

Electromagnetic compatibility (EMC)

Part 4-3: Testing and measurement
techniques — Radiated,
radio-frequency electromagnetic
field immunity test

ICS 33.100.20

National foreword

This British Standard is the UK implementation of EN 61000-4-3:2006+A2:2010. It is identical to IEC 61000-4-3:2006, incorporating amendments 1:2007 and 2:2010. It supersedes BS EN 61000-4-3:2006+A1:2008 which will be withdrawn on 1 July 2013.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to IEC text carry the number of the IEC amendment. For example, text altered by IEC amendment 1 is indicated by A1 A1.

National Annex NA (informative) reproduces CENELEC interpretation sheet 1 (February 2009).

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

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English version

Electromagnetic compatibility (EMC)
Part 4-3: Testing and measurement techniques -
Radiated, radio-frequency, and electromagnetic field immunity test
(IEC 61000-4-3:2006+A1:2007, A2:2010)

Compatibilité électromagnétique (CEM)
Partie 4-3: Techniques d'essai
et de mesure -
Essai d'immunité aux champs
électromagnétiques rayonnés
aux fréquences radioélectriques
(CEI 61000-4-3:2006+A1:2007, A2:2010)

Elektromagnetische Verträglichkeit (EMV)
Teil 4-3: Prüf- und Messverfahren -
Prüfung der Störfestigkeit
gegen hochfrequente
elektromagnetische Felder
(IEC 61000-4-3:2006+A1:2007, A2:2010)

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Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

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CENELEC members are the national electrotechnical committees of Austria, Belgium, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Foreword

The text of document 77B/485/FDIS, future edition 3 of IEC 61000-4-3, prepared by SC 77B, High frequency phenomena, of IEC TC 77, Electromagnetic compatibility, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61000-4-3 on 2006-03-01.

This European Standard supersedes EN 61000-4-3:2002 + A1:2002 + IS1:2004.

The test frequency range may be extended up to 6 GHz to take account of new services. The calibration of the field as well as the checking of power amplifier linearity of the primary chain are specified.

The following dates were fixed:

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Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61000-4-3:2006 was approved by CENELEC as a European Standard without any modification.

Foreword to amendment A1

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Foreword to amendment A2

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Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN and CENELEC shall not be held responsible for identifying any or all such patent rights.

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INTRODUCTION

This standard is part of the IEC 61000 series, 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: 61000-6-1).

This part is an International Standard which gives immunity requirements and test procedures related to radiated, radio-frequency, electromagnetic fields.

<http://www.china-gauges.com/>

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test

1 Scope and object

This part of IEC 61000 is applicable to the immunity requirements of electrical and electronic equipment to radiated electromagnetic energy. It establishes test levels and the required test procedures.

The object of this standard is to establish a common reference for evaluating the immunity of electrical and electronic equipment when subjected to radiated, radio-frequency electromagnetic fields. The test method documented in this part of IEC 61000 describes a consistent method to assess the immunity of an equipment or system against a defined phenomenon.

NOTE 1 As described in IEC Guide 107, this is a basic EMC publication for use by product committees of the IEC. As also stated in Guide 107, the IEC product committees are responsible for determining whether this immunity test standard should be applied or not, and if applied, they are responsible for determining the appropriate test levels and performance criteria. TC 77 and its sub-committees are prepared to co-operate with product committees in the evaluation of the value of particular immunity tests for their products.

This part deals with immunity tests related to the protection against RF electromagnetic fields from any source.

Particular considerations are devoted to the protection against radio-frequency emissions from digital radiotelephones and other RF emitting devices.

NOTE 2 Test methods are defined in this part for evaluating the effect that electromagnetic radiation has on the equipment concerned. The simulation and measurement of electromagnetic radiation is not adequately exact for quantitative determination of effects. The test methods defined are structured for the primary objective of establishing adequate repeatability of results at various test facilities for qualitative analysis of effects.

This standard is an independent test method. Other test methods may not be used as substitutes for claiming compliance with this standard.

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 61000-4-6, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

3 Terms and definitions

For the purposes of this part of IEC 61000, the following definitions, together with those in IEC 60050(161) apply.

3.1

amplitude modulation

process by which the amplitude of a carrier wave is varied following a specified law

3.2

anechoic chamber

shielded enclosure which is lined with radio-frequency absorbers to reduce reflections from the internal surfaces

3.2.1

fully anechoic chamber

shielded enclosure whose internal surfaces are totally lined with anechoic material

3.2.2

semi-anechoic chamber

shielded enclosure where all internal surfaces are covered with anechoic material with the exception of the floor, which shall be reflective (ground plane)

3.2.3

modified semi-anechoic chamber

semi-anechoic chamber which has additional absorbers installed on the ground plane

3.3

antenna

transducer which either emits radio-frequency power into space from a signal source or intercepts an arriving electromagnetic field, converting it into an electrical signal

3.4

balun

device for transforming an unbalanced voltage to a balanced voltage or vice versa

[IEV 161-04-34]

3.5

continuous waves (CW)

electromagnetic waves, the successive oscillations of which are identical under steady-state conditions, which can be interrupted or modulated to convey information

3.6

electromagnetic (EM) wave

radiant energy produced by the oscillation of an electric charge characterized by oscillation of the electric and magnetic fields

3.7

far field

region where the power flux density from an antenna approximately obeys an inverse square law of the distance.

For a dipole this corresponds to distances greater than $\lambda/2\pi$, where λ is the wavelength of the radiation

3.8 field strength

The term "field strength" is applied only to measurements made in the far field. The measurement may be of either the electric or the magnetic component of the field and may be expressed as V/m, A/m or W/m²; any one of these may be converted into the others.

NOTE For measurements made in the near field, the term "electric field strength" or "magnetic field strength" is used according to whether the resultant electric or magnetic field, respectively, is measured. In this field region, the relationship between the electric and magnetic field strength and distance is complex and difficult to predict, being dependent on the specific configuration involved. Inasmuch as it is not generally feasible to determine the time and space phase relationship of the various components of the complex field, the power flux density of the field is similarly indeterminate.

3.9 frequency band

continuous range of frequencies extending between two limits

3.10

E_c

field strength applied for calibration

3.11

E_t

carrier field strength applied for testing

3.12

full illumination

test method in which the EUT face being tested fits completely within the UFA (Uniform Field Area).

This test method may be applied for all test frequencies

3.13

human body-mounted equipment

equipment which is intended for use when attached to or held in close proximity to the human body.

This term includes hand-held devices which are carried by people while in operation (e.g. pocket devices) as well as electronic aid devices and implants

3.14

independent windows method

test method (using 0,5 m × 0,5 m UFA) in which the EUT face being tested does not fit completely within the UFA.

This test method may be applied for test frequencies greater than 1 GHz

3.15

induction field

predominant electric and/or magnetic field existing at a distance $d < \lambda/2\pi$, where λ is the wavelength, and the physical dimensions of the source are much smaller than distance d

3.16

intentional RF emitting device

device which radiates (transmits) an electromagnetic field intentionally. Examples include digital mobile telephones and other radio devices

3.17

isotropic

having properties of equal values in all directions

3.18

maximum RMS value

highest short-term RMS value of a modulated RF signal during an observation time of one modulation period.

The short-term RMS is evaluated over a single carrier cycle (for example, in Figure 1b), the maximum RMS voltage is:

$$V_{\text{maximum RMS}} = V_p \times (2 \times \sqrt{2}) = 1,8 \text{ V}$$

3.19

non-constant envelope modulation

RF modulation schemes in which the amplitude of the carrier wave varies slowly in time compared with the period of the carrier itself. Examples include conventional amplitude modulation and TDMA

3.20

P_c

forward power needed to establish the calibration field strength

3.21

partial illumination

test method (using a minimum sized UFA of 1,5 × 1,5 m) in which the EUT face being tested does not fit completely within the UFA.

This test method may be applied for all test frequencies.

3.22

polarization

orientation of the electric field vector of a radiated field

3.23

shielded enclosure

screened or solid metal housing designed expressly for the purpose of isolating the internal from the external electromagnetic environment. The purpose is to prevent outside ambient electromagnetic fields from causing performance degradation and to prevent emission from causing interference to outside activities

3.24

sweep

continuous or incremental traverse over a range of frequencies

3.25

TDMA (time division multiple access)

time multiplexing modulation scheme which places several communication channels on the same carrier wave at an allocated frequency. Each channel is assigned a time slot during which, if the channel is active, the information is transmitted as a pulse of RF power. If the channel is not active no pulse is transmitted, thus the carrier envelope is not constant. During the pulse, the amplitude is constant and the RF carrier is frequency- or phase-modulated

3.26

transceiver

combination of radio transmitting and receiving equipment in a common housing

3.27

uniform field area (UFA)

hypothetical vertical plane of the field calibration in which variations are acceptably small.

The purpose of field calibration is to ensure the validity of the test result. See 6.2

4 General

Most electronic equipment is, in some manner, affected by electromagnetic radiation. This radiation is frequently generated by such general purpose sources as the small hand-held radio transceivers that are used by operating, maintenance and security personnel, fixed-station radio and television transmitters, vehicle radio transmitters, and various industrial electromagnetic sources.

In recent years there has been a significant increase in the use of radio telephones and other RF emitting devices operating at frequencies between 0,8 GHz and 6 GHz. Many of these services use modulation techniques with a non-constant envelope (e.g. TDMA). See 5.2.

In addition to electromagnetic energy deliberately generated, there is also radiation caused by devices such as welders, thyristors, fluorescent lights, switches operating inductive loads, etc. For the most part, this interference manifests itself as conducted electrical interference and, as such, is dealt with in other parts of the IEC 61000-4 standard series. Methods employed to prevent effects from electromagnetic fields will normally also reduce the effects from these sources.

The electromagnetic environment is determined by the strength of the electromagnetic field. The field strength is not easily measured without sophisticated instrumentation nor is it easily calculated by classical equations and formulas because of the effect of surrounding structures or the proximity of other equipment that will distort and/or reflect the electromagnetic waves.

5 Test levels

The test levels are given in Table 1.

Table 1 – Test levels related to general purpose, digital radio telephones and other RF emitting devices

Level	Test field strength V/m
1	1
2	3
3	10
4	30
x	

NOTE x is an open test level and the associated field strength may be any value. This level may be given in the product standard.

This standard does not suggest that a single test level is applicable over the entire frequency range. Product committees shall select the appropriate test level for each frequency range needing to be tested as well as the frequency ranges. See Annex E for a guidance for product committees on the selection of test levels.

The test field strength column gives values of the unmodulated carrier signal. In testing of equipment, this carrier signal is 80 % amplitude modulated with a 1 kHz sine wave to simulate actual threats (see Figure 1). Details of how the test is performed are given in Clause 8.

5.1 Test levels related to general purposes

The tests are normally performed without gaps in the frequency range 80 MHz to 1 000 MHz.

NOTE 1 Product committees may decide to choose a lower or higher transition frequency than 80 MHz between IEC 61000-4-3 and IEC 61000-4-6 (see Annex G).

NOTE 2 Product committees may use alternative modulation schemes for equipment under test.

NOTE 3 IEC 61000-4-6 also defines test methods for establishing the immunity of electrical and electronic equipment against radiated electromagnetic energy. It covers frequencies below 80 MHz.

5.2 Test levels related to the protection against RF emissions from digital radio telephones and other RF emitting devices

The tests are normally performed in the frequency ranges 800 MHz to 960 MHz and 1,4 GHz to 6,0 GHz.

The frequencies or frequency bands to be selected for the test are limited to those where mobile radio telephones and other intentional RF emitting devices actually operate. It is not intended that the test needs to be applied continuously over the entire frequency range from 1,4 GHz to 6 GHz. For those frequency bands used by mobile radio telephones and other intentional RF emitting devices, specific test levels may be applied in the corresponding frequency range of operation.

Also if the product is intended to conform only to the requirements of particular countries, the measurement range 1,4 GHz to 6 GHz may be reduced to cover just the specific frequency bands allocated to digital mobile telephones and other intentional RF emitting devices in those countries. In this situation, the decision to test over reduced frequency ranges shall be documented in the test report.

NOTE 1 Annex A contains an explanation regarding the decision to use sine wave modulation for tests related to protection against RF emissions from digital radio telephones and other intentional RF emitting devices.

NOTE 2 Annex E contains guidance with regard to selecting test levels.

NOTE 3 The measurement ranges for Table 2 are the frequency bands generally allocated to digital radio telephones (Annex G contains the list of frequencies known to be allocated to specific digital radio telephones at the time of publication).

NOTE 4 The primary threat above 800 MHz is from radio telephone systems and other intentional RF emitting devices with power levels similar to that of radio telephones. Other systems operating in this frequency range, e.g. radio LANs operating at 2,4 GHz or higher frequencies, are generally very low power (typically lower than 100 mW), so they are much less likely to present significant problems.

6 Test equipment

The following types of test equipment are recommended:

- *Anechoic chamber*: of a size adequate to maintain a uniform field of sufficient dimensions with respect to the equipment under test (EUT). Additional absorbers may be used to damp reflections in chambers which are not fully lined.
- *EMI filters*: care shall be taken to ensure that the filters introduce no additional resonance effects on the connected lines.
- *RF signal generator(s)* capable of covering the frequency band of interest and of being amplitude modulated by a 1 kHz sine wave with a modulation depth of 80%. They shall have manual control (e.g., frequency, amplitude, modulation index) or, in the case of RF synthesizers, they shall be programmable with frequency-dependent step sizes and dwell times.

The use of low-pass or band-pass filters may be necessary to avoid problems caused by harmonics.

- *Power amplifiers*: to amplify signal (unmodulated and modulated) and provide antenna drive to the necessary field level. The harmonics generated by the power amplifier shall be such that any measured field strength in the UFA at each harmonic frequency shall be at least 6 dB below that of the fundamental frequency (see Annex D).
- *Field generating antennas (see Annex B)*: biconical, log periodic, horn or any other linearly polarized antenna system capable of satisfying frequency requirements.
- *An isotropic field sensor* with adequate immunity of any head amplifier and opto-electronics to the field strength to be measured, and a fibre optic link to the indicator outside the chamber. An adequately filtered signal link may also be used. ^[A1] Annex I provides a calibration method for E-field probes. ^[A1]
- *Associated equipment to record the power levels* necessary for the required field strength and to control the generation of that level for testing.

Care shall be taken to ensure adequate immunity of the auxiliary equipment.

6.1 Description of the test facility

Because of the magnitude of the field strengths generated, the tests shall be made in a shielded enclosure in order to comply with various national and international laws prohibiting interference to radio communications. In addition, since most test equipment used to collect data is sensitive to the local ambient electromagnetic field generated during the execution of the immunity test, the shielded enclosure provides the necessary "barrier" between the EUT and the required test instrumentation. Care shall be taken to ensure that the interconnection wiring penetrating the shielded enclosure adequately attenuates the conducted and radiated emission and preserves the integrity of the EUT signal and power responses.

The test facility typically consists of an absorber-lined shielded enclosure large enough to accommodate the EUT whilst allowing adequate control over the field strengths. This includes anechoic chambers or modified semi-anechoic chambers, an example of which is shown in Figure 2. Associated shielded enclosures should accommodate the field generating and monitoring equipment, and the equipment which exercises the EUT.

Anechoic chambers are less effective at lower frequencies. Particular care shall be taken to ensure the uniformity of the generated field at the lower frequencies. Further guidance is given in Annex C.

6.2 Calibration of field

The purpose of field calibration is to ensure that the uniformity of the field over the test sample is sufficient to ensure the validity of the test results. IEC 61000-4-3 uses the concept of a uniform field area (UFA, see Figure 3), which is a hypothetical vertical plane of the field in which variations are acceptably small. In a common procedure (field calibration), the capability of the test facility and the test equipment to generate such a field is demonstrated. At the same time, a database for setting the required field strength for the immunity test is obtained. The field calibration is valid for all EUTs whose individual faces (including any cabling) can be fully covered by the UFA.

The field calibration is performed with no EUT in place (see Figure 3). In this procedure, the relationship between field strength within the UFA and forward power applied to the antenna is determined. During the test, the required forward power is calculated from this relationship and the target field strength. The calibration is valid as long as the test setup used for it remains unchanged for testing. Therefore the calibration setup (antenna, additional absorber, cables, etc.) shall be recorded. It is important that the exact position, as much as is reasonably possible, of the generating antennas and cables is documented. Since even small displacements may significantly affect the field, the same positions shall be used also for the immunity test.

It is intended that the full field calibration process should be carried out annually and when changes have been made in the enclosure configuration (absorber replaced, area moved, equipment changed, etc.). Before each batch of testing (see Clause 8), the validity of the calibration shall be checked.

The transmitting antenna shall be placed at a distance sufficient to allow the UFA to fall within the beam of the transmitted field. The field sensor shall be at least 1 m from the field generating antenna. A distance of 3 m between the antenna and the UFA is preferred (see Figure 3). This dimension is measured from the centre of a biconical antenna, or the front tip of a log periodic or combination antenna, or from the front edge of horn or double ridge wave guide antenna. The calibration record and the test report shall state the distance used.

Unless the EUT and its wires can be fully illuminated within a smaller surface, the size of the UFA is at least 1,5 m × 1,5 m with its lower edge established at a height of 0,8 m above the floor. The size of the UFA shall not be less than 0,5 m × 0,5 m. During the immunity test, the EUT shall have the face to be illuminated coincident with this UFA (see Figures 5 and 6).

In order to establish the severity of the test for EUTs and cabling which must be tested close to the floor (earth reference plane), the magnitude of the field is also recorded at 0,4 m height. The obtained data is documented in the calibration record but is not considered for the suitability of the test facility and for the calibration database.

Due to reflections at the floor in a semi-anechoic room, it is difficult to establish a UFA close to an earth reference plane. Additional absorbing material on the earth reference plane may solve this problem (see Figure 2).

The UFA is subdivided into a grid with a grid spacing of 0,5 m (see Figure 4 as an example of an 1,5 m × 1,5 m UFA). At each frequency, a field is considered uniform if its magnitude measured at the grid points is within $\begin{matrix} -0 \\ +6 \end{matrix}$ dB of the nominal value for not less than 75 % of all grid points (e.g. if at least 12 of the 16 points of an 1,5 m × 1,5 m UFA measured are within the tolerance). For the minimum UFA of 0,5 m × 0,5 m, the field magnitude for all four grid points shall lie within this tolerance.

NOTE 1 At different frequencies, different measuring points may be within the tolerance.

The tolerance has been expressed as $\begin{matrix} -0 \\ +6 \end{matrix}$ dB to ensure that the field strength does not fall below nominal with an acceptable probability. The tolerance of 6 dB is considered to be the minimum achievable in practical test facilities.

In the frequency range up to 1 GHz, a tolerance greater than +6 dB up to +10 dB, but not less than -0 dB is allowed for a maximum of 3 % of the test frequencies, provided that the actual tolerance is stated in the test report. In case of dispute, the $\begin{matrix} -0 \\ +6 \end{matrix}$ dB tolerance takes precedence.

If the area intended to be occupied by the face of the actual EUT is larger than 1,5 m × 1,5 m and an UFA with sufficient dimensions (preferred method) can not be realised, then the area to be occupied by the EUT may be illuminated in a series of tests ("partial illumination"). Either:

- a calibration shall be performed at different radiating antenna locations so that the combined UFAs cover the area which will be occupied by the face of the EUT, and the EUT shall then be tested with the antenna in each of these positions successively,
- or the EUT shall be moved to different positions so that each part of it falls within the UFA during at least one of these tests.

NOTE 2 Each of the antenna positions requires a full field calibration.

Table 2 below demonstrates the concepts of full illumination and partial illumination as well as where and how they can be applied.

