BS IEC 61000-4-36:2020

BSI Standards Publication

Electromagnetic compatibility (EMC)

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

Documents
Document Sharing Hub

Full document details: BS IEC 61000-4-36:2020

National foreword

This British Standard is the UK implementation of IEC 61000-4-36:2020. It supersedes BS IEC 61000-4-36:2014, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/210/11, EMC - Standards Committee.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2020
Published by BSI Standards Limited 2020

ISBN 978 0 580 97324 6

ICS 33.100.20

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 April 2020.

Amendments/corrigenda issued since publication

Date	Text affected

Documents
Document Sharing Hub

Full document details: BS IEC 61000-4-36:2020

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

AVA Documents
Document Sharing Hub

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

AVA Documents
Document Sharing Hub
Full document details: BS IEC 61000-4-36:2020

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

AVA Documents
Document Sharing Hub
Full document details: BS IEC 61000-4-36:2020

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

AVA Documents
Document Sharing Hub
Full document details: BS IEC 61000-4-36:2020

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

Documents
Document Sharing Hub
Full document details: BS IEC 61000-4-36:2020

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.

Documents
Document Sharing Hub

Full document details: BS IEC 61000-4-36:2020

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.

Documents
Document Sharing Hub

Full document details: BS IEC 61000-4-36:2020

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).

Documents
Document Sharing Hub

Full document details: BS IEC 61000-4-36:2020

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: bandratio decades = log10(bandratio)

[1] Numbers in square brackets refer to the Bibliography.

Documents
Document Sharing Hub

Full document details: BS IEC 61000-4-36:2020

[SOURCE: IEC 61000-2-13:2005 [3], 3.3]

3.1.4
burst
sequence of a limited number of distinct pulses or oscillations of limited duration

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

SOURCE: [IEC 60050-161:1990 [19], 161-02-07, modified – The note has been added.]

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

[SOURCE: IEC 61000-2-13:2005 [3], 3.5]

3.1.6
continuous wave
CW
time waveform that has a fixed frequency and is continuous

[SOURCE: IEC 61000-2-13:2005 [3], 3.6]

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

[SOURCE: IEC 60050-161:2018, 161-01-07.]

3.1.8
electromagnetic disturbance
any electromagnetic phenomenon which can degrade the performance of a device, equipment or system

[SOURCE: IEC 60050-161:2018, [19] 161-01-05, modified – The last part of the definition, "or adversely affect living or inert matter", has been removed.]

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.

[SOURCE: IEC 60050-161:2018 [19], 161-01-06, modified – Notes 1 and 2 have been removed and a new Note 1 has been added.]

3.1.10
shield
<electromagnetic> electrically continuous housing for a facility, area, or component used to attenuate incident electric and magnetic fields by both absorption and reflection

Documents
Document Sharing Hub

Full document details: BS IEC 61000-4-36:2020

3.1.11
(electromagnetic) susceptibility
possibility of degradation to the performance of a device, equipment or system in the presence of an electromagnetic field

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

3.1.12
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.

[SOURCE: IEC 61000-2-13:2005 [3], 3.12]

3.1.13
high-power microwave
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.

[SOURCE: IEC 61000-2-13:2005 [3], 3.13]

3.1.14
hyperband signal
signal or waveform with a pbw (see 3.1.19) value between 163,4 % and 200 % or a bandratio > 10

[SOURCE: IEC 61000-2-13:2005 [3], 3.14]

3.1.15
hypoband signal
narrowband signal or waveform with a pbw (see 3.1.19) of < 1 % or a bandratio < 1,01

[SOURCE: IEC 61000-2-13:2005 [3], 3.15, modified – The second term "narrowband signal" has been removed.]

3.1.16
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], 3.16]

3.1.17
L band
radar frequency band between 1 GHz and 2 GHz

[SOURCE: IEC 61000-2-13:2005 [3], 3.17]

3.1.18
mesoband signal
signal or waveform with a pbw (see 3.1.19) value between 1 % and 100 % or a bandratio between 1,01 and 3

AVA Documents
Document Sharing Hub

Full document details: BS IEC 61000-4-36:2020

[SOURCE: IEC 61000-2-13:2005 [3], 3.18]

3.1.19
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.

[SOURCE: IEC 61000-2-13:2005 [3], 3.19]

3.1.20
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.

[SOURCE: IEC 61000-2-13:2005 [3], 3.20, modified – The second term "point-of-entry" has been removed.]

3.1.21
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

[SOURCE: IEC 61000-2-13:2005 [3], 3.21]

3.1.22
pulse repetition frequency
prf
number of pulses per unit time, measured in Hz

3.1.23
radiated HPEM environment
high-power electromagnetic fields with peak electric field levels that typically exceed 100 V/m

[SOURCE: IEC 61000-2-13:2005 [3], 3.22]

3.1.24
$rE_{\mathbf{far}}$
measured or known electric field multiplied by the distance at which it was measured to give an equivalent voltage at a distance of 1 m from the antenna

3.1.25
sub-hyperband signal
signal or a waveform with a pbw value between 100 % and 163,4 % or a bandratio between 3 and 10

[SOURCE: IEC 61000-2-13:2005 [3], 3.23]

Documents
Document Sharing Hub
Full document details: BS IEC 61000-4-36:2020

3.1.26
transient
pertaining to or designating a phenomenon or 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.

[SOURCE: IEC 60050-702:2019 [20], 702-07-781, modified – The words "pertaining to or designating a" and the note have been added.]

3.1.27
ultrawideband
UWB
signal that has a percent bandwidth greater than 25 %

[SOURCE: IEC 61000-2-13:2005 [3], 3.25]

3.2 Abbreviated terms

AC	Anechoic chamber
BCI	Bulk current injection
CWI	Complex waveform injection
DEW	Directed energy weapon
DS	Damped sinusoid
DSI	Damped sinusoid injection
EFT	Electrically fast transient
EM	Electromagnetic
EME	Electromagnetic environment
EMI	Electromagnetic interference
EMP	Electromagnetic pulse
ERTMS	European rail traffic management system
ESD	Electrostatic discharge
EUT	Equipment under test
FO	Fibre optic
FOL	Fibre optic link
FT	Fourier transform
GNSS	Global navigation satellite system
GPS	Global positioning system
GSM-R	Global system for mobile – railways
GTEM	Gigahertz transverse electromagnetic
HEMP	High-altitude electromagnetic pulse
HIRA	Half impulse radiating antenna
HIRF	High-intensity radiated field
HPD	Horizontally polarized dipole
HPEM	High-power electromagnetic
HPM	High-power microwave
IC	Integrated circuit
IEMI	Intentional electromagnetic interference

AVA Documents
Document Sharing Hub
Full document details: BS IEC 61000-4-36:2020

IFT	Inverse Fourier transform
IRA	Impulse radiating antenna
LEMP	Lightning electromagnetic pulse
LISN	Line impedance stabilization network
LLSC	Low level swept current
LLSF	Low level swept field
LNA	Low noise amplifier
MPA	Minimum phase algorithm
NEMP	Nuclear electromagnetic pulse
NLTL	Non linear transmission line
OATS	Open area test site
prf	Pulse repetition frequency
SAC	Semi-anechoic chamber
SE	Shielding effectiveness
TEM	Transverse electromagnetic mode
TMR	Triple modular redundancy
UAV	Unmanned aerial vehicle
UFA	Uniform field area
URSI	International radio scientific union
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]. A summary of failure mechanisms at equipment level is provided in Annex A.

