IEC 61000-4-23

Edition 2.1 2025-07

INTERNATIONAL STANDARD

CONSOLIDATED VERSION

BASIC EMC PUBLICATION

Electromagnetic compatibility (EMC) -
Part 4-23: Testing and measurement techniques - Test methods for protective devices for HEMP and other radiated disturbances

ICS 33.100.99

ISBN 978-2-8327-0620-6

IEC 61000-4-23:2016-10+AMD1:2025-07 CSV(en)

CONTENTS

FOREWORD 6
INTRODUCTION 8
1 Scope 9
2 Normative references 9
3 Terms and definitions 10
4 HEMP test concepts 15
4.1 General 15
4.2 Testing of shielding enclosures 16
4.2.1 General 16
4.2.2 Buildings 20
4.2.3 Shelters and shielded rooms 21
4.2.4 Cabinets, racks and boxes 22
4.3 Testing of shielded cables and connectors 24
4.3.1 General 24
4.3.2 Testing of cable shields 24
4.3.3 Testing of cable connectors 27
4.4 Testing of shielding materials 28
4.4.1 General 28
4.4.2 Conducting gaskets 28
4.4.3 Conducting sheets and screens 30
4.4.4 Cut-off waveguides and honeycombs 33
4.5 Summary of test concepts 34
5 Test methods for measuring the shielding effectiveness of HEMP protection facilities 35
5.1 General 35
5.2 Electromagnetic field testing 35
5.2.1 General 35
5.2.2 Pulse field testing 35
5.2.3 CW field testing 41
5.3 Current injection test procedures 65
5.3.1 General 65
5.3.2 Injection testing of enclosures 65
5.3.3 Transfer impedance and admittance of cable shields and connectors 67
5.3.4 Testing of gasket material 67
Annex A (informative) HEMP test concepts for electrical systems 70
A.1 Overview 70
A.2 Types of HEMP tests 70
A.2.1 General 70
A.2.2 System-level transient tests 70
A.2.3 CW field illumination tests 71
A.2.4 Current injection testing 71
A.2.5 Partial illumination testing 72
A.2.6 Subsystem and component testing 72
A.3 Definition of the testing interface 73
A.4 Use of test data 75
A.4.1 General 75

A.4.2 Acceptance of new systems 75
A.4.3 System assessments 75
A.4.4 Hardness surveillance monitoring 75
A.4.5 System design 75
A.5 Testing uncertainties 76
Annex B (informative) Characterization of shielded cables 77
B.1 Fundamentals of cable shielding 77
B.2 Definitions of transfer impedance and transfer admittance 78
B.3 Relative significance of Z'_t and Y'_t 81
Annex C (informative) Equipment for HEMP pulse measurements 82
C.1 General 82
C.2 Sensors for HEMP measurements 82
C.2.1 B- and H-field sensors 82
C.2.2 D- and E-field sensors 84
C.2.3 Current sensors 86
C.3 Signal transmission 87
C.3.1 General 87
C.3.2 Fibre optic links 87
C.3.3 Fibre optic transducers 88
C.4 Signal detection and processing 88
Annex D (informative) Equipment for CW testing 90
D.1 General 90
D.2 Antenna system 90
D.3 Power amplifier 92
D.4 Receiver (network analyser) 93
D.5 Reference and response sensors 93
D.6 Fibre optic system 95
D.7 Limitations of measurements 98
Annex E (informative) Characterization of a planar shield for HEMP protection 99
E.1 General 99
E.2 Problem geometry 100
E.3 Equivalent circuit representation 101
E.3.1 General 101
E.3.2 Chain parameter representation of the shield 102
E.3.3 Circuit responses 103
Annex F (informative) Inside-to-out measurement method 107
F.1 Purpose 107
F.2 Comparison of existing SE test methods 107
F.3 Inside-to-out SE test of shielded rooms 108
F.3.1 Measurements of the inside-to-out SE 108
F.3.2 Summary 111
Annex G (informative) Validity of the stirring effect in measuring the space-averaged magnitude for a transfer function for frequencies above 1 GHz 112
G.1 Purpose 112
G.2 Method validation by laboratory measurements 112
G.3 Method validation by real building measurements 117
Bibliography 119

