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BASIC EMC PUBLICATION

Electromagnetic compatibility (EMC) –

Part 4-20: Testing and measurement techniques – Emission and immunity testing in transverse electromagnetic (TEM) waveguides

*This **English-language** version is derived from the original **bilingual** publication by leaving out all French-language pages. Missing page numbers correspond to the French-language pages.*

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-20: Testing and measurement techniques – Emission and immunity testing in transverse electromagnetic (TEM) waveguides

FOREWORD

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International Standard IEC 61000-4-20 has been prepared by CISPR subcommittee A: Radio interference measurements and statistical methods, in cooperation with subcommittee 77B: High-frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

This standard forms Part 4-20 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107.

This consolidated version of IEC 61000-4-20 consists of the first edition (2003) [documents CIS/A/419/FDIS and CIS/A/435/RVD] and its amendment 1 (2006) [documents 77B/520/FDIS and 77B/528/RVD].

The technical content is therefore identical to the base edition and its amendment and has been prepared for user convenience.

It bears the edition number 1.1.

A vertical line in the margin shows where the base publication has been modified by amendment 1.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of the base publication and its amendments will remain unchanged until the maintenance result date indicated on the IEC web site 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- withdrawn,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.

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, 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: 61000-6-1).

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-20: Testing and measurement techniques – Emission and immunity testing in transverse electromagnetic (TEM) waveguides

1 Scope and object

This part of IEC 61000 relates to emission and immunity test methods for electrical and electronic equipment using various types of transverse electromagnetic (TEM) waveguides. This includes open (for example, striplines and EMP simulators) and closed (for example, TEM cells) structures, which can be further classified as one-, two-, or multi-port TEM waveguides. The frequency range depends on the specific testing requirements and the specific TEM waveguide type.

The object of this standard is to describe

- TEM waveguide characteristics, including typical frequency ranges and EUT-size limitations;
- TEM waveguide validation methods for EMC measurements;
- the EUT (i.e. EUT cabinet and cabling) definition;
- test set-ups, procedures, and requirements for radiated emission testing in TEM waveguides and
- test set-ups, procedures, and requirements for radiated immunity testing in TEM waveguides.

NOTE Test methods are defined in this standard for measuring the effects of electromagnetic radiation on equipment and the electromagnetic emissions from equipment concerned. The simulation and measurement of electromagnetic radiation is not adequately exact for quantitative determination of effects for all end-use installations. The test methods defined are structured for a primary objective of establishing adequate repeatability of results at various test facilities for qualitative analysis of effects.

This standard does not intend to specify the tests to be applied to any particular apparatus or system(s). The main intention of this standard is to provide a general basic reference for all interested product committees of the IEC. For radiated emissions testing, product committees should select emission limits and test methods in consultation with CISPR. For radiated immunity testing, product committees remain responsible for the appropriate choice of immunity tests and immunity test limits to be applied to equipment within their scope. This standard describes test methods that are separate from those of IEC 61000-4-3. These other distinct test methods may be used when so specified by product committees, in consultation with CISPR and TC 77.

2 Normative references

The following referenced documents are indispensable for the application 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) – Chapter 161: Electromagnetic compatibility*

IEC 60068-1, *Environmental testing – Part 1: General and guidance.*

IEC 61000-2-11, *Electromagnetic compatibility (EMC) – Part 2-11: Environment – Classification of HEMP environments.* Basic EMC publication

IEC 61000-4-23, *Electromagnetic compatibility (EMC) – Part 4-23: Testing and measurement techniques – Test methods for protective devices for HEMP and other radiated disturbances.* Basic EMC publication

IEC/TR 61000-4-32, *Electromagnetic compatibility (EMC) – Part 4-32: Testing and measurement techniques – HEMP simulator compendium*

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

CISPR 16-1-1, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus*

CISPR 16-1-4, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-4: Ancillary equipment – Radiated disturbances*

CISPR 16-2-3, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-3: Methods of measurement of disturbances and immunity – Radiated disturbance measurements*

CISPR 16-2-4, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-4: Methods of measurement of disturbances and immunity – Immunity measurements*

CISPR 22, *Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement*

3 Definitions and abbreviations

3.1 Definitions

For the purposes of this part of IEC 61000, the definitions given in IEC 60050(161) (IEV), as well as the following, apply.

3.1.1
transverse electromagnetic (TEM) mode
waveguide mode in which the components of the electric and magnetic fields in the propagation direction are much less than the primary field components across any transverse cross-section

3.1.2
TEM waveguide
open or closed transmission line system, in which a wave is propagating in the transverse electromagnetic mode to produce a specified field for testing purposes

3.1.3
TEM cell
enclosed TEM waveguide, often a rectangular coaxial line, in which a wave is propagated in the transverse electromagnetic mode to produce a specific field for testing purposes. The outer conductor completely encloses the inner conductor

3.1.4
two-port TEM waveguide
TEM waveguide with input/output measurement ports at both ends

3.1.5
one-port TEM waveguide
TEM waveguide with a single input/output measurement port. Such TEM waveguides typically feature a broadband line termination at the non-measurement-port end

3.1.6
stripline
terminated transmission line consisting of two or more parallel plates between which a wave is propagated in the transverse electromagnetic mode to produce a specific field for testing purposes. Usually the sides are open for EUT access and monitoring

3.1.7
inner conductor or septum
inner conductor of a coaxial transmission line system, often flat in the case of a rectangular cross-section. The inner conductor may be positioned symmetrically or asymmetrically with respect to the outer conductor

