

INTERNATIONAL STANDARD



BASIC EMC PUBLICATION

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



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2020 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
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 It also gives information on projects, replaced and withdrawn publications.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.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

67 000 electrotechnical terminology entries in English and French extracted from the Terms and definitions clause of IEC publications issued between 2002 and 2015. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

Preview generated by EVS

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

ICS 33.100.20

ISBN 978-2-8322-7942-7

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

CONTENTS

FOREWORD.....	7
INTRODUCTION.....	9
1 Scope.....	10
2 Normative references	10
3 Terms, definitions and abbreviated terms	10
3.1 Terms and definitions.....	10
3.2 Abbreviated terms.....	14
4 General	15
5 IEMI environments and interaction.....	16
5.1 General.....	16
5.2 IEMI environments	17
5.2.1 Technical capability groups	17
5.2.2 IEMI deployment scenarios.....	17
5.2.3 Radiated IEMI environment summary	17
5.2.4 Published conducted IEMI environments.....	18
5.3 Interaction with victim equipment, systems and installations	18
5.3.1 General	18
5.3.2 Protection level.....	19
6 Test methods.....	20
6.1 Derivation of applicable test methods.....	20
6.2 Derivation of transfer functions	21
6.3 Radiated tests using IEMI simulator	22
6.4 Radiated tests using a reverberation chamber	22
6.5 Complex waveform injection (CWI)	22
6.6 Damped sinusoidal injection (DSI)	22
6.7 Electrostatic discharge (ESD)	22
6.8 Electrically fast transient (EFT)	22
6.9 Antenna port injection	23
7 Test parameters	23
7.1 Derivation of immunity test parameters	23
7.2 Radiated test parameters.....	23
7.2.1 Generic hyperband test parameters (skilled capability group)	23
7.2.2 Generic mesoband test parameters (skilled capability group).....	25
7.2.3 Generic hypoband test parameters (skilled capability group)	27
7.3 Generic conducted IEMI test parameters.....	28
7.3.1 General	28
7.3.2 Characteristics and performance of the fast damped oscillatory wave generator.....	29
7.4 Tailored test level derivation	30
7.5 Relevance of EMC immunity data	30
Annex A (informative) Failure mechanisms and performance criteria	31
A.1 General.....	31
A.2 Failure mechanisms	31
A.2.1 General	31
A.2.2 Noise	32

A.2.3	Parameter offset and drifts	32
A.2.4	System upset or breakdown.....	33
A.2.5	Component destruction	33
A.3	Effect of pulse width.....	34
A.4	Performance criteria	34
A.5	References	35
Annex B (informative)	Developments in IEMI source environments	37
B.1	General.....	37
B.2	IEMI environment.....	38
B.3	IEMI sources.....	39
B.4	Published radiated IEMI environments	43
B.4.1	IEC 61000-2-13 [B.14]	43
B.4.2	Mil-Std-464C	43
B.4.3	Selection of parameters for mesoband immunity test	45
B.4.4	International Telecommunication Union (ITU)	47
B.5	Summary	47
B.6	References	48
Annex C (informative)	Interaction with buildings.....	50
C.1	Building attenuation	50
C.2	Coupling to cables	51
C.3	Low voltage cable attenuation.....	52
C.4	References	53
Annex D (informative)	Relation between plane wave immunity testing and immunity testing in a reverberation chamber	55
D.1	General.....	55
D.2	Relation between measurements of shielding effectiveness in the two environments	56
D.3	Relation between immunity testing in the two environments	59
D.4	Additional aspects.....	61
D.5	References	61
Annex E (informative)	Complex waveform injection – Test method.....	64
E.1	General.....	64
E.2	Prediction	64
E.2.1	General	64
E.2.2	Example	68
E.3	Construction	70
E.4	Injection.....	74
E.5	Summary	76
E.6	References	76
Annex F (informative)	Significance of test methodology margins	78
F.1	General.....	78
F.2	Examples.....	78
F.2.1	General	78
F.2.2	Negative contributions	79
F.2.3	Positive contributions.....	81
F.2.4	Summary	83
F.3	References	83
Annex G (informative)	Intentional EMI – The issue of jammers	84
G.1	General.....	84

