BRITISH STANDARD

BS EN 61000-4-3:2002
Incorporating Amendment No. 1

Electromagnetic compatibility (EMC) —

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

The European Standard EN 61000-4-3:2002, with the incorporation of amendment A1:2002, has the status of a British Standard

ICS 33.100.20

National foreword

This British Standard is the official English language version of EN 61000-4-3:2002, including amendment A1:2002. It is identical with IEC 61000-4-3:2002, including amendment 1:2002. It supersedes BS EN 61000-4-3:1997 which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags [A) (A]. Tags indicating changes to text carry the number of the amendment. For example, text altered by IEC amendment is indicated by [A) (A].

The UK participation in its preparation was entrusted by Technical Committee GEL/210, EMC – Policy committee, to Subcommittee GEL/210/12, EMC product standards, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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

From 1 January 1997, all IEC publications have the number 60000 added to the old number. For instance, IEC 27-1 has been renumbered as IEC 60027-1. For a period of time during the change over from one numbering system to the other, publications may contain identifiers from both systems.

Cross-references

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Supersedes EN 61000-4-3:1996 + A1:1998 + A2:2001

English version

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

(includes amendment A1:2002)
(IEC 61000-4-3:2002 + A1:2002)

Compatibilité électromagnétique (CEM)
Partie 4-3: Techniques d'essai
et de mesure -
Essai d'immunité aux champs
électromagnétiques rayonnés
aux fréquences radioélectriques
(inclut l'amendement A1:2002)
(CEI 61000-4-3:2002 + A1:2002)

Elektromagnetische Verträglichkeit (EMV)
Teil 4-3: Prüf- und Messverfahren -
Prüfung der Störfestigkeit
gegen hochfrequente
elektromagnetische Felder
(enthält Änderung A1:2002)
(IEC 61000-4-3:2002 + A1:2002)

This European Standard was approved by CENELEC on 2002-04-01 and amendment A1 was approved by CENELEC on 2002-10-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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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

Ref. No. EN 61000-4-3:2002 + A1:2002 E

Foreword

The text of document 77B/339/FDIS, future edition 2 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 2002-04-01.

This European Standard supersedes EN 61000-4-3:1996 + A1:1998 + A2:2001.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2003-01-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2005-04-01

Annexes designated "normative" are part of the body of the standard.
Annexes designated "informative" are given for information only.
In this standard, annexes J and ZA are normative and annexes A to I as well as K are informative.
Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61000-4-3:2002 was approved by CENELEC as a European Standard without any modification.

Foreword to amendment A1

The text of document 77B/352/FDIS, future amendment 1 to IEC 61000-4-3:2002, 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 amendment A1 to EN 61000-4-3:2002 on 2002-10-01.

The following dates were fixed:

– latest date by which the amendment has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2003-07-01
– latest date by which the national standards conflicting with the amendment have to be withdrawn	(dow)	2005-10-01

Annexes designated "informative" are given for information only.
In this standard, annex K is informative.

Endorsement notice

The text of amendment 1:2002 to the International Standard IEC 61000-4-3:2002 was approved by CENELEC as an amendment to the European Standard without any modification.

CONTENTS

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 9: Miscellaneous

Each part is further subdivided into sections which are to be published either as International Standards or as technical reports.

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

ELECTROMAGNETIC COMPATIBILITY (EMC) –

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

1 Scope and object

This section of IEC 61000-4 is applicable to the immunity of electrical and electronic equipment to radiated electromagnetic energy. It establishes test levels and the required test procedures.

The object of this section is to establish a common reference for evaluating the performance of electrical and electronic equipment when subjected to radio-frequency electromagnetic fields. Testing is not required at frequencies other than those specified in clause 5 of this standard. The possible future introduction of new radio services which may degrade the performance of electrical and electronic equipment may result in test levels being specified in other frequency bands.

This section deals with immunity tests related to general purposes. Particular considerations are devoted to the protection against radiofrequency emissions from digital radio telephones.

NOTE Test methods are defined in this section for measuring 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 section does not intend to specify the tests to be applied to particular apparatus or systems. Its main aim is to give a general basic reference to all concerned product committees of the IEC. The product committees (or users and manufacturers of equipment) remain responsible for the appropriate choice of the tests and the severity level to be applied to their equipment.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050(161):1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

IEC 61000-4-6:1996, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 6: Immunity to conducted disturbances induced by radio-frequency fields*

3 General

Most electronic equipment is, in some manner, affected by electromagnetic radiation. This radiation is frequently generated by such 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 radio transmitters operating at frequencies between 0,8 GHz and 3 GHz. Many of these services use modulation techniques with a non-constant envelope (e.g. TDMA).

In addition to electromagnetic energy deliberately generated, there is also spurious 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 this standard. 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 (field strength in volts per metre). The field strength is not easily measured without sophisticated instrumentation nor is it easily calculated by classical equations and formulae because of the effect of surrounding structures or the proximity of other equipment that will distort and/or reflect the electromagnetic waves.

4 Definitions

For the purposes of this section of IEC 61000-4, the following definitions, together with those in IEC 60050(161) apply.

4.1
amplitude modulation
process by which the amplitude of a carrier wave is varied following a specified law

4.2
anechoic chamber
shielded enclosure which is lined with radio-frequency absorbers to reduce reflections from the internal surfaces

4.2.1
fully anechoic chamber
shielded enclosure whose internal surfaces are totally lined with anechoic material

4.2.2
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)

4.2.3
modified semi-anechoic chamber
semi-anechoic chamber which has additional absorbers installed on the ground plane

4.3
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

4.4
balun
device for transforming an unbalanced voltage to a balanced voltage or vice versa [IEV 161-04-34]

4.5
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

4.6
electromagnetic (EM) wave
radiant energy produced by the oscillation of an electric charge characterized by oscillation of the electric and magnetic fields

4.7
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

4.8
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/m^2; 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.