Table 2 – Requirements for uniform field area for application of full illumination, partial illumination and independent windows method

Frequency range	Requirements of UFA size and calibration when the EUT fits completely within UFA (Full Illumination, the preferred method)	Requirements of UFA size and calibration when the EUT does not fit completely within UFA (Partial Illumination and Independent Windows, the alternative methods)
Less than 1 GHz	<p>Minimum UFA size 0,5 m × 0,5 m</p> <p>UFA size in 0,5 m grid size steps (e.g., 0,5 m × 0,5 m; 0,5 m × 1,0 m; 1,0 m × 1,0 m; etc)</p> <p>Calibration in 0,5 m × 0,5 m grid steps</p> <p>75 % of calibration points within specifications if UFA is larger than 0,5 m × 0,5 m. 100 % (all 4 points) must be in specifications for 0,5 m × 0,5 m UFA.</p>	<p>PARTIAL ILLUMINATION</p> <p>Minimum UFA size 1,5 m × 1,5 m</p> <p>UFA size in 0,5 m grid size steps (e.g., 1,5 m × 1,5 m; 1,5 m × 2,0 m; 2,0 m × 2,0 m; etc)</p> <p>Calibration in 0,5 m × 0,5 m grid steps</p> <p>75 % of calibration points within specifications</p>

Table 2 (continued)

Frequency range	Requirements of UFA size and calibration when the EUT fits completely within UFA (Full Illumination, the preferred method)	Requirements of UFA size and calibration when the EUT does not fit completely within UFA (Partial Illumination and Independent Windows, the alternative methods)
Greater than 1 GHz	Minimum UFA size 0,5 m × 0,5 m UFA size in 0,5 m grid size steps (e.g., 0,5 m × 0,5 m; 0,5 m × 1,0 m; 1,0 m × 1,0 m; etc) Calibration in 0,5 m × 0,5 m grid steps 75 % of calibration points within specifications if UFA is larger than 0,5 m × 0,5 m. 100 % (all 4 points) must be in specifications for 0,5 m × 0,5 m UFA.	INDEPENDENT WINDOWS METHOD 1,5 m × 0,5 m window (See Annex H) PARTIAL ILLUMINATION 1,5 m × 1,5 m and larger size windows in 0,5 m increments (e.g., 1,5 m × 2,0 m; 2,0 m × 2,0 m; etc) Calibration in 0,5 m × 0,5 m grid steps 75 % of calibration points within specifications if UFA is larger than 0,5 m × 0,5 m. 100 % (all 4 points) must be in specifications for 0,5 m × 0,5 m UFA.

If the requirements of this subclause can only be satisfied up to a certain limiting frequency (higher than 1 GHz), for example because the beam width of the antenna is insufficient to illuminate the entire EUT, then for frequencies higher than this, a second alternative method (known as “the independent window method”), described in Annex H, may be used.

Generally the calibration of the field in anechoic and semi-anechoic chambers has to be performed using the test setup shown in Figure 7. The calibration shall always be performed with an unmodulated carrier for both horizontal and vertical polarisations in accordance with the steps given below. It is required to ensure that the amplifiers can handle the modulation and are not saturated during testing. The preferred method to ensure the amplifiers are not saturated during testing is to carry out the calibration with a field strength at least 1,8 times as high as the field strength to be applied to the EUT. Denote this calibration field strength by E_c . E_c is the value which is applicable only to field calibration. The test field strength E_t shall not exceed $E_c / 1,8$.

NOTE 3 Other methods to ensure avoiding saturation may be used.

Two different calibration methods are described below using an 1,5 m × 1,5 m UFA (16 grid points) as an example. These methods are considered to give the same field uniformity.

6.2.1 Constant field strength calibration method

The constant field strength of the uniform field shall be established and measured via a calibrated field sensor at each particular frequency and at each of the 16 points one after the other (see Figure 4) using the step size given in Clause 8, by adjusting the forward power accordingly.

The forward power necessary to establish the field strength chosen shall be measured in accordance with Figure 7 and is to be recorded in dBm for the 16 points.

Procedure to be followed at both horizontal and vertical polarisations:

- a) Position the sensor at one of the 16 points in the grid (see Figure 4), and set the frequency of the signal generator output to the lowest frequency in the range of the test (for example 80 MHz).
- b) Adjust the forward power to the field-generating antenna so that the field strength obtained is equal to the required calibration field strength E_c . Record the forward power reading.
- c) Increase the frequency by a maximum of 1 % of the present frequency.
- d) Repeat steps b) and c) until the next frequency in the sequence would exceed the highest frequency in the range of the test. Finally, repeat step b) at this highest frequency (for example 1 GHz).
- e) Repeat steps a) to d) for each point in the grid.

At each frequency:

- f) Sort the 16 forward power readings into ascending order.
- g) Start at the highest value and check if at least the 11 readings below this value are within the tolerance of -6 dB to $+0$ dB of that value.
- h) If they are not within this tolerance of -6 dB to $+0$ dB, go back to the same procedure, starting by the reading immediately below and so on (notice that there are only five possibilities for each frequency).
- i) Stop the procedure if at least 12 numbers are within 6 dB and record the maximum forward power out of the numbers. Denote this forward power by P_c ;
- j) Confirm that the test system (e.g. the power amplifier) is not in saturation. Assuming that E_c has been chosen as 1,8 times E_t , perform the following procedure at each calibration frequency:
 - j-1) Decrease the output from the signal generator by 5,1 dB from the level needed to establish a forward power of P_c , as determined in the above steps. ($-5,1$ dB is the same as $E_c / 1,8$.);
 - j-2) Record the new forward power delivered to the antenna;
 - j-3) Subtract the forward power measured in step j-2 from P_c . If the difference is between 3,1 and 5,1 dB, then the amplifier is not saturated and the test system sufficient for testing. If the difference is less than 3,1 dB, then the amplifier is saturated and is not suitable for testing.

NOTE 1 If at a specific frequency, the ratio between E_c and E_t is R (dB), where $R = 20 \log(E_c/E_t)$, then the test power $P_t = P_c - R$ (dB). The subscripts c and t refer to calibration and test respectively. The field is modulated in accordance with Clause 8.

A description of an example for the calibration is given in D.4.1.

NOTE 2 At each frequency it has to be ensured that the amplifier used is not saturated. This can best be done by checking the 1 dB compression of the amplifier. However, the 1 dB compression of the amplifier is verified with a 50Ω termination when the impedance of an antenna to be used for the test is different from 50Ω . The saturation of the test system is assured by confirming the 2 dB compression point described to step j). For more information refer to the Annex D.

6.2.2 Constant power calibration method

The field strength of the uniform field shall be established and measured via a calibrated field sensor at each particular frequency and at each of the 16 points one after the other (see Figure 4) using the step size given in Clause 8, by adjusting the forward power accordingly.

The forward power necessary to establish the field strength at the starting position shall be measured in accordance with Figure 7 and noted. The same forward power shall be applied for all 16 positions. The field strength created by this forward power is to be recorded at each of the 16 points.

Procedure to be followed at both horizontal and vertical polarisations:

- a) Position the sensor at one of the 16 points in the grid (see Figure 4), and set the frequency of the signal generator output to the lowest frequency in the range of the test (for example 80 MHz).
- b) Apply a forward power to the field-generating antenna so that the field strength obtained equals E_c (taking into account that the test field will be modulated). Record the forward power and field strength readings.
- c) Increase the frequency by a maximum of 1% of the present frequency.
- d) Repeat steps b) and c) with the next frequency in the sequence would exceed the highest frequency in the range of the test. Finally, repeat step b) at this highest frequency (for example 1 GHz).
- e) Move the sensor to another position in the grid. At each of the frequencies and used in steps a) to d), apply the forward power recorded in step b) for that frequency, and record the field strength reading.
- f) Repeat step e) for each point in the grid.

At each frequency :

- g) Sort the 16 field strength readings into ascending order.
- h) Select one field strength as the reference and calculate the deviation from this reference for all other positions in decibels.
- i) Start at the lowest value of the field strength and check if at least 11 readings above this value are within the tolerance of $\begin{matrix} -0 \\ +6 \end{matrix}$ dB of that lowest value.
- j) If they are not within the tolerance of $\begin{matrix} -0 \\ +6 \end{matrix}$ dB, go back to the same procedure, starting by the reading immediately above and so on (notice that there are only five possibilities for each frequency).
- k) Stop the procedure if at least 12 numbers are within 6 dB and take from these numbers the position where the minimum field strength was obtained as the reference.
- l) Calculate the forward power necessary to create the required field strength in the reference position. Denote this forward power by P_c .
- m) Confirm that the test system (e. g. the power amplifier) is not in saturation. Assuming that E_c has been chosen as 1,8 times E_t , perform the following procedure at each calibration frequency:
 - m-1) Decrease the output from the signal generator by 5,1 dB from the level needed to establish a forward power of P_c , as determined in the above steps. (-5,1 dB is the same as $E_c / 1,8$.)
 - m-2) Record the new forward power delivered to the antenna.
 - m-3) Subtract the forward power measured in step m-2 from P_c . If the difference is between 3,1 dB and 5,1 dB, then the amplifier is not saturated and the test system is sufficient for testing. If the difference is less than 3,1 dB, then the amplifier is saturated and is not suitable for testing.

NOTE 1 If at a specific frequency, the ratio between E_c and E_t is $R(\text{dB})$, where $R = 20 \log(E_c/E_t)$, then the test power $P_t = P_c - R(\text{dB})$. The subscripts c and t refer to calibration and test respectively. The field is modulated in accordance with Clause 8.

A description of an example for the calibration is given in D.4.2.

NOTE 2 At each frequency it has to be ensured that the amplifier used is not saturated. This can best be done by checking the 1 dB compression of the amplifier. However, the 1 dB compression of the amplifier is verified with a 50 Ω termination when the impedance of an antenna to be used for the test is different from 50 Ω . The saturation of the test system is assured by confirming the 2 dB compression point described to step m). For more information refer to the Annex D.

7 Test setup

All testing of equipment shall be performed in a configuration as close as possible to actual installation conditions. Wiring shall be consistent with the manufacturer's recommended procedures, and the equipment shall be in its normal operating condition with all covers and access panels in place, unless otherwise stated.

If the equipment is designed to be mounted in a panel, rack or cabinet, it shall be tested in this configuration.

A metallic ground plane is not required. When a means is required to support the test sample, it shall be constructed of a non-metallic, non-conductive material. Low dielectric constant (low permittivity) materials, such as rigid polystyrene, should be considered. However, grounding of housing or case of the equipment shall be consistent with the manufacturer's installation recommendations.

When an EUT consists of floor-standing and table-top components, the correct relative positions shall be maintained.

Typical EUT setups are shown in Figures 5 and 6.

NOTE 1 Non-conductive supports are used to prevent accidental earthing of the EUT and distortion of the field. To ensure the latter, the support should be bulk non-conductive, rather than an insulating coating on a metallic structure.

NOTE 2 At higher frequencies (e.g., above 1 GHz), tables or supports made from wood or glass reinforced plastic can be reflective. So, a low dielectric constant (low permittivity) material, such as rigid polystyrene, should be used to avoid field perturbations and to reduce degradation of field uniformity.

7.1 Arrangement of table-top equipment

The equipment to be tested is placed in the test facility on a non-conductive table 0,8 m high.

The equipment is then connected to power and signal wires according to relevant installation instructions.

7.2 Arrangement of floor-standing equipment

Floor-standing equipment should be mounted on a non-conductive support 0,05 m to 0,15 m above the supporting plane. The use of non-conductive supports prevents accidental earthing of the EUT and distortion of the field. To ensure the latter, the support shall be bulk non-conducting, rather than an insulating coating on a metallic structure. Floor-standing equipment which is capable of being stood on a non-conductive 0,8 m high platform, i.e. equipment which is not too large or heavy, or where its elevation would not create a safety hazard, may be so arranged. This variation in the standard method of test shall be recorded in the test report.

NOTE Non-conductive rollers may be used as the 0,05 m to 0,15 m support.

The equipment is then connected to power and signal wires according to relevant installation instructions.

7.3 Arrangement of wiring

Cables shall be attached to the EUT and arranged on the test site according to the manufacturer's installation instructions and shall replicate typical installations and uses as much as possible.

The manufacturer's specified wiring types and connectors shall be used. If the wiring to and from the EUT is not specified, unshielded parallel conductors shall be used.

If the manufacturer's specification requires a wiring length of less than or equal to 3 m, then the specified length shall be used. If the length specified is greater than 3 m or is not specified, then the length of cable used shall be chosen according to typical installation practices. If possible, a minimum of 1 m of cable is exposed to the electromagnetic field. Excess length of cables interconnecting units of the EUT shall be bundled low-inductively in the approximate center of the cable to form a bundle 30 cm to 40 cm in length.

If a product committee determines excess cable length needs to be decoupled (for example, for cables leaving the test area), then the decoupling method used shall not impair the operation of the EUT.

7.4 Arrangement of human body-mounted equipment

Human body-mounted equipment (see Definition 3.13) may be tested in the same manner as table top items. However, this may involve over-testing or under-testing because the characteristics of the human body are not taken into account. For this reason, product committees are encouraged to specify the use of a human body simulator with appropriate dielectric characteristics.

8 Test procedure

The test procedure includes:

- the verification of the laboratory reference conditions;
- the preliminary verification of the correct operation of the equipment;
- the execution of the test;
- the evaluation of the test results.

8.1 Laboratory reference conditions

In order to minimize the effect of environmental parameters on test results, the test shall be carried out in climatic and electromagnetic reference conditions as specified in 8.1.1 and 8.1.2.

8.1.1 Climatic conditions

Unless otherwise specified by the committee responsible for the generic or product standard, the climatic conditions in the laboratory shall be within any limits specified for the operation of the EUT and the test equipment by their respective manufacturers.

Tests shall not be performed if the relative humidity is so high as to cause condensation on the EUT or the test equipment.

NOTE Where it is considered that there is sufficient evidence to demonstrate that the effects of the phenomenon covered by this standard are influenced by climatic conditions, this should be brought to the attention of the committee responsible for this standard.

8.1.2 Electromagnetic conditions

The electromagnetic conditions of the laboratory shall be such to guarantee the correct operation of the EUT in order not to influence the test results.

8.2 Execution of the test

The test shall be carried out on the basis of a test plan that shall include the verification of the performances of the EUT as defined in the technical specification.

The EUT shall be tested in normal operating conditions.

The test plan shall specify:

- the size of the EUT;
- representative operating conditions of the EUT;
- whether the EUT shall be tested as table-top or floor-standing, or a combination of the two;
- for floor-standing equipment, the height of the support;
- the type of test facility to be used and the position of the radiating antennas;
- the type of antennas to be used;
- the frequency range, dwell time and frequency steps;
- the size and shape of the uniform field area;
- whether any partial illumination is used;
- the test level to be applied;
- the type(s) and number of interconnecting wires used and the interface port (of the EUT) to which these are to be connected;
- the performance criteria which are acceptable;
- a description of the method used to exercise the EUT.

The test procedures described in this clause are for the use of field generating antennas as defined in Clause 6.

Before testing the intensity of the calibrated field strength should be checked to verify that the test equipment/system is operating properly.

After the calibration has been verified, the test field can be generated using the values obtained from the calibration (see 6.2).

The EUT is initially placed with one face coincident with the calibration plane. The EUT face being illuminated shall be contained within the UFA unless partial illumination is being applied. See Clause 6.2 regarding field calibration and use of partial illumination.

The frequency ranges to be considered are swept with the signal modulated according to 5.1 and 5.2, pausing to adjust the RF signal level or to switch oscillators and antennas as necessary. Where the frequency range is swept incrementally, the step size shall not exceed 1 % of the preceding frequency value.

The dwell time of the amplitude modulated carrier at each frequency shall not be less than the time necessary for the EUT to be exercised and to respond, but shall in no case be less than 0,5 s. The sensitive frequencies (e.g., clock frequencies) shall be analyzed separately according to the requirements in product standards.

The test shall normally be performed with the generating antenna facing each side of the EUT. When equipment can be used in different orientations (i.e. vertical or horizontal) all sides shall be exposed to the field during the test. When technically justified, some EUTs can be tested by exposing fewer faces to the generating antenna. In other cases, as determined for example by the type and size of EUT or the frequencies of test, more than four azimuths may need to be exposed.

NOTE 1 As the electrical size of the EUT increases, the complexity of its antenna pattern also increases. The antenna pattern complexity can affect the number of test orientations necessary to determine minimum immunity.

NOTE 2 If an EUT consists of several components, it is not necessary to modify the position of each component within the EUT while illuminating it from different sides.

The polarization of the field generated by each antenna necessitates testing each selected side twice, once with the antenna positioned vertically and again with the antenna positioned horizontally.

Attempts shall be made to fully exercise the EUT during testing, and to interrogate all the critical exercise modes selected for the immunity test. The use of special exercising programmes is recommended.

9 Evaluation of test results

The test results shall be classified in terms of the loss of function or degradation of performance of the equipment under test, relative to a performance level defined by its manufacturer or the requestor of the test, or agreed between the manufacturer and the purchaser of the product. The recommended classification is as follows:

- a) normal performance within limits specified by the manufacturer, requestor or purchaser;
- b) temporary loss of function or degradation of performance which ceases after the disturbance ceases, and from which the equipment under test recovers its normal performance, without operator intervention;
- c) temporary loss of function or degradation of performance, the correction of which requires operator intervention;
- d) loss of function or degradation of performance which is not recoverable, owing to damage to hardware or software, or loss of data.

The manufacturer's specification may define effects on the EUT which may be considered insignificant, and therefore acceptable.

This classification may be used as a guide in formulating performance criteria, by committees responsible for generic, product and product-family standards, or as a framework for the agreement on performance criteria between the manufacturer and the purchaser, for example where no suitable generic, product or product-family standard exists.

