

INTERNATIONAL STANDARD



BASIC EMC PUBLICATION

**Electromagnetic compatibility (EMC) –
Part 4-36: Testing and measurement techniques – IEMI immunity test methods
for equipment and systems**

IEC 61000-4-36:2014

<https://standards.iteh.ai/catalog/standards/sist/9c399f8d-70ef-4a5c-be5d-8d6ad0409edc/iec-61000-4-36-2014>



THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2014 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
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 corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub

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 It also gives information on projects, replaced and withdrawn publications.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 also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in 14 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

More than 55 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

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: csc@iec.ch.

<https://standards.iteh.org/standards/iec/61000-36-2014>

61000-36-2014

INTERNATIONAL STANDARD



BASIC EMC PUBLICATION

**Electromagnetic compatibility (EMC) –
Part 4-36: Testing and measurement techniques – IEMI immunity test methods
for equipment and systems**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE

XC

ICS 33.100.20

ISBN 978-2-8322-1904-1

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	9
2 Normative references	9
3 Terms, definitions and abbreviations	9
3.1 Terms and defintions	9
3.2 Abbreviations.....	12
4 General	13
5 IEMI environments and interaction.....	13
5.1 General.....	13
5.2 IEMI environments	14
5.2.1 Technical capability groups	14
5.2.2 IEMI deployment scenarios.....	14
5.2.3 Radiated IEMI environment summary	15
5.2.4 Published conducted IEMI environments.....	15
5.3 Interaction with fixed installations	16
5.3.1 General	16
5.3.2 Protection level.....	17
6 Test methods.....	17
6.1 Derivation of applicable test methods.....	17
6.2 Derivation of transfer functions	18
6.3 Radiated tests using IEMI simulator	19
6.4 Radiated tests using a reverberation chamber	19
6.5 Complex waveform injection (CWI)	19
6.6 Damped sinusoidal injection (DSI)	19
6.7 Electrostatic discharge (ESD)	19
6.8 Electrically fast transient (EFT)	19
6.9 Antenna port injection	20
7 Test parameters	20
7.1 Derivation of immunity test parameters	20
7.2 Radiated test parameters.....	21
7.2.1 Generic hyperband test parameters (skilled capability group)	21
7.2.2 Generic mesoband test parameters (skilled capability group).....	21
7.2.3 Generic hypoband/narrowband test parameters (skilled capability group).....	23
7.3 Generic conducted IEMI test parameters.....	24
7.3.1 General	24
7.3.2 Characteristics and performance of the fast damped oscillatory wave generator.....	25
7.4 Tailored test level derivation	26
7.5 Relevance of EMC immunity data	26
8 Bibliography	27
Annex A (informative) Failure mechanisms and performance criteria	29
A.1 General.....	29
A.2 Failure mechanisms.....	29
A.2.1 General	29

A.2.2	Noise	30
A.2.3	Parameter offset and drifts	30
A.2.4	System upset or breakdown	31
A.2.5	Component destruction	31
A.3	Effect of pulse width	32
A.4	Performance criteria	32
A.5	References	33
Annex B (informative)	Developments in IEMI source environments	35
B.1	General	35
B.2	IEMI environment	36
B.3	IEMI sources	37
B.4	Published radiated IEMI environments	41
B.4.1	IEC 61000-2-13	41
B.4.2	Mil-Std-464C	41
B.4.3	The International Telecommunication Union (ITU)	42
B.4.4	Practical determination of a tailored test level – An example	42
B.5	Summary	43
B.6	References	44
Annex C (informative)	Interaction with buildings	46
C.1	Building attenuation	46
C.2	Coupling to cables	47
C.3	Low voltage cable attenuation	48
C.4	References	49
Annex D (informative)	Relation between plane wave immunity testing and immunity testing in a reverberation chamber	51
D.1	General	51
D.2	Relation between measurements of shielding effectiveness in the two environments	52
D.3	Relation between immunity testing in the two environments	55
D.4	Additional aspects	57
D.5	References	57
Annex E (informative)	Complex waveform injection – Test method	60
E.1	General	60
E.2	Prediction	60
E.2.1	General	60
E.2.2	Example	64
E.3	Construction	66
E.4	Injection	70
E.5	Summary	72
E.6	References	72
Annex F (informative)	Significance of test methodology margins	74
F.1	General	74
F.2	Examples	74
F.2.1	General	74
F.2.2	Negative contributions	75
F.2.3	Positive contributions	77
F.2.4	Summary	79
F.3	References	79
Annex G (informative)	Intentional EMI – The issue of jammers	80