Figure 1 – Example of measured magnitude and phase of the transfer function $T(\omega) = H_{in}/H_{out}$ for a shielded enclosure 17
Figure 2 – Electric field and magnetic field shielding effectiveness of a 0,5 mm thick aluminium enclosure [29] 19
Figure 3 – Measured magnetic field shielding effectiveness SE_H for a building 20
Figure 4 – Conceptual illustration of the HEMP test of a building 20
Figure 5 – Illustration of a shielded room or enclosure excited by HEMP fields 22
Figure 6 – Illustration of equipment racks, cabinets and box excited by internal HEMP disturbance 22
Figure 7 – A general shield excited by current injection 23
Figure 8 – Basic configuration for transfer impedance measurement 25
Figure 9 – Measured transfer impedance magnitude and phase of transfer impedance per unit length for four braided shield cables with good shielding properties 26
Figure 10 – Basic configuration for transfer admittance measurement 27
Figure 11 – Test configuration for transfer impedance measurement of a cable connector 27
Figure 12 – Examples of conducting gaskets used as HEMP protection devices 29
Figure 13 – Circuit model representing the behaviour of a conducting gasket for HEMP protection 29
Figure 14 – Measurement configuration for the resistivity of a sample 30
Figure 15 – Test concept for measuring the resistivity with surface probes 31
Figure 16 – Concepts for shielding effectiveness measurement of conducting sheets and screens 33
Figure 17 – Example of the calculated plane-wave shielding effectiveness of a 0,01 mm thick plate of different material as a function of frequency 33
Figure 18 – Cut-off waveguides and honeycomb used as protective elements 34
Figure 19 – Examples of full-scale, pulse-radiating HEMP simulators 38
Figure 20 – Test procedure for the pulse test 40
Figure 21 – Typical configuration of a CW test facility 41
Figure 22 – Example CW measurement set-up 42
Figure 23 – Test and analysis procedures for conducting a CW test 43
Figure 24 – Analysis flow diagram for extrapolating a measured CW spectrum to the HEMP response 44
Figure 35 – Multi-point measurement set-up 45
Figure 36 – Procedure for the multi-point measurement 47
Figure 37 – Single-point measurement set-up with the stirring effect 49
Figure 38 – Procedure of the single-point measurement with the stirring effect 49
Figure 25 – Example scan from 9 kHz to 3 GHz for the ambient electromagnetic field from communication signals 51
Figure 26 – Test procedure for the ambient EM excitation test 54
Figure 27 – Double-ended TEM cell for field illumination testing of small enclosures 55
Figure 28 – Example test set-up for field illumination in the TEM cell 55
Figure 29 – Illustration of the single-ended TEM cell and associated equipment 57
Figure 30 – Test set-up for ~~the plane-wave~~ near field CW shielding effectiveness measurements for continuous metal shields 60
Figure 31 – Test set-up for the H-field shielding effectiveness measurements 61