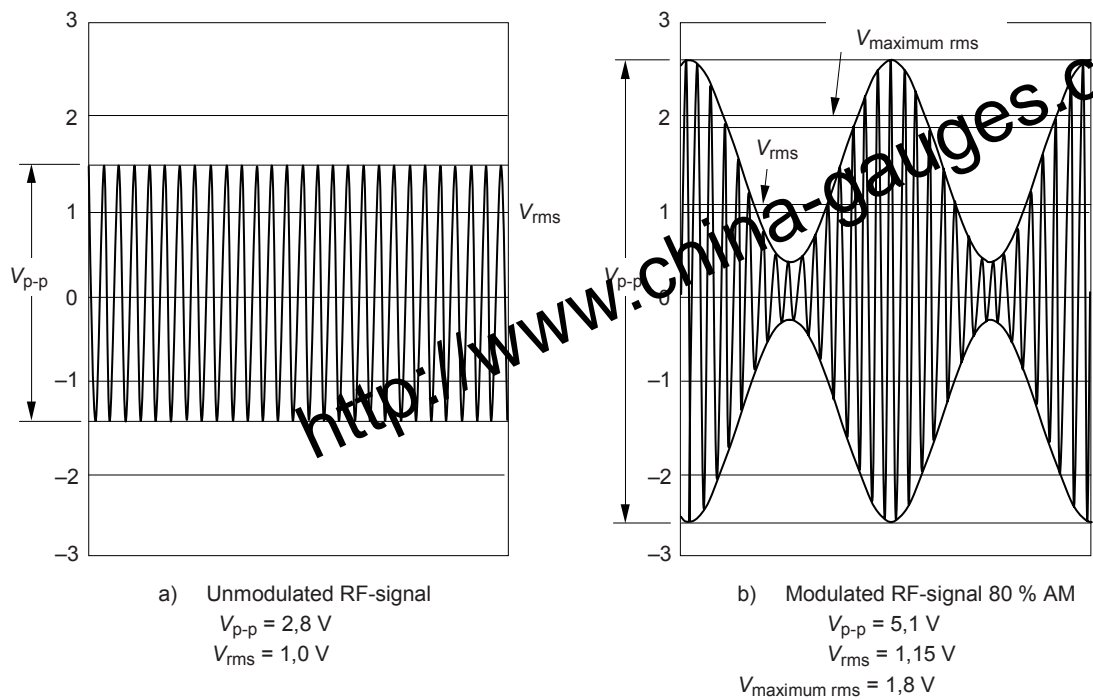
10 Test report

The test report shall contain all the information necessary to reproduce the test. In particular, the following shall be recorded:

- the items specified in the test plan required by Clause 8 of this standard;
- identification of the EUT and any associated equipment, for example, brand name, product type, serial number;

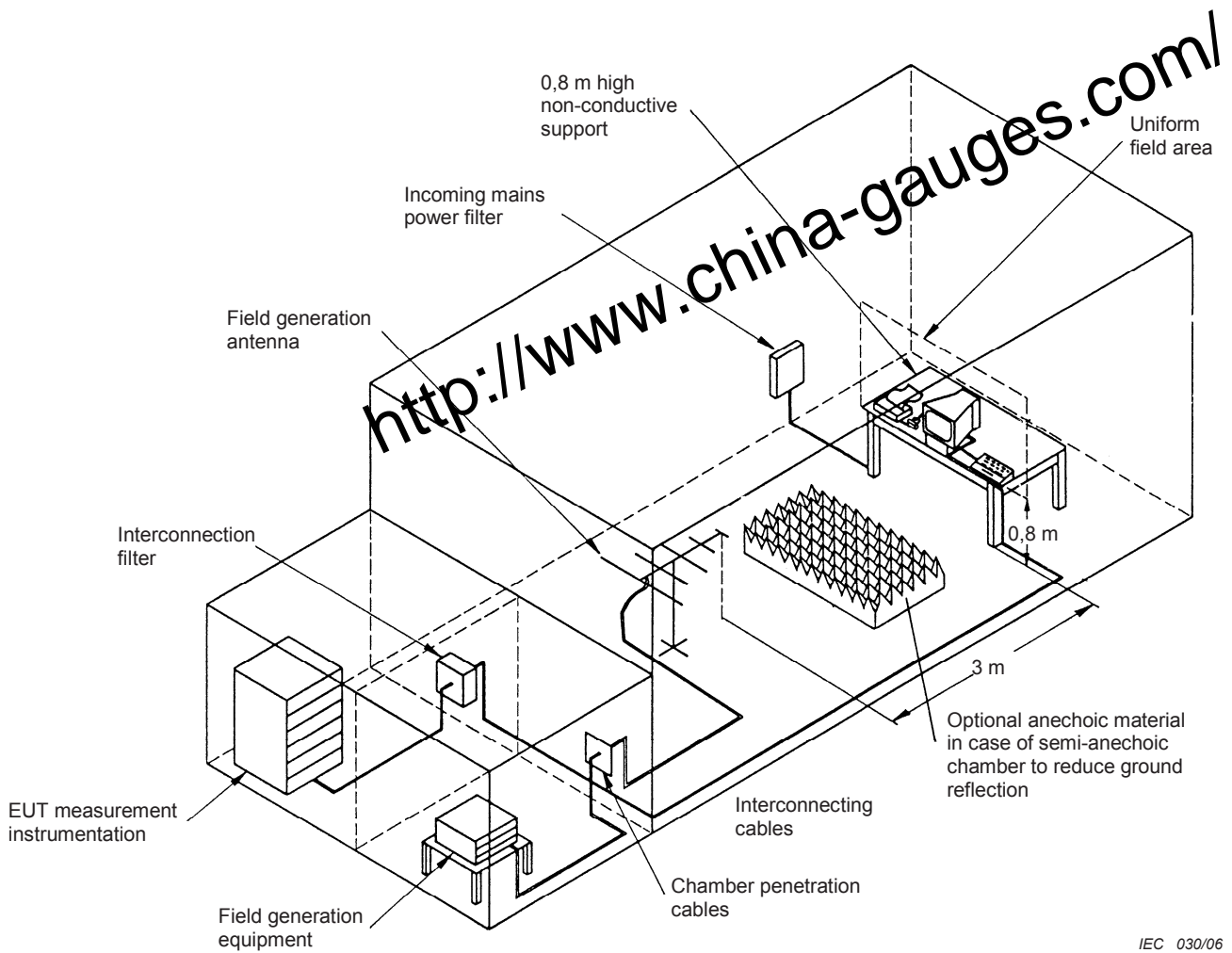
- identification of the test equipment, for example, brand name, product type, serial number;
- any special environmental conditions in which the test was performed;
- any specific conditions necessary to enable the test to be performed;
- performance level defined by the manufacturer, requestor or purchaser;
- performance criterion specified in the generic, product or product-family standard;
- any effects on the EUT observed during or after the application of the test disturbance, and the duration for which these effects persist;
- the rationale for the pass/fail decision (based on the performance criterion specified in the generic, product or product-family standard, or agreed between the manufacturer and the purchaser);
- any specific conditions of use, for example, cable length or type, shielding or grounding, or EUT operating conditions, which are required to achieve compliance;
- a complete description of the cabling and equipment position and orientation shall be included in the test report; in some cases a picture may be sufficient for that.

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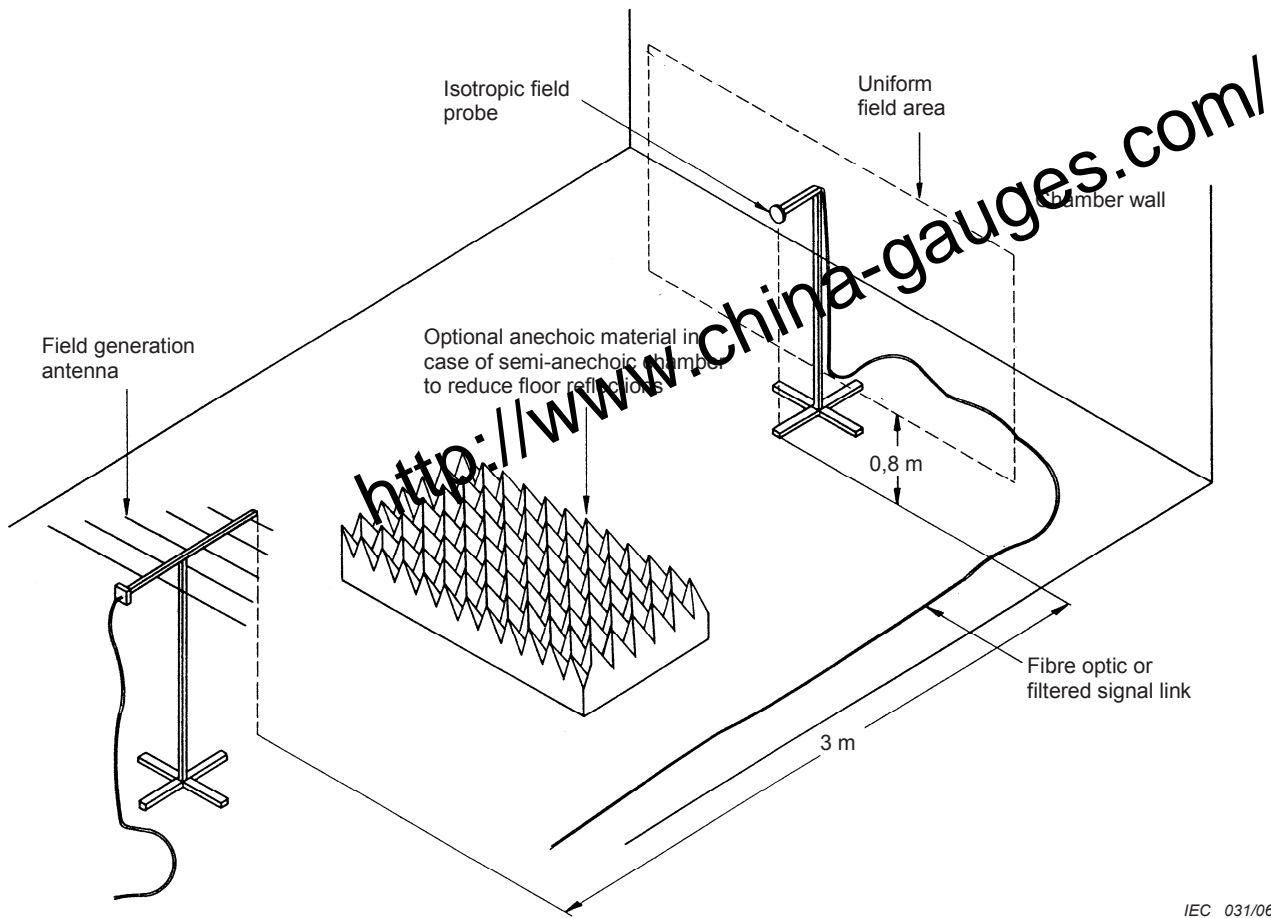
Figure 1 – Definition of the test level and the waveshapes occurring at the output of the signal generator



IEC 030/06

NOTE Anechoic lining material on walls and ceiling has been omitted for clarity.

Figure 2 – Example of suitable test facility



IEC 031/06

Figure 3 – Calibration of field

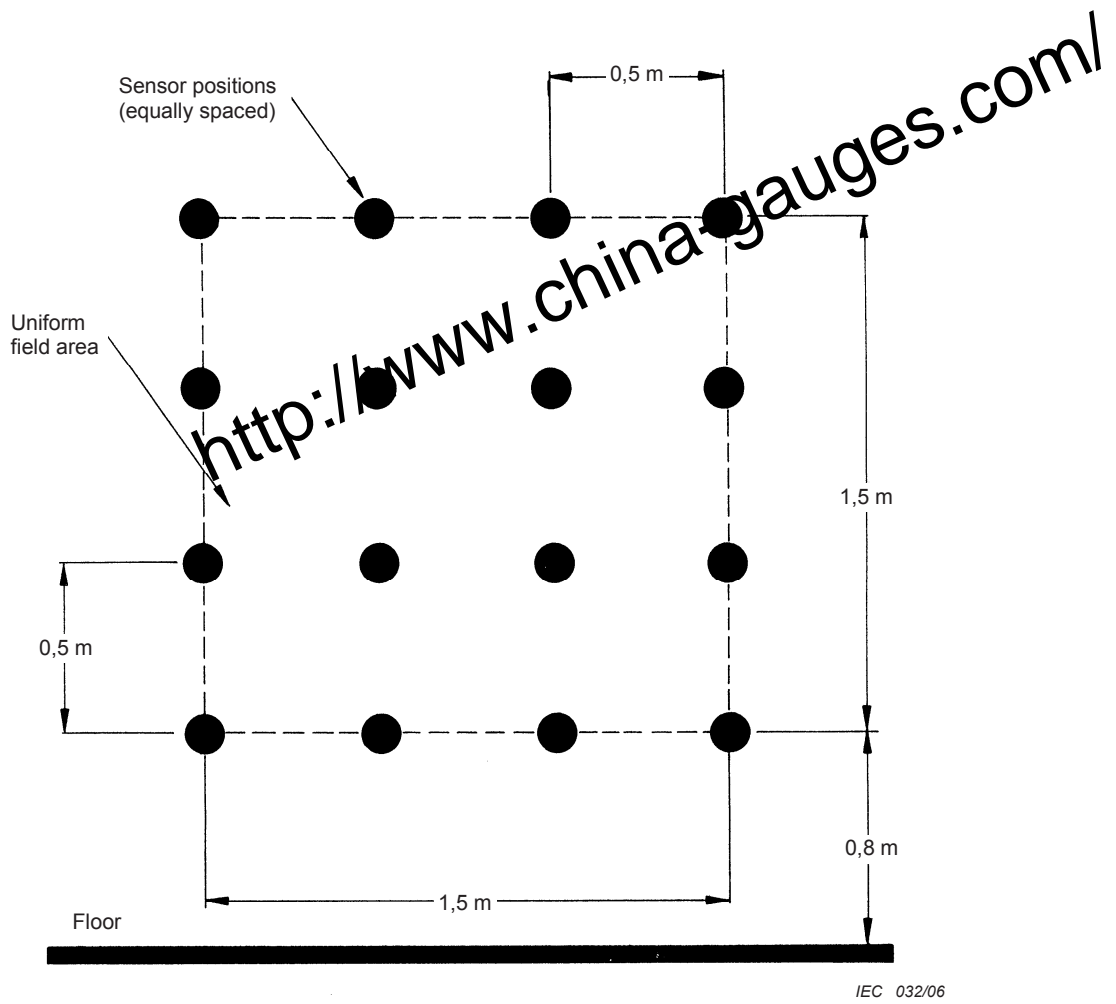
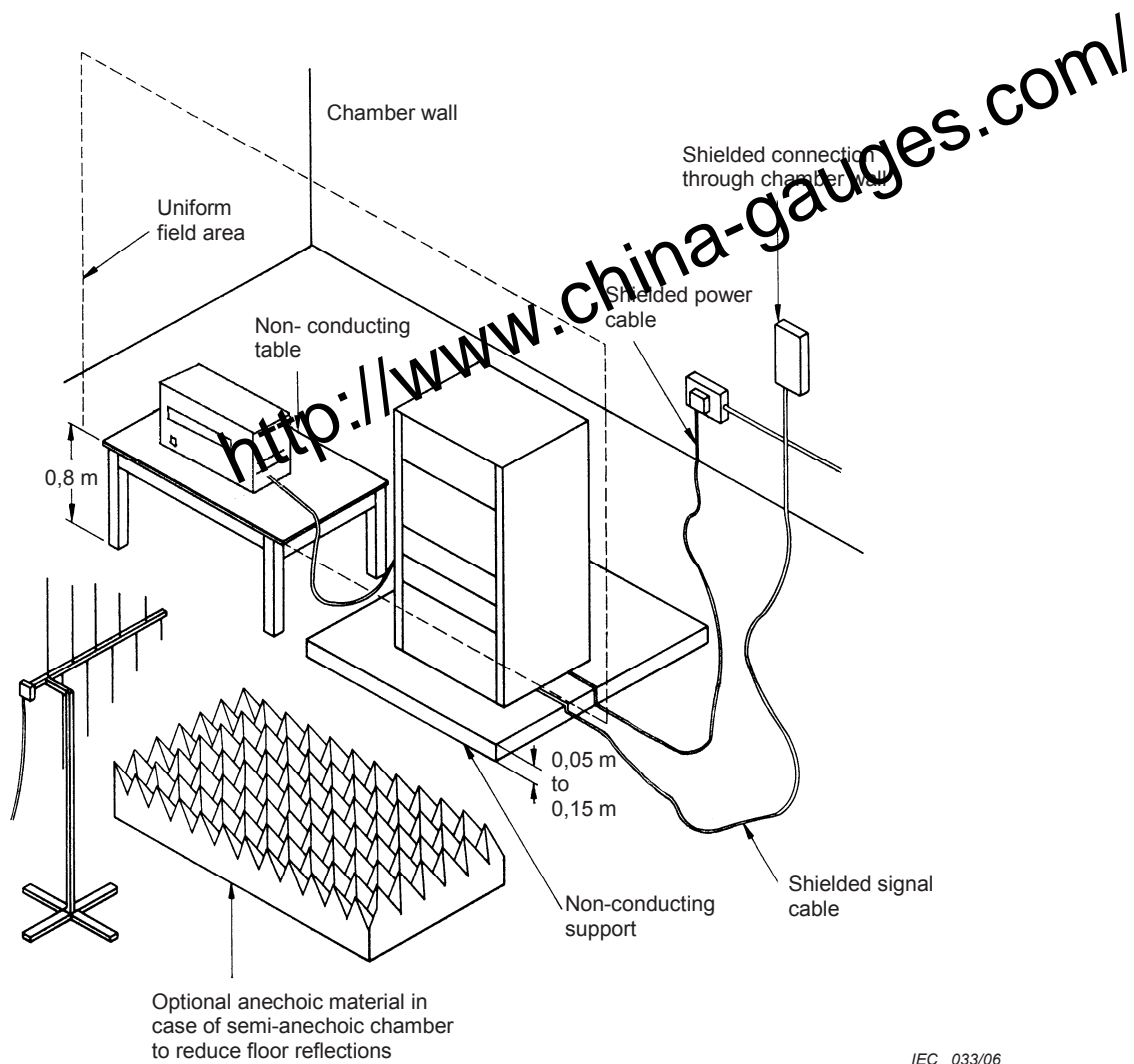


Figure 4 – Calibration of field, dimensions of the uniform field area



IEC 033/06

NOTE Anechoic lining material has been omitted from walls for clarity.

Figure 5 – Example of test setup for floor-standing equipment

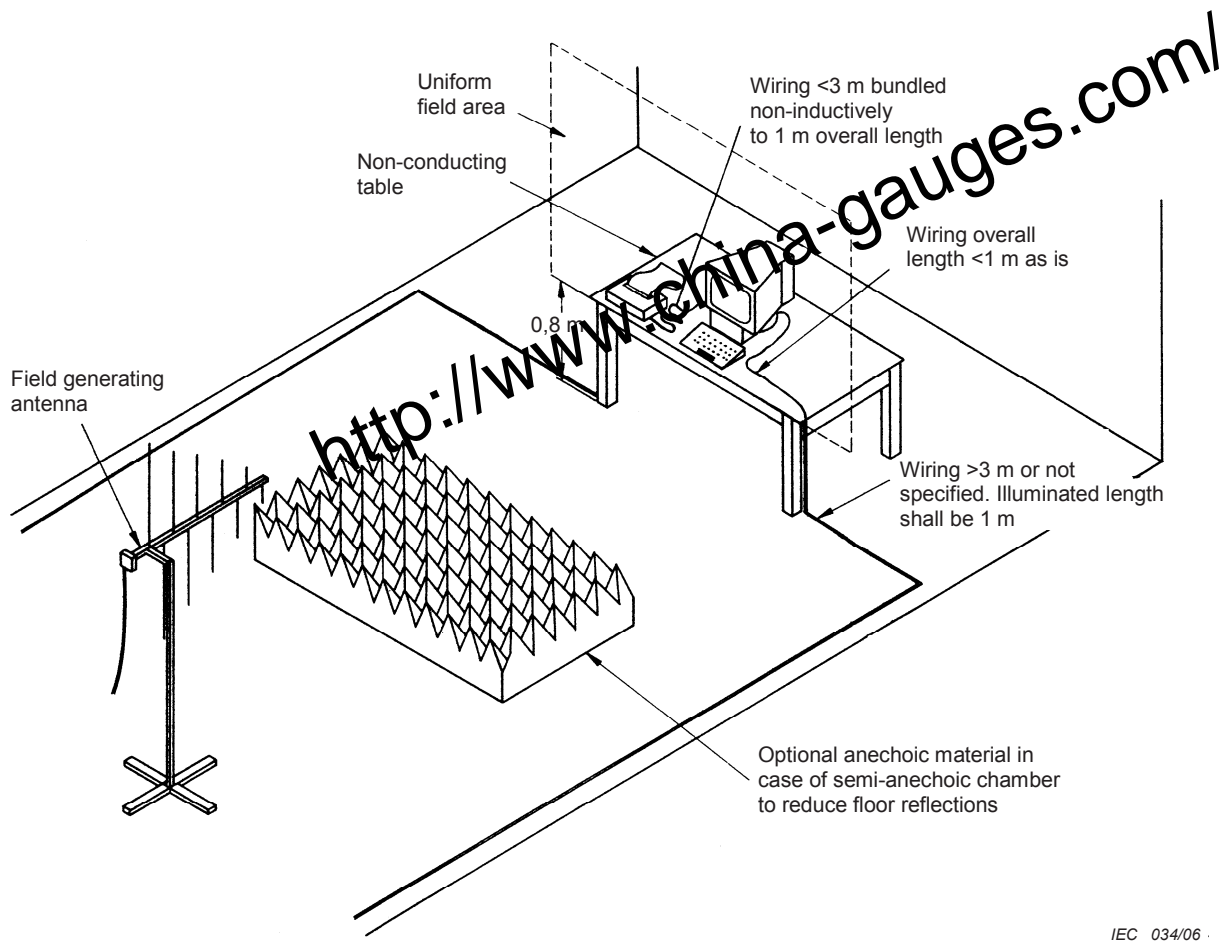
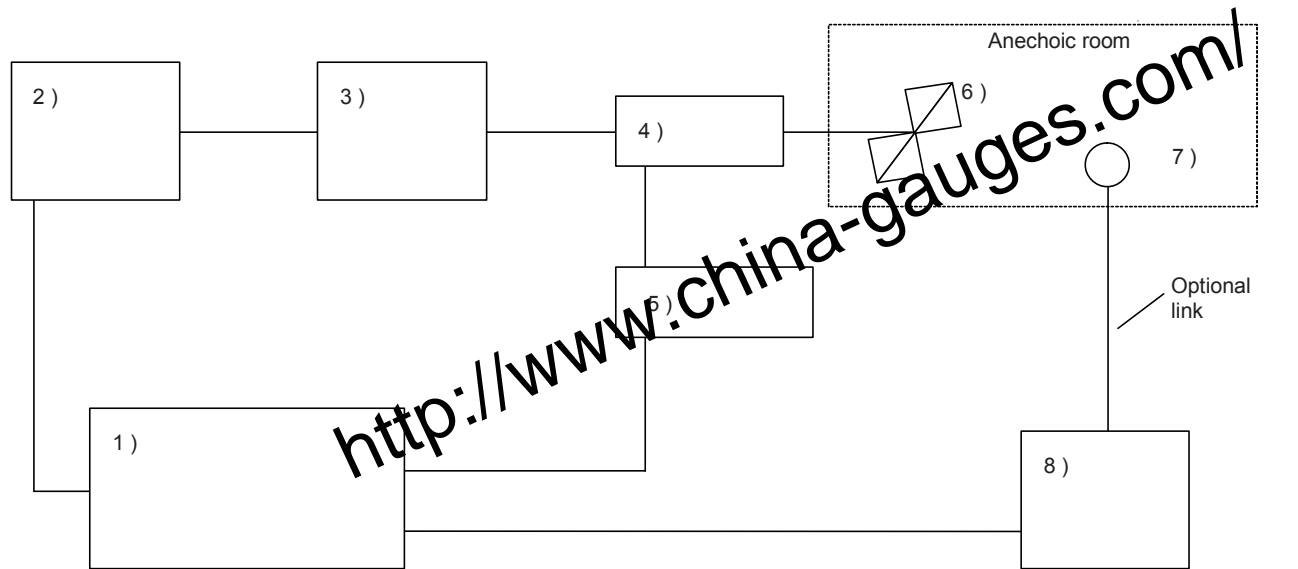


Figure 6 – Example of test setup for table-top equipment



IEC 035/06

- 1) Controller, for example PC
- 2) Signal generator
- 3) Power amplifier
- 4) Directional coupler ^a
- 5) Measuring instrument ^a
- 6) Transmitting antenna
- 7) Field sensor
- 8) Field meter

^a The directional coupler and power meter may be replaced by a forward power detector or monitor inserted between amplifier 3) and antenna 6).