4.9
frequency band
continuous range of frequencies extending between two limits

4.10
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

4.11
isotropic
having properties of equal values in all directions

4.12
polarization
orientation of the electric field vector of a radiated field

4.13
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

4.14
stripline
terminated transmission line consisting of two parallel plates between which a wave is propagated in the transverse electromagnetic mode to produce a specified field for testing purposes [IEV 161-04-31]

4.15
spurious radiation
any undesired electromagnetic emission from an electrical device

4.16
sweep
continuous or incremental traverse over a range of frequencies

4.17
transceiver
combination of radio transmitting and receiving equipment in a common housing

4.18
human body-mounted equipment
equipment which is intended for use when attached to the human body. This definition includes hand-held devices which are carried by people while in operation (e.g. pocket devices) as well as electronic aid devices and implants

4.19
maximum RMS value
the 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:

$$V_{\text{maximum RMS}} = V_{\text{p-p}} / (2 \times \sqrt{2}) = 1{,}8 \text{ volts}$$

4.20
non-constant envelope modulation
RF modulation schemes where 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

4.21
TDMA (time division multiple access)
a 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

5 Test levels

5.1 Test levels related to general purposes

The preferential range of test levels is given in table 1.

Frequency range: 80 MHz to 1 000 MHz.

Table 1 – Test levels

Level	Test field strength V/m
1	1
2	3
3	10
x	Special
NOTE x is an open test level. This level may be given in the product specification.	

Table 1 gives details of the field strength of the unmodulated signal. For testing of equipment, this signal is 80 % amplitude modulated with a 1 kHz sinewave to simulate actual threats (see figure 1). Details of how the test is performed are given in clause 8.

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 H).

NOTE 2 Product committees may select alternative modulation schemes.

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

The preferred range of test levels is given in table 2 for the frequency ranges from 800 MHz to 960 MHz and from 1,4 GHz to 2,0 GHz.

Table 2 – Frequency ranges: 800 MHz to 960 MHz and 1,4 GHz to 2,0 GHz

Level	Test field strength V/m
1	1
2	3
3	10
4	30
x	Special
NOTE x is an open test level. This level may be given in the product standard.	

The test field strength column gives values of the unmodulated carrier signal. For 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.

If the product is intended to conform only to the requirements of particular countries, the measurement range 1,4 GHz to 2,0 GHz may be reduced to cover just the specific frequency bands allocated to digital mobile telephones in those countries. In this situation, the decision to test over reduced frequency ranges shall be documented in the test report.

Product committees shall specify the applicable test level for each of the frequency ranges. In the frequency range mentioned in both tables 1 and 2, the test need only be performed at the higher of the two test levels.

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

NOTE 2 Annex F 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 I contains the list of frequencies known to be allocated to specific digital radio telephones at the time of publication).

NOTE 4 The principle threat above 800 MHz is from radio telephone systems. Other systems operating in this frequency range, e.g. radio LANs operating at 2,4 GHz, 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.

  NOTE Alternative methods of generating EM fields include TEM cells and stripline circuits, unlined screened rooms, partially lined shielded rooms, and open area test sites.

  These devices have limitations in the size of equipment which can be accommodated in the uniform field, the frequency range, or infringement of local regulations.

  Care should be taken to ensure that the conditions of test are equivalent to those in the anechoic chamber.

- *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 which can be amplitude modulated by a 1 kHz sinewave to 80 % depth. They shall have either an automated sweep capability of $1{,}5 \times 10^{-3}$ decade/s or slower or, in the case of r.f. synthesizers, be capable of being programmed with frequency-dependent step-sizes and dwell times. They shall also be capable of being set manually.

  The use of low-pass or band-pass filters may be necessary to avoid problems caused by harmonics to equipment which is intended to receive signals for monitoring purposes.
- *Power amplifiers:* to amplify signal (unmodulated and modulated) and provide antenna drive to the necessary field level. The harmonics and distortion produced by the power amplifier shall be at a level less than or equal to 15 dB below carrier level.
- *Field generating antennas (see annex B):* biconical, log periodic or any other linearly polarized antenna system capable of satisfying frequency requirements. Circularly polarized antennas are under consideration.

- *A horizontally and vertically polarized or an isotropic field strength monitoring antenna* with dipoles about 0,1 m total length or less, 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.
- *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 preferred test facility consists of an absorber-lined shielded enclosure that shall be large enough to accommodate the EUT whilst allowing adequate control over the field strengths. Associated shielded enclosures shall accommodate the field generating and monitoring equipment, and the equipment which exercises the EUT. This includes anechoic chambers or modified semi-anechoic chambers, an example of which is shown in figure 2.

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. Modulation is not present during the calibration to ensure the proper indication of any field sensor.

IEC 61000-4-3 uses the concept of a "uniform area" (see figure 3), which is a hypothetical vertical plane of the field in which variations are acceptably small. This uniform area is 1,5 m × 1,5 m, unless the EUT and its wires can be fully illuminated within a smaller surface; the size of the uniform area shall not be less than 0,5 m × 0,5 m (i.e. a four-point grid).

In the test set-up, the EUT shall have the face to be illuminated coincident with this plane (see figures 5 and 6).

Because it is impossible to establish a uniform field close to an earth reference plane, the calibrated area is established at a height no closer than 0,8 m above the earth reference plane and, where possible, the EUT is located at this height.

In order to establish the severity of the test for EUTs and wires which must be tested close to the earth reference plane or which have larger sides than 1,5 m × 1,5 m, the intensity of the field is also recorded at 0,4 m height, and for the full width and height of the EUT, and reported in the test report.

The uniform area is calibrated in the empty enclosure. The set-up and positioning of the antenna, additional absorber (if used), etc. are recorded and kept. These can then be used in the chamber verification that is carried out before each batch of testing (see clause 8). It is intended that the full area calibration should be carried out at least annually and when changes have been made in the enclosure configuration (absorber replaced, area moved, equipment changed, etc.).

The transmitting antenna shall be placed at a distance sufficient to allow a calibration area of 1,5 m × 1,5 m to fall within the beam width of the transmitted field. If the area intended to be occupied by the face of the actual EUT is larger than 1,5 m × 1,5 m, 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 calibration areas cover the area which will be occupied by the face of the EUT; 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 calibration area during at least one of these tests.

If a calibration area corresponding to the face of an EUT which is larger than 1,5 m × 1,5 m can satisfy the field uniformity requirement, partial illumination need not be applied.

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 simultaneously, then for frequencies higher than this, the illumination method described in annex J shall be used.

The field sensor shall be at least 1 m from the field generating antenna. A distance of 3 m between the antenna and the EUT is preferred. This dimension is taken from the centre of a biconical antenna or from the tip of a log periodic antenna. The test report shall state the test distance used from the field generating antenna to the calibrated area.

In case of dispute, measurements at 3 m take precedence.