IEMI can be included within the set of HPEM environments, which also include high-intensity radiated fields (HIRFs) generated by radio and radar systems, lightning electromagnetic pulse (LEMP) and electrostatic discharge (ESD).

The IEC defines IEMI (see 3.1.16) 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.

Documents
Document Sharing Hub

Full document details: BS IEC 61000-4-36:2020

5 IEMI environments and interaction

5.1 General

There are many types of sources which are capable of generating electromagnetic environments potentially causing 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,
   2) peak and average power of the source
   3) pulse width, pulse repetition frequency, burst length of the source,
   4) source mobility,
   5) technical complexity of the source,
   6) antenna characteristics and/or conducted injection method characteristics
b) the protection level of the equipment, system or installation
   1) the range or distance between the IEMI source and the victim electronics,
   2) the propagation channel loss including the properties of the intervening barriers (attenuation and absorption).

Once these characteristics of the IEMI source and environment are well understood, then appropriate test methods and test levels for ports on the victim equipment can be determined.

One approach would be to take all of the IEMI source parameters of interest and combine them such that one set of test levels is derived. The disadvantage of this approach is that, should effects be observed, it would be difficult to assign them to any single IEMI parameter set. In addition the combination of widely varying waveform characteristics would likely result in an extreme set of test levels.

Some IEMI sources generate waveforms/environments that are similar to other electromagnetic (EM) environments, for example electrostatic discharge (ESD) or lightning electromagnetic pulse (LEMP). Analytical methods can be used to determine the amount of similarity between IEMI environments and other EM environments, in particular through the use of waveform norms (see IEC 61000-4-33 [4]). Any deficiencies in the test evidence could be made up through increasing the distance between the IEMI source and the electronic systems of interest or by undertaking testing focussed on specific frequencies.

Documents
Document Sharing Hub

Full document details: BS IEC 61000-4-36:2020

5.2 IEMI environments

5.2.1 Technical capability groups

IEMI sources vary in complexity. It is therefore important to understand the relationship between this complexity and the technical capability of the perpetrator. This document defines three levels:

a) Novice – Individuals or small groups with minimal technical or financial support.

b) Skilled – Moderately well-funded adversaries with training and expertise in relevant technology.

c) Specialist – Well-funded adversaries with post-graduate level training and access to substantial research capabilities, resources and funding.

When considering the IEMI sources of interest it is important to consider the deployment scenario.

5.2.2 IEMI deployment scenarios

IEMI sources can be packaged and deployed in different ways, although this generally depends on the technical capability of the designer and the available resources. A set of potential scenarios for deployment of IEMI generators is given in Table 1.

Table 1 – Possible IEMI deployment scenarios

Deployment scenarios	Example use	Victim interaction	Technical capability group
Man portable	Carried to the victim and used while in possession of the adversary. Could be assembled in place.	Direct Radiated Conducted	Novice Skilled
Hand delivered	Carried to the victim and concealed, perhaps remotely activated. Could be assembled in place.	Direct Radiated Conducted	Novice Skilled
Fixed installation	Set-up in a space adjacent to the victim, i.e. an adjoining room or building.	Radiated Conducted	Novice Skilled Specialist
Automotive / marine delivered	Mounted inside a pick-up truck or on the after deck of a marine vessel.	Radiated Conducted	Skilled Specialist
Air delivered	Installed inside an aircraft bay, carried as a pod, or dropped (i.e., E-bomb).	Radiated	Specialist

5.2.3 Radiated IEMI environment summary

Table 2 provides a summary of threat source environments defined by capability group.

Documents
Document Sharing Hub

Full document details: BS IEC 61000-4-36:2020

Table 2 – Summary of high power radiated IEMI source output (rE_{far}) by capability group

Category	IEMI source type	IEMI source name or technology type	rE_{far} (V)	Far field boundary (approx.)
Novice	Hyperband	ESD gun	5 000	1 m
	Hypoband	Microwave oven magnetron	2 000	1 m
Skilled	Hyperband	Commercially available solid state pulser (e.g. pockels cell driver)	60 000	1 m
	Mesoband	Commercially available pulser	120 000	2 m
	Hypoband	Radar	450 000	5 m
Specialist	Hyperband	Military demonstrator (e.g. jolt)	5 300 000	50 m
	Mesoband	Military mesoband demonstrator	500 000	5 m
	Hypoband	Military hypoband demonstrator	30 000 000	50 m

NOTE Table 2 does not include jammers. These are discussed in Annex G.

5.2.4 Published conducted IEMI environments

Unlike the situation with radiated IEMI sources, examples of conducted IEMI sources are less common. However, it has been shown that many conducted EMC tests exist within published civilian EMC documents such as IEC 61000-4-18 [5], IEC 61000-4-4 [6] and IEC 61000-4-25 [2] and that the sources that generate these test waveforms can be uprated or applied to equipment ports in a different way or otherwise used for malicious effect. There are also various military standards that contain relevant conducted tests.

5.3 Interaction with victim equipment, systems and installations

5.3.1 General

The magnitude of the IEMI environment impinging on a victim system is primarily dependent upon two factors:

1) the range or distance between the IEMI source and the victim electronics;
2) the propagation loss, including the attenuation properties of intervening barriers.

It is important to note that radiated IEMI interacts not only with apertures and structures, but also cables. The total EM disturbance presented to the victim electronics inside is therefore a function of the direct radiated IEMI and the coupling of this IEMI to EM conductors such as cables, pipe-work and ducting. When determining an appropriate test level for a particular radiated IEMI environment of concern, an assessment of the transfer of the IEMI to the victim electronics inside the building is required and this should include any attenuation afforded by the building material, propagation loss and any other aspects that can affect the resulting currents or voltages presented to the equipment.