Figure 7 – Measuring set-up

Annex A (informative)

Rationale for the choice of modulation for tests related to the protection against RF emissions from digital radio telephones

A.1 Summary of available modulation methods

The essential threat above 800 MHz comes from digital radio telephones using non-constant envelope modulation. During the development of this standard, the following modulation methods were considered for the electromagnetic field:

- sine wave amplitude modulation, 80 % AM at 1 kHz rate;
- square wave amplitude modulation, 1:2 duty cycle, 100 % AM at 200 Hz rate;
- pulsed RF signal approximately simulating the characteristics of each system, e.g. 1:8 duty cycle at 200 Hz for GSM, 1:24 duty cycle at 100 Hz for DECT portables, etc. (see Annex G for definitions of GSM and DECT);
- pulsed RF signal simulating exactly the characteristics of each system, e.g. for GSM: 1:8 duty cycle at 200 Hz plus secondary effects such as discontinuous transmission mode (2 Hz modulation frequency) and multi-frame effects (8 Hz frequency component).

The merits of the respective systems are summarised in Table A.1.

Table A.1 – Comparison of modulation methods

(see Annex G for definitions of GSM and DECT)

Modulation method	Advantages	Disadvantages
Sine wave AM	1 Experimentation has shown that good correlation may be established between the interfering effects of different types of non-constant envelope modulation provided the maximum RMS levels remains the same. 2 It is not necessary to specify (and measure) the rise time of the TDMA signal. 3 Used in this standard and EC 61000-4-6. 4 Field generation and monitoring equipment is readily available. 5 For analogue audio equipment, demodulation in the equipment under test produces an audio response which can be measured with a narrow band level meter, thereby reducing background noise. 6 Has already been shown to be effective at simulating the effects of other modulation types (e.g. FM, phase modulation, pulse modulation) at lower frequencies.	1 Does not simulate TDMA. 2 Slight over-test for second law receptors. 3 May miss some failure mechanisms.
Square wave AM	1 Similar to TDMA. 2 Can be applied universally. 3 May reveal "unknown" failure mechanisms (sensitive to the large rate of change of the RF envelope).	1 Does not exactly simulate TDMA. 2 Requires non-standard equipment to generate the signal. 3 Demodulation in EUT produces a broadband audio response which shall be measured with a broadband level meter, thereby raising background noise. 4 Necessary to specify the rise time.
Pulsed RF	1 Good simulation of TDMA. 2 May reveal "unknown" failure mechanisms (sensitive to the large rate of change of the RF envelope).	1 Requires non-standard equipment to generate the signal. 2 The details of the modulation need to be varied to match each of the different systems (e.g. GSM, DECT, etc.). 3 Demodulation in EUT produces a broadband audio response which shall be measured with a broadband level meter, thereby raising background noise. 4 Necessary to specify the rise time.

A.2 Experimental results

A series of experiments has been performed to assess the correlation between the modulation method used for the disturbing signal and the interference produced.

The modulation methods investigated were as follows:

- a) sine wave 80 % AM at 1 kHz;
- b) "GSM-like" pulsed RF, duty cycle 1:8 at 200 Hz;
- c) "DECT-like" pulsed RF, duty cycle 1:2 at 100 Hz (base station);
- d) "DECT-like" pulsed RF, duty cycle 1:24 at 100 Hz (portable).

Only one of the "DECT-like" modulations was used in each case.

The results are summarised in Tables A.2 and A.3.

Table A.2 – Relative interference levels ^a

Modulation method ^b		Sine wave 80 % AM at 1 kHz	"GSM-like" duty cycle 1:8 at 200 Hz	"DECT-like" duty cycle 1:24 at 100 Hz
↓ Equipment	↓ Audio response	dB	dB	dB
Hearing aid ^c	Unweighted 21 Hz – 21 kHz	0 ^d	0	–3
	A-weighted	0	–4	–7
Analogue telephone set ^e	Unweighted	0 ^d	–3	–7
	A-weighted	–1	–6	–8
Radio set ^f	Unweighted	0 ^d	+1	–2
	A-weighted	–1	–3	–7

^a The audio response to the disturbance is the interference level. A low interference level means a high-immunity level.

^b Important: the carrier amplitude is adjusted so that the maximum RMS value (see Clause 3) of the disturbing signal (exposure) is the same for all modulations.

^c The exposure is produced by an incident electromagnetic field at 900 MHz. The duty cycle for the DECT-like modulation is 1:2 instead of 1:24. The audio response is the acoustical output measured with an artificial ear connected via a 0,5 m PVC tube.

^d This case is chosen as the reference audio response, i.e. 0 dB.

^e The exposure is an RF current injected into the telephone cable at 900 MHz. The audio response is the audio-frequency voltage measured on the telephone line.

^f The exposure is an RF current injected into the mains cable at 900 MHz. The audio response is the audio output from the loudspeaker measured with a microphone.

Table A.3 – Relative immunity levels ^a

Modulation method ^b		Sine wave 80 % AM at 1 kHz	"GSM-like" duty cycle 1:8 at 200 Hz	"DECT-like" duty cycle 1:2 at 100 Hz
↓ Equipment	↓ Response	dB	dB	dB
TV set ^c	Noticeable interference	0 ^d	-2	-2
	Strong interference	+4	+1	+2
	Screen off	+19	+18	+19
Data terminal with RS232 interface ^e	Interference on the video screen	0 ^d	0	-
	Data errors	> +16	> +16	-
RS232 modem ^f	Data errors (injected on telephone interface)	0 ^d	0	0
	Data errors (injected on RS232 interface)	> +9	> +9	> +9
Regulated laboratory supply ^g	2 % error in DC output current	0 ^d	+3	+7
SDH cross connect ^h	Bit error threshold	0 ^d	0	-

^a The numbers in the table are a relative measure of the maximum RMS level (see Clause 3) of the disturbing signal (exposure) necessary to produce the same degree of interference with all modulations. A high decibel level means high immunity.

^b The disturbing signal is adjusted so that the same response (interference) is produced with all modulations.

^c The exposure is an RF current injected into the mains cable at 900 MHz. The response is the degree of interference produced on the screen. The assessment is rather subjective as the interference patterns are different for the different cases.

^d This case is chosen as the reference immunity level, i.e. 0 dB.

^e The exposure is an RF current injected into the RS232 cable at 900 MHz.

^f The exposure is an RF current injected into either the telephone or the RS232 cable at 900 MHz.

^g The exposure is an RF current at 900 MHz injected into the d.c. output cable.

^h SDH = synchronous digital hierarchy. The exposure is an incident electromagnetic field at 935 MHz.

The following items of digital equipment were tested using both sine wave AM and pulse modulation (duty cycle 1:2) at field strengths of up to 30 V/m:

- hand dryer with microprocessor control;
- 2 Mb modem with 75 Ω coaxial cable;
- 2 Mb modem with 120 Ω twisted pair cable;
- industrial controller with microprocessor, video display and RS485 interface;
- train display system with microprocessor;
- credit card terminal with modem output;
- digital multiplexer 2/34 Mb;
- Ethernet repeater (10 Mb/s).

All failures were associated with the analogue functions of the devices.

A.3 Secondary modulation effects

When trying to simulate exactly the modulation used in a digital radio telephone system, it is important not only to simulate the primary modulation but also to consider the impact of any secondary modulation which may be present.

For example, with GSM and DCS 1800, there are multi-frame effects caused by the suppression of a burst every 120 ms (thereby creating a frequency component at approximately 8 Hz). There may also be additional modulation at 2 Hz from the optional discontinuous transmission (DTX) mode.

A.4 Conclusion

It can be seen from the cases studied that the items tested responded to the disturbances independently of the modulation method used. When comparing the effects of different modulations, it is important to ensure that the same maximum RMS level of interfering signal is used.

Where significant differences existed between the effects of different modulation types, sine wave AM was always the most severe.

Where different responses are observed for sine wave modulation and TDMA, the product specific difference may be corrected by appropriate adjustment of the compliance criteria in the product standard.

In summary, sine wave modulation has the following advantages:

- narrow band detection response in analogue systems reducing background noise problems;
- universal applicability, i.e. no attempt to simulate the behaviour of the disturbing source;
- same modulation at all frequencies;
- always at least as severe as pulse modulation.

For the reasons stated above, the modulation method defined in this standard is 80 % AM sine wave. It is recommended that product committees change the modulation method only if there are specific reasons requiring a different type of modulation.

Annex B (informative)

Field generating antennas

B.1 Biconical antenna

This antenna consists of a coaxial balun and three-dimensional element which provide a broad frequency range and can be used both for transmitting and receiving. The antenna factor curve is a substantially smooth line, typically increasing with frequency.

The compact size of these antennas makes them ideal for use in restricted areas such as anechoic chambers as proximity effects are minimized.

B.2 Log-periodic antenna

A log-periodic antenna is an array of dipoles of different lengths connected to a transmission line.

These broadband antennas have a relatively high gain and low VSWR.

When choosing an antenna for the generation of fields, it should be established that the balun can handle the necessary power.

B.3 Horn antenna and double ridge wave guide antenna

Horn antennas and double ridge wave guide antennas produce linearly polarised electromagnetic fields. They are typically used at frequencies above 1 000 MHz.

Annex C (informative)

Use of anechoic chambers

C.1 General anechoic chamber information

A semi-anechoic chamber is a shielded enclosure having radio absorbing material on the walls and ceiling. Anechoic chambers also have such lining on the floor.

The purpose of this lining is to absorb the RF energy, preventing reflections back into the chamber. Such reflections, by interfering in a complex way with the directly radiated field, can produce maxima and minima in the intensity of the generated field.

The reflection loss of the absorbing material generally depends on the frequency of the incident wave and its angle to the normal. The loss (absorption) is typically greatest at normal incidence and decreases as the angle of incidence increases.

In order to break up reflections and enhance absorption, the absorbing material is often shaped into wedges or cones.

For semi-anechoic chambers, modification by the addition of extra RF absorbing material on the floor helps to achieve the required field uniformity at all frequencies. Experimentation will reveal the materials and positions for such additions.

The additional absorbing material should not be placed in the direct illumination path from the antenna to the EUT, but should be positioned in the identical location and orientation for testing as used during the calibration procedure.

Uniformity can also be improved by placing the field generating antenna off the axis of the chamber, such that any reflections are not symmetrical.

Anechoic chambers are less effective at low frequencies (below 30 MHz), whereas ferrite-lined chambers may also be less effective at frequencies above 1 GHz. Care shall be taken to ensure the uniformity of the generated field at the lowest and highest frequencies, and it may be necessary to rework the chamber.

C.2 Suggested adjustments to adapt for use at frequencies above 1 GHz ferrite-lined chambers designed for use at frequencies up to 1 GHz

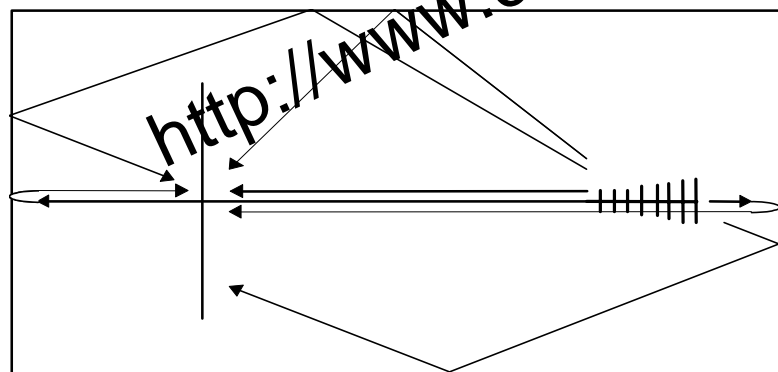
Most of the existing small anechoic chambers which use ferrite as an absorber are designed for use at frequencies up to 1 GHz. At frequencies above 1 GHz, it may be difficult or impossible for such chambers to satisfy the field uniformity requirement of 6.2 of this standard.

This paragraph presents information on the procedures to adapt such chambers for testing at frequencies above 1 GHz using the method described in Annex H.

C.2.1 Problems caused by the use of ferrite-lined chambers for radiated field immunity tests at frequencies above 1 GHz

The problem described below may occur, for example, in a small ferrite-lined anechoic chamber, or in a small (typically 7 m (l) \times 3 m (w) \times 3 m (h)) anechoic chamber lined with a combination of ferrite and carbon-loaded absorbers.

At frequencies above 1 GHz, the ferrite tiles usually behave as reflectors rather than as absorbers. It is very difficult to establish a uniform field over a $1,5\text{ m} \times 1,5\text{ m}$ area at these frequencies owing to multiple reflections from the inner surfaces of the chamber (see Figure C.1).



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Figure C.1 – Multiple reflections in an existing small anechoic chamber

At the frequencies of the radio telephone bands, the wavelength is shorter than 0,2 m. This means that test results are very sensitive to the positioning of the field-generating antenna and the field sensor or EUT.

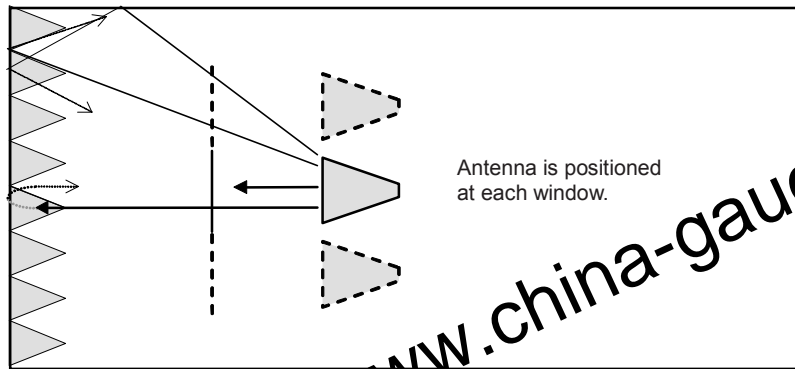
C.2.2 Possible solution

In order to solve existing problems, the following procedures are suggested.

- Use a horn antenna or a double-ridge wave guide antenna to reduce the field radiated backwards. This also decreases reflections from the side walls of the chamber because of the narrow beam width of the antenna.
- Shorten the distance between the transmitting antenna and EUT to minimize reflections from the side walls (the distance between the antenna and EUT can be reduced to 1 m). Use the method of $0,5\text{ m} \times 0,5\text{ m}$ independent windows (Annex H) to ensure that the EUT is exposed to a uniform field.
- Attach medium-loaded carbon type anechoic material to the rear wall facing the EUT to eliminate direct reflection. This reduces the sensitivity of the test to the positioning of the EUT and antenna. It also may improve field uniformity at frequencies below 1 GHz.

NOTE If a highly-loaded carbon type anechoic material is used, it may be difficult to satisfy the requirement for field uniformity at frequencies below 1 GHz.

Following the above procedures will eliminate most of the reflected waves (see Figure C.2).



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Figure C.2 Most of the reflected waves are eliminated

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Annex D (informative)

Amplifier non-linearity and example for the calibration procedure according to 6.2

D.1 Objective of limiting amplifier distortion

The goal is to keep amplifier non-linearity at a level low enough such that it does not dominate the uncertainty of the value of the field strength. Consequently, a guideline is given to assist test laboratories in understanding and limiting amplifier saturation effects.

D.2 Possible problems caused by harmonics and saturation

Overloading the amplifier may result in the following scenarios.

- a) The harmonics may contribute significantly to the field.
 - 1) If this occurs during calibration, the field strength at the intended frequency is incorrectly measured, as the broadband field probe will measure the fundamental and its harmonics. For example, assume that the third harmonic is 15 dB below the fundamental frequency at the antenna terminal and all other harmonics can be ignored. Further assume that the effective antenna factor is 5 dB lower at the frequency of the third harmonic than at the fundamental frequency. The field strength of the fundamental frequency will be only 10 dB larger than the field strength of the third harmonic. If a total field strength of 10 V/m is measured, the fundamental frequency will contribute 9,5 V/m. This is an acceptable error, as it is smaller than the field probe amplitude uncertainty.
 - 2) If harmonics are significantly present during a test, they may cause an EUT failure although the EUT is robust at the intended fundamental frequency but not robust at the harmonic frequency.
- b) Harmonics may also affect the test result, even if they are very well suppressed in special situations. For example, if a 900 MHz receiver is tested, even very weak harmonics of a 300 MHz signal may overload the receiver input. A similar scenario may also occur if the signal generator outputs non-harmonically-related signals.
- c) Saturation may be present without measurable harmonics. This occurs if the amplifier has a low pass output filter which suppresses the harmonics. This situation may also lead to incorrect results.
 - 1) If this occurs during calibration, wrong calibration data will be derived as the assumption of linearity is used in the algorithm described in 6.2.
 - 2) During a test, this type of saturation will lead to an incorrect modulation index and harmonics of the modulation frequency (usually 1 000 Hz).

From the examples given above, it is clear that a numerical limit for amplifier distortion can not be given, as the effect of distortion depends heavily on the type of EUT tested.