Figure 32 – Example of antenna locations for the localized antenna tests for a hypothetical shielded enclosure or facility 62
Figure 33 – Test concept and equipment configuration for current injection testing of a shielded enclosure or box 66
Figure 34 – Surface probe for volume resistivity measurement 69
Figure A.1 – Sample HEMP interaction diagram illustrating penetration mechanisms, system responses and generic test interface locations 74
Figure B.1 – Geometry of a shielded coaxial line with an internal circuit 77
Figure B.2 – Coaxial cable located over a conducting ground plane 78
Figure B.3 – Two per-unit-length circuits formed by the sheath and its ground return, and the sheath and the internal conductor 79
Figure C.1 – Magnetic field sensors [23] 83
Figure C.2 – Single-slot, cylindrical coil sensor [23] 83
Figure C.3 – Two- and four-slot cylindrical coil sensors [23] 84
Figure C.4 – Electrical configuration of an E-field sensor [23] 84
Figure C.5 – Biconical E-field sensor 85
Figure C.6 – E-field sensor mounted on a conducting ground plane [23] 85
Figure C.7 – Equipotential shapes for an optimally designed E-field sensor [23] 85
Figure C.8 – Rogowski coil used for current measurements [23] 86
Figure C.9 – Toroidal current sensor made of magnetic material [23] 86
Figure C.10 – Voltage pick-up points on the edges of the toroidal sensor [23] 86
Figure C.11 – Example of a single-channel fibre optic transmission system [23] 87
Figure C.12 – Attenuation of coaxial lines and fibre optic cables as a function of frequency 88
Figure D.1 – Various antennas for CW testing 91
Figure D.2 – Relationship between the CW antenna and the incident HEMP field 92
Figure D.3 – Incident and ground-reflected field contributions to the reference sensor excitations 94
Figure D.4 – Measured reference H-field spectrum and its inverse Fourier transform 95
Figure D.5 – Measured sensor responses and calibration function 97
Figure D.6 – Measured transfer function, corrected by calibration file 97
Figure E.1 – Example of a general shielding problem 99
Figure E.2 – Behaviour of the impedance ratio EH as a function of distance from a source [29] 100
Figure E.3 – Conducting slab of thickness, d, and infinite extent serving as an electromagnetic barrier 101
Figure E.4 – Equivalent circuit representation of the shielding problem 102
Figure E.5 – Two-port representation of a circuit 103
Figure F.1 – Test set-up for the outside-to-in and inside-to-out SE measurement 110
Figure G.1 – Test facility inside an EMC chamber 113
Figure G.2 – Multi- and single-point measurement set-up 113
Figure G.3 – Signal measurement using the test facility 115
Figure G.4 – Attenuation measurement results 117

Table 1 – Recommended test procedure for different test objects 35

Table 2 – Dimensions and composition of distances d_1 to d_3, with reference to Figure 30 60
Table 3 – Dimensions and composition of distances d_1 to d_3, with reference to Figure 31 61
Table 4 – Measurement frequencies and antennas in plane-wave 62
Table 5 – Measurement frequencies and antennas in magnetic field 64
Table E.1 – Surface resistance and electrical parameters for selected materials 105
Table F.1 – Comparison with other standards 108
Table F.2 – Test shielded rooms 109
Table F.3 – Comparison of the SE measurement results 111
Table G.1 – Single-point measurement results 116
Table G.2 – Comparison of the attenuation measurement results 118

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

Electromagnetic compatibility (EMC) - Part 4-23: Testing and measurement techniques - Test methods for protective devices for HEMP and other radiated disturbances

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) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch. IEC shall not be held responsible for identifying any or all such patent rights.

This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC 61000-4-23 edition 2.1 contains the second edition (2016-10) [documents 77C/253/CDV and 77C/257/RVC] and its amendment 1 (2025-07) [documents 77C/351/FDIS and 77C/353/RVD].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

International Standard IEC 61000-4-23 has been prepared by subcommittee 77C: High power transient phenomena, of IEC technical committee 77: Electromagnetic compatibility.

It forms Part 4-23 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 2000. This edition constitutes a technical revision.

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

a) updates to the shielding effectiveness (SE) test method in Clause 5;

b) a new Annex F describing methods for testing ‘inside-to-out’ has been added.

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

CDV	Report on voting
77C/253/CDV	77C/257/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 document and its amendment will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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, 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).

The IEC has initiated the preparation of standardized methods to protect civilian society from the effects of high power electromagnetic (HPEM) environments. Such effects could disrupt systems for communications, electric power, information technology, etc.