G.2	Effects	84
G.3	Published accounts of jamming	85
G.4	Risk assessment	85
G.5	Mitigation	85
G.6	References	86
Annex H (normative) Hyperband and mesoband radiated transients immunity test method		88
H.1	Overview	88
H.2	Test equipment	88
H.2.1	General	88
H.2.2	Test facility	88
H.2.3	Hyperband transient pulse radiating test system	89
H.2.4	Mesoband transient pulse radiating test system	89
H.2.5	Measurement chain	89
H.3	Field uniformity assessment	90
H.3.1	Field uniformity assessment in an anechoic chamber	90
H.3.2	Field uniformity in GTEM waveguide	93
H.4	Test set-up	93
H.4.1	General	93
H.4.2	Arrangement of table-top equipment	95
H.4.3	Arrangement of floor-standing equipment	95
H.4.4	Arrangement of wiring	95
H.5	Test procedure	96
H.5.1	General	96
H.5.2	Laboratory reference conditions	96
H.5.3	Execution of the test	96
H.5.4	Evaluation of test results	98
H.6	Test report	98
H.7	References	99
Annex I (informative) Calibration method and measurement uncertainty of sensors for the measurement of radiated hyperband and mesoband transient fields		100
I.1	General	100
I.2	Calibration method in TEM waveguides in IEC 61000-4-20:2010, Annex E [I.1]	100
I.2.1	General	100
I.2.2	Probe calibration requirements	101
I.2.3	Field probe calibration procedure in case of a one-port TEM waveguide	102
I.3	Calibration procedures for D-dot sensors in the time domain	103
I.3.1	General	103
I.4	Measurement uncertainty	105
I.5	References	106
Bibliography		107
Figure 1 – Example of radiated and conducted IEMI interaction with a building		19
Figure 2 – Assessment options		21
Figure 3 – Examples of ports		23
Figure 4 – Example of hyperband waveform		25
Figure 5 – Example of mesoband waveform		27
Figure 6 – Typical hypoband/narrowband waveform		28

Figure 7 – Waveform of the damped oscillatory wave (open circuit voltage)	29
Figure A.1 – IEMI induced offset of sensor output – Corruption of information	32
Figure A.2 – Collision of an induced disturbance with data bits [A.1]	33
Figure A.3 – Examples of destruction on a chip [A.2]	33
Figure A.4 – Generic failure trend as a function of pulse width	34
Figure B.1 – A comparison of HPEM and IEMI spectra [B.6]	37
Figure B.2 – Representation of typical IEMI radiation and coupling onto systems [B.3]	39
Figure B.3 – Parameter space in power/frequency occupied by sophisticated IEMI (i.e. DEW) sources in comparison to common RF systems [B.1]	40
Figure B.4 – Peak power and energy from continuous and pulsed (durations shown) microwave sources, narrowband and wideband	40
Figure B.5 – Peak powers of various types of pulsed hypoband/narrowband sources [B.1] ...	41
Figure B.6 – Peak versus average power for microwave sources with duty factors indicated	41
Figure B.7 – Phase coherence leading to a compact HPM source with N^2 scaling of output power	42
Figure B.8 – Briefcase mesoband DS source sold by Diehl-Rheinmetall [B.3]	42
Figure B.9 – A do-it-yourself electromagnetic weapon made from an oven magnetron [B.13]	43
Figure B.10 – Wideband (mesoband and hyperband) EME derived from [B.17]	45
Figure B.11 – Plot of entire narrowband system weight as a function of output microwave power for land-mobile and land-transportable systems	48
Figure C.1 – Typical unprotected low-rise building plane wave E-field attenuation collected from references	50
Figure C.2 – Cable coupling and resonance region	52
Figure C.3 – Mains cable attenuation profile	53
Figure E.1 – LLSC reference field measurement set-up	65
Figure E.2 – LLSC induced current measurement set-up	66
Figure E.3 – Typical LLSC magnitude-only transfer function	66
Figure E.4 – Prediction of induced current using minimum phase constraints	67
Figure E.5 – IEC 61000-2-9 early-time (E1) HEMP environment	68
Figure E.6 – Overlay of transfer function and threat (frequency domain)	69
Figure E.7 – Predicted current	69
Figure E.8 – Example of de-convolution result	71
Figure E.9 – Damped sinusoidal waveforms – Ten-component fit	71
Figure E.10 – Approximated and predicted transient	72
Figure E.11 – Approximated and predicted transient (0 ns to 100 ns)	72
Figure E.12 – Approximation and prediction transient – Frequency domain comparison	73
Figure E.13 – Variation in error for an increasing number of damped sinusoids	74
Figure E.14 – Complex injection set-up	75
Figure E.15 – Amplifier requirements for various current levels	75
Figure E.16 – Comparison of predicted (green) and injected (red) current	76
Figure F.1 – Variation in induced currents as a result of configuration	79
Figure F.2 – Comparison of HPD and VPD induced currents	80
Figure F.3 – System variability	80