A field is considered uniform if its magnitude over the defined area is within –0 dB to +6 dB of the nominal value, over 75 % of the surface (e.g. if at least 12 of the 16 points measured are within the tolerance).

For the minimum uniformity area of 0,5 m × 0,5 m, the four points of the grid shall lie within this tolerance.

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

The tolerance has been expressed as –0 dB to +6 dB to ensure that the field strength does not fall below nominal. The tolerance of 6 dB is considered to be the minimum achievable in practical test facilities.

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 –0 dB to +6 dB tolerance takes precedence.

A1 Generally the calibration of the field in anechoic and semi-anechoic chambers has to be performed using the test set up shown in figure 7. The calibration shall always be performed with an unmodulated carrier for both horizontal and vertical polarizations in accordance with the steps given below. Calibration shall be carried out with a field strength at least 1,8 times as high as the field strength to be applied to the EUT to ensure that the amplifiers can handle the modulated signal and are not saturated. 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 1 Other methods to ensure avoiding saturation may be used.

Two different calibration methods are described below. These methods are considered to give the same field uniformity if they are applied in the right way.

NOTE 2 The field calibration requirements are fulfilled if a maximum of 3 % of the frequencies does not meet the 6 dB criterion but are at least within the tolerance of –0 dB to +10 dB.

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

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 test 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. A1

A1 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 note the maximum forward power out of the numbers.

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 K.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 system. The amplifier saturation can be checked by using spot frequencies, and with frequency steps recommended as follows:

- 20 MHz from 80 MHz to 200 MHz;
- 50 MHz from 250 MHz to 1 000 MHz;
- 100 MHz from 1 400 MHz to 2 000 MHz.

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

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) 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) Move the sensor to another position in the grid. At each of the frequencies 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. A1

[A1) 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 –0 dB to +6 dB of that lowest value.

j) If they are not within the tolerance of –0 dB to +6 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.

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 K.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 system. The amplifier saturation can be checked by using spot frequencies, and with frequency steps recommended as follows:

– 20 MHz from 80 MHz to 200 MHz;
– 50 MHz from 250 MHz to 1 000 MHz;
– 100 MHz from 1 400 MHz to 2 000 MHz. (A1]

The calibration is valid for all EUTs whose individual faces (including any cabling) can be fully enclosed by the "uniform area".

The antennas and cables which have been used to establish the calibrated field shall be used for the testing. Since the same antennas and cables are used, the cable losses and antenna factors of the field generating antennas are not relevant.

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

7 Test set-up

All testing of equipment shall be performed in a configuration as close as possible to the installed case. Wiring shall be consistent with the manufacturer's recommended procedures, and the equipment shall be in its housing 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-conducting material. 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 set-ups are shown in figures 5 and 6.

7.1 Arrangement of table-top equipment

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

NOTE The use of non-conducting supports prevents accidental earthing of the EUT and distortion of the field. To ensure the latter, the support should be bulk non-conducting, rather than an insulating coating on a metallic structure.

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 shall be mounted on a non-conducting support 0,1 m above the supporting plane. The use of non-conducting 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-conducting 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, if specifically required by the product committees. This variation in the standard method of test shall be recorded in the test report.

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

7.3 Arrangement of wiring

If the wiring to and from the EUT is not specified, unshielded parallel conductors shall be used.

Wiring is left exposed to the electromagnetic field for a distance of 1 m from the EUT.

Wiring between enclosures of the EUT shall be treated as follows:

- the manufacturer's specified wiring types and connectors 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. The wiring shall be bundled low-inductively to 1 m length;
- if the specified length is greater than 3 m, or is not specified, then the illuminated length shall be 1 m. The remainder is decoupled, for instance via lossy r.f. ferrite tubes.

The EMI filtering used shall not impair the operation of the EUT. The method used shall be recorded in the test report.

In one EUT position, the wires shall be arranged parallel to the uniform area of the field to minimize immunity.

All results shall be accompanied by a complete description of the wiring and equipment position and orientation so that results can be repeated.

The bundled length of exposed wiring is run in a configuration which essentially simulates normal wiring; that is, the wiring is run to the side of the EUT, then either up or down as specified in the installation instructions. The horizontal/vertical arrangement helps to ensure worst-case conditions.

7.4 Arrangement of human body-mounted equipment

Human body-mounted equipment 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 procedures

The EUT shall be tested within its intended operating and climatic conditions. The temperature and relative humidity shall be recorded in the test report.

The test procedures described in this clause are for the use of biconical and log-periodic antennas, in a modified semi-anechoic chamber. Guidance on alternative test procedures is given in annex D.

Before testing, the intensity of the established field strength shall be checked by placing the field sensor at a calibration grid point, and with the field generating antenna and cables in the same positions as used for the calibration, the forward power needed to give the calibrated field strength can be measured. This shall be the same as recorded during the calibration. Spot checks shall be made at a number of calibration grid points over the frequency ranges to be considered. Both polarizations shall be checked.

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 frequency ranges to be considered are swept with the signal 80 % amplitude modulated with the signal 80 % amplitude modulated with a 1 kHz sinewave, pausing to adjust the r.f. signal level or to switch oscillators and antennas as necessary. [A1) *Text deleted* (A1]. Where the frequency range is swept incrementally, the step size shall not exceed 1 % of fundamental with linear interpolation between calibrated points.

NOTE The expression "not exceeding 1 % of fundamental" means that the frequency of each step is less than, or equal to, the frequency of the previous step after multiplication by a factor of 1,01 (for a 1 % step size).

[A1) 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. (A1]

The test shall normally be performed with the generating antenna facing each of the four sides of the EUT. When equipment can be used in different orientations (i.e. vertical or horizontal), the test shall be performed on all sides.

NOTE 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 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.

Testing shall be performed according to a test plan, which shall be included in the test report.

This shall include:

- 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, whether it is to be tested at a height above the ground plane of 0,1 m or 0,8 m;
- the type of test facility to be used and the position of the radiating antennas;
- the type of antennas to be used;
- the rate of sweep of frequency, dwell time and frequency steps;
- 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 EUT exercising method.

It may be necessary to carry out some investigatory testing in order to establish some aspects of the test plan.

The test documentation shall include the test conditions, a statement of calibration and the test results.

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, for example, shielded enclosure;
- 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.