This part of IEC 61000 is an international standard that establishes the test concepts, set-ups, required equipment, and test procedures for protective devices against HEMP radiated disturbances.

Annex F provides examples of the SE test method placing the TX antenna inside the barrier.

1 Scope

This part of IEC 61000 provides a protective devices test method for HEMP and other radiated disturbances. It is primarily intended for HEMP testing but can be applied to other externally generated radiated disturbances where appropriate. It provides a brief description of the most important concepts for testing of shielding elements. For each test, the following basic information is provided:

– theoretical foundation of the test (the test concepts);
– test set-up including outside-to-in and inside-to-out measurements;
– required equipment;
– test procedures;
– data processing.

This international standard does not provide information on requirements for specific levels for testing.

This part of IEC 61000 has been updated to include a new test method.

Due to the available space, a transmitting antenna position outside the barrier has mainly been suggested. However, nowadays, many EMP protection facilities in practical use do not actually have enough space available outside the electromagnetic barrier due to physical constraints such as concrete walls or soil to allow the method described in IEC 61000-4-23:2000 (edition 1) to be applied correctly. From experience many facilities have available space for a 1 m separation or less only.

Therefore, in many practical cases it is not possible to measure shielding effectiveness according to the test method of previous documents. The constructors for EMP protection facilities are also unwilling to build facilities with extra space for measurements with the transmitting antenna outside the barrier due to the great expense and inefficiency of the operational working area for new or existing buildings.

This document provides additionally a method that allows the transmitting antenna to be placed inside the enclosure and the receiving antenna outside the barrier (‘inside-to-out’ method). Annex F includes test set-up and procedure examples.

2 Normative references

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

IEC 60050-161, *International Electrotechnical Vocabulary (IEV) – Part 161: Electromagnetic compatibility* (available at www.electropedia.org)

IEC 61000-2-9, *Electromagnetic compatibility (EMC) – Part 2: Environment – Section 9: Description of HEMP environment – Radiated disturbance*

IEC 61000-5-3, *Electromagnetic compatibility (EMC) – Part 5-3: Installation and mitigation guidelines – HEMP protection concepts*

CONTENTS

FOREWORD 6
INTRODUCTION 8
1 Scope 9
2 Normative references 9
3 Terms and definitions 10
4 HEMP test concepts 15
4.1 General 15
4.2 Testing of shielding enclosures 16
4.2.1 General 16
4.2.2 Buildings 19
4.2.3 Shelters and shielded rooms 20
4.2.4 Cabinets, racks and boxes 21
4.3 Testing of shielded cables and connectors 23
4.3.1 General 23
4.3.2 Testing of cable shields 23
4.3.3 Testing of cable connectors 26
4.4 Testing of shielding materials 27
4.4.1 General 27
4.4.2 Conducting gaskets 27
4.4.3 Conducting sheets and screens 29
4.4.4 Cut-off waveguides and honeycombs 32
4.5 Summary of test concepts 33
5 Test methods for measuring the shielding effectiveness of HEMP protection facilities 34
5.1 General 34
5.2 Electromagnetic field testing 34
5.2.1 General 34
5.2.2 Pulse field testing 34
5.2.3 CW field testing 40
5.3 Current injection test procedures 61
5.3.1 General 61
5.3.2 Injection testing of enclosures 61
5.3.3 Transfer impedance and admittance of cable shields and connectors 63
5.3.4 Testing of gasket material 63
Annex A (informative) HEMP test concepts for electrical systems 66
A.1 Overview 66
A.2 Types of HEMP tests 66
A.2.1 General 66
A.2.2 System-level transient tests 66
A.2.3 CW field illumination tests 67
A.2.4 Current injection testing 67
A.2.5 Partial illumination testing 68
A.2.6 Subsystem and component testing 68
A.3 Definition of the testing interface 69
A.4 Use of test data 71
A.4.1 General 71