Figure 1 shows a typical radiated and conducted IEMI scenario with a vehicle-mounted IEMI source illuminating a building and separately injecting into a power cable. The fields generated by the radiating source penetrate through apertures and separately couple to conductors (both outside and inside the building), generating induced currents and voltages that can affect the victim electronic equipment. The current/voltage generated by the conducted source is coupled to the conductor, allowing it to propagate inside the building and potentially affect electronic equipment.

Documents
Document Sharing Hub
Full document details: BS IEC 61000-4-36:2020

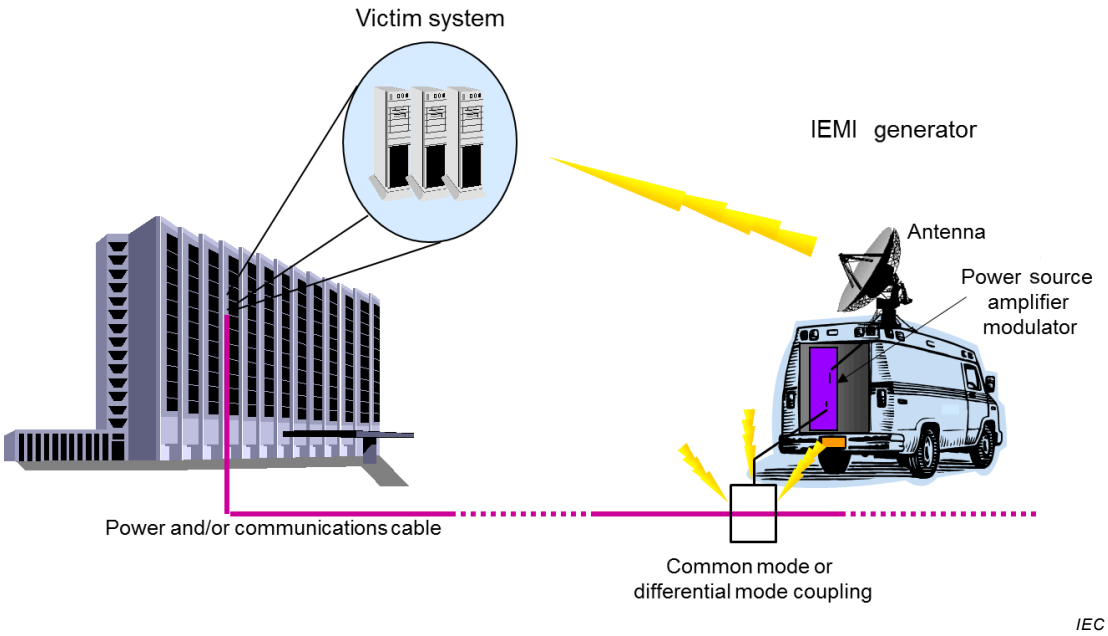


Figure 1 – Example of radiated and conducted IEMI interaction with a building

It should be noted that cable attenuation and attenuation afforded by lumped components (such as transformers) should be considered when determining the currents and voltages presented at the electronic equipment. It should also be noted that different coupling modes (i.e. common mode or differential mode) can result in very different path losses during the propagation.

5.3.2 Protection level

Given the discussion above it can be implied that victim electronics located inside equipment, systems or installations will have an "inherent protection level" which is a function of the physical distance between the IEMI source and the victim electronics and the loss in the propagation channel. A discussion on the radiated and conducted interaction of IEMI sources within buildings is provided in Annex C.

Examples of protection levels are indicated in Table 3. These levels have been identified using the information in Annex C. However, it is highly important that the actual protection level is quantified through measurements, possibly as part of a site survey. Test methods which can be used to assess the barrier attenuation/propagation loss are discussed in Clause 6.

Table 3 – Examples of protection levels

Example of protection level (EPL) rating	Assumed range to victim (m)	Path loss (dB)	Assumed barrier attenuation (dB)	Total EPL (dB)
EPL0	2	6	0	6
EPL1	10	20	0	20
EPL2	12	22	4	26
EPL3	18	25	7	32
EPL4	30	29,5	11	40,5
EPL5	30	29,5	18	47,5
EPL6	35	31	29	60
NOTE The path loss equates to the assumed threat to the victim range expressed in dB relative to 1 m.				

AVA Documents
Document Sharing Hub
Full document details: BS IEC 61000-4-36:2020

The EPL should be considered when deriving the applicable IEMI immunity test parameters discussed in Clause 7. In the absence of actual data the generic EPLs in Table 3 can be used.

6 Test methods

6.1 Derivation of applicable test methods

A detailed discussion on test methods is included in IEC TS 61000-5-9 [7]. The test methods summarised below encompass the evaluation of the "example protection level" and the immunity test level for potential victim equipment.

As IEMI falls into two main categories, namely radiated and conducted, the methods for testing against IEMI fall broadly into the same categories.

Testing against radiated IEMI can be undertaken with the IEMI source of interest, a simulated environment such as that shown in IEC TR 61000-4-35 [8], or by injecting the signal expected to be induced into conductors by exposure to the IEMI radiated environment. The latter relies on knowledge of the transfer function[2] of each conductor of concern (typically these conductors are cable bundles that carry power and/or data that is vital to the continuing function of the equipment or system).

Testing against conducted IEMI is typically undertaken with either the IEMI source directly or with a conducted simulator. Although it is possible to use a radiated method to assess against the effects of conducted IEMI, it is not commonplace.

Once the preferred test methodology has been agreed, it is possible to determine the required test levels.

Figure 2 shows the options available when undertaking an assessment of the effects of IEMI on equipment or systems.

[2] A measure of internally induced current or electromagnetic field as a result of an externally illuminating electromagnetic environment.