D.3 Options for controlling amplifier non-linearity

D.3.1 Limiting the harmonic content in the field

The harmonic content of the field can be limited with the use of an adjustable/tracking/tunable low-pass filter at the output of the amplifier.

For all frequencies where harmonics are produced at the output of the amplifier, the rejection of these harmonics in the field by more than 6 dB below the fundamental is adequate, with exception of the scenario discussed in D.2 b).

This would limit the field strength error to 10%. For example, a 10 V/m signal measured broadband would be caused by 9 V/m from the fundamental and 4,5 V/m from the harmonics. This is a situation which is acceptable for calibration uncertainty.

For amplifiers containing a fixed low-pass filter in their output, the upper fundamental frequency concerned is about 1/3 of the maximum specified frequency of the amplifier.

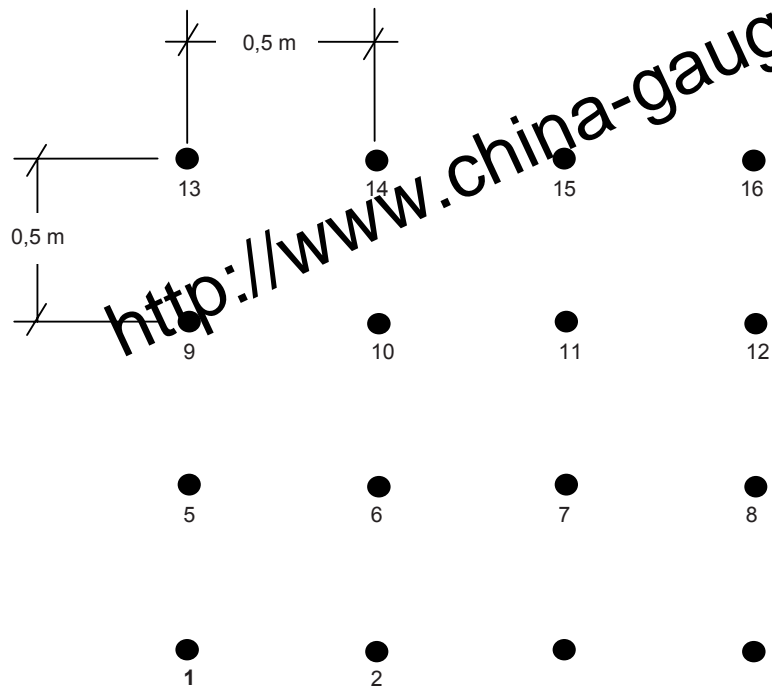
D.3.2 Measuring the harmonic content of the field

The harmonic content of the field can be either be measured directly using a selective field probe or indirectly by

- determining first the effective antenna factor (the ratio between input power and field strength for a given chamber and antenna position) and then the ratio between the forward powers at the fundamental frequency and the harmonics or
- with a coupler by taking account of the antenna factor at the harmonics as provided by the antenna manufacturer.

For situations in which a low pass filter suppresses harmonics of a saturated amplifier it is suggested under no circumstances (for example worst frequency, maximum field strength with modulation) to exceed the 2 dB compression point of the amplifier. At the 2 dB compression point, the peak amplitude (in voltage) would be reduced by 20 %. This would cause a reduction of the 80 % modulation index down to 64 %, in other words, a 20 % reduction of a voltage rectified within the EUT.

D.4 Examples showing the equivalence of the two calibration methods



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Figure D.1 – Measuring positions of the uniform field area

Figure D.1 shows the 16 positions where the field uniformity has to be measured. The distance between each of the 16 points has been fixed at 0,5 m.

D.4.1 Example for the calibration procedure using the constant field strength calibration method as described in 6.2.1

To create a constant field strength of $E_c = 6 \text{ V/m}$ (as an example) the following forward power values shown in Table D.1 have been measured at one particular frequency using the measuring setup according to Figure 7.

Table D.1 – Forward power values measured according to the constant field strength calibration method

Position	Forward power dBm
1	27
2	22
3	37
4	33
5	31
6	29
7	23
8	27
9	28
10	30
11	30
12	31
13	40
14	30
15	31
16	31

Table D.2 – Forward power values sorted according to rising value and evaluation of the measuring result

Position	Forward power dBm
2	22
7	23
1	27
8	27
9	28
6	29
10	30
11	30
14	30
5	31
12	31
15	31
16	31
4	33
3	37
13	40

NOTE
 Position 13 : $40 - 6 = 34$, only 2 positions comply.
 Position 3 : $37 - 6 = 31$, only 6 positions comply.
 Position 4 : $33 - 6 = 27$, 12 positions comply.

In this example the measuring points 2, 3, 7 and 13 lie outside the ${}_{+6}^{-0}$ dB criterion but at least (in this example) 12 out of 16 points are within the criterion. Thus, at this particular frequency, the criterion is fulfilled. In this case, the forward power to be applied is 33 dBm. This ensures that for the 12 points the field strength E_c is at least 6 V/m (position 4) and at most 12 V/m (positions 1 and 8).

D.4.2 Example for the calibration procedure using the constant power calibration method as described in 6.2.2

Point No. 1 has been chosen as a first calibration point, where a target field strength E_c of 6 V/m has been produced. At the same forward power, the following field strengths shown in Table D.3 have been recorded at one particular frequency using the measuring setup according to Figure 7.

Table D.3 – Forward power and field strength values measured according to the constant power calibration method

Position	Forward power dBm	Field strength V/m	Field strength dB relative to position 1
1	27	6,0	0
2	27	10,7	5
3	27	1,9	-13
4	27	3,0	-6
5	27	3,8	-4
6	27	4,8	-2
7	27	9,5	4
8	27	6,0	0
9	27	5,3	-1
10	27	4,2	-1
11	27	4,2	-3
12	27	3,8	-4
13	27	1,3	-13
14	27	4,2	-3
15	27	3,8	-4
16	27	3,8	-4

Table D.4 – Field strength values sorted according to rising value and evaluation of the measuring result

Position	Forward power dBm	Field strength V/m	Field strength dB relative to position 1
13	27	1,3	-13
3	27	1,9	-10
4	27	3,0	-6
5	27	3,8	-4
12	27	3,8	-4
15	27	3,8	-4
16	27	3,8	-4
10	27	4,2	-3
11	27	4,2	-3
14	27	4,2	-3
6	27	4,8	-2
9	27	5,3	-1
1	27	6,0	0
8	27	6,0	0
7	27	9,5	4
2	27	10,7	5

NOTE
Position 13 : $-13 + 6 = -7$, only 2 positions comply.
Position 3 : $-10 + 6 = -4$, only 6 positions comply.
Position 4 : $-6 + 6 = 0$, 12 positions comply.

In this example the measuring points 13, 3, 7 and 2 lie outside the $\begin{matrix} -0 \\ +6 \end{matrix}$ dB criterion but at least (in this example exactly) 12 out of 16 points are within the criterion. Thus at this particular frequency the criterion is fulfilled. In this case the forward power to be applied for the field strength $E_c = 6$ V/m is $27 \text{ dBm} + 20 \log(6 \text{ V/m}/3 \text{ V/m}) = 33 \text{ dBm}$. This ensures that for the 12 points the field strength E_c is at least 6 V/m (position 4) but in maximum 12 V/m (positions 1 and 8).

Annex E (informative)

Guidance for product committees on the selection of test levels

E.1 Introduction

The transmitted power of radio transmitters is often specified in terms of ERP (effective radiated power) referred to a half-wave dipole. Therefore, the generated field strength, for the far field, can be directly obtained by the following dipole formula:

$$E = k \sqrt{P} / d \quad (\text{Equation E.1})$$

where

E is the field strength (RMS value) (V/m);

k is a constant, with a value of 7, for free-space propagation in the far field;

P is the power (ERP) (W);

d is the distance from the antenna (m).

Nearby reflecting and absorbing objects alter the field strength.

If the ERP of the transmitter is not known, the power provided to the antenna may be used in Equation E.1 instead. In this case, a value of $k = 3$ is typically applicable for mobile radio transmitters.

E.2 Test levels related to general purposes

The test levels and the frequency bands are selected in accordance with the electromagnetic radiation environment to which the EUT can be exposed when finally installed. The consequences of failure should be borne in mind in selecting the test level to be applied. A higher level should be considered if the consequences of failure are significant.

If the EUT is to be installed at only a few sites, then an inspection of local RF sources will enable a calculation of field strengths likely to be encountered. If the powers of the sources are not known, it may be possible to measure the actual field strengths at the location(s) concerned.

For equipment intended for operation in a variety of locations, the following guidance may be used in selecting the test level to be applied.

The following classes are related to the levels listed in Clause 5; they are considered as general guidelines for the selection of the corresponding levels.

- *Class 1*: Low-level electromagnetic radiation environment. Levels typical of local radio/television stations located at more than 1 km, and transmitters/receivers of low power.

- *Class 2*: Moderate electromagnetic radiation environment. Low power portable transceivers (typically less than 1 W rating) are in use, but with restrictions on use in close proximity to the equipment. A typical commercial environment.
- *Class 3*: Severe electromagnetic radiation environment. Portable transceivers (2 W rating or more) are in use relatively close to the equipment but not less than 1 m. High power broadcast transmitters are in close proximity to the equipment and ISM equipment may be located close by. A typical industrial environment.
- *Class 4*: Portable transceivers are in use within less than 1 m of the equipment. Other sources of significant interference may be within 1 m of the equipment.
- *Class x*: x is an open level which might be negotiated and specified in the product standard or equipment specification.

E.3 Test levels related to the protection against RF emissions from digital radio telephones

The test levels should be selected in accordance with the expected electromagnetic field, i.e. considering the power of the radio telephone equipment and the likely distance between its transmitting antenna and the equipment to be tested. Usually, mobile stations will give rise to more severe requirements than base stations (because mobiles tend to be located much closer to potentially susceptible devices than base stations).

The cost for establishing the required immunity and the consequences of failure should be borne in mind when selecting the test level to be applied. A higher level should only be considered if the consequences of failure are large.

Higher exposures than the selected test level may occur in practice with a lower rate of occurrence. In order to prevent unacceptable failures in those situations, it may be necessary to perform a second test at a higher level and accept a reduced performance (i.e. defined degradation accepted).

Table E.1 gives examples of test levels, performance criteria and the associated protection distances. The protection distance is the minimum acceptable distance to a digital radio telephone, when testing has been performed at the stated test level. These distances are calculated from Equation E.1, using $k = 7$ and assuming testing is carried out with an 80 % sinusoidal AM.

Table E.1 – Examples of test levels, associated protection distances and suggested performance criteria

Test level	Carrier field strength V/m	Maximum RMS field strength V/m	Protection distance for			Performance criteria ^a	
			2W GSM m	8W GSM m	¼W DECT m	Example 1 ^b	Example 2 ^c
1	1	1,8	5,5	11	1,1	–	–
2	3	5,4	1,8	3,7	0,6	a	–
3	10	18	0,6	1,1	~ 0,2 ^d	b	a
4	30	54	~ 0,2 ^d	0,4	~ 0,1 ^d	–	b

^a According to Clause 9.
^b Equipment for which the consequences of failure are not severe.
^c Equipment for which the consequences of failure are severe.
^d At these and closer distances, the far field Equation E.1 is not accurate.

The following issues were considered when formulating the above table:

- for GSM, most terminals on the market today are of class 4 (maximum ERP 2 W). A substantial number of mobile terminals in operation are classes 3 and 2 (maximum ERP 5 W and 8 W, respectively). The ERP of GSM terminals is often lower than maximum except in areas of poor reception;
- the coverage indoors is worse than outdoors, which implies that the ERP indoors may more often than not adjust to the maximum of the class. This is the worst case situation from an EMC point of view since most of the victim equipment is also concentrated indoors;
- as described in Annex A, the immunity level of an item of equipment is well correlated with the maximum RMS value of the modulated field. For that reason, the maximum RMS field strength has been inserted into Equation E.1 instead of the carrier field strength to calculate the protection distance;
- the estimated minimum distance for safe operation, also called protection distance, has been calculated with $k = 7$ in Equation E.1 and does not take into account the statistical fluctuations of the field strength, due to reflections from walls, floor and ceiling, which are on the order of ± 6 dB;
- the protection distance according to Equation E.1 depends on the effective radiated power of the digital radio telephone and not on its operating frequency.

E.4 Special measures for fixed transmitters

The levels derived from the information in this Annex are typical values which are rarely exceeded in the described locations. At some locations these values will be exceeded e.g. radar installations, the proximity of high-power transmitters or ISM equipment located in the same building. In such cases, it may be preferable to shield the room or building and filter the signal and power wires to the equipment, rather than specify all equipment to be immune to such levels.

Annex F
(informative)

Selection of test methods

This standard and IEC 61000-4-6 define two methods for testing the immunity of electrical and electronic equipment against radiated electromagnetic energy.

In general, tests with conducted signals are more useful at lower frequencies, and tests with radiated signals more useful at higher frequencies.

There is a range of frequencies for which the test methods which appear in either standard are useable. It is possible to use the test method defined in IEC 61000-4-6 up to 230 MHz. It is also possible to use the test method defined in this part down to 26 MHz. The purpose of this annex is to provide a guide to product committees and product specification writers in the selection of the most appropriate test method to ensure repeatability, based on the design and type of EUT.

Consideration should be given to:

- the wavelength of the radiated field compared to the mechanical dimensions of the EUT;
- the relative dimensions of the cabinets and wires of the EUT;
- the number of wires and enclosures which constitute the EUT.

Annex G (informative)

Description of the environment

G.1 Digital radio telephones

Tables G.1, G.2 and G.3 list radio system parameters relevant to EMC.

The abbreviations and definitions listed hereafter are used in the aforementioned tables:

- **CDMA (Code Division Multiple Access)**: multiplexing where the transmitter encodes the signal using a pseudo-random sequence which the receiver also knows and can use to decode the received signal. Each different random sequence corresponds to a different communication channel;
- **CT-2 (Cordless Telephone, second generation)**: cordless telephone system, widely used in some European countries;
- **DCS 1800 (Digital Cellular System)**: cellular mobile telecommunication system, low cost, worldwide use;
- **DECT (Digital Enhanced Cordless Telecommunications)**: cordless cellular telecommunication system, low cost, widely used in Europe;
- **DTX (Discontinuous Transmission)**: significantly reduced burst repetition frequency, used for power saving, when no information needs to be transmitted;
- **ERP (Effective Radiated Power)**: effective radiated power referred to a half-wave dipole;
- **FDD (Frequency Division Duplex)**: multiplexing in which different frequencies are allocated to the transmit and receive channels;
- **FDMA (Frequency Division Multiple Access)**: multiplexing in which separate frequency bands are allocated to each channel;
- **GSM (Global System for Mobile Communications)**: cellular mobile telecommunication system, worldwide use;
- **HIPERLAN**: High performance radio local area network;
- **IMT-2000 (International Mobile Telecommunication 2000)**: 3rd generation cellular phone technology which according to the size and speed of transmissions, allow users to receive high quality colour video images;
- **NADC (North American Digital Cellular)**: digital cellular mobile communication system, widely used in North America. A popular term used to describe digital cellular systems that comply with Telecommunications Industry Association Interim Standard – 54; also known as D-AMPS;
- **PDC (Personal Digital Cellular System)**: cellular mobile telecommunication system, widely used in Japan;
- **PHS (Personal Handy Phone System)**: cordless telephone system, widely used in Japan;
- **RFID (Radio Frequency Identification)**: RFID systems include automatic article identification, asset tracking, alarm systems, personnel identification, access control, proximity sensors;

- **RTTT (Road Traffic & Transport Telematics)**: includes road toll systems.
- **TDMA (Time Division Multiple Access)**: see Clause 4;
- **TDD (Time Division Duplex)**: multiplexing in which different time slots are allocated to the transmit and receive channels.

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Table G.1 – Mobile and portable units

Parameters	System name									
	GSM	DCS 1800	DECT	CT-2	PDC	PHS	NADC	IMT-2000 TDD	IMT-2000 FDD	
Transmitter frequency range	890 MHz to 915 MHz	1,71 GHz to 1,784 GHz	1,88 GHz to 1,96 GHz	864 MHz to 868 MHz	940 MHz to 956 MHz and 1,429 GHz to 1,453 GHz	1,895 GHz to 1,918 GHz	825 MHz to 845 MHz	1 900 MHz to 1 920 MHz	1 920 MHz to 1 980 MHz	
Access Technique	TDMA	TDMA	TDMA/ TDD	FDMA/ TDD	TDMA	TDMA/ TDD	TDMA	CDMA/ TDMA	CDMA/ FDMA	
Burst repetition frequency	217 Hz	217 Hz	100 Hz	500 Hz	50 Hz	200 Hz	50 Hz	NA	NA	
Duty cycle	1:8	1:8	1:24 (also 1:48 and 1:12)	1:12	1:3	1:8	1:3	Continuous	Continuous	
Maximum ERP	0,8 W; 2 W; 5 W; 8 W; 20 W	0,25 W; 1 W; 4 W	0,25 W	<10 mW	0,8 W; 2 W	10 mW	<6 W	0,25 W	0,25 W	
Secondary modulation	2 Hz (DTX) and 0,16 Hz to 8,3 Hz (multi-frame)	2 Hz (DTX) and 0,16 Hz to 8,3 Hz (multi-frame)	None	None	None	None	None	None	None	
Geographical area	Worldwide	Worldwide	Europe	Europe	Japan	Japan	USA	Europe	Europe	

NOTE CT-3 is considered to be covered by DECT.

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Table G.2 – Base stations

Parameters	System name									
	GSM	DCS 1800	DECT	CT-2	PDC	PHS	NADC	IMT-2000 TDD	IMT-2000 FDD	
Transmitter frequency range	935 MHz to 960 MHz	1,805 GHz to 1,88 GHz	1,88 GHz to 1,96 GHz	864 MHz to 868 MHz	810 MHz to 826 MHz and 1,477 GHz to 1,501 GHz	1,895 GHz to 1,918 GHz	870 MHz to 890 MHz	1 900 MHz to 1 920 MHz	2 110 MHz to 2 170 MHz	
Access Technique	TDMA	TDMA	TDMA/TDD	FDMA/TDD	TDMA	TDMA/TDD	TDMA	CDMA/TDMA/TDD	CDMA/FDMA/FDD	
Burst repetition frequency	217 Hz	217 Hz	100 Hz	500 Hz	50 Hz	200 Hz	50 Hz	NA	NA	
Duty cycle	1:8 to 8:8	1:8 to 8:8	1:2	1:2	1:3 to 3:3	1:8	1:3 to 3:3	Continuous	Continuous	
Maximum ERP	2,5 W to 320 W	2,5 W to 200 W	0,25 W	0,25 W	1 W to 96 W	10 mW to 500 mW	500 W	20 W	20 W	
Secondary modulation	2 Hz (DTX) and 0,16 Hz to 8,3 Hz (multi-frame)	2 Hz (DTX) and 0,16 Hz to 8,3 Hz (multi-frame)	None	None	None	None	None	None	None	
Geographical area	Worldwide	Worldwide	Europe	Europe	Japan	Japan	USA	Europe	Europe	

NOTE CT-3 is considered to be covered by DECT.

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Table G.3 – Other RF devices

Parameters	System name					
	RFID	RTTT	Wideband data transmission systems and HIPERLANs	Wideband data transmission systems and HIPERLANs	Wideband data transmission systems and HIPERLANs	Non specific short range devices
Transmitter frequency in MHz	2 446 – 2 454	5 795 – 5 815	2 400 – 2 483,5	5 150 – 5 350	5 470 – 5 725	2 400 – 2 483,5 5 725 – 5 875
Modulation type	FHSS if more than 500 mW	None	FHSS	None	None	None
Maximum ERP	a) 500 mW b) 4 W	2 W or 8 W	100 mW and spectrum power density limitation	200 mW mean	1 W mean	10 mW 25 mW
Duty cycle	a) up to 100 % b) <15 % within 200 ms period	No restrictions	No restrictions	No restrictions	No restrictions	No restrictions
Channel spacing	None	5 MHz or 10 MHz within some frequency ranges	None	None	None	None
Geographical area	Worldwide	Worldwide	Worldwide	Worldwide	Worldwide	Worldwide

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Annex H (normative)

Alternative illumination method for frequencies above 1 GHz ("independent windows method")

H.1 Introduction

When testing at frequencies above 1 GHz, the test distance shall be 1 m when using the independent windows method (for example, the radio-telephone bands). Compliance with the field uniformity requirement shall be verified for the selected test distance.