G.1	General.....	80
G.2	Effects	80
G.3	Published accounts of jamming.....	81
G.4	Risk assessment.....	81
G.5	Mitigation	81
G.6	References	82
Figure 1	– Example of radiated and conducted IEMI interaction with a building.....	16
Figure 2	– Assessment options	18
Figure 3	– Examples of ports	20
Figure 4	– Typical hyperband waveform.....	21
Figure 5	– Typical mesoband waveform	23
Figure 6	– Typical hypoband/narrowband waveform.....	24
Figure 7	– Waveform of the damped oscillatory wave (open circuit voltage).....	25
Figure A.1	– IEMI induced offset of sensor output – Corruption of information	30
Figure A.2	– Collision of an induced disturbance with data bits [1]	31
Figure A.3	– Examples of destruction on a chip [2]	31
Figure A.4	– Generic failure trend as a function of pulse width	32
Figure B.1	– A comparison of HPEM and IEMI spectra [6].....	35
Figure B.2	– Representation of typical IEMI radiation and coupling onto systems [3].....	37
Figure B.3	– Parameter space in power/frequency occupied by sophisticated IEMI (i.e. DEW) sources [1].....	38
Figure B.4	– Peak power and energy from continuous and pulsed (durations shown) microwave sources, narrowband and wideband	38
Figure B.5	– Peak powers of various types of pulsed HPM sources [1].....	39
Figure B.6	– Peak vs. average power for microwave sources with duty factors indicated.....	39
Figure B.7	– Phase coherence leading to a compact HPM source with N^2 scaling of output power.....	40
Figure B.8	– Briefcase mesoband UWB source sold by Diehl-Rheinmetall [3]	40
Figure B.9	– A do-it-yourself electromagnetic weapon made from an oven magnetron [13]	41
Figure B.10	– Plot of entire narrowband system weight as a function of output microwave power for land-mobile and land-transportable systems	43
Figure C.1	– Typical unprotected low-rise building plane wave E-field attenuation collected from references.....	46
Figure C.2	– Cable coupling – Resonance region.....	48
Figure C.3	– Mains cable attenuation profile	49
Figure E.1	– LLSC reference field measurement set-up	61
Figure E.2	– LLSC induced current measurement set-up	62
Figure E.3	– Typical LLSC magnitude-only transfer function	62
Figure E.4	– Prediction of induced current using minimum phase constraints.....	63
Figure E.5	– IEC 61000-2-9 early-time (E1) HEMP environment	64
Figure E.6	– Overlay of transfer function and threat (frequency domain)	65
Figure E.7	– Predicted current	65
Figure E.8	– Example of de-convolution result	67

Figure E.9 – Damped sinusoidal waveforms – Ten-component fit.....	67
Figure E.10 – Approximated and predicted transient.....	68
Figure E.11 – Approximated and predicted transient (0 ns to 100 ns).....	68
Figure E.12 – Approximation and prediction transient – Frequency domain comparison.....	69
Figure E.13 – Variation in error for increasing number of damped sinusoids.....	70
Figure E.14 – Complex injection set-up.....	71
Figure E.15 – Amplifier requirements for various current levels.....	71
Figure E.16 – Comparison of predicted (green) and injected (red) current.....	72
Figure F.1 – Variation in induced currents as a result of configuration.....	75
Figure F.2 – Comparison of HPD and VPD induced currents.....	76
Figure F.3 – System variability.....	76
Figure F.4 – Comparison of single- and multi-port injection.....	77
Figure F.5 – Example transfer functions and worst-case envelope.....	78
Figure F.6 – Comparison of individual and worst-case transfer function predictions.....	78
Figure F.7 – Comparison between predicted and measured induced currents.....	79
Table 1 – Possible IEMI Deployment Scenarios.....	15
Table 2 – Summary of radiated IEMI source output (E_{far}) by capability group.....	15
Table 3 – Example protection levels.....	17
Table 4 – Generic hyperband test parameters (skilled capability group).....	21
Table 5 – Generic mesoband test parameters (skilled capability group).....	22
Table 6 – Generic hypoband/narrowband test parameters (skilled capability group).....	23
Table 7 – Conducted IEMI test levels.....	24
Table 8 – Open circuit specifications.....	25
Table 9 – Short Circuit Specifications.....	26
Table A.1 – Recommended performance criteria.....	33
Table B.1 – IEMI environments from IEC 61000-2-13.....	41
Table B.2 – Hypoband/narrowband HPM environment.....	42
Table B.3 – Hyperband/wideband HPM environment.....	42
Table C.1 – Shielding effectiveness measurements for various power system buildings and rooms.....	47
Table E.1 – Time waveform norms.....	66

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –**Part 4-36: Testing and measurement techniques –
IEMI immunity test methods for equipment and systems**

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.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 61000-4-36 has been prepared by subcommittee 77C: High-power transient phenomena, of IEC technical committee 77: Electromagnetic compatibility.