3.1.8
outer conductor or housing
outer conductor of a coaxial transmission line system, often having a rectangular cross-section

3.1.9
characteristic impedance
for any constant phase wave-front, the magnitude of the ratio of the voltage between the inner conductor and the outer conductor to the current on either conductor. The characteristic impedance is independent of the voltage/current magnitudes and depends only on the cross-sectional geometry of the transmission line. TEM waveguides are typically designed to have a 50 Ω characteristic impedance. TEM waveguides with a 100 Ω characteristic impedance are often used for transient testing

3.1.10
anechoic material
material that exhibits the property of absorbing, or otherwise reducing, the level of electromagnetic energy reflected from that material

3.1.11
broadband line termination
termination which combines a low-frequency discrete-component load, to match the characteristic impedance of the TEM waveguides (typically 50 Ω), and a high-frequency anechoic-material volume

3.1.12
correlation algorithm
mathematical routine for converting TEM waveguide voltage measurements to open-area test sites (OATS), semi-anechoic chamber (SAC), or free space field strength levels

3.1.13
EUT type
grouping of products with sufficient similarity in electromagnetic characteristics to allow testing with the same test installation and the same test protocol

3.1.14
exit cable
cable that connects the EUT to equipment external to the TEM waveguide or exiting the usable test volume defined in 5.1.2.

3.1.15
interconnecting cable
cable that connects subcomponents of the EUT within the test volume but does not exit the test volume

3.1.16
test set-up support
non-reflecting, non-conducting, low-permittivity support and positioning reference that allows for precise rotations of the EUT as required by a correlation algorithm or test protocol

NOTE 1 A typical material is foamed polystyrene. Wooden supports are not recommended (see [7][1]).

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1 Figures in square brackets refer to the bibliography.

3.1.17
ortho-angle
angle that the diagonal of a cube makes to each side face at the trihedral corners of the cube. Assuming that the cube is aligned with the TEM waveguide Cartesian coordinate system, the azimuth and elevation angles of the projection of the cube diagonal are 45°, and the angles to the face edges are 54,7° (see Figure A.2a)

NOTE 2 When associated with the EUT, this angle is usually referred to as the ortho-axis.

3.1.18
primary (field) component
electric field component aligned with the intended test polarization

NOTE 3 For example, in conventional two-port TEM cells, the septum is parallel to the horizontal floor, and the primary mode electric field vector is vertical at the transverse centre of the TEM cell.

3.1.19
secondary (field) component
in a Cartesian coordinate system, either of the two electric field components orthogonal to the primary field component and orthogonal to each other

3.1.20
resultant field (amplitude)
root-sum-squared values in V/m of the primary and the two secondary field components

3.1.21
manipulator
any type of manual or automatic non-metallic fixtures similar to a turntable, and capable of supporting an affixed EUT throughout numerous positions as required by a correlation algorithm or test protocol. The material has to meet the requirements defined for the test set-up support (see 3.1.16). For example, see Figure A.2

3.1.22
hyper-rotated TEM waveguide
TEM waveguide that has been reorientated such that its ortho-axis is normal to the Earth's surface (see [6])

3.1.23
gravity-dependent / -independent
the gravitation force of the earth has a fixed direction. The EUT can be rotated around all three axes. Due to different rotation positions the EUT is affected by the gravitation force in different directions. The EUT is gravity-independent if it is working properly in all positions, which means working properly regardless of the direction of the gravity vector relative to the EUT. The EUT is gravity-dependent if it does not work properly in one or more test positions

3.2 Abbreviations

BALUN	Balanced-to-unbalanced transformer
DFT	Discrete Fourier Transform
EUT	Equipment under test
FFT	Fast Fourier Transform
GTEM	Gigahertz transverse electromagnetic mode
HEMP	High-altitude electromagnetic pulse
OATS	Open-area test site
PoE	Points of entry
RF	Radiofrequency
SAC	Semi-anechoic chamber
SPD	Surge protective device
TDR	Time-domain reflectometer
TE	Transverse electric (mode), (H-mode)
TEM	Transverse electromagnetic mode
TM	Transverse magnetic (mode), (E-mode)
VSWR	Voltage-standing-wave-ratio

4 General

This standard describes basic characteristics and limitations of TEM waveguides, namely test volume, field uniformity, purity of the TEM mode, and frequency ranges. An introduction and some fundamental characteristics of TEM waveguides are given in Annex D.

Radiated emission measurements in a TEM waveguide are usually correlated with the open-area test site (OATS) and semi-anechoic chamber (SAC) methods, which provide valid and repeatable measurement results of disturbance field strength from equipment. In this case so-called correlation algorithms are used to convert TEM waveguide measurement results to OATS-equivalent data, as described in Annex A. Product committees should demonstrate that good correlation exists between measurement results using typical product types.

TEM waveguides can also be used as field generators for testing the immunity of equipment to electromagnetic fields. Details are given in Annex B. Immunity testing in TEM waveguides is cited in several other standards listed in Annex E.

TEM waveguide measurements are not restricted to radiated measurements on fully assembled equipment; they may also be applied to the testing of components, integrated circuits, and the shielding effectiveness of gasket materials and cables.

5 TEM waveguide requirements

TEM waveguides can be used for emission and immunity measurements when certain requirements are met. For the validation of a TEM waveguide the following methods shall be applied.

NOTE This clause focuses on general validation aspects such as the dominant TEM mode and field homogeneity. Specific validation requirements for emission, immunity, and transient testing are given in the annexes.