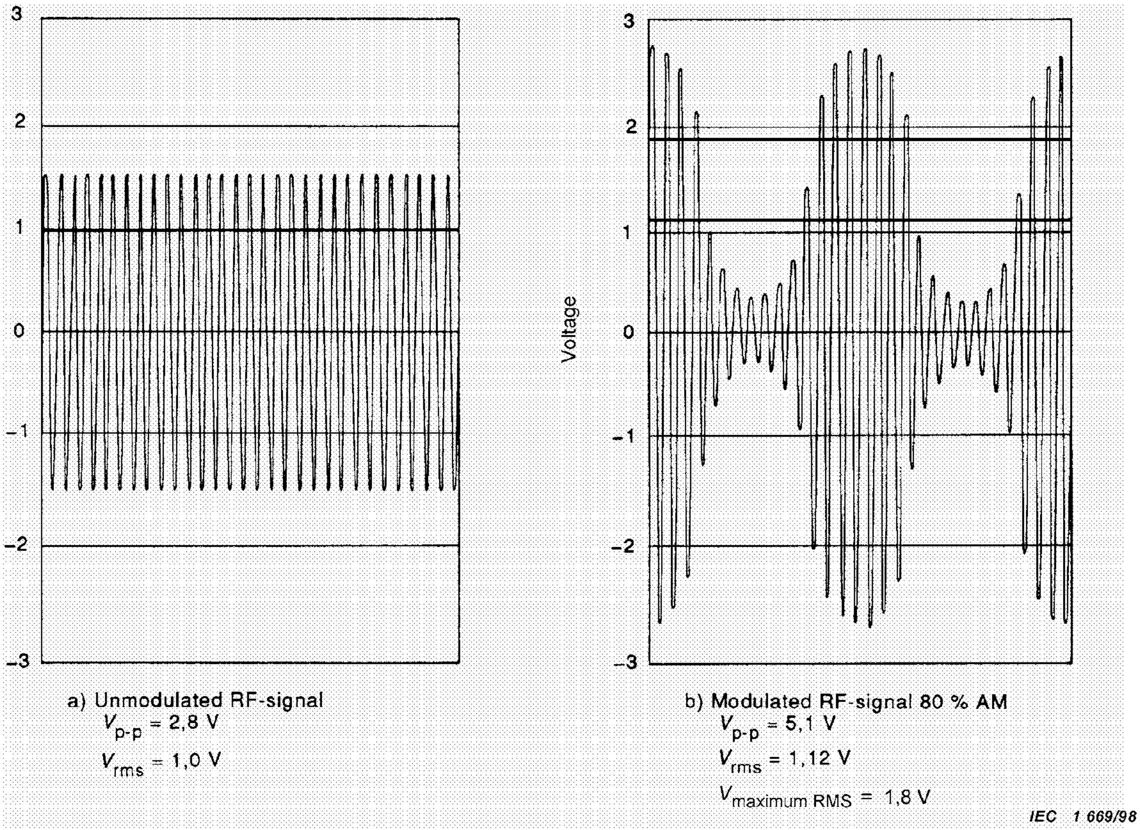
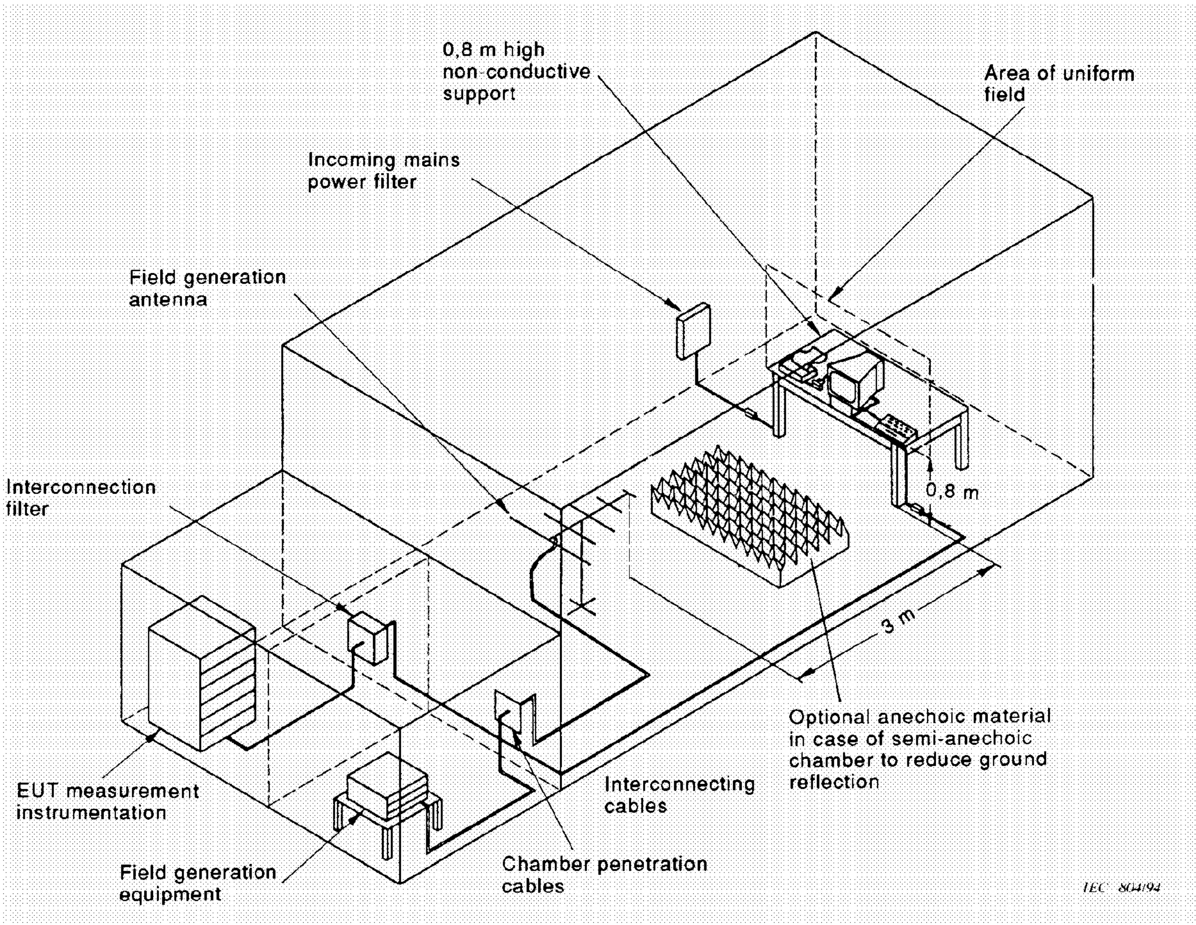