NOTE 1 With a test distance of 1 m, using an antenna with a narrow beam width or a ferrite-lined chamber at frequencies above 1 GHz, it may be difficult to satisfy the field uniformity requirement over the 1,5 m × 1,5 m calibration area.

The alternative method for frequencies above 1 GHz divides the calibration area into a suitable array of 0,5 m × 0,5 m windows such that the whole area to be occupied by the face of the EUT is covered (see Figures H.1a and H.1b). The field uniformity shall be independently calibrated over each window (see Figure H.2), using the procedure given below. The field generating antenna shall be placed 1 m from the calibration area.

NOTE 2 Cable length and geometry are less critical at these high frequencies; therefore, the face area of the EUT is the determining factor for the size of the calibration area.

H.2 Calibration of field

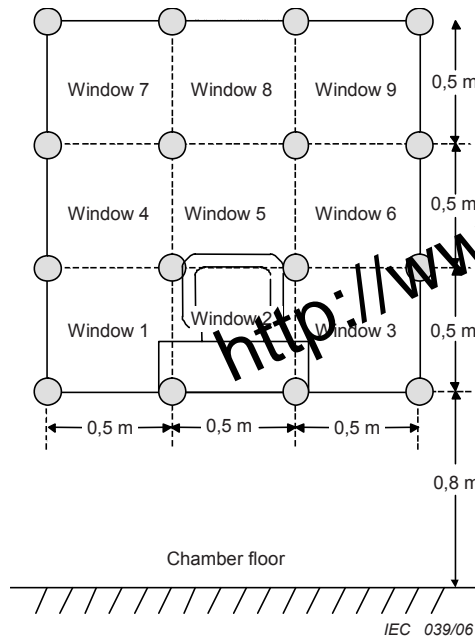
The following steps shall be performed on each window:

- a) position the field sensor at one of the four corners of the window;
- b) apply a forward power to the field generating antenna so that the field strength obtained is in the range 3 V/m to 10 V/m, through the frequency range in steps of 1 % of the starting frequency (and thereafter the preceding frequency) and record both (power and field strength) readings;
- c) with the same forward power, measure and record the field strength at the remaining three corners; all four field strengths shall lie within a range of 0 dB to 6 dB;
- d) take the location with the lowest field strength as reference (this ensures that the ${}^{-0}_{+6}$ dB requirement is met);
- e) forward power and the field strength being known, the necessary forward power for the required test field strength can be calculated (for example if, at a given point, 80 W gives 9 V/m, then 8,9 W is needed for 3 V/m). The calculation shall be recorded;
- f) repeat steps a) to e) for both horizontal and vertical polarizations.

The antennas and cables used for this uniform field calibration shall be used for testing. Therefore, the cable losses and the antenna factors of the field-generating antennas do not have to be taken into consideration.

The position of the generating antennas and cables shall be recorded as precisely as possible. Since even small displacements will significantly affect the field, the same positions shall be used for testing.

During the test, at each frequency the forward power established in step e) above shall be applied to the field-generating antenna. The test shall be repeated with the field-generating antenna repositioned to illuminate each of the required windows in turn (see Figures H.1 and H.2).

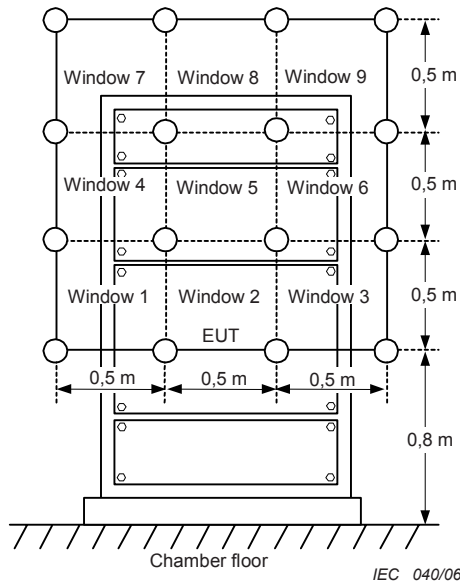


Concept of windows

1. Divide the calibration area into 0,5 m × 0,5 m windows.
2. Calibration is required for all windows intended to be occupied by the face of the actual EUT and cables.

(In this example, windows 1 to 3 and 5 are used for calibration and test)

Figure H.1a – Example of division for table-top equipment



Concept of windows

1. Divide the calibration area into 0,5 m × 0,5 m windows.
2. Calibration is required for all windows intended to be occupied by the face of the actual EUT and cables.

(In this example, windows 1 to 9 are used for calibration and test)

Figure H.1b – Example of division for floor-standing equipment

Figure H.1 – Examples of division of the calibration area into 0,5 m × 0,5 m windows

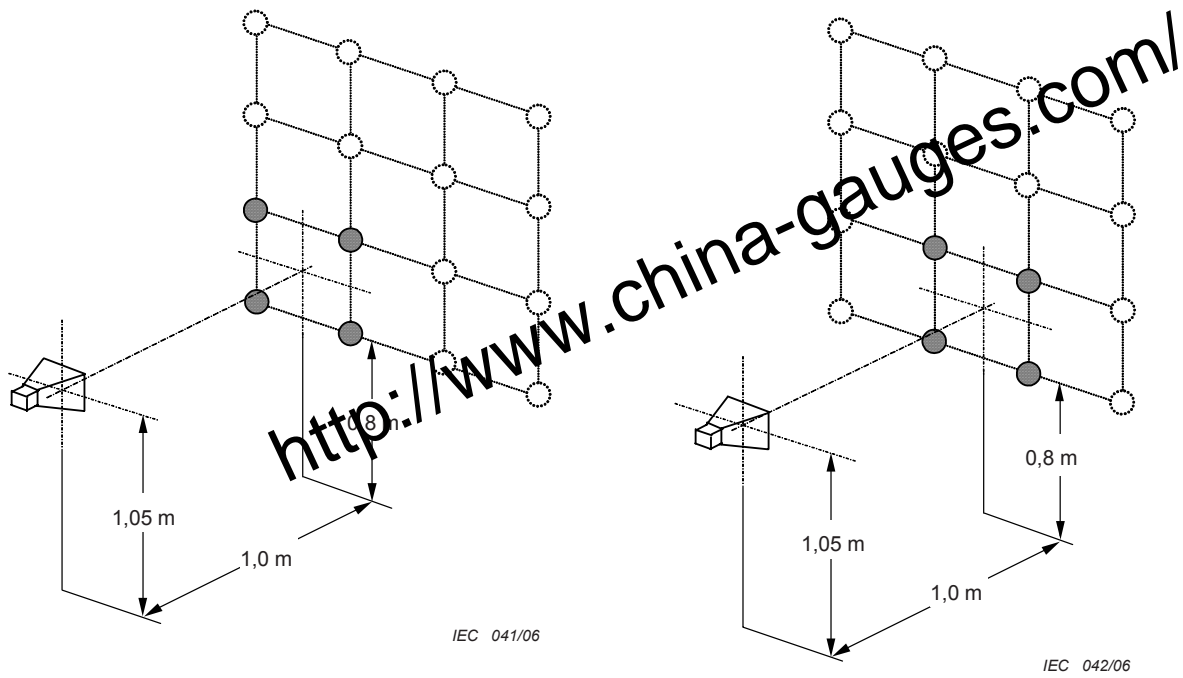


Figure H.2 – Example of illumination of successive windows

Annex I
(informative)

Calibration method for E-field probes

I.1 Overview

E-field probes with broad frequency range and large dynamic response are extensively used in the field uniformity calibration procedures in accordance with IEC 61000-4-3. Among other aspects, the quality of the field probe calibration directly impacts the uncertainty budget of a radiated immunity test.

Generally, probes are subjected to relatively low field strengths, e.g. 1 V/m – 30 V/m, during the field uniformity calibration in accordance with IEC 61000-4-3. Therefore a calibration of the E-field probes used within IEC 61000-4-3 shall take the intended frequency and dynamic ranges into consideration.

Currently probe calibration results may show differences when the probe is calibrated in different calibration laboratories. Therefore the environment and method for a field probe calibration are to be specified. This annex provides relevant information on calibration of probes to be used in IEC 61000-4-3.

For frequencies above the several hundred megahertz to gigahertz range, using standard gain horn antennas to establish a standard field inside an anechoic chamber is one of the most widely used methods for calibrating probes for IEC 61000-4-3 applications. However, there is a lack of an established method for validating the test environment for field probe calibrations.

In using this method, differences have been observed between calibration laboratories, beyond their reported measurement uncertainties.

Field probe calibrations in the 80 MHz to a few hundred megahertz range that are usually carried out in TEM waveguides are generally found to be more reproducible.

This informative annex therefore concentrates on improving the probe calibration procedures with horn antennas in anechoic chambers to which a comprehensive calibration procedure is depicted.

I.2 Probe calibration requirements

I.2.1 General

The calibration of E-Field probes intended to be used for UFA calibration procedure as defined in IEC 61000-4-3 shall satisfy the following requirements.

I.2.2 Calibration frequency range

The frequency range shall normally cover 80 MHz to 6 GHz but it may be limited to the frequency range required by the tests.

I.2.3 Frequency steps

To be able to compare test results between different calibration laboratories, it is necessary to use fixed frequencies for the calibration. ^(A1)

A1 80 MHz to 1 GHz:

Use the following frequencies for the calibration of E-field probes (typically 50 MHz step width)

80, 100, 150, 200, ..., 950, 1 000 MHz

1 GHz to 6 GHz:

Use the following frequencies for the calibration of E-field probes (200 MHz step width)

1 000, 1 200, 1 400, ..., 5 800, 6 000 MHz

NOTE It is not intended to measure a probe at 1 GHz twice, but in case it is used up to or from 1 GHz, the probe needs to be measured at that frequency.

I.2.4 Field strength

The field strength at which a probe is calibrated should be based on the field strength required for the immunity test. As the preferred method for uniformity field calibration is carried out at field strength of at least 1,8 times the field strength to be applied to the EUT, it is recommended that the probe calibration be carried out at twice the intended test field strength (see Table I.1). If a probe is to be used at different field levels, it has to be calibrated at multiple levels according to its linearity, at least the minimum and maximum levels. See also I.3.2.

NOTE 1 This also covers the 1 dB compression requirement of the power amplifier.

NOTE 2 The calibration is performed using CW signals without modulation.

Table I.1 – Calibration field strength level

Calibration level	Calibration field strength
1	2 V/m
2	6 V/m
3	20 V/m
4	60 V/m
X	Y V/m

NOTE X,Y is an open calibration level which can be higher or lower than one of the other levels 1-4. This level may be given in the product specification or test laboratory.

I.3 Requirements for calibration instrumentation

I.3.1 Harmonics and spurious signals

Any harmonics or spurious signals from the power amplifiers shall be at least 20 dB below the level at the carrier frequency. This is required for all field strength levels used during calibration and linearity check. Since the harmonic content of power amplifiers is usually worse at higher power levels, the harmonic measurement may be performed only at the highest calibration field strength. The harmonic measurement can be performed using a calibrated spectrum analyzer which is connected to the amplifier output through an attenuator, or through a directional coupler.

NOTE 1 The antenna may have additional influence on harmonic content and may need to be checked separately.

Calibration laboratories shall perform a measurement to validate that the harmonic and/or spurious signals from the amplifier satisfy the requirements for all measurement setups. This **A1**

A1 may be done by connecting a spectrum analyzer to Port 3 of the directional coupler (replacing the power meter sensor with the spectrum analyzer input – see Figure I.2).

NOTE 2 It should be assured that the power level does not exceed the maximum allowable input power of the spectrum analyzer. An attenuator may be used.

The frequency span shall cover at least the third harmonic of the intended frequency. The validation measurement shall be performed at the power level that will generate the highest intended field strength.

Harmonic suppression filters may be used to improve the spectrum purity of the power amplifier(s) (see Annex D).

I.3.2 Linearity check for probe

The linearity of the probe when used for the chamber validation according to I.4.2.5 shall be within $\pm 0,5$ dB from an ideal linear response in the required dynamic range (see Figure I.1). Linearity shall be confirmed for all intended range settings if the probe has multiple ranges or gain settings.

In general probe linearity does not change significantly with frequency. Linearity checking can be performed at a spot frequency that is close to the central region of the intended use of frequency range, and where the probe response versus frequency is relatively flat. The selected spot frequency is to be documented in the calibration certificate.

The field strength for which the linearity of the probe is measured should be within -6 dB to $+6$ dB of the field strength which is used during the validation of the chamber, with a sufficiently small step size, e.g. 1 dB. Table I.2 shows an example of the field strength levels to be checked for a 20 V/m application.

Table I.2 – Example for the probe linearity check

Signal level dB	Calibration field strength V/m
-6,0	13,2
-5,0	14,4
-4,0	14,8
-3,0	15,2
-2,0	16,3
-1,0	18,0
0	20,0
1,0	22,2
2,0	24,7
3,0	27,4
4,0	30,5
5,0	34,0
6,0	38,0

A1

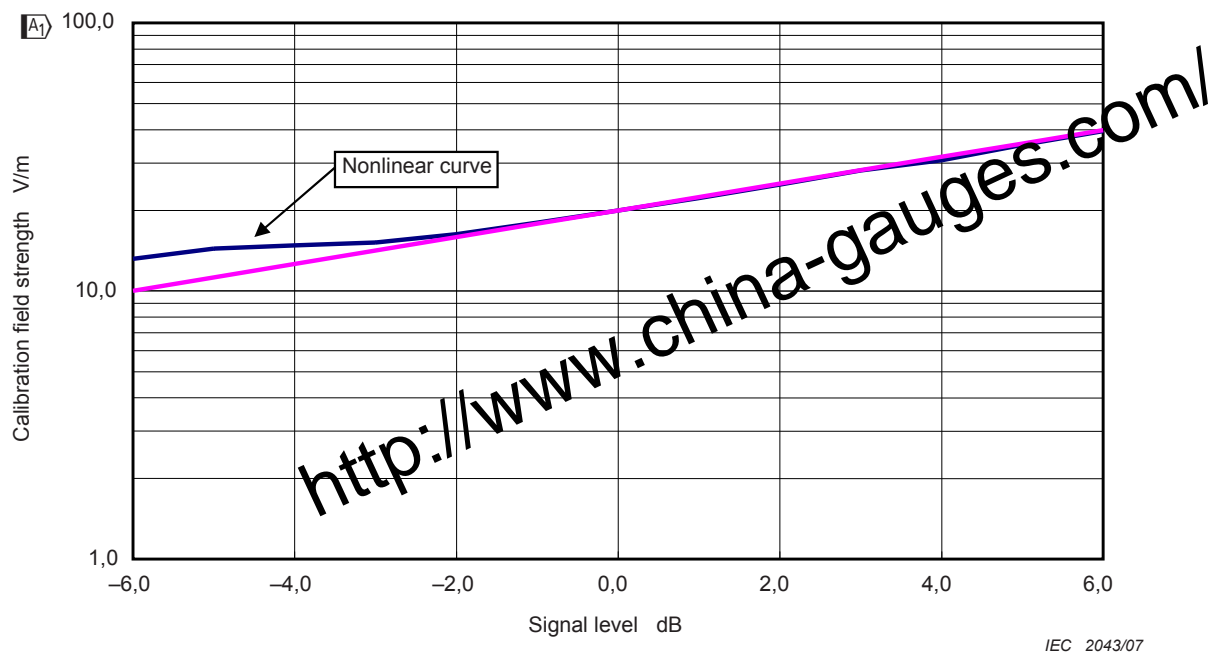


Figure I.1 – Example of linearity for probe

I.3.3 Determination of the gain of the standard horn antennas

Far field gain of the standard pyramidal horn antennas can be determined fairly accurately (less than 0,1 dB of uncertainties have been reported in [1]¹). The far-field gain is typically valid for distances greater than $8D^2 / \lambda$ (where D is the largest dimension of the horn aperture, and λ is the wavelength). Calibrations of field probes at such distances may not be practical due to the large anechoic chamber and high power amplifiers required. Field probes are typically calibrated in the near field region of the transmitting antennas. The near-field gain of standard gain horn antennas have been determined by using equations such as those described in [2]. The gain is computed based on the physical dimensions of a standard pyramidal horn, and by assuming a quadratic phase distribution at the horn aperture. The gain determined in this manner is inadequate for use in performing the chamber VSWR test and subsequent probe calibrations.

The equations (as given in [2]) were derived using aperture integration, by assuming that no reflection occurs at the aperture of the horn and that the field incident on the aperture is a TE₁₀ mode, but with a quadratic phase distribution across the aperture. Some approximations were applied during the integration to obtain the close form result. Other effects such as multiple reflections from the horn edge, and higher order modes at the aperture are not accounted for. Depending on the frequency and horn design, the error is generally in the order of $\pm 0,5$ dB, but can be larger.

For better accuracy, a numerical method using full wave integration can be used. For example, the uncertainties in the gain calculation by a numerical method can be reduced to less than 5 % [3].

The gain of a horn antenna can also be determined experimentally. For example, the gain can be determined at reduced distances with a three-antenna method by an extrapolation technique, such as that described in [4], or some variations of the method. $\overline{A_1}$

¹) Figures in square brackets refer to the reference documents in Clause I.6.

[A1] It is recommended that the distance between the horn antenna and the probe under test be at least $0,5D^2 / \lambda$ during the calibration. Large uncertainties in determining gains can result from a closer distance. The standing waves between the antenna and the probe can also be large for closer distances, which again would result in large measurement uncertainties in the calibration.

I.4 Field probe calibration in anechoic chambers

I.4.1 Calibration environments

The probe calibration should be performed in a fully anechoic room (FAR) or in a semi-anechoic chamber with absorbers on the ground plane which satisfies the requirement of I.4.2.

When a FAR is used, the recommended minimum size of the FAR internal working volume for performing the probe calibration is 5 m (D) × 3 m (W) × 3 m (H).

NOTE 1 For frequencies above several hundred MHz, using standard gain horn antennas to establish a standard field inside an anechoic chamber is one of the most widely used methods for calibrating field probes for IEC 61000-4-3 applications. At lower frequencies, such as 80 MHz to several hundred MHz, the use of an anechoic chamber may not be practical. So the field probe may be calibrated in other facilities also used for immunity tests against electromagnetic fields. Therefore, TEM waveguides etc. are included in this annex as alternative calibration environments for these lower frequencies.

The system and the environment used for probe calibration shall meet the following requirements.

NOTE 2 Alternatively, the electric field can be established using a transfer probe (see I.5.4).

I.4.2 Validation of anechoic chambers for field probe calibration

The probe calibration measurements assume a free space environment. A chamber VSWR test using a field probe shall be performed to determine whether it is acceptable for subsequent probe or sensor calibration. The validation method characterizes the performance of the chamber and absorbing material.

Each probe has a specific volume and physical size, for example the battery case and/or the circuit board. In other calibration procedures, a spherical quiet zone is guaranteed in the calibration volume. The specific requirements of this annex concentrate on a VSWR test for test points located at the antenna beam axes.

Test fixtures and their influences (such as the fixtures to hold the probe, which may be exposed to electromagnetic fields and interfere with the calibration) cannot be entirely evaluated. A separate test is required to validate the influences of the fixtures.