A.4.2 Acceptance of new systems 71
A.4.3 System assessments 71
A.4.4 Hardness surveillance monitoring 71
A.4.5 System design 71
A.5 Testing uncertainties 72
Annex B (informative) Characterization of shielded cables 73
B.1 Fundamentals of cable shielding 73
B.2 Definitions of transfer impedance and transfer admittance 74
B.3 Relative significance of Z'_t and Y'_t 77
Annex C (informative) Equipment for HEMP pulse measurements 78
C.1 General 78
C.2 Sensors for HEMP measurements 78
C.2.1 B- and H-field sensors 78
C.2.2 D- and E-field sensors 80
C.2.3 Current sensors 82
C.3 Signal transmission 83
C.3.1 General 83
C.3.2 Fibre optic links 83
C.3.3 Fibre optic transducers 84
C.4 Signal detection and processing 84
Annex D (informative) Equipment for CW testing 86
D.1 General 86
D.2 Antenna system 86
D.3 Power amplifier 88
D.4 Receiver (network analyser) 89
D.5 Reference and response sensors 89
D.6 Fibre optic system 91
D.7 Limitations of measurements 94
Annex E (informative) Characterization of a planar shield for HEMP protection 95
E.1 General 95
E.2 Problem geometry 96
E.3 Equivalent circuit representation 97
E.3.1 General 97
E.3.2 Chain parameter representation of the shield 98
E.3.3 Circuit responses 99
Annex F (informative) Inside-to-out measurement method 103
F.1 Purpose 103
F.2 Comparison of existing SE test methods 103
F.3 Inside-to-out SE test of shielded rooms 104
F.3.1 Measurements of the inside-to-out SE 104
F.3.2 Summary 107
Annex G (informative) Validity of the stirring effect in measuring the space-averaged magnitude for a transfer function for frequencies above 1 GHz 108
G.1 Purpose 108
G.2 Method validation by laboratory measurements 108
G.3 Method validation by real building measurements 113
Bibliography 115

Figure 1 – Example of measured magnitude and phase of the transfer function $T(\omega) = H_{in}/H_{out}$ for a shielded enclosure 17
Figure 2 – Electric field and magnetic field shielding effectiveness of a 0,5 mm thick aluminium enclosure [29] 18
Figure 3 – Measured magnetic field shielding effectiveness SE_H for a building 19
Figure 4 – Conceptual illustration of the HEMP test of a building 19
Figure 5 – Illustration of a shielded room or enclosure excited by HEMP fields 21
Figure 6 – Illustration of equipment racks, cabinets and box excited by internal HEMP disturbance 21
Figure 7 – A general shield excited by current injection 22
Figure 8 – Basic configuration for transfer impedance measurement 24
Figure 9 – Measured transfer impedance magnitude and phase of transfer impedance per unit length for four braided shield cables with good shielding properties 25
Figure 10 – Basic configuration for transfer admittance measurement 26
Figure 11 – Test configuration for transfer impedance measurement of a cable connector 26
Figure 12 – Examples of conducting gaskets used as HEMP protection devices 28
Figure 13 – Circuit model representing the behaviour of a conducting gasket for HEMP protection 28
Figure 14 – Measurement configuration for the resistivity of a sample 29
Figure 15 – Test concept for measuring the resistivity with surface probes 30
Figure 16 – Concepts for shielding effectiveness measurement of conducting sheets and screens 32
Figure 17 – Example of the calculated plane-wave shielding effectiveness of a 0,01 mm thick plate of different material as a function of frequency 32
Figure 18 – Cut-off waveguides and honeycomb used as protective elements 33
Figure 19 – Examples of full-scale, pulse-radiating HEMP simulators 37
Figure 20 – Test procedure for the pulse test 39
Figure 21 – Typical configuration of a CW test facility 40
Figure 22 – Example CW measurement set-up 41
Figure 23 – Test and analysis procedures for conducting a CW test 42
Figure 24 – Analysis flow diagram for extrapolating a measured CW spectrum to the HEMP response 43
Figure 35 – Multi-point measurement set-up 44
Figure 36 – Procedure for the multi-point measurement 46
Figure 37 – Single-point measurement set-up with the stirring effect 48
Figure 38 – Procedure of the single-point measurement with the stirring effect 48
Figure 25 – Example scan from 9 kHz to 3 GHz for the ambient electromagnetic field from communication signals 49
Figure 26 – Test procedure for the ambient EM excitation test 51
Figure 27 – Double-ended TEM cell for field illumination testing of small enclosures 52
Figure 28 – Example test set-up for field illumination in the TEM cell 52
Figure 29 – Illustration of the single-ended TEM cell and associated equipment 54
Figure 30 – Test set-up for near field CW shielding effectiveness measurements for continuous metal shields 56
Figure 31 – Test set-up for the H-field shielding effectiveness measurements 57