Figure 1 – Definition of the test level and the waveshapes occurring at the output of the signal generator



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

Figure 2 – Example of suitable test facility

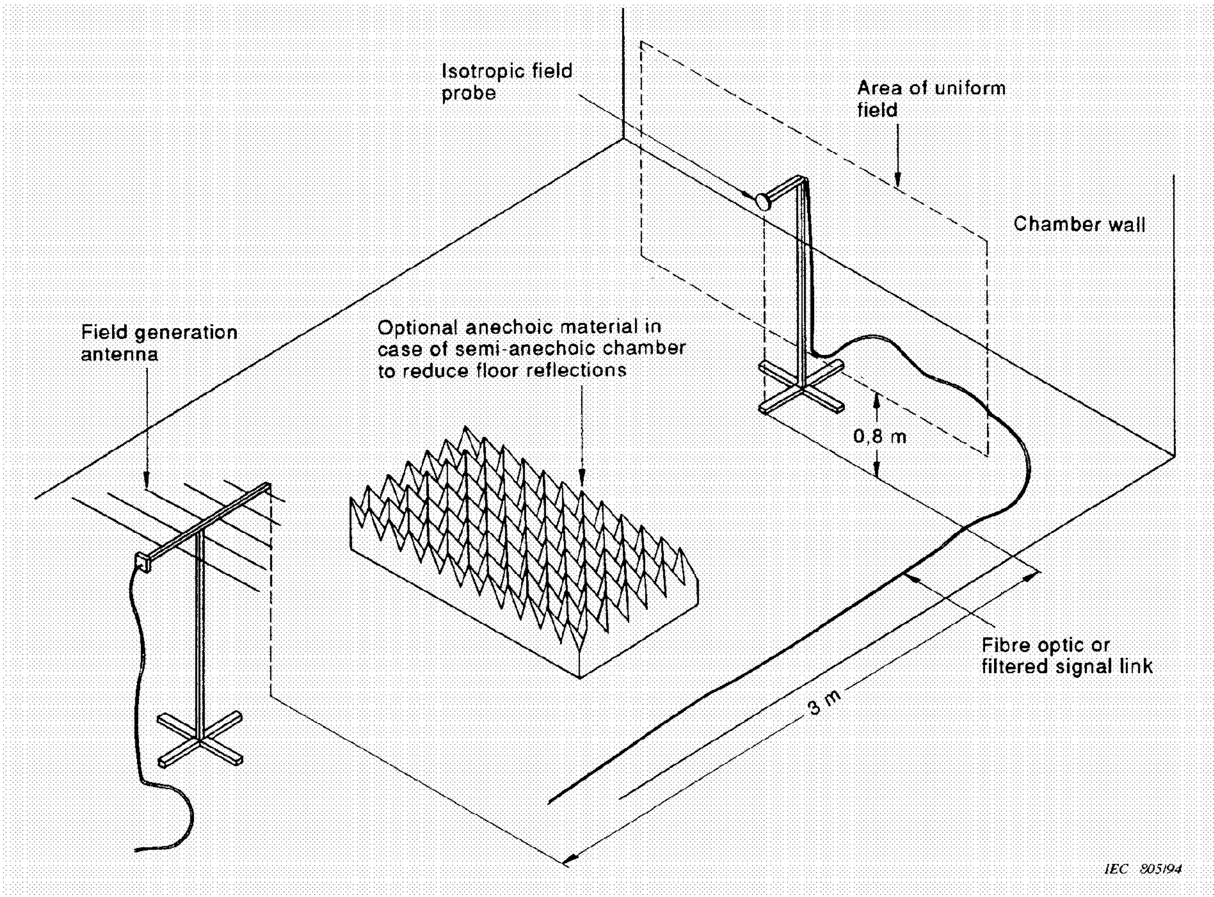


Figure 3 – Calibration of field

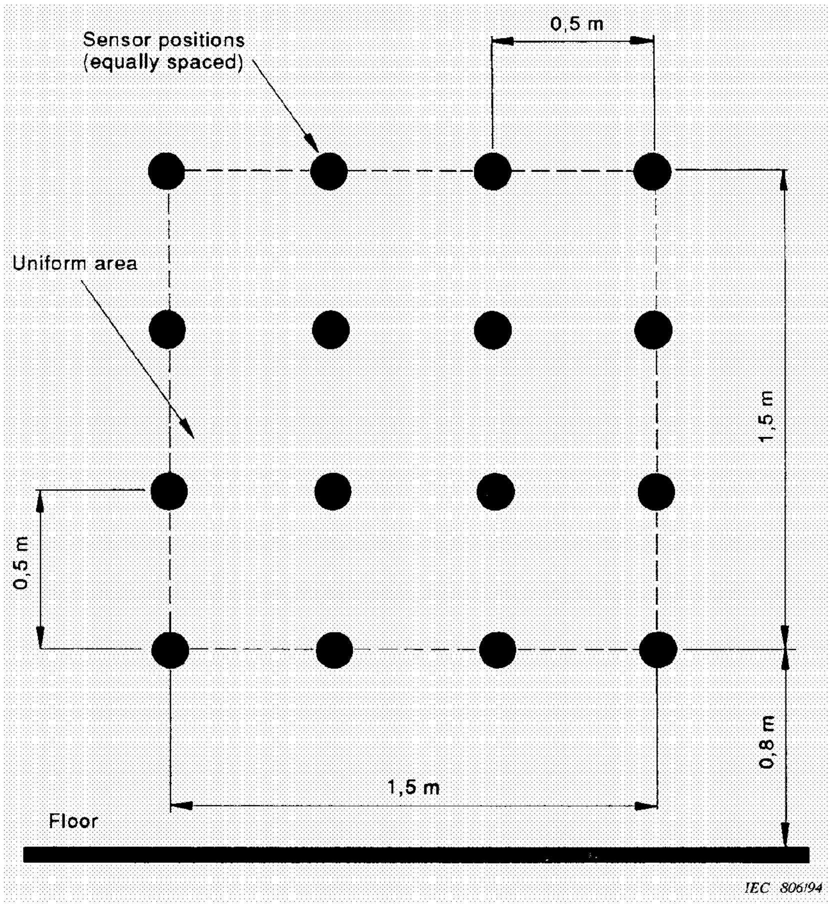
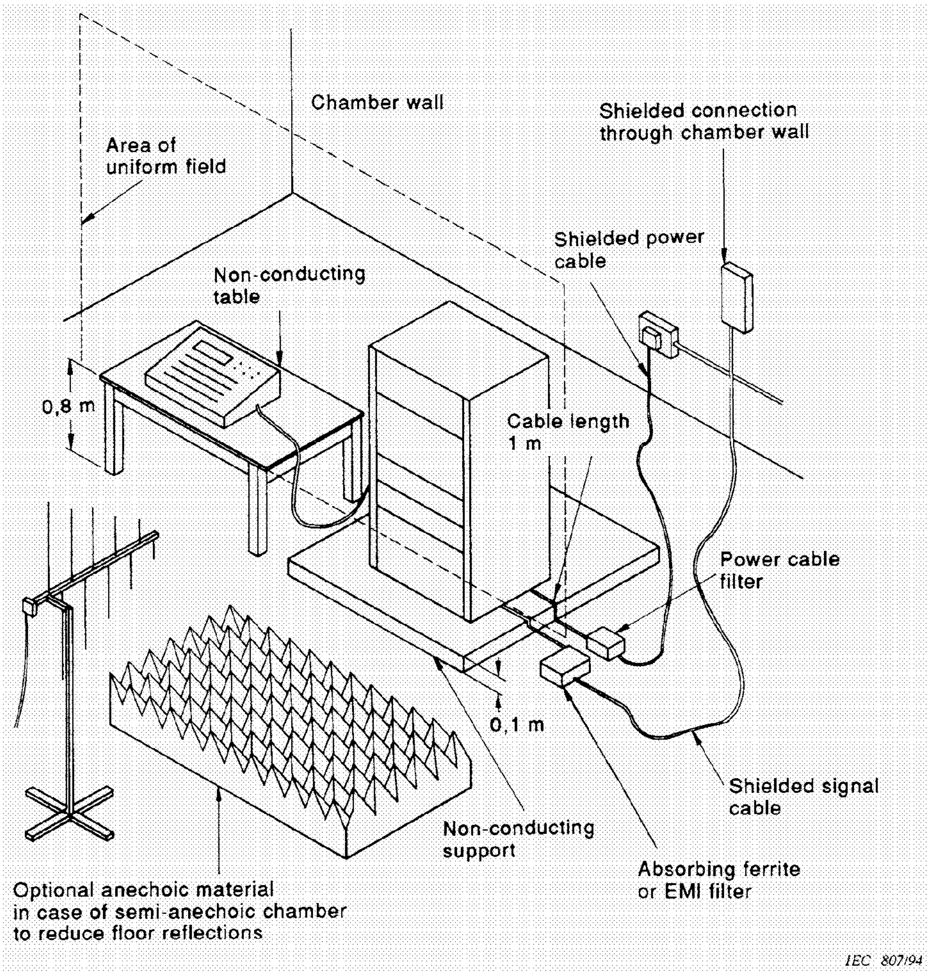


