IEC 61000-4-21

Edition 2.0 2011-01

INTERNATIONAL STANDARD

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BASIC EMC PUBLICATION

PUBLICATION FONDAMENTALE EN CEM

Electromagnetic compatibility (EMC) –
Part 4-21: Testing and measurement techniques – Reverberation chamber test methods

Compatibilité électromagnétique (CEM) –
Partie 4-21: Techniques d'essai et de mesure – Méthodes d'essai en chambre réverbérante

IEC 61000-4-21:2011

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

PRICE CODE
CODE PRIX
XE

ICS 33.100.10; 33.100.20

ISBN 978-2-88912-324-7

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-21: Testing and measurement techniques – Reverberation chamber test methods

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.
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International Standard IEC 61000-4-21 has been prepared by subcommittee 77B: High frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility, in co-operation with CISPR subcommittee A: Radio-interference measurements and statistical methods.

It forms Part 4-21 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 2003. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the first edition.

- In Clause 8, the use and specifications of *E*-field probes for application to reverberation chambers has been added. Additional Notes refer to general aspects and procedures of probe calibrations. The specified range for linearity of the probe response is larger and covers an asymmetric interval compared to that for use in anechoic chambers (see Annex I of IEC 61000-4-3), because

– the fluctuations of power and fields in reverberation chambers exhibit a larger dynamic range, and
– the chamber validation procedure is based on using maximum field values, as opposed to the field itself or its average value,

respectively.

- In Annex A, additional guidance and clarifications on the use of reverberation chambers at relatively low frequencies of operation (i.e., close to the lowest usable frequency of a given chamber) are given, and its implications on the estimation of field uncertainty are outlined. Guidelines on cable-layout have been added. A rationale has been added that explains the relaxation of the field uniformity requirement below 400 MHz, being a compromise between scientific-technical and economical reasons when using chambers around 100 MHz. A first-order correction for the threshold value of the correlation coefficient at relatively low numbers of tuner positions has been added. Issues regarding the use of non-equidistant tuner positions at low frequencies are discussed in an additional Note.
- In Annex B, symmetric location of the field probes when the chamber exhibits cylindrical symmetry has been disallowed, as such placement could otherwise yield a false indication of field uniformity and chamber performance at different locations. The difference between start frequency for chamber validation and lowest test frequency has been clarified. The tuner sequencing for chamber validation and testing is now specified to be equal in both cases. In sample requirements for chamber validation, emphasis is now on the required minimum number of independent tuner steps to be used, whereas the minimum recommended number of samples per frequency interval has been replaced with he number of independent samples that the tuner can provide per frequency, for use in case when the chamber validation fails for the required minimum number.

- Annex C now contains more quantitative guidance on the setting of the maximum permissible stirring speeds that warrant quasi-static conditions of operation for chamber validation and testing. Consideration is given to all characteristic time scales of all components or subsystems of a measurement or test. Specific issues relating to chamber validation, immunity testing and bandwidth are addressed. Particular requirements for field probes when used with mode stirred operation are listed.
- In Annex D, a requirement for the EUT and equipment not to occupy more than 8 % of the total chamber volume in immunity testing has been added. The maximum number of frequency points and the formula to calculate these points have been generalized. A mandatory specification for including the measurement equipment, test plan and cable layout in the test report has been added to resolve any dispute in case of discrepancies, particularly for low-frequency immunity testing.
- Annex E has been extended with further guidance on the value of EUT directivity to be used in the estimation of radiated power and field. Extended estimates have been added for the maximum directivity of electrically large, anisotropically radiating EUTs and for radiated emissions in the presence of a ground plane. A mandatory specification for including the measurement equipment, test plan and cable layout in the test report has been added to resolve any dispute in case of discrepancies, particularly for low-frequency emissions testing.
- In Annex I, some clarifications on antenna efficiency measurements have been added.
- A new Annex K has been added that covers measurement uncertainty in reverberation chambers. The intrinsic field uncertainty for chamber validation, immunity and emissions measurements is quantified. Other contributors to measurement uncertainty are listed.

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

CDV	Report on voting
77B/619/CDV	77B/640/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.

The committee has decided that the contents of this publication will remain unchanged until the stability 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.