AVA Documents
Document Sharing Hub

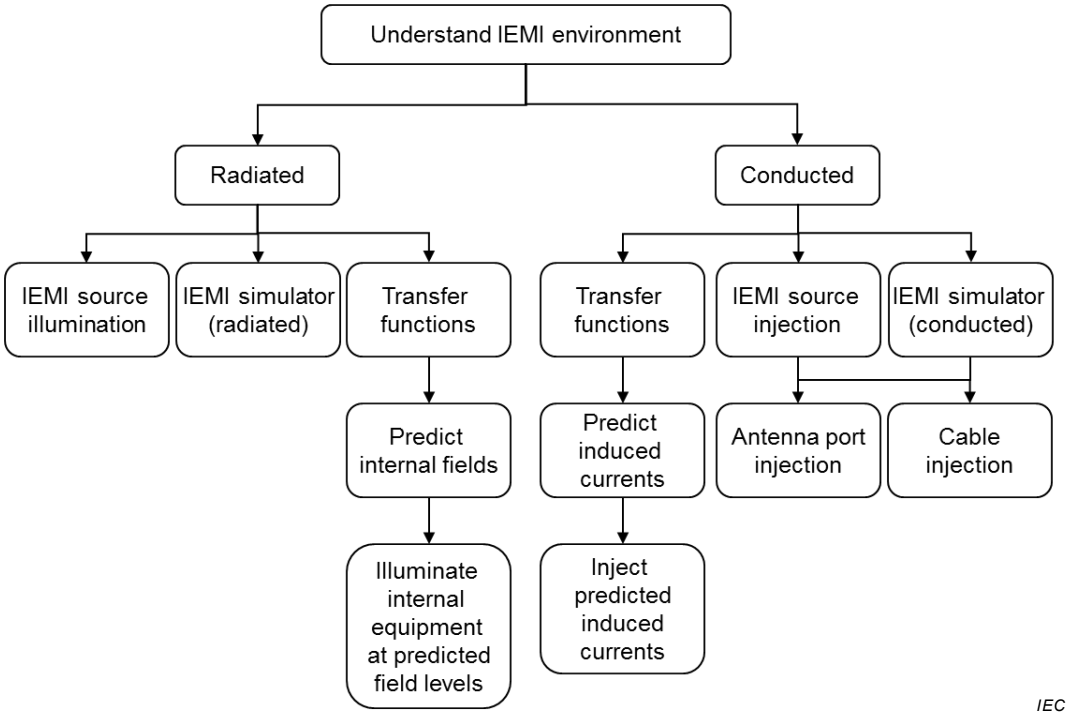


Figure 2 – Assessment options

It is essential that testing is conducted in a representative configuration and that careful consideration is given to those aspects of the test set-up that can have a significant impact on test results, for example cable layout. If the requirement is for equipment to be immune to IEMI when in a power-off configuration, then testing with the equipment powered off is applicable. For all other cases, testing with the equipment powered and functioning is essential. Research has shown that transient effects can be significantly enhanced when the equipment is being operated functionally, for example with computer equipment that is constantly conducting hard drive operations or memory intensive functions.

A summary of test methods that can be used for the assessment of equipment or systems to the effects of IEMI is provided below.

6.2 Derivation of transfer functions

Transfer functions are essential for any equipment or system that is to be tested against the effects of a radiated IEMI source using conducted methods and can also be used to evaluate the protection level of a victim installation.

Transfer functions can either be measured (using techniques such as those discussed in IEC TS 61000-5-9 [7]) or generated analytically using some understanding of relevant geometry.

Transfer functions provide the means of estimating induced currents or voltages on conductors as a result of an EM field illuminating the conductor or from an EM source injected onto external cabling. Transfer functions are generally measured over a broad frequency range (e.g. ~1 MHz to ~1 GHz) and enable predictions to be computed for any IEMI environment with similar frequency content. Transfer functions can be extended to tens of GHz by measuring internally induced EM fields and reflecting the change in dominance of the interaction mechanism from cable coupling to aperture coupling.

For applicable test methods and test set-up see IEC TS 61000-5-9 [7].

Documents
Document Sharing Hub
Full document details: BS IEC 61000-4-36:2020

6.3 Radiated tests using IEMI simulator

IEMI simulators are becoming increasingly available as the threat of IEMI is understood and accepted to pose real risk to the continuing operation of electronic equipment. IEC TR 61000-4-35 [8] contains details on IEMI simulators and their respective parameters. The equipment under test (EUT) shall be set-up in a representative condition of its intended use for the results to be indicative of the EUT response when fielded. The use of IEMI simulators to assess the protection level of an operational installation is not recommended since it can present a significant interference risk.

For applicable test methods and test set-up of IEMI sources see IEC TR 61000-4-35 [8].

6.4 Radiated tests using a reverberation chamber

IEC TR 61000-4-35 [8] also provides some examples of reverberation chambers. Reverberation chambers can be used to produce the high field levels for equipment level testing and are useful for testing of a material's shielding effectiveness in accordance with IEC 61000-4-21 [9].

Care should be taken to understand how the results of measurements made within a reverberation chamber compare with the realistic case of IEMI interaction which is closer to a plane wave phenomenon. This difference is discussed in Annex D.

For applicable test methods and test set-up see IEC 61000-4-21 [9].

6.5 Complex waveform injection (CWI)

This method takes the predicted currents from transfer functions and injects them onto conductors one-by-one whilst monitoring for effects. The injected waveforms are a function of the resonances measured by the transfer function and the environment itself and are complex in nature, i.e. they contain many frequencies. Further details on this method can be found in Annex E.

6.6 Damped sinusoidal injection (DSI)

This method uses single frequency damped sinusoidal waveforms and is generally required to be repeated across many frequencies to give an indication of how an EUT can respond to an IEMI environment. For applicable test methods and test set-up see IEC 61000-4-12 [10] and IEC 61000-4-18 [5].

6.7 Electrostatic discharge (ESD)

Testing to IEC 61000-4-2 [11] provides confidence of the continuing operation of the EUT as a result of ESD. ESD is a complex event generally characterised by a fast transient with a rise-time of the order of hundreds of picoseconds and a pulse-width of tens of nanoseconds. This information may be used to infer likely susceptibility to certain IEMI environments via the generation of radiated fields.

For applicable test methods and test set-up see IEC 61000-4-2 [11].

6.8 Electrically fast transient (EFT)

The EFT test has parameters that compare favourably with certain IEMI conducted environments, and data from the test defined in IEC 61000-4-4 [6] may be used to indicate the response of an EUT to IEMI.

For applicable test methods and test set-up see IEC 61000-4-4 [6].

Documents
Document Sharing Hub

Full document details: BS IEC 61000-4-36:2020

6.9 Antenna port injection

This type of test provides valuable information on the response of transceiver systems to the effects of IEMI including jammers which are discussed in Annex G. The IEMI environment of interest shall either be used directly to inject signals into the antenna port or to determine (through the use of transfer functions) those signals that would exist at the associated electronics. Figure 3 shows a typical EUT with various ports including an antenna port.