Figure 32 – Example of antenna locations for the localized antenna tests for a hypothetical shielded enclosure or facility 58
Figure 33 – Test concept and equipment configuration for current injection testing of a shielded enclosure or box 62
Figure 34 – Surface probe for volume resistivity measurement 65
Figure A.1 – Sample HEMP interaction diagram illustrating penetration mechanisms, system responses and generic test interface locations 70
Figure B.1 – Geometry of a shielded coaxial line with an internal circuit 73
Figure B.2 – Coaxial cable located over a conducting ground plane 74
Figure B.3 – Two per-unit-length circuits formed by the sheath and its ground return, and the sheath and the internal conductor 75
Figure C.1 – Magnetic field sensors [23] 79
Figure C.2 – Single-slot, cylindrical coil sensor [23] 79
Figure C.3 – Two- and four-slot cylindrical coil sensors [23] 80
Figure C.4 – Electrical configuration of an E-field sensor [23] 80
Figure C.5 – Biconical E-field sensor 81
Figure C.6 – E-field sensor mounted on a conducting ground plane [23] 81
Figure C.7 – Equipotential shapes for an optimally designed E-field sensor [23] 81
Figure C.8 – Rogowski coil used for current measurements [23] 82
Figure C.9 – Toroidal current sensor made of magnetic material [23] 82
Figure C.10 – Voltage pick-up points on the edges of the toroidal sensor [23] 82
Figure C.11 – Example of a single-channel fibre optic transmission system [23] 83
Figure C.12 – Attenuation of coaxial lines and fibre optic cables as a function of frequency 84
Figure D.1 – Various antennas for CW testing 87
Figure D.2 – Relationship between the CW antenna and the incident HEMP field 88
Figure D.3 – Incident and ground-reflected field contributions to the reference sensor excitations 90
Figure D.4 – Measured reference H-field spectrum and its inverse Fourier transform 91
Figure D.5 – Measured sensor responses and calibration function 93
Figure D.6 – Measured transfer function, corrected by calibration file 93
Figure E.1 – Example of a general shielding problem 95
Figure E.2 – Behaviour of the impedance ratio EH as a function of distance from a source [29] 96
Figure E.3 – Conducting slab of thickness, d, and infinite extent serving as an electromagnetic barrier 97
Figure E.4 – Equivalent circuit representation of the shielding problem 98
Figure E.5 – Two-port representation of a circuit 99
Figure F.1 – Test set-up for the outside-to-in and inside-to-out SE measurement 106
Figure G.1 – Test facility inside an EMC chamber 109
Figure G.2 – Multi- and single-point measurement set-up 109
Figure G.3 – Signal measurement using the test facility 111
Figure G.4 – Attenuation measurement results 113