I.4.2.1 Measuring net power to a transmitting device using directional couplers

Net power delivered to a transmitting device can be measured with a 4-port bi-directional coupler, or two 3-port single directional couplers connected back-to-back (forming the so-called “dual directional coupler”). A common setup using a bi-directional coupler to measure the net power to a transmitting device is shown in Figure I.2. **[A1]**

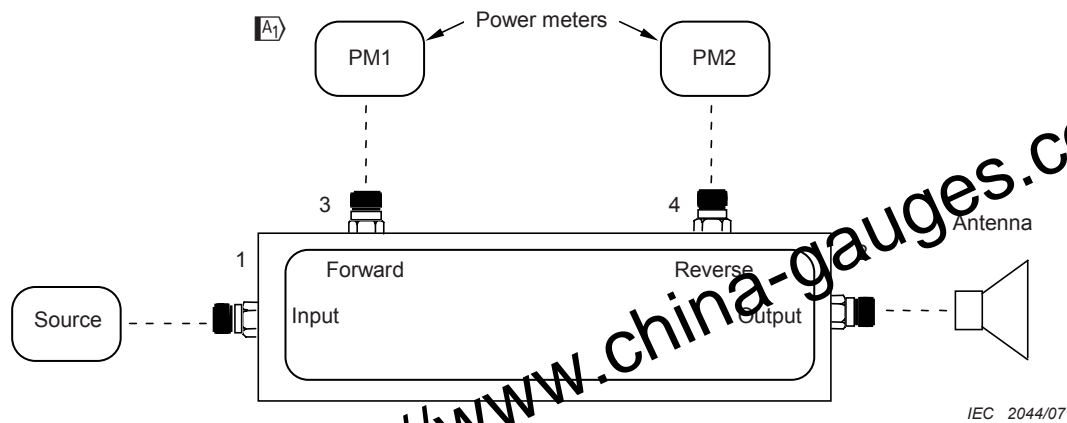


Figure I.2 – Setup for measuring net power to a transmitting device

The forward coupling, reverse coupling and transmission coupling are defined as the following equations in case where each port is connected with a matched load and a matched source:

$$C_{\text{fwd}} = \frac{P_3}{P_1},$$

$$C_{\text{rev}} = \frac{P_4}{P_2},$$

$$C_{\text{trans}} = \frac{P_2}{P_1},$$

where P_1, P_2, P_3, P_4 are the respective powers at each port of the directional coupler.

The net power delivered to the transmitting device is then:

$$P_{\text{net}} = \frac{C_{\text{trans}}}{C_{\text{fwd}}} PM_1 - \frac{PM_2}{C_{\text{rev}}},$$

where PM_1 and PM_2 are the power meter readings in linear units.

Where the VSWR of the antenna is known, then a single three-port coupler can be used. For example, when the antenna has a VSWR of 1,5 this is equivalent to a voltage reflection coefficient (VRC) of 0,2.

The accuracy is affected by the directivity of the coupler. The directivity is a measure of the coupler's ability to isolate the forward and the reverse signals. For a well-matched transmitting device, the reverse power is much smaller than the forward power. The effect of the directivity is therefore less important than in a reflectivity application. For example, when the transmitting antenna has a VSWR of 1,5 and the coupler has a directivity of 20 dB, the absolute maximum uncertainty in the net power due to the finite directivity is 0,22 dB – 0,18 dB = 0,04 dB with a U-shaped distribution (where the 0,22 dB is the loss of the apparent incident power due to VSWR of 1,5).

The net power delivered to the transmitting device is then:

$$P_{\text{net}} = C_{\text{fwd}} PM_1 (1 - VRC^2) \quad \text{A1}$$

A1 I.4.2.2 Establishing a standard field using horn antennas

The gain of the horn antenna is determined by the methods described in I.3.3. The on-axis electric field (in V/m) is determined by

$$E = \sqrt{\frac{\eta_0 P_{\text{net}} g}{4\pi}} \frac{1}{d},$$

where $\eta_0 = 377 \Omega$ for free space, P_{net} (in W) is the net power determined by the method described in I.4.2.1, g is the numeric gain of the antenna determined by I.3.3 and d (in m) is the distance from the antenna aperture.

I.4.2.3 Chamber validation test frequency range and frequency steps

The chamber VSWR test shall cover the frequency range for which the calibration of the probe is intended, and use the same frequency steps as given in I.2.3.

VSWR tests shall be carried out in the chamber at the lowest and highest frequencies of operation of each antenna. Where narrow band absorbers are used, e.g. ferrites, more frequency points may need to be measured. The chamber should be used for probe calibration only in the frequency range where it meets the VSWR criteria.

I.4.2.4 Chamber validation procedure

The chamber used for the probe calibration shall be verified by the following procedure, except in cases where the physical conditions of the chamber do not allow it to be used. In such cases the alternative method of I.4.2.7 can be applied.

The probe shall be located at the measurement position using a support material with a low permittivity (e.g. styrene foam) in accordance with Figure I.3 and Figure I.4.

A field probe is placed at the location where it will be used for calibration. Its polarization and position along the boresight of the transmitting horn antenna will be varied to determine the chamber VSWR. The transmit antenna shall be the same for both the chamber VSWR test and the probe calibration.

The arrangements of the standard gain horn antenna and the probe inside the chamber are shown in Figure I.3. The probe and the horn antenna shall be set on the same horizontal axis with a separation distance L measured from the front face of the antenna to the centre of the probe.

In every case the field probe shall be laterally positioned in the centre of the horn antenna face. **A1**

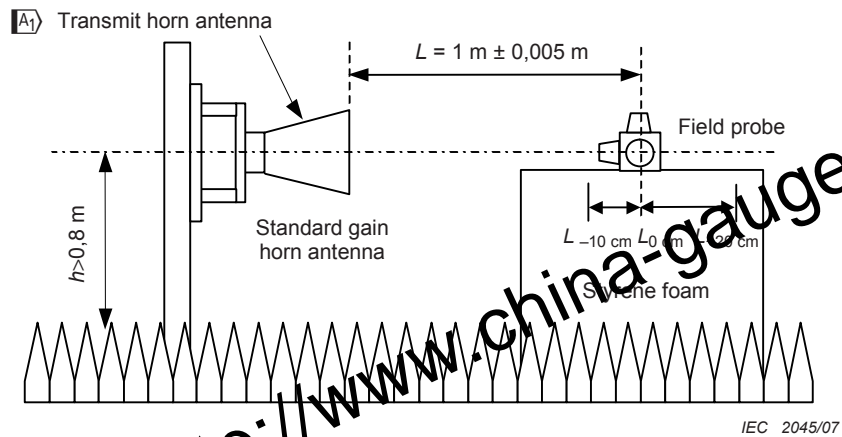


Figure I.3 – Test setup for chamber validation test

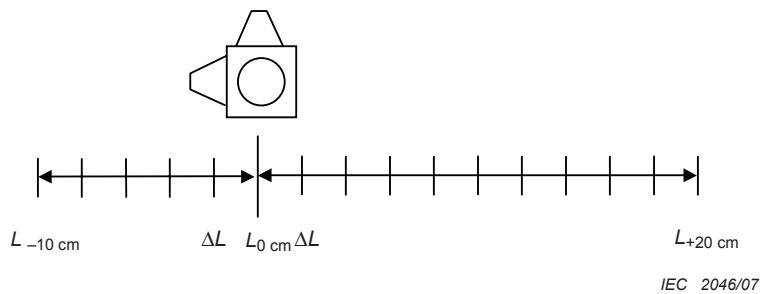


Figure I.4 – Detail for measurement position ΔL

The setup is illustrated in Figure I.3 and Figure I.4, where $L_{-10 \text{ cm}}$ to $L_{+20 \text{ cm}}$ is the probe calibration distance, measured from the face of the horn antenna to the centre of the field probe. $L_{0 \text{ cm}}$ is defined as position 0.

The positions will be $L - 10 \text{ cm}$, $L - 8 \text{ cm}$, $L - 6 \text{ cm}$, ..., L_0 , $L + 2 \text{ cm}$, $L + 4 \text{ cm}$, ..., $L + 20 \text{ cm}$, $\Delta L = 2 \text{ cm}$.

If the probe is placed in the near field of the transmitting horn antenna (distance $< 2 D^2/\lambda$, where D is the largest dimension of the antenna and λ is the free space wavelength), the gain of the transmitting antenna is not constant, and may need to be determined for each position.

A constant power creating certain field strength (e.g. 20 V/m) at 1 m distance is applied for all probe positions. With the transmit antenna and field probe both vertically polarized, the probe readings for all positions at all frequencies are recorded. The test is repeated with antenna and probe horizontally polarized.

All the readings shall satisfy the requirement shown in I.4.2.5.

I.4.2.5 VSWR acceptance criteria

VSWR measurement results shall be compared by using the following procedure. For the calculation of the field strength, refer to I.4.2.2.

- a) Calculation of the field strength $\boxed{A_1}$

A1 The electrical field strength in the spatial area between the distances 90 cm and 120 cm is calculated in 2 cm steps for each frequency.

This calculation is based on the E-field strength of a 1 m distance used for verification.

b) Data adjustment

Data is adjusted with the following process because the probe used for the VSWR measurement may not deliver a reading equal to the calculated field strength.

- E-field strength indication value of the probe at a 1 m distance shall be adjusted to the 1 m position of the calculation. The obtained difference between probe indications and calculated strength is used as the correction value k for all the data at 90 cm and 120 cm.

For example: comparison between probe measurement value V_{mv} (e.g. 21 V/m) and calculated value V_{cv} (e.g. 20 V/m) at 1 m distance. In this case the correction value k is $V_{cv} - V_{mv} = -1$ V/m.

- The correction value k shall be added to the data that is observed at 90 cm to 120 cm measurement positions.
- The same calculation shall be applied to all measurement values of all measured frequencies. In the case of the above example, $k = -1$ V/m. Therefore $k = -1$ is added to all probe measurement value data.

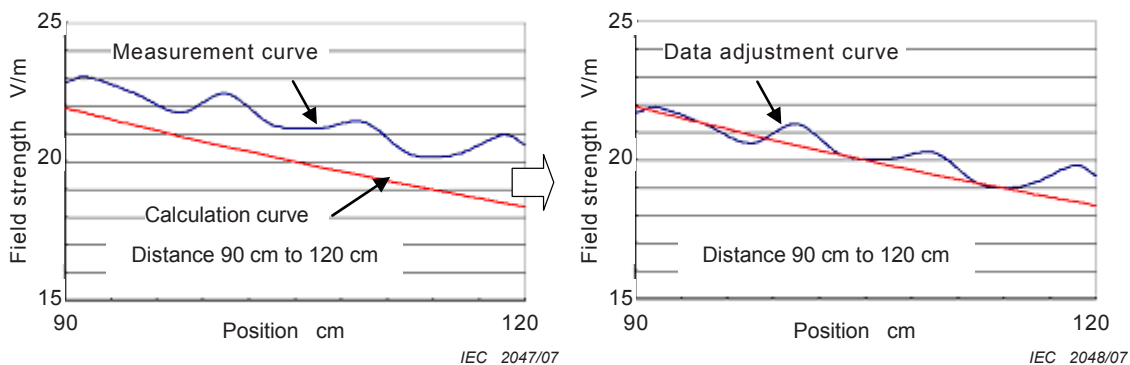


Figure I.5 – Example of data adjustment

c) Comparison of measurement data and calculation data

When the data difference in calculation curve and measurement curve exceeds $\pm 0,5$ dB in any measurement position, the chamber shall not be used for probe calibration.

NOTE The 0,5 dB criterion is established according to the measurement uncertainty budget and has been verified in several existing chambers that are suitable for calibration of field probes (including at least one national measurement institute calibration facility). It is anyhow only one contributor to the overall uncertainty.

Some field probes have a metal box or a pole such as the battery or a circuit. These units may cause reflection errors at certain distances and frequencies. When these probes are used, the influence of the reflection shall be minimized e.g. by rotating the probe or changing its orientation.

I.4.2.6 Probe fixture validation

The probe fixture may cause reflections of electromagnetic fields during the probe calibration. Therefore, the influence of the fixture on the calibration results shall be checked in advance.

The procedure defined in this clause shall be performed for any new probe fixtures to be used. **A1**

A1 Procedure:

- a) Place the probe on a reference support made of a material with a relative permittivity of less than 1,2 and a dielectric loss tangent less than 0,005. The location of the probe shall be the same as for the calibration setup. The reference fixture should be as small as possible. Any other supporting structures shall be as non-intrusive as possible and at least 50 cm away from the probe. Support structures in front (between the antenna and the probe) or behind the probe should be avoided.
- b) Generate a standard field that is within the dynamic range of the probe at the calibration position.
- c) Record the probe reading for all calibration frequency points. Rotate or re-position the probe as necessary for all calibration geometries (for three-axis isotropic field probes, each axis may need to be aligned separately), and repeat steps 1 and 2. Record probe readings for all orientations.
- d) Remove the reference fixture and replace it with the calibration fixture to be qualified. Repeat steps 2, and 3.
- e) Compare results from steps 3 and 4. The difference between the readings with the two fixtures for the same probe orientation shall be less than $\pm 0,5$ dB.

I.4.2.7 Alternative chamber validation procedure

This alternative chamber validation procedure is applicable when the validation procedure of I.4.2.4 cannot be applied.

A field probe is placed at the location where it will be used for calibration. Its polarization and position along the boresight of the transmitting horn antenna will be varied to determine the chamber VSWR. The transmit antenna shall be the same for both the chamber VSWR test and the probe calibration.

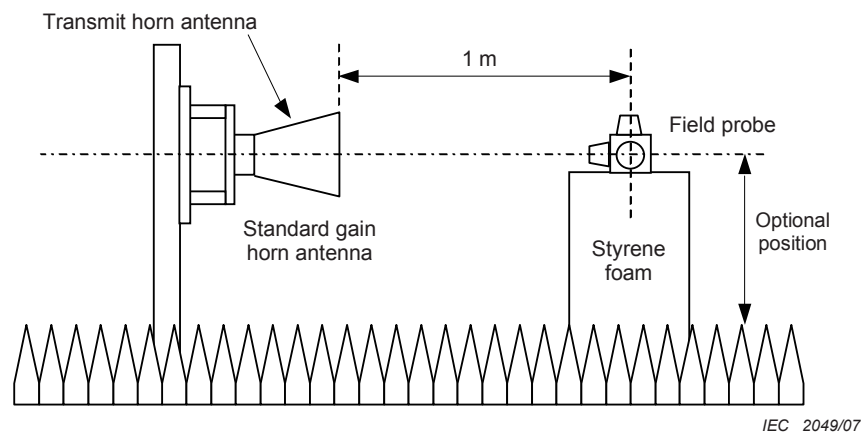


Figure I.6 – Example of the test layout for antenna and probe **A1**

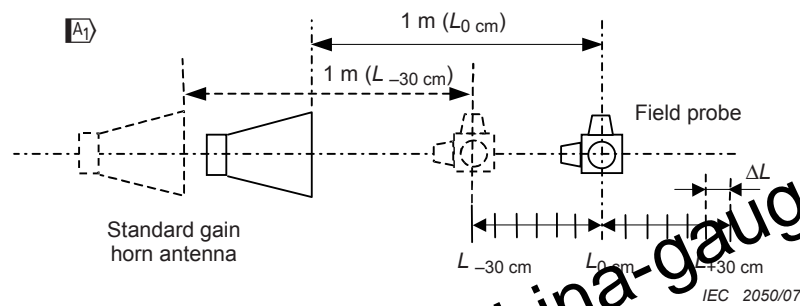


Figure I.7 – Test setup for chamber validation test

The setup is illustrated in Figures I.6 and I.7, where the probe calibration distance, measured from the face of the horn antenna to the centre of the field probe is maintained at a fixed distance, i.e. 1 m.

It is desirable to use material with low permittivity for the probe fixture to avoid influences on the measurement. The fixture used for probe calibration shall be evaluated separately (see I.4.2.6).

The positions will be $L - 30$ cm, $L - 25$ cm, $L - 20$ cm, ..., L_0 , $L + 5$ cm, $L + 10$ cm, ..., $L + 30$ cm, ΔL is 5 cm.

A constant field, e.g. 20 V/m, is generated for all positions. The generated field strength needs to be within the dynamic range of the field probe. With the transmit antenna and field probe both vertically polarized: record the probe reading for all positions at all frequencies. Repeat the test with the antenna and probe horizontally polarized.

At each frequency, there will be 26 independent probe readings (13 positions, and two polarizations). The maximum spread of the readings at each frequency shall be less than $\pm 0,5$ dB.

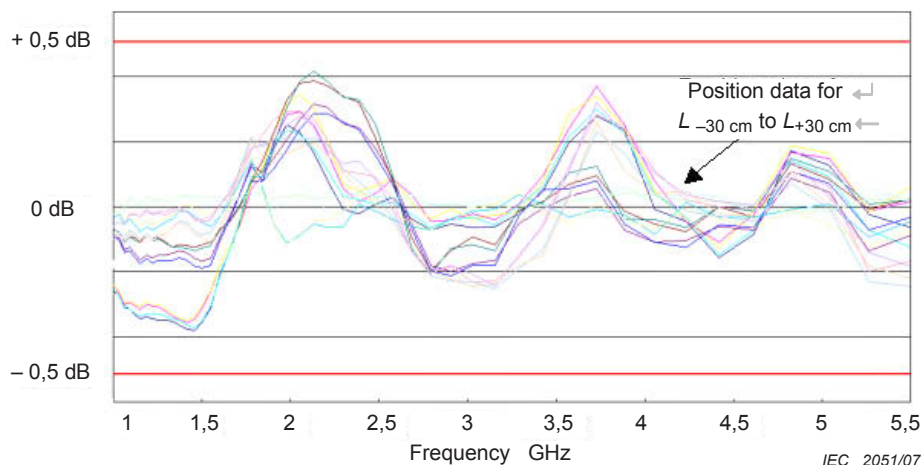


Figure I.8 – Example alternative chamber validation data

I.4.3 Probe calibration procedure

Many modern probes have internal correction factors to provide a linear response. Calibration laboratories may adjust the factors during calibration to give a probe response of $\pm 0,5$ dB from the ideal. If adjustments are made, the calibration laboratory should report the response both before and after adjustment. \triangleleft

A1 The linearity check process should be applicable to the probe to be calibrated. For the influences of linearity on the calibration system, refer to I.3.2.

NOTE When it is not possible to adjust the probe, any non-linearity should be compensated for by the user when carrying out the field uniformity calibration.

The probe calibration shall use the measurement system/environment, which satisfies the requirement of I.4.

I.4.3.1 Test setup

A fixture that is not fully qualified according to 4.2.6 can result in large measurement uncertainties. Therefore, the probe fixture validated per I.4.2.6 shall be used.

The calibration of the field probe should be done according preferably to the user specification or manufacturer's specification regarding the probe orientation. This orientation shall also be used in the test laboratory to limit the effect of isotropy. If the manufacturer does not specify any field probe orientation in the data sheet, the calibration should be performed in the probe orientation which can be considered as the "normal use" orientation of the probe or according to a preferred orientation defined by the test lab (which will use the probe). In any case the calibration report shall include the field probe orientation for which the calibration was undertaken.

The example of the measurement setup is shown in the Figures I.9 and I.10.