It forms part 4-36 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107.

The text of this standard is based on the following documents:

CDV	Report on voting
77C/231/CDV	77C/236/RVC

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.

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 publication will remain unchanged until the stability date indicated on the IEC website 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.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication 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.

iTeh STANDARD PREVIEW
(standards.iteh.ai)

IEC 61000-4-36:2014

<https://standards.iteh.ai/catalog/standards/sist/9-399f8d-70ef-4a5c-be5d-8d6ad0409edc/iec-61000-4-36-2014>

Withhold

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).

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-36: Testing and measurement techniques – IEMI immunity test methods for equipment and systems

1 Scope

This part of IEC 61000 provides methods to determine test levels for the assessment of the immunity of equipment and systems to intentional electromagnetic interference (IEMI) sources. It introduces the general IEMI problem, IEMI source parameters, derivation of test limits and summarises practical test methods.

2 Normative references

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

IEC 61000-4-4, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-12, *Electromagnetic compatibility (EMC) – Part 4-12: Testing and measurement techniques – Ring wave immunity test*

IEC 61000-4-18, *Electromagnetic compatibility (EMC) – Part 4-18: Testing and measurement techniques – Damped oscillatory wave immunity test*

3 Terms, definitions and abbreviations

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

3.1 Terms and definitions

3.1.1

attenuation

reduction in magnitude (as a result of absorption and/or scattering) of an electric or magnetic field or a current or voltage, usually expressed in decibels

3.1.2

bandratio

br

ratio of the high and low frequencies between which there is 90 % of the energy

Note 1 to entry: If the spectrum has a large dc content, the lower limit is nominally defined as 1 Hz (see IEC 61000-2-13 for further details).

3.1.3

bandratio decades

brd

bandratio expressed in decades as: $brd = \log_{10}(br)$

3.1.4

burst

time frame in which a series of pulses occurs with a given repetition rate

Note 1 to entry: When multiple bursts occur, the time between bursts is usually defined.

3.1.5

conducted HPEM environment

high-power electromagnetic currents and voltages that are either coupled or directly injected to cables and wires with voltage levels that typically exceed 1 kV

3.1.6

continuous wave

CW

time waveform that has a fixed frequency and is continuous

3.1.7

electromagnetic compatibility

EMC

ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

3.1.8

electromagnetic disturbance

any electromagnetic phenomenon which may degrade the performance of a device, equipment or system

3.1.9

electromagnetic interference

EMI

degradation of the performance of a device, transmission channel or system caused by an electromagnetic disturbance

Note 1 to entry: Disturbance and interference are respectively cause and effect.

3.1.10

(electromagnetic) shield

electrically continuous housing for a facility, area, or component used to attenuate incident electric and magnetic fields by both absorption and reflection

3.1.11

(electromagnetic) susceptibility

inability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance

Note 1 to entry: Susceptibility is a lack of immunity.

3.1.12

equipment under test

EUT

equipment being subjected to the test

3.1.13

high-altitude electromagnetic pulse

HEMP

electromagnetic pulse produced by a nuclear explosion outside the earth's atmosphere

Note 1 to entry: Typically above an altitude of 30 km.

3.1.14**high-power microwaves****HPM**

narrowband signals, nominally with peak power in a pulse, in excess of 100 MW at the source

Note 1 to entry: This is a historical definition that depended on the strength of the source. The interest in this document is mainly on the EM field incident on an electronic system.

3.1.15**hyperband signal**

signal or waveform with a pbw (see 3.1.20) value between 163,4 % and 200 % or a bandratio > 10

3.1.16**hypoband signal**

narrowband signal or waveform with a pbw of < 1 % or a bandratio < 1,01

3.1.17**intentional electromagnetic interference****IEMI**

intentional malicious generation of electromagnetic energy introducing noise or signals into electric and electronic systems, thus disrupting, confusing or damaging these systems for terrorist or criminal purposes

[SOURCE: IEC 61000-2-13:2005, 3.16]

3.1.18**L band**

radar frequency band between 1 GHz and 2 GHz

3.1.19**mesoband signal**

signal or waveform with a pbw value between 1 % and 100 % or a bandratio between 1,01 and 3

3.1.20**percentage bandwidth****pbw**

bandwidth of a waveform expressed as a percentage of the centre frequency of that waveform

Note 1 to entry: The pbw has a maximum value of 200 % when the centre frequency is the mean of the high and low frequencies. The pbw does not apply to signals with a large dc content (e.g., HEMP) for which the bandratio decades is used.