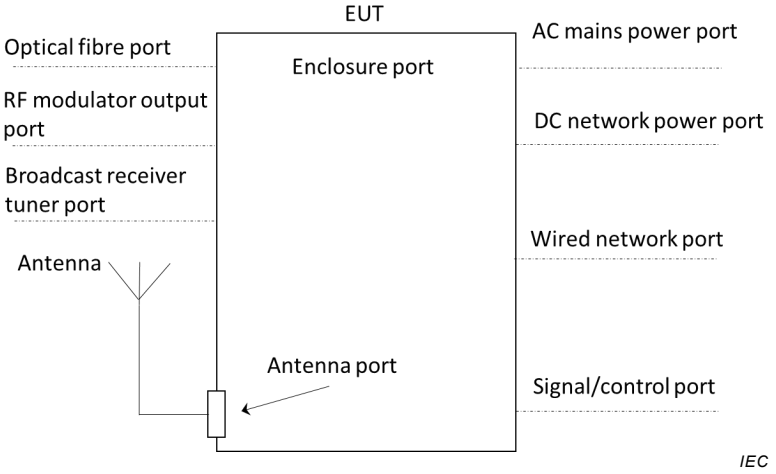


Figure 3 – Examples of ports

In general, antenna ports are commonly subjected to an ESD test. Also covered under 6.7, this is likely to provide useful information concerning the response of antenna ports to IEMI environments.

7 Test parameters

7.1 Derivation of immunity test parameters

The key to deriving immunity test levels lies in understanding the IEMI source of interest, the immunity requirement of the equipment or system that is to be assessed and the protection level for a given scenario.

For example, if the equipment or system is to be located within a secure facility (assuming 20 dB of attenuation for physical barriers) and such that an IEMI source cannot be any closer than 50 m (distance) away, this provides a useful bound on the test level. It can be prudent to consider some margin to deal with issues such as measurement uncertainty or measurement limitation to ensure that the test results carry a high level of confidence. This gives a solid foundation for developing the required test level. Once this is understood, the test levels can be derived using a radiated IEMI source or simulator or with the use of transfer functions as discussed in 6.2.

Subclause 7.2 indicates generic test parameters based on the skilled category using the environment levels derived in Table 2 and the examples of protection levels indicated in Table 3.

7.2 Radiated test parameters

7.2.1 Generic hyperband test parameters (skilled capability group)

Table 4 defines the immunity test levels for hyperband IEMI environments (i.e. those with a bandratio ≥ 10).

Documents
Document Sharing Hub
Full document details: BS IEC 61000-4-36:2020

Table 4 – Generic hyperband test parameters (skilled capability group)

EPL	Amplitude (V/m)	Rise time (ps)	Pulse width (ns)	prf (Hz)	Burst duration (s)
EPL0	30 000	100 to 500	0,2 to 5	1 to 1 000	1 to 10
EPL1	6 000				
EPL2	3 000				
EPL3	1 500				
EPL4	565				
EPL5	252				
EPL6	60				
NOTE Any combination of waveform parameters in Table 4 will result in a different frequency spectrum of the waveform applied during the test. In some cases, this will result in a test that is less severe when considering the overall content or the associated maximum derivative of the applied waveform.					

All combinations of the parameter ranges given in Table 4 are not simultaneously achievable with existing IEMI test sources. Once a test level is selected, some parameter variation is recommended within the stated parameter ranges, if possible.

Table 5 shows a description of the radiated hyperband test waveform and other important test parameters.

Table 5 – Radiated hyperband test waveform and other pulse parameters

Bandratio	≥ 10[a]
Pulse to pulse amplitude reproducibility	amplitude (E-field) ± 10 %[b]
Rise time	100 ps to 500 ps ± 20 %
Pulse width	0,2 ns to 5 ns ± 20 %
Pulse repetition frequency	1 Hz to 1 000 Hz ± 10 % [b]
Burst duration	1 s to 10 s ± 10 % [b]
Minimum number of bursts	1
Minimum burst interval (period)	2 s ± 20 %
Radiated E-field exposure test level	selectable according to Table 4 ± 20 %
Field polarization	selectable, horizontal or vertical, or both

[a] The 3 dB bandratio of the hyperband waveform is measured and confirmed that it is greater than or equal to 10.

[b] The mean amplitude of the pulses in a burst is used. The reproducibility of the pulse amplitude (the flatness of the burst envelope) is important to control in order to accurately describe the test level used during exposure.

An example of a hyperband waveform is given in Figure 4.

Documents
Document Sharing Hub

Full document details: BS IEC 61000-4-36:2020

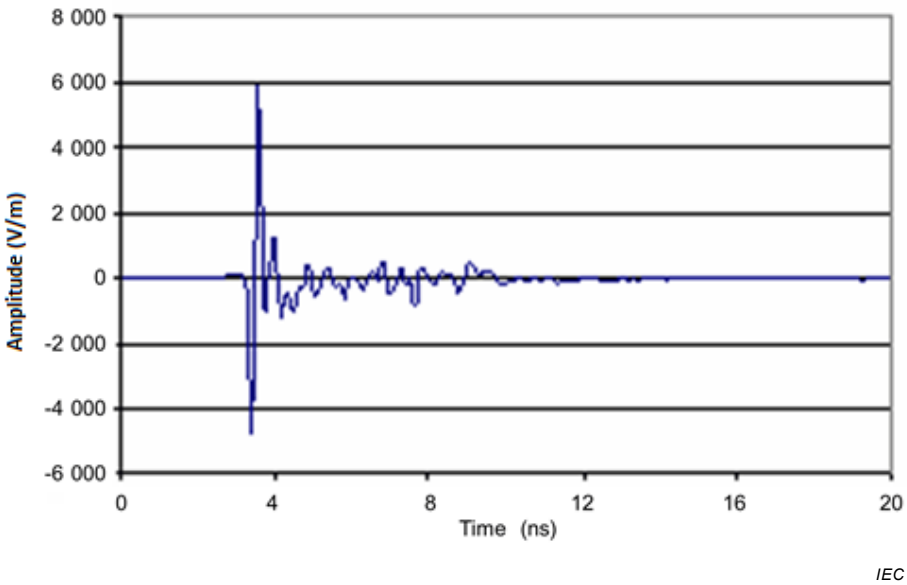


Figure 4 – Example of hyperband waveform

7.2.2 Generic mesoband test parameters (skilled capability group)

These types of IEMI environment are characterised by a damped sinusoidal waveform. Table 6 contains the test levels and associated parameters. It should be noted that any combination of waveform parameters in Table 6 will result in a different frequency spectrum of the waveform applied during the test. In some cases, this will result in a test that is less strenuous when considering the overall content or the associated maximum time derivative of the applied waveform.

Table 6 – Generic mesoband test parameters (skilled capability group)

EPL	Amplitude E_{pk} (V/m)	Dominant frequency, f_d (MHz)	Damping factor, Q	Pulse repetition frequency (prf) (Hz)	Burst duration (s)
EPL0	60 000	80 to 500	5 to 20	1 to 1 000	1 to 10
EPL1	12 000				
EPL2	6000				
EPL3	3 000				
EPL4	1 130				
EPL5	504				
EPL6	120				

It should be noted that not all combinations of the parameter ranges given in Table 6 are simultaneously achievable with existing IEMI sources. Once a test level is selected, some parameter variation is recommended within the stated parameter ranges if possible.