Figure 4 – Calibration of field, dimensions of the uniform area



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

Figure 5 – Example of test set-up for floor-standing equipment

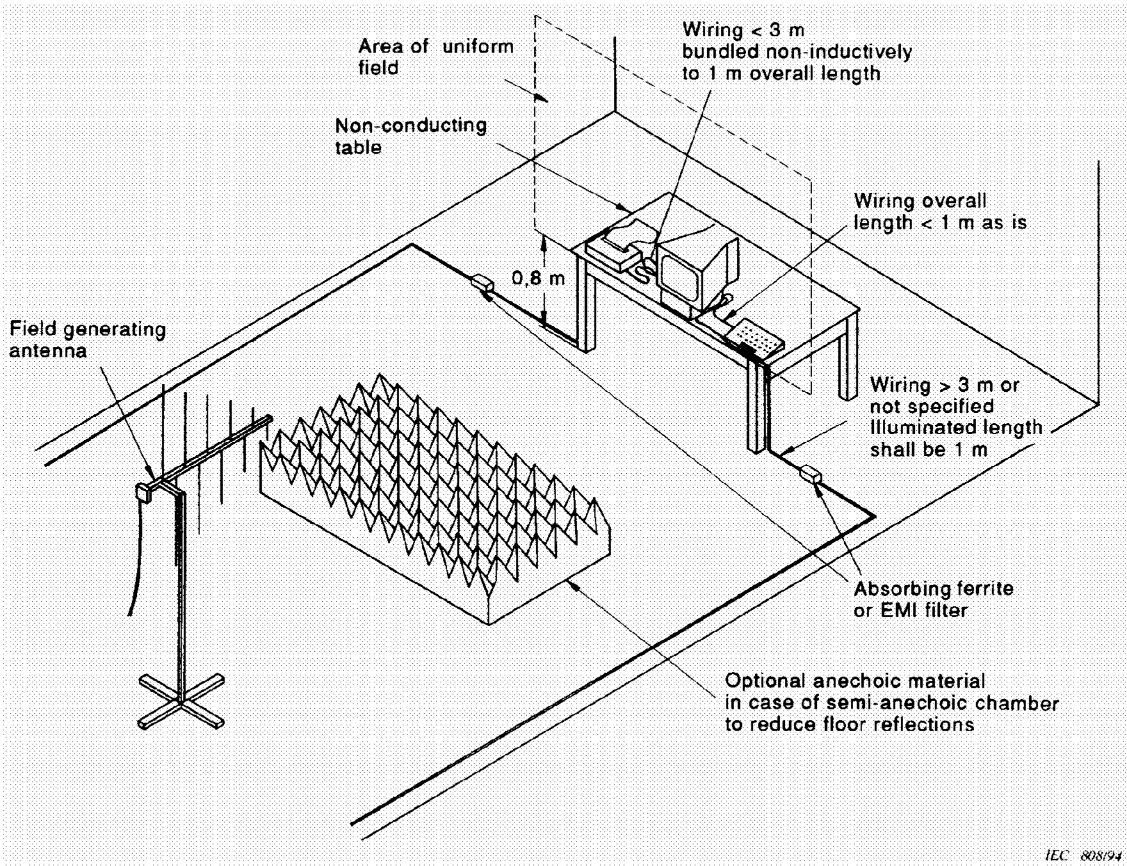


Figure 6 – Example of test set-up for table-top equipment

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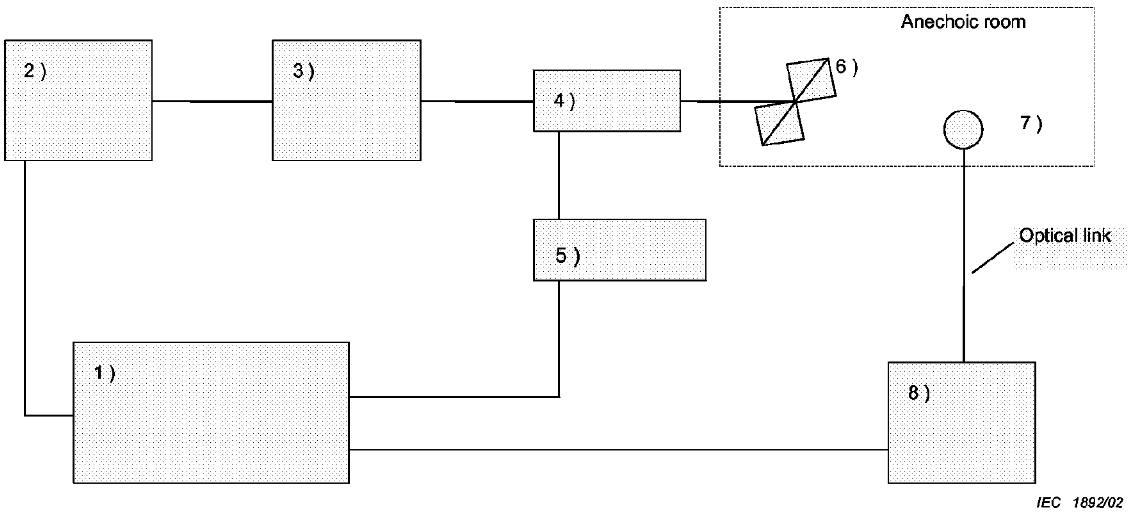


Key

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

⟨A1

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 production 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 I 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 I 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 pulse. 3 Used in this standard and in IEC 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 (note 1)

Modulation method (note 2)		**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 (note 3)	Unweighted 21 Hz – 21 kHz	0 (note 4)	0	–3
	A-weighted	0	–4	–7
Analogue telephone set (note 5)	Unweighted	0 (note 4)	–3	–7
	A-weighted	–1	–6	–8
Radio set (note 6)	Unweighted	0 (note 4)	+1	–2
	A-weighted	–1	–3	–7

NOTE 1 The audio response to the disturbance is the interference level. A low interference level means a high-immunity level.

NOTE 2 Important: the carrier amplitude is adjusted so that the maximum RMS value (see clause 4) of the disturbing signal (exposure) is the same for all modulations.

NOTE 3 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.

NOTE 4 This case is chosen as the reference audio response, i.e. 0 dB.

NOTE 5 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.

NOTE 6 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 (note 1)

Modulation method (note 2)		**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**	↓ **Response**	dB	dB	dB
TV set (note 3)	Noticeable interference	0 (note 4)	−2	−2
	Strong interference	+4	+1	+2
	Screen off	~+19	+18	+19
Data terminal with RS232 interface (note 5)	Interference on the video screen	0 (note 4)	0	–
	Data errors	> +16	> +16	–
RS232 modem (note 6)	Data errors (injected on telephone interface)	0 (note 4)	0	0
	Data errors (injected on RS232 interface)	> +9	> +9	> +9
Regulated laboratory supply (note 7)	2 % error in DC output current	0 (note 4)	+3	+7
SDH cross connect (note 8)	Bit error threshold	0 (note 4)	0	–