3.1.21**port-of-entry****PoE**

physical location (point) on an electromagnetic barrier, where EM energy may enter or exit a topological volume, unless an adequate PoE protective device is provided

Note 1 to entry: A PoE is not limited to a geometrical point.

Note 2 to entry: PoEs are classified as aperture PoEs or conductive PoEs according to the type of penetration. They are also classified as architectural, mechanical, structural or electrical PoEs according to the functions they serve.

3.1.22**pulse**

transient waveform that usually rises to a peak value and then decays, or a similar waveform that is an envelope of an oscillating waveform

3.1.23

pulse repetition frequency

prf

number of pulses per unit time, measured in Hz (per second)

3.1.24

radiated HPEM environment

high-power electromagnetic fields with peak electric field levels that typically exceed 100 V/m

3.1.25

rE_{far}

electric field normalised at a distance of 1 m from the antenna as derived from an E-field measurement at a given distance in the far-field

3.1.26

sub-hyperband signal

signal or a waveform with a pbw value between 100 % and 163,4 % or a bandratio between 3 and 10

3.1.27

transient

pertaining to or designating a phenomenon or a quantity which varies between two consecutive steady states during a time interval which is short compared with the time-scale of interest

Note 1 to entry: A transient can be a unidirectional impulse of either polarity or a damped oscillatory wave with the first peak occurring in either polarity.

3.1.28

ultrawideband

UWB

signal that has a percent bandwidth greater than 25 %

3.2 Abbreviations

DS	Damped sinusoid
EMI	Electromagnetic interference
ESD	Electrostatic discharge
HEMP	High-altitude electromagnetic pulse
HIRF	High-intensity radiated fields
HPD	Horizontally polarized dipole
HPEM	High-power electromagnetic
HPM	High-power microwave
LEMP	Lightning electromagnetic pulse
LLSF	Low level swept field
LLSC	Low level swept current
NEMP	Nuclear electromagnetic pulse
SE	Shielding effectiveness
UWB	Ultra wideband

VPD

Vertically polarized dipole

4 General

The use of electromagnetic sources to generate intentional electromagnetic interference (IEMI) is of increasing concern as the reliance of society on technology increases significantly. Many technical papers have been published that show the effects of IEMI are cause for concern; they are summarised in [1]¹. A summary of failure mechanisms at equipment level is provided in Annex A.

The effects of IEMI on equipment can be similar to the effects caused by high-power electromagnetic (HPEM) environments. HPEM environments include high-intensity radiated fields (HIRF) generated by radio and radar systems, lightning electromagnetic pulse (LEMP) and electrostatic discharge (ESD). Some of these HPEM environments have similar characteristics to those sources used to cause IEMI but are unintentional EMI sources, i.e. non-malicious. However, it is possible to use information regarding qualification of equipment and systems to these environments to inform the likely response to IEMI.

The IEC defines IEMI within 3.1.17 as 'intentional malicious generation of electromagnetic energy introducing noise or signals into electric and electronic systems, thus disrupting, confusing or damaging these systems for terrorist or criminal purposes'.

Within this definition it is possible to also include jammers, which are designed to overload antenna receiver circuits (front doors) by operating at or close to the victim receiver frequency of operation. Jammers typically require low power to operate due to the fact that receivers are designed to operate at very low power levels (nW or less). More information on the issue of jammers can be found in Annex G.

This document complements IEC 61000-4-25 [2], which deals with high-altitude electromagnetic pulse (HEMP) immunity test methods for equipment and systems.

5 IEMI environments and interaction

5.1 General

There are many types of sources that can generate electromagnetic environments that can potentially be used to cause intentional electromagnetic interference (IEMI). IEC 61000-2-13 [3] discusses the various environments that can be generated and categorises them in terms of time characteristics, frequency range and bandratio. Further details and actual examples are included within Annex B.

A key requirement of developing IEMI test methods and test levels is to achieve a good understanding of the environment in which the victim equipment or system will be required to operate. Within this document specific focus is provided for victim equipment that is integrated within a site or other fixed installation and it is generally assumed that such equipment is housed within a building.

IEMI phenomena are unlike other EMC standardised phenomena where assumptions can be made about the general or average disturbance level arriving at victim equipment ports. Important parameters related to the IEMI interaction with victim systems which will affect the test level include:

- a) IEMI source parameters
 - 1) frequency range of the source,

¹ Numbers in square brackets refer to the Bibliography in Clause 8.