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INTRODUCTION

IEC 61000 is published in separate parts according to the following structure:

Part 1: General

General considerations (introduction, fundamental principles)

Definitions, terminology

Part 2: Environment

Description of the environment

Classification of the environment

Compatibility levels

Part 3: Limits

Emission limits

Immunity limits (in so far as they do not fall under the responsibility of the product committees)

Part 4: Testing and measurement techniques

Measurement techniques

Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines

Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

Each part is further subdivided into several parts, published either as international standards or as technical specifications or technical reports, some of which have already been published as sections. Others will be published with the part number followed by a dash and a second number identifying the subdivision (example: IEC 61000-6-1).

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-21: Testing and measurement techniques – Reverberation chamber test methods

1 Scope

This part of IEC 61000 considers tests of immunity and intentional or unintentional emissions for electric and/or electronic equipment and tests of screening effectiveness in reverberation chambers. It establishes the required test procedures for performing such tests. Only radiated phenomena are considered.

The objective of this part is to establish a common reference for using reverberation chambers to evaluate the performance of electric and electronic equipment when subjected to radio-frequency electromagnetic fields and for determining the levels of radio-frequency radiation emitted from electric and electronic equipment.

NOTE Test methods are defined in this part for measuring the effect of electromagnetic radiation on equipment and the electromagnetic emissions from equipment concerned. The simulation and measurement of electromagnetic radiation is not adequate for quantitative determination of effects. The defined test methods are organized with the aim to establish adequate reproducibility and repeatability of test results and qualitative analysis of effects.

This part of IEC 61000 does not intend to specify the tests to be applied to a particular apparatus or system. Its main aim is to give a general basic reference to all concerned product committees of the IEC. The product committees should select emission limits and test methods in consultation with CISPR. The product committees remain responsible for the appropriate choice of the immunity tests and the immunity test limits to be applied to their equipment. Other methods, such as those covered in IEC 61000-4-3, CISPR 16-2-3 and CISPR 16-2-4 may be used.[1]

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):1990, *International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility*

Amendment 1 (1997)

Amendment 2 (1998)

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

IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

Amendment 1 (2007)

[1] For further information consult with CISPR (International Special Committee on Radio Interference) or Technical Committee 77 (Electromagnetic compatibility).

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

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions together with those in IEC 60050(161) apply.

3.1.1
antenna
that part of a radio transmitting or receiving system which is designed to provide the required coupling between a transmitter or a receiver and the medium in which the radio wave propagates

[IEC 60050-712:1992, 712-01-01]

NOTE For the purpose of this procedure, antennas are assumed to have an efficiency of 75 % or greater.

3.1.2
electromagnetic wave
EM wave
wave characterized by the propagation of a time-varying electromagnetic field and caused by acceleration of electric charges

[IEC 60050-705:1995, 705-01-09, modified]

3.1.3
far field region
that region of the electromagnetic field of an antenna or unintentional radiator wherein the predominant components of the field are those which represent a propagation of energy and wherein the angular field distribution is essentially independent of the distance from the antenna

NOTE 1 In the far field region, all the components of the electromagnetic field decrease in inverse proportion to the distance from the antenna.

NOTE 2 For a broadside antenna having a maximum overall dimension, D, which is large compared to the wavelength, λ, the far field region is commonly taken to exist at distances greater than $2D^2/\lambda$ from the antenna in the direction of maximum radiation.

[IEC 60050-712:1992, 712-02-02]

the region far from a source or aperture where the radiation pattern does not vary with distance from the source

[IEC 60050-731:1991, 731-03-92]

3.1.4
field strength
magnitude of the electromagnetic field created at a given point by a radio transmitting system operating at a specified characteristic frequency with specified installation and modulation conditions

[IEC 60050-705:1995, 705-08-31]

NOTE 1 The term "electric field strength" (in V/m) or "magnetic field strength" (in A/m) is used according to whether the magnitude of the electric or magnetic field, respectively, is measured. In the near-field region, the relationship between the electric and magnetic field strength and distance depends on the specific configuration involved. The power flux density of the field is similarly indeterminate.

NOTE 2 In the far zone, field strength is sometimes identified with power flux density *P*. For a plane wave in free space, $P = E^2 / \eta_V$, where

E is the electric field strength, and

η_V is the intrinsic impedance of free space, approximately equal to 120π Ω.