NOTE 1 The numbers in the table are a relative measure of the maximum RMS level (see clause 4) of the disturbing signal (exposure) necessary to produce the same degree of interference with all modulations. A high decibel level means high immunity.

NOTE 2 The disturbing signal is adjusted so that the same response (interference) is produced with all modulations.

NOTE 3 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.

NOTE 4 This case is chosen as the reference immunity level, i.e. 0 dB.

NOTE 5 The exposure is an RF current injected into the RS232 cable at 900 MHz.

NOTE 6 The exposure is an RF current injected into either the telephone or the RS232 cable at 900 MHz.

NOTE 7 The exposure is an RF current at 900 MHz injected into the d.c. output cable.

NOTE 8 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 (20 MHz – 300 MHz)

This antenna consists of a coaxially wound balun and three-dimensional element which provide a broad frequency range which 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 antenna makes them ideal for use in restricted areas such as anechoic chambers as proximity effects are minimized. Typical dimensions are: width 1 430 mm, depth 810 mm and diameter 530 mm.

B.2 Log-periodic antenna (80 MHz – 1 000 MHz)

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.

Typical dimensions are height 60 mm, width 1 500 mm and depth 1 500 mm.

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

B.3 Circularly polarized antenna

Antennas which produce electromagnetic fields of circular polarization, such as conical log spiral antennas, may only be used after an increase equivalent to 3 dB has been made to the output power from the power amplifier.

B.4 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.

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 J.

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*) × 3 m (*w*) × 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 m × 1,5 m area at these frequencies owing to multiple reflections from the inner surfaces of the chamber (see figure C.1).

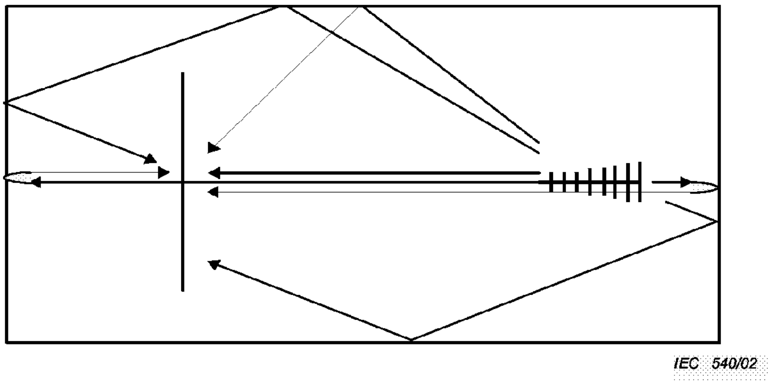


Figure C.1 – Multiple reflections in an existing small anechoic chamber

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.

a) 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.

b) 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 m × 0,5 m independent windows (annex J) to ensure that the EUT is exposed to a uniform field.

c) 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)