The waveform shape is well described by damped sine waves as shown in Formula (1).

$$E(t) = kE_{pk}\, e^{-\pi f_d t / Q} \sin(2\pi f_d t) \qquad (1)$$

Documents
Document Sharing Hub
Full document details: BS IEC 61000-4-36:2020

where, k is a normalising factor, f_d is the dominant frequency of the oscillation and t is time. The mesoband bandratio values of 1,01 to 3 can be shown by Formula (1) to correspond to Q-factor values of ~5 to 100, as shown in Table 7, however Q-factor values of between ~5 to 20 are more typically observed from IEMI generators and through IEMI and HEMP coupling to cables. Further information can be found in IEC 61000 2-13 [3].

Table 7 – Comparison of quality factor (Q) with bandratio

Quality factor Q	Normalising factor k	Bandratio
4,8	1,171	3,00
5,0	1,164	2,87
10,0	1,080	1,81
15,0	1,053	1,51
20,0	1,040	1,36
100,0	1,008	1,01

Table 8 shows a description of the radiated mesoband test waveform and other important test parameters. For more detail information, see Annex B.

Table 8 – Radiated mesoband waveform and other pulse parameters

Dominant oscillation frequencies[a]	80 MHz to 500 MHz ± 10 %[b]
Bandratio	shall be within the range 1,01 to 3[c]
Pulse to pulse amplitude reproducibility	amplitude (E-field) ± 10 %[d]
Pulse repetition frequency	1 Hz to 1 000 Hz [b]
Burst duration	1s to 10s ± 20 % [b]
Minimum number of bursts	1
Minimum burst interval (period)	2 s ± 20 %
Radiated E-field exposure test level	selectable according to Table 6 ± 20 %
Field polarization	selectable, horizontal and vertical or circular

[a] Dominant oscillation frequency is defined as the dominant frequency (the frequency with the highest spectral magnitude contribution) identified from a Fourier transformation of the measured time domain waveform.

[b] These are ranges of recommended values. The user selects values appropriate to the situation. A minimum number of three frequencies is recommended to cover the frequency range of mesoband sources.

[c] The 3 dB bandratio of the mesoband waveform is measured and it is confirmed that it lies within the range 1,01 to 3.

[d] The mean amplitude of the pulses in a burst is used. The reproducibility of the pulse amplitude (the flatness of the burst envelope) is important to control in order to accurately describe the test level used during exposure.

An example of a mesoband waveform is given in Figure 5.

Documents
Document Sharing Hub
Full document details: BS IEC 61000-4-36:2020

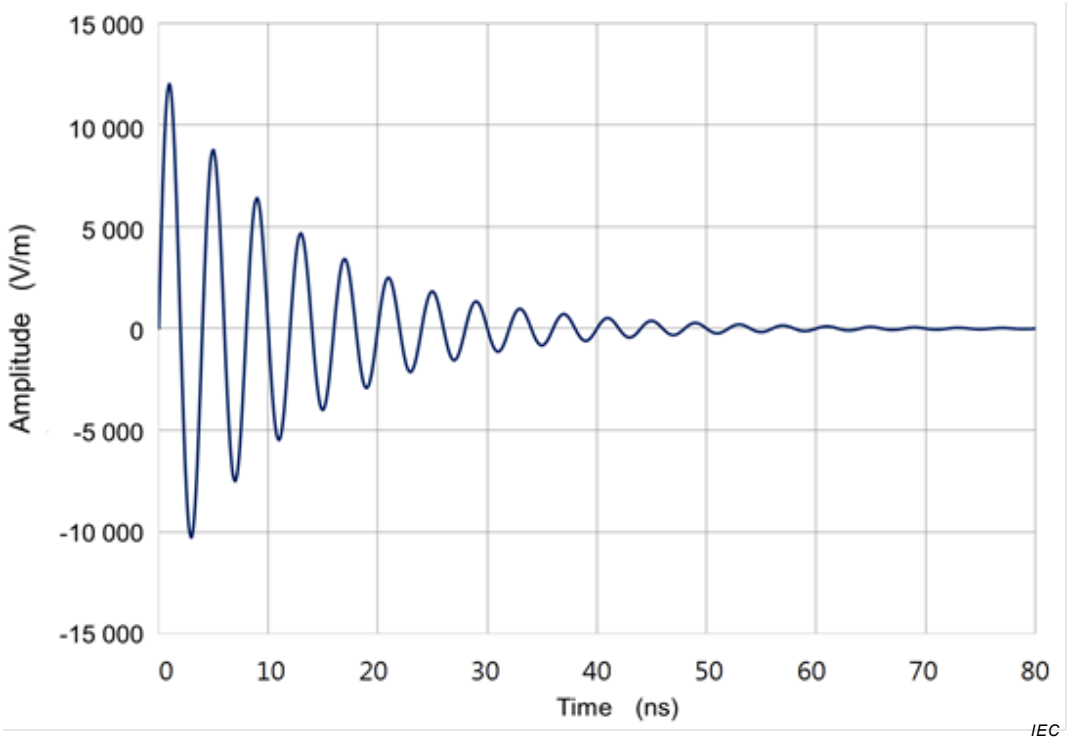


Figure 5 – Example of mesoband waveform

7.2.3 Generic hypoband test parameters (skilled capability group)

Table 9 gives the test levels for hypoband/narrowband IEMI which are characterised by low relative bandwidth, centre frequencies of ≥ 1 GHz and an associated pulse repetition frequency of ≤ 1000 Hz.