Figure F.4 – Comparison of single- and multi-port injection	81
Figure F.5 – Example of transfer functions and worst-case envelope	82
Figure F.6 – Comparison of individual and worst-case transfer function predictions	82
Figure F.7 – Comparison between predicted and measured induced currents	83
Figure H.1 – Measurement chain for field uniformity assessment and transient responses	89
Figure H.2 – Test set-up for field uniformity assessment in anechoic chamber	91
Figure H.3 – Example of test set-up for table-top equipment/system	94
Figure H.4 – Example of test set-up for floor-standing equipment/system	94
Figure H.5 – Example of test set-up in GTEM waveguide	95
Figure I.1 – Example of the measurement points for the validation	102
Figure I.2 – Set-up for calibration of E-field probe in one-port TEM waveguide	103
Figure I.3 – Cone and ground plane sensor calibration set-up	104
Table 1 – Possible IEMI deployment scenarios	17
Table 2 – Summary of high power radiated IEMI source output (rE_{far}) by capability group	18
Table 3 – Examples of protection levels	19
Table 4 – Generic hyperband test parameters (skilled capability group)	24
Table 5 – Radiated hyperband test waveform and other pulse parameters	24
Table 6 – Generic mesoband test parameters (skilled capability group)	25
Table 7 – Comparison of quality factor (Q) with bandratio	26
Table 8 – Radiated mesoband waveform and other pulse parameters	26
Table 9 – Generic hypoband/narrowband test parameters (skilled capability group)	27
Table 10 – Conducted IEMI test levels	28
Table 11 – Open circuit specifications	29
Table 12 – Short circuit specifications	30
Table A.1 – Recommended performance criteria	35
Table B.1 – IEMI environments from IEC 61000-2-13	43
Table B.2 – Hypoband/narrowband HPM environment from [B.17]	44
Table B.3 – Wideband (mesoband/hyperband) HPM environment from [B.17]	44
Table C.1 – Shielding effectiveness measurements for various power system buildings and rooms	51
Table E.1 – Time waveform norms	70
Table I.1 – Calibration frequencies	102
Table I.2 – Type B expanded uncertainties for sensor calibrations in GTEM cell field generation system	105
Table I.3 – Type B expanded uncertainties for sensor calibrations in the cone and ground plane cell field generation system	106

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.

This second edition cancels and replaces the first edition published in 2014. This edition constitutes a technical revision.

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

- a) addition of a hyperband and mesoband radiated transients immunity test method in Annex H;
- b) addition of a calibration method of sensors for radiated hyperband and mesoband transient fields and measurement uncertainty in Annex I.

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

FDIS	Report on voting
77C/295/FDIS	77C/299/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.

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.

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.

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

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

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

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

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

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

[SOURCE: IEC 61000-2-13:2005 [3]¹, 3.1]

3.1.2

bandratio

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 [3] for further details).

[SOURCE: IEC 61000-2-13:2005 [3], 3.2, modified – The second part of the definition has been made into a note.]

3.1.3

bandratio decades

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

¹ Numbers in square brackets refer to the Bibliography.