Table 1 – Recommended test procedure for different test objects 34

Table 2 – Dimensions and composition of distances d_1 to d_3, with reference to Figure 30 57
Table 3 – Dimensions and composition of distances d_1 to d_3, with reference to Figure 31 57
Table 4 – Measurement frequencies and antennas in plane-wave 59
Table 5 – Measurement frequencies and antennas in magnetic field 60
Table E.1 – Surface resistance and electrical parameters for selected materials 101
Table F.1 – Comparison with other standards 104
Table F.2 – Test shielded rooms 105
Table F.3 – Comparison of the SE measurement results 107
Table G.1 – Single-point measurement results 112
Table G.2 – Comparison of the attenuation measurement results 114

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

Electromagnetic compatibility (EMC) - Part 4-23: Testing and measurement techniques - Test methods for protective devices for HEMP and other radiated disturbances

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) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch. IEC shall not be held responsible for identifying any or all such patent rights.

This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC 61000-4-23 edition 2.1 contains the second edition (2016-10) [documents 77C/253/CDV and 77C/257/RVC] and its amendment 1 (2025-07) [documents 77C/351/FDIS and 77C/353/RVD].

This Final version does not show where the technical content is modified by amendment 1. A separate Redline version with all changes highlighted is available in this publication.

International Standard IEC 61000-4-23 has been prepared by subcommittee 77C: High power transient phenomena, of IEC technical committee 77: Electromagnetic compatibility.

It forms Part 4-23 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 2000. This edition constitutes a technical revision.

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

a) updates to the shielding effectiveness (SE) test method in Clause 5;
b) a new Annex F describing methods for testing ‘inside-to-out’ has been added.

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

CDV	Report on voting
77C/253/CDV	77C/257/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 document and its amendment will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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, 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).

The IEC has initiated the preparation of standardized methods to protect civilian society from the effects of high power electromagnetic (HPEM) environments. Such effects could disrupt systems for communications, electric power, information technology, etc.

This part of IEC 61000 is an international standard that establishes the test concepts, set-ups, required equipment, and test procedures for protective devices against HEMP radiated disturbances.

Annex F provides examples of the SE test method placing the TX antenna inside the barrier.

1 Scope

This part of IEC 61000 provides a protective devices test method for HEMP and other radiated disturbances. It is primarily intended for HEMP testing but can be applied to other externally generated radiated disturbances where appropriate. It provides a brief description of the most important concepts for testing of shielding elements. For each test, the following basic information is provided:

– theoretical foundation of the test (the test concepts);
– test set-up including outside-to-in and inside-to-out measurements;
– required equipment;
– test procedures;
– data processing.

This international standard does not provide information on requirements for specific levels for testing.

This part of IEC 61000 has been updated to include a new test method.

Due to the available space, a transmitting antenna position outside the barrier has mainly been suggested. However, nowadays, many EMP protection facilities in practical use do not actually have enough space available outside the electromagnetic barrier due to physical constraints such as concrete walls or soil to allow the method described in IEC 61000-4-23:2000 (edition 1) to be applied correctly. From experience many facilities have available space for a 1 m separation or less only.

Therefore, in many practical cases it is not possible to measure shielding effectiveness according to the test method of previous documents. The constructors for EMP protection facilities are also unwilling to build facilities with extra space for measurements with the transmitting antenna outside the barrier due to the great expense and inefficiency of the operational working area for new or existing buildings.

This document provides additionally a method that allows the transmitting antenna to be placed inside the enclosure and the receiving antenna outside the barrier (‘inside-to-out’ method). Annex F includes test set-up and procedure examples.

2 Normative references

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

IEC 60050-161, *International Electrotechnical Vocabulary (IEV) – Part 161: Electromagnetic compatibility* (available at www.electropedia.org)

IEC 61000-2-9, *Electromagnetic compatibility (EMC) – Part 2: Environment – Section 9: Description of HEMP environment – Radiated disturbance*

IEC 61000-5-3, *Electromagnetic compatibility (EMC) – Part 5-3: Installation and mitigation guidelines – HEMP protection concepts*