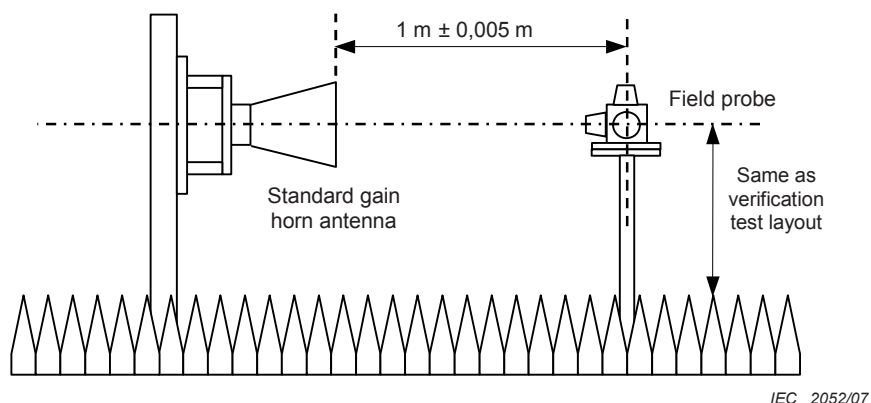


Figure I.9 – Field probe calibration layout

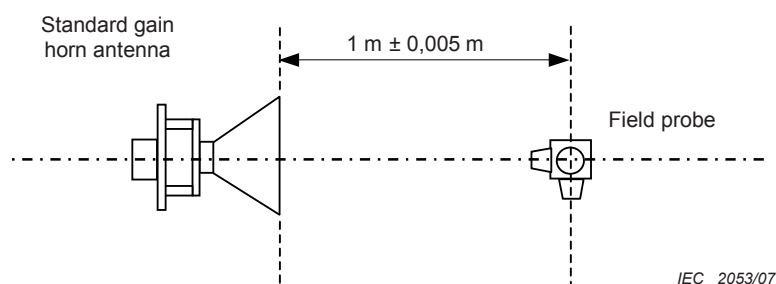


Figure I.10 – Field probe calibration layout (Top view) **A1**

A1 1.4.3.2 Calibration report

The measurement results obtained in consideration of 1.4.3.1 shall be reported as a calibration report.

This calibration report shall contain at least the following:

- a) calibration environment;
- b) probe manufacturer;
- c) type designation;
- d) serial number;
- e) calibration date;
- f) temperature and humidity;
- g) details of the calibration data:
 - frequency;
 - applied field strength (V/m);
 - probe reading (V/m);
 - probe orientation;
- h) measurement uncertainty.

NOTE IEEE Std 1309 [2] includes some guidance for probe-calibration measurement uncertainty.

1.5 Alternative probe calibration environments and methods

This clause describes the environment requirement for alternative calibration sites, e.g. necessary for the calibration in the low frequency range.

The calibration can be done in environments defined as independent from the test environment described in IEC 61000-4-3. In contrast to the equipment, which is tested for immunity, field probes are typically small and usually not equipped with conducting cables.

1.5.1 Field probe calibration using TEM cells

A rectangular TEM cell can be used to establish standard fields for field probe calibrations. The upper usable frequency of a TEM cell can be determined by methods described in 5.1 of IEC 61000-4-20. The upper frequency of a TEM cell is typically a few hundreds MHz. The field at the centre of a TEM cell between the septum and the top or bottom plate is calculated from:

$$E = \frac{\sqrt{Z_0 P_{\text{net}}}}{h} \text{ (V/m)},$$

where Z_0 is the characteristic impedance of the TEM cell (typically 50 Ω), P_{net} is the net power in Watt, which is determined according to 1.4.2.1, h is the separation distance between the septum and the top or bottom plate (in m).

The VSWR of the TEM cell should be kept small, e.g. less than 1,3 to minimize the measurement uncertainties.

An alternative method of measuring P_{net} is to use a calibrated, low VSWR attenuator and power sensor connected to the output port of the TEM cell. **A1**

A1) 1.5.2 Field probe calibration using waveguide chambers

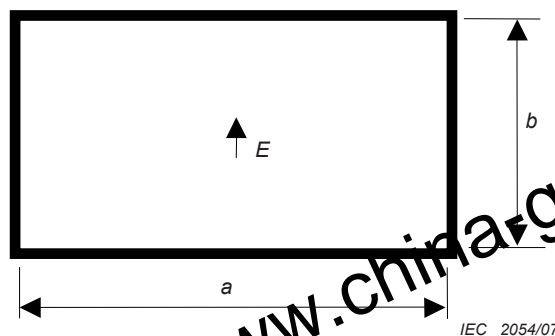


Figure I.11 – Cross-sectional view of a waveguide chamber

Calibration labs shall ensure that waveguide chambers operate in their dominant TE₁₀ mode. Frequencies that can excite higher order modes shall be avoided. Waveguide manufacturers typically specify the frequency ranges for which only a dominant mode can exist. This can also be determined from the dimensions of the waveguide. The use of waveguide chambers is limited to approximately 300 MHz to 1 000 MHz with typical sized probes.

For a waveguide chamber with inner dimensions of a (m) x b (m) ($a > b$), the cut-off frequency of the dominant TE₁₀ mode is:

$$(f_c)_{10} = \frac{1}{2a\sqrt{\mu\epsilon}},$$

where μ and ϵ are the permeability and permittivity of the waveguide media. For air-filled waveguides, $\mu = \mu_0 = 400\pi \text{ nHm}^{-1}$ and $\epsilon = \epsilon_0 = 8,854 \text{ pFm}^{-1}$. The cut-off frequency for an air-filled waveguide chamber is:

$$(f_c)_{10} = \frac{150}{a} \text{ MHz.}$$

The root-mean-square electric field at the centre of the waveguide is:

$$E = \sqrt{\frac{2\eta_0 P_{\text{net}}}{ab\sqrt{1 - ((f_c)_{10} / f)^2}}} \text{ (V/m),}$$

where f (in MHz) is the frequency of operation, $\eta_0 = 377 \Omega$ for air-filled waveguide, P_{net} (in W) is the net power delivered to the waveguide, and is determined by the method described in I.4.2.1. Note that the field inside a waveguide chamber is not a TEM wave, and the field is the largest at the centre of the waveguide (with a sinusoidal distribution, tapering to zero on the sidewalls). It is recommended that field probe calibrations be performed at the centre of the waveguide, where the field distribution has less variation (is more uniform) than at other locations. For more information on waveguide including how to calculate cut-off frequencies for other modes, refer to [5].

1.5.3 Field probe calibration using open-ended waveguides

An analytical solution and an empirical solution for the near-field gain of open-ended waveguides are provided in [6]. Since a simple theoretical solution for the near-field gain of open-ended waveguides is not available, one should determine the near-field gain of an open-ended waveguide by either full-wave numerical techniques or by measurement techniques as described in [4]. **A1**

Ⓐ) Once the near-field gain of the open-ended waveguides is determined, the calibration shall follow the procedure listed in I.4.3.

I.5.4 Calibration of field probes by gain transfer method

A transfer probe can be used to establish standard fields in a field-generating device (working standard device). The transfer probe response can be either determined by theoretical computations (for probes such as dipoles), or by calibrations performed according to the methods described in I.5.1 or I.5.2. The transfer function of the working standard, such as a GHz TEM cell, can be determined from the transfer probe. The field distribution in the working standard device should be mapped by the transfer probe. The field has to be measured at as many locations as necessary to assess the field homogeneity in the test volume. Once the transfer function of the working standard device is known, probe calibration can be performed at other power levels provided that the working standard device is linear. A probe to be calibrated shall be placed at the same location where the transfer probe has been.

The transfer method is accurate if the following conditions are met:

- the setup does not change between the transfer and calibration procedures;
- the probe position during measurements is reproduced;
- the transmitted power remains the same;
- the probe under test is similar in construction (size and element design) to the transfer probe;
- the cables connecting the sensor head and readout do not disturb or pick up the field;
- the working standard device is largely anechoic.

References [7] and [8] have more information on this method.

I.6 Reference documents

- [1] STUBENRAUCH, C., NEWELL, C. A. C., REPJAR, A. C. A., MacREYNOLDS, K., TAMURA D. T., LARSON, F. H., LEMANCZYK, J., BEHE, R., PORTIER, G., ZEHREN, J. C., HOLLMANN, H., HUNTER, J. D., GENTLE, D. G., and De VREEDE, J. P. M. International Intercomparison of Horn Gain at X-Band. *IEEE Trans. On Antennas and Propagation*, October 1996, Vol. 44, No. 10.
- [2] IEEE 1309, *Calibration of Electromagnetic Field Sensors and Probes, Excluding Antennas, from 9 kHz to 40 GHz*.
- [3] KANDA, M. and KAWALKO, S. Near-zone gain of 500 MHz to 2.6 GHz rectangular standard pyramidal horns. *IEEE Trans. On EMC*, 1999, Vol. 41, No. 2.
- [4] NEWELL, Allen C., BAIRD, Ramon C. and Wacker, Paul F. Accurate measurement of antenna gain and polarization at reduced distances by extrapolation technique. *IEEE Trans. On Antennas and Propagation*, July 1973, Vol. AP-21, No. 4.
- [5] BALANIS, C. A.. *Advanced Engineering Electromagnetics*. John Wiley & Sons, Inc., 1989, pp 363-375.
- [6] WU, Doris I. and KANDA, Motohisa. Comparison of theoretical and experimental data for the near field of an open-ended rectangular waveguide. *IEEE Trans. On Electromagnetic Compatibility*, November 1989, Vol. 31, No. 4.
- [7] GLIMM, J., MÜNTER, K., PAPE, R., SCHRADER, T. and SPITZER, M. *The New National Standard of EM Field Strength; Realisation and Dissemination*. 12th Int. Symposium on EMC, Zurich, Switzerland, February 18-20, 1997, ISBN 3-9521199-1-1, pp. 611-613. Ⓐ)

- [A₁] [8] GARN, H., BUCHMAYR, M., and MULLNER, W. Precise calibration of electric field sensors for radiated-susceptibility testing. *Frequenz* 53 (1999) 9-10, Page 190-194. [A₁]

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A₂ Annex J
(informative)

Measurement uncertainty due to test instrumentation

J.1 General

This annex gives information related to measurement uncertainty (MU) of the test level setting according to the particular needs of the test method contained in the main body of the standard. Further information can be found in ¹.

This annex shows an example of how an uncertainty budget can be prepared based upon level setting. Other parameters of the disturbance quantity such as modulation frequency and modulation depth, harmonics produced by the amplifier may also need to be considered in an appropriate way by the test laboratory. The methodology shown in this annex is considered to be applicable to all parameters of the disturbance quantity.

The uncertainty contribution for field homogeneity including test site effects is under consideration.

J.2 Uncertainty budgets for level setting

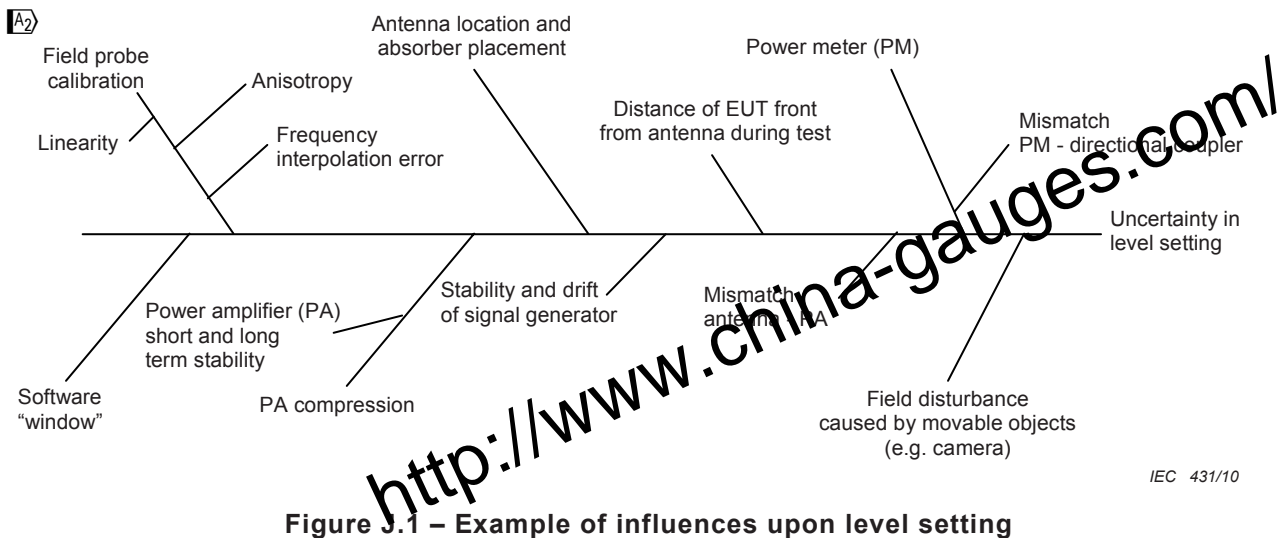
J.2.1 Definition of the measurand

The measurand is the hypothetical test electric field strength (without an EUT) at the point of the UFA selected according to the process of 6.2.1 step a) and 6.2.2 step a) of this standard.

J.2.2 MU contributors of the measurand

The following influence diagram (see Figure J.1) gives an **example** of influences upon level setting. It applies to both calibration and test processes and it should be understood that the diagram is not exhaustive. The most important contributors from the influence diagram have been selected for the uncertainty budget Tables J.1 and J.2. As a minimum, the contributions listed in Tables J.1 and J.2 shall be used for the calculation of the uncertainty budgets in order to get comparable budgets for different test sites or laboratories. It is noted that a laboratory may include additional contributors in the calculation of the MU, on the basis of its particular circumstances.

¹ Figures in square brackets refer to the reference documents in Clause J.4. **A₂**



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Figure J.1 – Example of influences upon level setting

J.2.3 Calculation examples for expanded uncertainty

It shall be recognized that the contributions that apply for calibration and for test may not be the same. This leads to different uncertainty budgets for each process.

In this basic standard, the field inside the chamber is calibrated before the test upon an EUT. Depending on the test setup, several contributors may not be a factor in calculating MU. Examples include those that are compensated by level control of the amplifier output power or that remain unchanged between calibration and test (e.g. mismatch between antenna and amplifier).

The field probe and the power monitoring instrumentation (repeatability rather than absolute measurement accuracy and linearity) are not included in the level control of the amplifier output power and their contributions shall be considered in evaluating MU.

Tables J.1 and J.2 give examples of an uncertainty budget for level setting. The uncertainty budget consists of two parts, the uncertainty for calibration and the uncertainty for test.

Table J.1 – Calibration process

Symbol	Uncertainty Source X_i	$U(x_i)$	Unit	Distribution	Divisor	$u(x_i)$	Unit	c_i	$u_i(y)$	Unit	$u_i(y)^2$
FP	Field probe calibration	1,7	dB	normal $k=2$	2	0,85	dB	1	0,85	dB	0,72
PM_c	Power meter	0,3	dB	rect	1,73	0,17	dB	1	0,17	dB	0,03
PA_c	PA rapid gain variation	0,2	dB	rect	1,73	0,12	dB	1	0,12	dB	0,01
SW_c	SW levelling precision	0,6	dB	rect	1,73	0,35	dB	1	0,35	dB	0,12
$\Sigma u_i(y)^2$											0,88
$\sqrt{\Sigma u_i(y)^2}$											0,94
Expanded uncertainty $U(y)$ (CAL) $k=2$											1,88 dB $\langle A_2 \rangle$

Table J.2 – Level setting

Symbol	Uncertainty Source X_i	$U(x_i)$	Unit	Distribution	Divisor	$u(x_i)$	Unit	c_i	$u_i(y)$	Unit	$u_i(y)^2$
CAL	Calibration	1.88	dB	normal $k=2$	2.00	0.94	dB	1	0.94	dB	0.88
AL	Antenna location variation and absorber placement	0.38	dB	$k = 1$	1	0.38	dB	1	0.38	dB	0.14
PM_t ^{a)}	Power meter	0.3	dB	rect	1.73	0.17	dB	1	0.17	dB	0.03
PA_t	PA rapid gain variation	0.2	dB	rect	1.73	0.12	dB	1	0.12	dB	0.01
SW_t	SW levelling precision	0.6	dB	rect	1.73	0.35	dB	1	0.35	dB	0.12
SG	Signal generator stability	0.13	dB	rect	1.73	0.08	dB	1	0.08	dB	0.01
$\Sigma u_i(y)^2$											1.20
$\sqrt{\Sigma u_i(y)^2}$											1.10
Expanded uncertainty $U(y) k = 2$											2.19 dB

a) If a level control of the signal generator output level based on a power meter is used, the PM_t enters into the table, otherwise the stability and drift of the signal generator as well as the power amplifier have to be taken into account. In this example, the power amplifier does not contribute to the uncertainty budget because it is part of the power amplifier output control, therefore it is sufficient to consider the power meter contribution.

J.2.4 Explanation of terms

FP is a combination of calibration uncertainty, field probe unbalance (anisotropy), field probe frequency response and temperature sensitivity. Normally this data can be obtained from the probe data sheet and/or calibration certificate.

PM_c is the uncertainty of the power meter, including its sensors, taken from either the manufacturer's specification (and treated as a rectangular distribution) or a calibration certificate (and treated as a normal distribution). If the same power meter is used for both calibration and test, this contribution can be reduced to the repeatability and linearity of the power meter. This approach is applied within the table.

PA_c is including the uncertainty derived from rapid gain variation of the power amplifier after the steady status has been reached.

SW_c is the uncertainty derived from the discrete step size of the frequency generator and software windows for level setting during the calibration process. The software window can usually be adjusted by the test laboratory.

CAL is the expanded uncertainty associated with the calibration process.

AL is the uncertainty derived from removal and replacement of the antenna and absorbers. Referring to ISO/IEC Guide 98-3, the antenna location variation and absorber placement are type A contributions, that is their uncertainty can be evaluated by statistical analysis of series of observations. Type A contributions are normally not part of the uncertainty of measurement equipment, however, these contributions were taken into account because of their high importance and their close relation to the measurement equipment.

PM_t is the uncertainty of the power meter, including its sensors, taken from either the manufacturer's specification (and treated as a rectangular distribution) or a calibration certificate (and treated as a normal distribution). If the same power meter is used for both calibration and test, this contribution can be reduced to the repeatability and linearity of the power meter. This approach is applied within the table.

This contribution can be omitted if a measuring setup without power amplifier output control is used for the test process (in contrast to Figure 7 of this standard). In this case, the uncertainties of the signal generator and power amplifier have to be reviewed.

PA_t is including the uncertainty derived from rapid gain variation of the power amplifier after the steady status has been reached. ^{A2}

A_2 SW_t is the uncertainty derived from the discrete step size of the frequency generator and software windows for level setting during the test process. The software window can usually be adjusted by the test laboratory.

SG is the drift of the signal generator during the dwell time.

J.3 Application

The calculated MU number (expanded uncertainty) may be used for a variety of purposes, for example, as indicated by product standards or for laboratory accreditation. It is not intended that the result of this calculation be used for adjusting the test level that is applied to EUTs during the test process.

J.4 Reference documents

- [1] IEC TC77 document 77/349/INF, *General information on measurement uncertainty of test instrumentation for conducted and radiated r.f. immunity tests*
- [2] UKAS, M3003, Edition 2, 2007, *The Expression of Uncertainty and Confidence in Measurement*, free download on www.ukas.com
- [3] ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)* A_2

Annex ZA
(normative)

**Normative references to international publications
with their corresponding European publications**

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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60050-161	- ¹⁾	International Electrotechnical Vocabulary (IEV) Chapter 161: Electromagnetic compatibility	-	-
IEC 61000-4-6	- ¹⁾	Electromagnetic compatibility (EMC) Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields	-	-

¹⁾ Undated reference.

National Annex (informative)
CENELEC interpretation sheet 1 February 2009



EN 61000-4-3/IS1

Interpretation Sheet 1

EN 61000-4-3:2006

English version

<http://www.china-gauges.com/>

Foreword

This Interpretation Sheet to the European Standard EN 61000-4-3:2006 was prepared by the Interpretation Panel of the Technical Committee CENELEC TC 210, Electromagnetic compatibility (EMC). The text of the draft was submitted to the Unique Acceptance Procedure and was approved by CENELEC on 2008-11-14.

Clause 5 Test levels

Table 1 – Test levels

Question:

How to apply the test field strengths ?

Interpretation:

The test field strengths are to be applied as stated in Table 1, or as defined in the product standard, without any increase to take into account uncertainties in the calibration of the field.

Validity:

This interpretation remains valid until an amendment or updated standard dealing with this issue is published by CENELEC.

February 2009

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