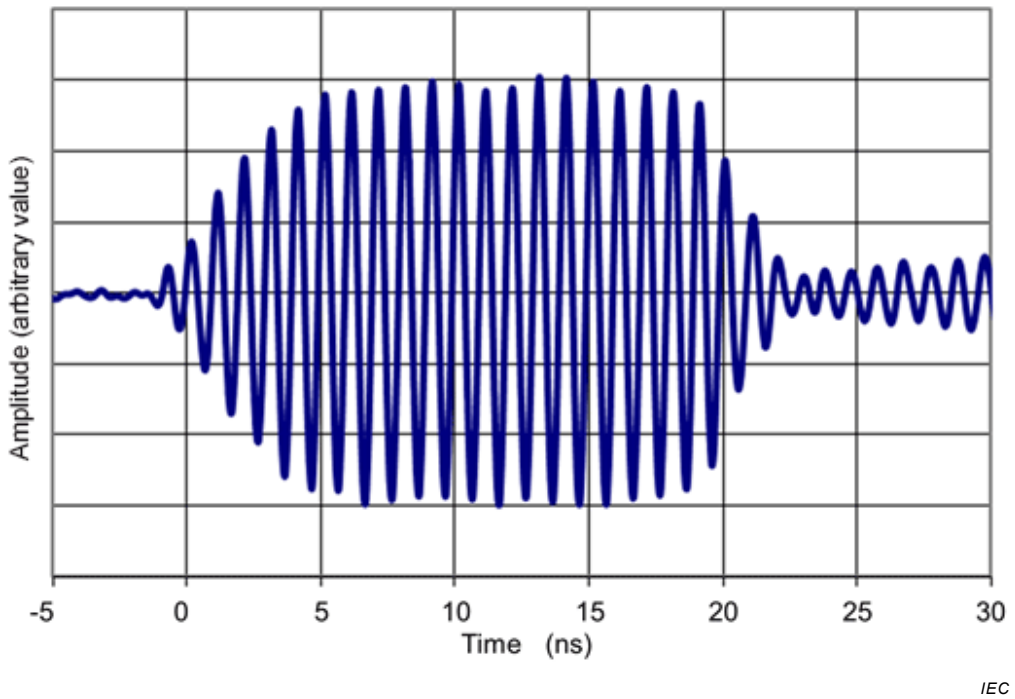
Table 9 – Generic hypoband/narrowband test parameters (skilled capability group)

EPL	Amplitude (V/m)	Pulse width (µs)	Pulse repetition frequency (Hz)	Burst duration (s)
EPL0	225 500	0,01 to 10	1 to 1 000	1 to 10
EPL1	45 000			
EPL2	22 550			
EPL3	11 300			
EPL4	4 240			
EPL5	1 890			
EPL6	450			
NOTE Any combination of waveform parameters in Table 9 will result in a different frequency spectrum of the waveform applied during the test. In some cases, this will result in a test that is less severe when considering the overall content or the associated maximum derivative of the applied waveform.				

All combinations of the parameter ranges given in Table 9 are simultaneously achievable with existing IEMI test sources. Once a test level is selected, some parameter variation is recommended within the stated parameter ranges, if possible.

An example of a hypoband/narrowband waveform is shown in Figure 6.

Documents
Document Sharing Hub
Full document details: BS IEC 61000-4-36:2020



NOTE The y-axis is amplitude (scale intentionally removed).

Figure 6 – Typical hypoband/narrowband waveform

7.3 Generic conducted IEMI test parameters

7.3.1 General

This document defines conducted IEMI test levels in Table 10. The user shall define specific test levels relevant to a specific IEMI environment by following the process in Clause 6.

Table 10 – Conducted IEMI test levels

V_{oc} V	I_{sc} A	Waveform	Basic document
100	2	Damped sinusoids[a]	IEC 61000-4-18 [5]
250	5	Damped sinusoids[a]	IEC 61000-4-18 [5]
500	10	Damped sinusoids[a]	IEC 61000-4-18 [5]
1 000	20	Damped sinusoids[a]	IEC 61000-4-18 [5]
2 000	40	Damped sinusoids[a]	IEC 61000-4-18 [5]
4 000	80	Damped sinusoids[a]	IEC 61000-4-18 [5]
4 000	80	5/50 ns	IEC 61000-4-4 [6]
8 000	160	5/50 ns	IEC 61000-4-4 [6]
16 000	320	5/50 ns	IEC 61000-4-4 [6]

NOTE 1 Voltage and current levels shown in the table are for common mode values.

NOTE 2 For the two highest immunity test levels, it is sufficient to test with a single pulse.

[a] IEC 61000-4-18 [5] defines the following test frequencies: 3 MHz, 10 MHz and 30 MHz. Depending on the characteristics of the incident IEMI electric field, tests can be recommended for damped sinusoids with frequencies of 100 MHz or 300 MHz using the waveshape defined in IEC 61000-4-18 [5].

Documents
Document Sharing Hub
Full document details: BS IEC 61000-4-36:2020

7.3.2 Characteristics and performance of the fast damped oscillatory wave generator

Subclause 7.3.2 details the characteristics and performance requirements of the fast damped oscillatory wave generator required to undertake the testing referred to in Table 10, footnote a.

The waveform of the fast damped oscillatory wave is given in Figure 7.

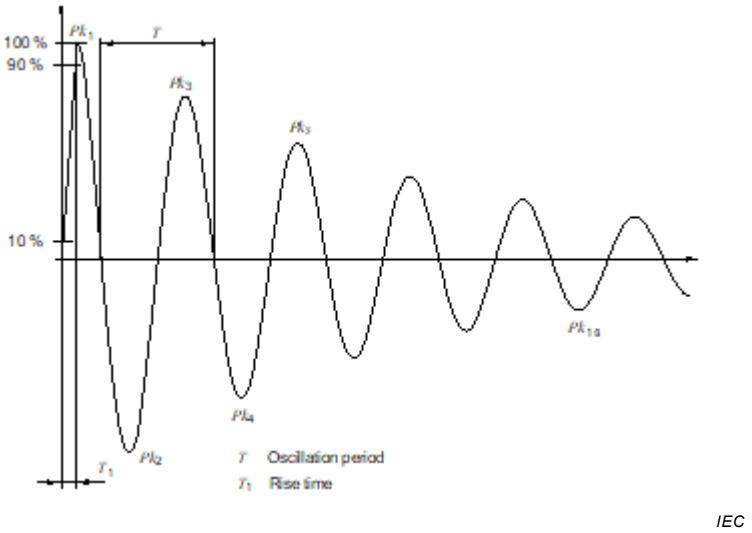


Figure 7 – Waveform of the damped oscillatory wave (open circuit voltage)

Open circuit specifications associated with Figure 7 are given in Table 11:

Table 11 – Open circuit specifications

Voltage rise time (T_1 in Figure 7)	5 ns ± 30 %
Voltage oscillation frequencies[a]	3 MHz, 10 MHz and 30 MHz ± 10 %
Pulse repetition frequency	5 000 Hz ± 10 %
Decaying (see Figure 7)	Pk_5 shall be > 50 % of the Pk_1 value and Pk_{10} shall be < 50 % of the Pk_1 value
Burst duration	3 MHz: 50 ms ± 20 %
Burst period	300 ms ± 20 %
Output impedance	50 Ω ± 20 %
Open circuit voltage	Pk_1 value, 100 V to 4 kV ± 10 % (see Figure 7)
Phase relationship with the power frequency	No requirement
Polarity of the first half-period	Positive and negative
[a] Oscillation frequency is defined as the reciprocal of the period between the first and third zero crossings after the initial peak. This period is shown as T in Figure 7.	