3.1.5
polarization
property of a sinusoidal electromagnetic wave or field vector defined at a fixed point in space by the direction of the electric field strength vector or of any specified field vector; when this direction varies with time, the property may be characterized by the locus described by the extremity of the considered field vector

[IEC 60050-726:1982, 726-04-01]

3.1.6
reverberation chamber
room specially designed to have a very long reverberation time

[IEC 60050-723:1997, 723-03-30]

(reverberation room) room having a long reverberation time, especially designed to make the field therein as diffuse as possible

NOTE 1 The room consists of a shielded enclosure that is generally equipped with mechanical tuners/stirrers that change (stir) the boundary conditions within the enclosure and, thus, alter the structure of the electromagnetic fields within the enclosure.

[IEC 60050-801:1994, 801-31-13, modified]

NOTE 2 Reverberation rooms are used in particular for the measurement of absorption coefficients of materials and measurement of the power emitted by intentional or unintentional radiating sources.

NOTE 3 Testing in a reverberation chamber can be described as a stochastic process in which the mechanical tuners/stirrers “stir” the “modes” inside the enclosure. Therefore, such chambers is also called stirred-mode, mode-stirred or mode-tuned chamber.

3.1.7
quality factor (of a reverberation chamber)
Q
(quality factor) frequency-dependent measure of sharpness of the resonance, equal to 2π times the ratio of the maximum stored energy to the energy dissipated during one period

[IEC 60050-151:2001, 151-15-46, modified]

measure of how well the chamber stores energy (see Clause A.6 [2][2])

NOTE For a given chamber, *Q* varies as a function of frequency and can be calculated using the following formula:

$$Q = \frac{16\pi^2 V}{\eta_{Tx}\eta_{Rx}\lambda^3}\left\langle \frac{P_{AveRec}}{P_{Input}} \right\rangle_n \qquad (4)$$

where

V is the chamber volume (in m^3),

2 Numbers in square brackets refer to the reference documents in the respective annexes.

λ is the wavelength (in m),

P_{AveRec}/P_{Input} is the ratio of the received power to the input power, each averaged over one complete tuner/stirrer sequence,

$\langle\ \rangle_n$ denotes averaging with respect to the number of antenna locations and orientations, *n*,

η_{Tx} and η_{Rx} are the antenna efficiency factors (dimensionless) for the Transmit (Tx) and Receive (Rx) antennas, respectively. If manufacturer's data is not available then the efficiency can be assumed to be 0,75 for log periodic antennas and 0,9 for horn antennas,

n is the number of antenna locations and orientations that the *Q* is evaluated for. Only one location is required as a minimum; however, multiple locations and orientations may be evaluated and the data averaged over them.

3.1.8
***Q*-bandwidth** (of a reverberation chamber)
BW_Q
measure of the frequency range over which the modes in a reverberation chamber are correlated (see Clause A.2)

NOTE The BW_Q of a reverberation chamber can be calculated using the following formula:

$$BW_Q = f/Q \quad (5)$$

where

f is the frequency (in Hz),

Q is the quality factor defined in 3.1.7.

3.1.9
malfunction
loss of capability of the equipment to initiate or sustain a required function, or the initiation of undesired spurious action which might result in adverse consequences

NOTE The criteria of functional acceptance have to be precisely specified.

[IEC 60050-393:2003, 393-17-79]

3.1.10
emission
phenomenon by which energy emanates from a source in the form of waves or particles

[IEC 60050-702:2003, 702-02-03]

3.1.11
tuner/stirrer
mechanical device constructed from low-loss electrically conductive material which alters the electromagnetic boundary conditions inside a reverberation chamber

NOTE In general, a reverberation chamber is a shielded enclosure with the smallest dimension being large with respect to the wavelength at the lowest usable frequency. The chamber is normally equipped with a mechanical tuning/stirring device whose dimensions are significant fractions of the chamber dimensions and of the wavelength at the lowest usable frequency. When the chamber is excited with RF energy, the boundary conditions of the resulting multi-mode electromagnetic environment can be altered by the mechanical tuner/stirrer. The resulting environment is statistically uniform and statistically isotropic (i.e., the energy arriving from all aspect angles with all directions of polarizations) when considered over a sufficiently large number of positions of the mechanical tuner/stirrer.

