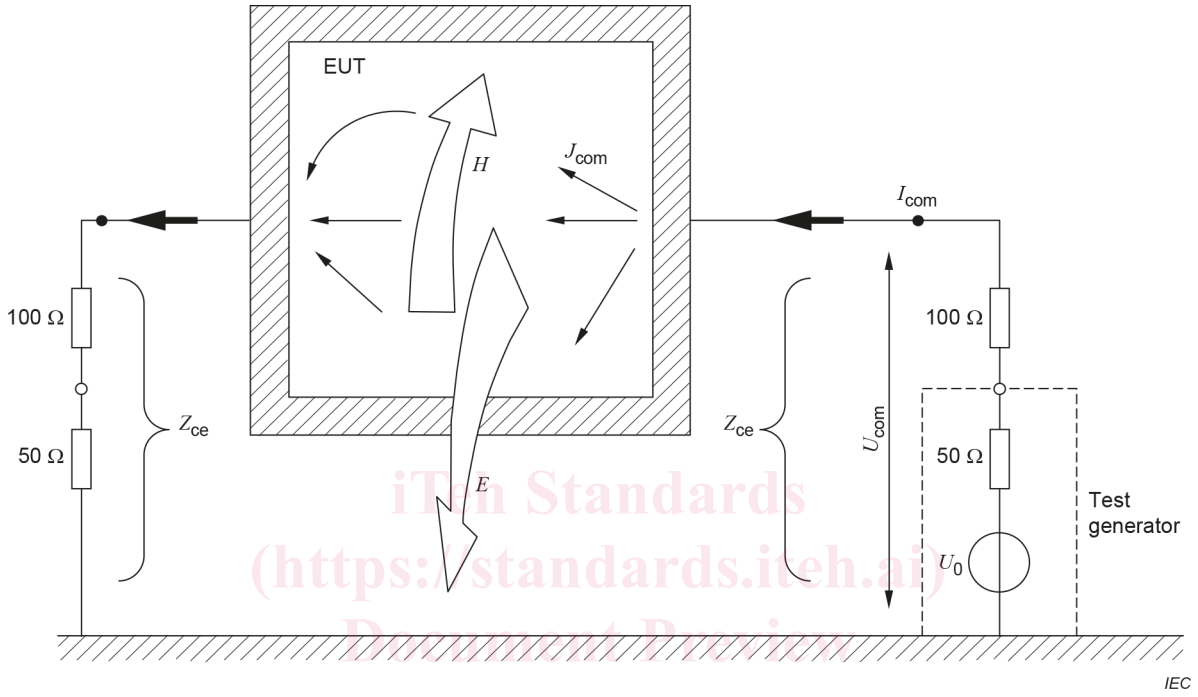
The source of disturbance covered by this document is basically an electromagnetic field, coming from intended RF transmitters, that can act on the whole length of cables connected to installed equipment. The dimensions of the disturbed equipment, mostly a sub-part of a larger system, are assumed to be small compared with the wavelengths of the interfering signals. The leads entering and exiting the EUT (e.g. mains, communication lines, interface cables) behave as passive receiving antenna networks and signal conduction paths for both intentional and unintentional signals.

Between those cable networks, the susceptible equipment is exposed to currents flowing "through" the equipment. Cable systems connected to an equipment are assumed to be in resonant mode ($\lambda/4$, $\lambda/2$ 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 reference ground plane. For the method described herein, the EUT is connected between two 150 Ω common-mode impedance connections: one providing an RF source and the other providing a return path for the current.

This test method subjects the EUT to a source of disturbance comprising electric and magnetic fields, simulating those coming from intentional RF transmitters. These disturbing fields (E and H) are approximated by the electric and magnetic near-fields resulting from the voltages and currents caused by the test setup as shown in Figure 1.

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

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



Z_{ce} Common-mode impedance of the CDN, Z_{ce} = 150 Ω

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

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

I_{com} Common-mode current through the EUT

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

E, H Electric and magnetic fields

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

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