Short circuit specifications associated with Figure 7 are given in Table 12:

Documents
Document Sharing Hub
Full document details: BS IEC 61000-4-36:2020

Table 12 – Short circuit specifications

Current rise time (T_1 in Figure 7):	3 MHz: < 330 ns 10 MHz: < 100 ns 30 MHz: < 33 ns
Current oscillation frequencies[a]	3 MHz, 10 MHz and 30 MHz ± 30 %
Decaying (see Figure 7)	Pk_5 shall be > 25 % of the Pk_1 value and Pk_{10} shall be < 25 % of the Pk_1 value
Short circuit current (Pk_1 value)	5 A to 80 A ± 20 %
[a] Oscillation frequency is defined as the reciprocal of the period between the first and third zero crossings after the initial peak. This period is shown as T in Figure 7.	

7.4 Tailored test level derivation

The test levels defined within 7.2 and 7.3 are provided to allow the reader to apply generic IEMI test levels to equipment and systems where prior knowledge of a particular IEMI environment is not available.

For situations where one or more specific IEMI environments are the subjects of the assessment, tailored test levels shall be derived by considering the source-to-victim path using the following steps:

a) understand the IEMI threat environment of particular interest
b) measure the protection level by obtaining transfer function (coupling) data
   1) develop analytically
   2) measure
c) predict induced currents/voltages/fields/power at the location of the equipment/systems
d) create an envelope predictions
e) assess immunity of equipment/systems
   1) inject predicted induced waveforms into equipment/systems
   2) compare injected results with existing immunity data (if available)

7.5 Relevance of EMC immunity data

Immunity data from general EMC testing can be useful in determining whether testing to the levels presented within this document is necessary to declare immunity to IEMI environments. A rigorous mathematical approach utilising waveform norms should be used as the basis for such assessments. Further information on the application of waveform norms can be found in IEC 61000-4-33 [4].

Measurement uncertainties, whose quantitative calculations are possible, for example, intensity of projected electric field, discharge voltage of static electric test facilities, current induced in cables, etc., shall be included in any test report. It can be necessary to consider the use of additional test margins to take account of limitations in test methods; further details on this subject can be found in Annex F. Additionally, any test reports shall include the statement that test results are dependent on the test conditions and configuration of the tested equipment, and the note that the test results are, therefore, only valid for the cases specifically under identical test conditions, test methods and equipment configuration.

Information and determination of measurement uncertainty for EMC testing can be found in CISPR TR 16-4-1 [12], CISPR 16-4-2 [13] , CISPR 16 4-3 [14], CISPR16-4-4 [15] and IEC TR 61000-1-6 [16] and are equally applicable to the determination of measurement uncertainty for IEMI test results.

Documents
Document Sharing Hub
Full document details: BS IEC 61000-4-36:2020

Annex A
(informative)

Failure mechanisms and performance criteria

A.1 General

Electronic components and subsystems are essential parts of modern systems like airplanes, communication, IT infrastructure, traffic management, industrial controls or safety systems. Since these electronic components have begun to control safety critical functions, concern is growing over the vulnerability of electronic systems. Therefore the susceptibility of critical systems is of vital interest since an upset or failure in these systems could cause major accidents or economic disasters. As a consequence, the investigation of the susceptibility of electronic systems as well as their protection and hardening against IEMI threats is of great interest [A.1][3], [A.2], [A.3], [A.4] and [A.5].

There have been several documented cases, where high-power electromagnetic (HPEM) environments caused unwanted action or failure. In addition the last decade has witnessed worldwide numerous IEMI susceptibility investigations. Published reports of such investigations document a variety of observed effects such as:

– disturbed screens (flickering of screens, distorted displays, black screens),
– display of wrong data,
– corruption of signals and data (signal drifts, corruption of signals, lost data),
– false response of sensors and systems,
– unintentional response or action of systems (movement of actuator, change of course),
– decreased performance (reduction of computational performance, data transfer),
– hang up of software,
– reboot of digital devices (computer, controller, processor),
– destruction of components.

Due to the large range of observed effects, the systematic assessment (fail/pass) as well as the development of sufficient protection measures require a classification of the effects and the failure mechanisms, which summarise the essential information.

A.2 Failure mechanisms

A.2.1 General

If the observed effects are analysed with regard to the underlying failure mechanism, five main categories can be extracted:

1) noise
2) parameter offset and drifts
3) corruption of information
4) system upset or breakdown
5) component destruction

[3] Numbers in square brackets refer to the references in Clause A.5.

Documents
Document Sharing Hub

Any of these mechanisms can occur on a system as a result of an incident EM environment, sometimes with disastrous consequences. Further details are given for each of the categories below.

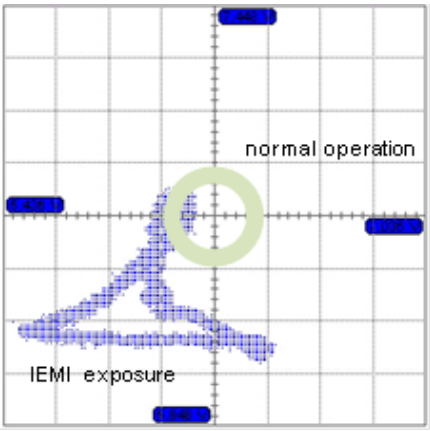
A.2.2 Noise

Electromagnetic disturbances can raise the noise level on signal and power lines, which results in flashing of displays or reduced data rates.

In a particular case of jamming the IEMI source (jammer) operates at or close to the frequency of operation and the induced noise level overloads the receiver circuits. Due to the fact that receivers are designed to operate at very low signal levels, jamming typically requires less radiated power.

A.2.3 Parameter offset and drifts

Parameters of analogue circuits are subject to changes (e.g. offset, drift) caused by induced signals. According to the application, these parameter changes can result in distortions of signals and/or false control signals and affect control circuits as well as the system status. This is shown in Figure A.1:



IEC

[Source: Bundeswehr Research Institute for Protective Technologies and NBC-Protection, WIS.]

Figure A.1 – IEMI induced offset of sensor output – Corruption of information

Injected signals are capable of changing bits of a data stream and of corrupting transferred information. In the worst case the receiving subsystem interprets the injected signal or the corrupted data stream as valid information or instructions. Typical effects of this class are the activation of a pop up menu, the opening and closing of programs, device failure messages, wrong sensor readings, and movements of actuators. This is shown in Figure A.2:

Documents
Document Sharing Hub
Full document details: BS IEC 61000-4-36:2020