3.1.12
electromagnetic mode
one solution of Maxwell's equations representing an electromagnetic field in a certain space domain and belonging to a family of independent solutions defined by specified boundary conditions

[IEC 60050-705:1995, 705-01-12]

3.1.13
validation
process of confirming that a finalized instrumentation, control system (hardware and software) and test facility complies with all of its functional, performance and interface requirements

[IEC 60050-394:2007, 394-40-42, modified]

3.1.14
chamber validation
process of confirming that a chamber complies with all of its functional, performance and interface requirements

[IEC 60050-394:2007, 394-40-42, modified]

3.1.15
intrinsic field uncertainty
IFU
contribution to the overall uncertainty budget that is caused by the random (statistical) nature of the field inside a reverberation chamber

NOTE Typically, the intrinsic field uncertainty is considerably larger than the measurement instrumentation uncertainty in typical operation of a reverberation chamber, except when the chamber has an exceptionally high quality factor. As a result, the IFU is typically the only or main contribution to be considered in estimating the overall uncertainty during test or measurement.

3.1.16
working volume
region defined by 8 points inside the chamber at sufficient distance away from the walls to avoid boundary effects, for rectangular chambers typically defined by the corners of a cubic or parallelepiped region at quarter-wavelength distance from the nearest walls

NOTE For frequencies below 100 MHz, the distances can be restricted to 0,75 m.

3.2 Abbreviations

AVF	Antenna Validation Factor
CVF	Chamber Validation Factor
CDF	Cumulative Distribution Function
CISPR	Comité International Spécial des Perturbations Radioélectriques[3]
CLF	Chamber Loading Factor
CW	Continuous Wave
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EUT	Equipment Under Test
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IF	Image Frequency
IFU	Intrinsic Field Uncertainty
IL	Insertion Loss
ISO	International Organization for Standardization

3 International Special Committee on Radio Interference

LUF	Lowest Usable Frequency
MIU	Measurement Instrumentation Uncertainty
MU	Measurement Uncertainty
OATS	Open Area Test Site
PDF	Probability Density Function
RC	Reverberation Chamber
RE	Radiated Emissions
RF	Radio Frequency
RMS	Root Mean Square
rps	revolutions per second
RSS	Root Sum of the Squares
Rx	Receive (antenna)
SE	Shielding Effectiveness
SW	Square Wave modulation
TFVF	Test Fixture Validation Factor
Tx	Transmit (antenna)

4 General

Most electronic equipment is, in some manner, affected by electromagnetic radiation. Sources of radiation can be natural or man-made in origin and can be intentional or unintentional. Examples of intentional radiators are wireless and personal communication systems. Examples of unintentional radiators are welders, thyristors, high-speed data buses, fluorescent lights, switches operating inductive loads, etc.

Realistic environments for propagation of electromagnetic waves are often characterized by multiple reflections and multipath effects. Reverberation chambers go some way to simulate such complex environments in an extreme manner (worst-case effect) and may be more representative than other EMC test methods in this respect. An advantage of reverberation chambers is the ability to generate a statistically isotropic, homogeneous, unpolarized and uncorrelated interior field, through action of the tuner/stirrer.

High-level electromagnetic fields are easily and safely generated using reverberation chambers. The high quality factor or “Q” of such chambers allows fairly high field strengths to be generated with relatively moderate input powers (resonant fields). The absence of absorber makes generation of high field levels safer as the risk of igniting absorbers is eliminated. Adequate screening of the enclosure confines the high fields to the interior of the chamber.

5 Test environments and limitations

The reverberation chamber method is suitable for performing tests from relatively low to extremely high field levels. Due to the high level of isolation from the ambient environment, both emissions and immunity tests can be performed for most commercial requirements without limitations. At present, the IEC sets the transition frequency between radiated and conducted testing at 80 MHz for immunity testing.

NOTE IEC 61000-4-6 also defines test methods for establishing the immunity of electrical and electronic equipment against conducted electromagnetic energy. It covers frequencies below 80 MHz.

As stated in Annex A, the frequency range of tests is determined by the size and construction of the chamber and the effectiveness of the mechanical tuner(s) in altering the spatial field pattern. There are no fundamental restrictions with regard to the shape and size of enclosures