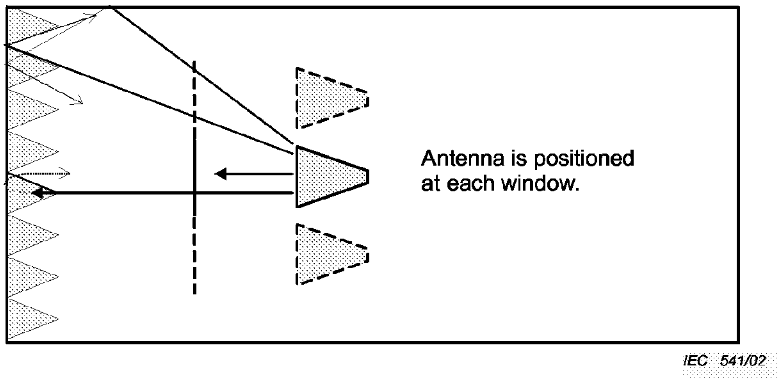


Figure C.2 – Most of the reflected waves are eliminated

Annex D
(informative)

Other test methods – TEM cells and striplines

Striplines are useful for the efficient generation of linear fields for testing small EUTs (size of the order 0,3 m × 0,3 m × 0,3 m) from d.c. to 150 MHz. As lateral radiation is produced the EUT should be rotated to test horizontal and vertical polarization.

Uniformity and external field reduction can be improved by the use of r.f. absorbing material, and maintaining a distance of at least 2 m between the stripline and other reflecting objects.

TEM cells have the advantage of enclosing the generated field, but typically can only accommodate even smaller EUTs in a frequency range of d.c. to 200 MHz. Special designs (e.g. GTEM cells) have higher frequency ranges and can accommodate larger EUT.

As with striplines, the EUT should be rotated in the TEM cell in order to test both horizontal and vertical polarization.

Striplines and TEM cells may only be used if the field homogeneity requirements are met, and if the EUT and wires can be arranged as required by this section of IEC 61000-4.

Additionally, the arrangement of the EUT and associated wiring cannot exceed one-third of the dimension between the septum and outer conductor.

Annex E
(informative)

Other test facilities

E.1 Partially lined screened rooms

A screened room modified with a quantity of r.f. absorbing material in an attempt to damp resonances which occur in unlined rooms, but at a lower cost than semi- or fully anechoic lining. The material is placed at the main reflecting points of the walls and ceiling.

Such rooms may be used providing that a uniform field can be established.

E.2 Open area test site

This method is acceptable in less populated areas of the country, provided legal limits are met. Absorbing material is necessary to reduce floor reflections.

Annex F
(informative)

Guidance for product committees on the selection of test levels

F.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:

$$E = k \sqrt{P} / d \qquad \text{(equation F.1)}$$

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 into the antenna may be used in equation F.1 instead. In this case, a value of k = 3 is typically applicable for mobile radio transmitters.

F.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 x:* x is an open level which might be negotiated and specified in the product standard or equipment specification.

F.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 F.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 F.1, using k = 7 and assuming testing is carried out with an 80 % sinusoidal AM.

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

Test level	Carrier field strength	Maximum RMS field strength	Protection distance for			Performance criteria (note 3)	
	V/m	V/m	2W GSM m	8W GSM m	¼W DECT m	Example 1 (note 1)	Example 2 (note 2)
1	1	1,8	5,5	11	1,9	–	–
2	3	5,4	1,8	3,7	0,6	a	–
3	10	18	0,6	1,1	~ 0,2[1)]	b	a
4	30	54	~ 0,2[1)]	0,4	~ 0,1[1)]	–	b

NOTE 1 Equipment where the consequences of failure are not severe.

NOTE 2 Equipment where the consequences of failure are severe.

NOTE 3 According to clause 9.

1) At these and closer distances, the far field equation F.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 F.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 F.1 and does not take into account the statistical fluctuations of the field strength, due to reflections from walls, floor and ceiling which are in the order of ±6 dB;
- the protection distance according to equation F.1 depends on the effective radiated power of the digital radio telephone and not on its operating frequency.

Annex G
(informative)

Special measures for fixed transmitters

The levels derived from the information in annex F 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 H
(informative)

Selection of test methods

This section of IEC 61000-4 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 section 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 I
(informative)

Description of the environment

I.1 Digital radio telephones

Tables I.1 and I.2 list radio system parameters relevant to EMC.

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

- **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;
- **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;
- **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;
- **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.

Table I.1 – Mobile and portable units

System name Parameters	GSM	DCS 1800	DECT	CT-2	PDC	PHS	NADC
Transmitter frequency	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
Modulation type	TDMA	TDMA	TDMA/ TDD	FDMA/ TDD	TDMA	TDMA/ TDD	TDMA
Burst repetition frequency	217 Hz	217 Hz	100 Hz	500 Hz	50 Hz	200 Hz	50 Hz
Duty cycle	1:8	1:8	1:24 (also 1:48 and 1:12)	1:12	1:3	1:8	1:3
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
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
Geographical area	Worldwide	Worldwide	Europe	Europe	Japan	Japan	USA
NOTE CT-3 is considered to be covered by DECT.							

Table I.2 – Base stations

System name Parameters	GSM	DCS 1800	DECT	CT-2	PDC	PHS	NADC
Transmitter frequency	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
Modulation type	TDMA	TDMA	TDMA/ TDD	FDMA/ TDD	TDMA	TDMA/ TDD	TDMA
Burst repetition frequency	217 Hz	217 Hz	100 Hz	500 Hz	50 Hz	200 Hz	50 Hz
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
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
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
Geographical area	Worldwide	Worldwide	Europe	Europe	Japan	Japan	USA
NOTE CT-3 is considered to be covered by DECT.							

Annex J
(normative)

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

J.1 Introduction

Anechoic chambers are less effective at low frequencies (below 30 MHz), whereas ferrite-lined chambers may also be less effective but rather 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. Further guidance is given in annex C.

The test distance should be 1 m, particularly when testing at frequencies above 1 GHz which use the independent window 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 3 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 J.1A and J.1B). The field uniformity shall be independently verified over each window (see figure J.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.

J.2 Calibration of field

The following steps shall be performed on each window:

m) position the field sensor at one of the four corners of the window;

n) 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;

o) 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;

p) take the location with the lowest field strength as reference (this ensures that the –0 dB to +6 dB requirement is met);

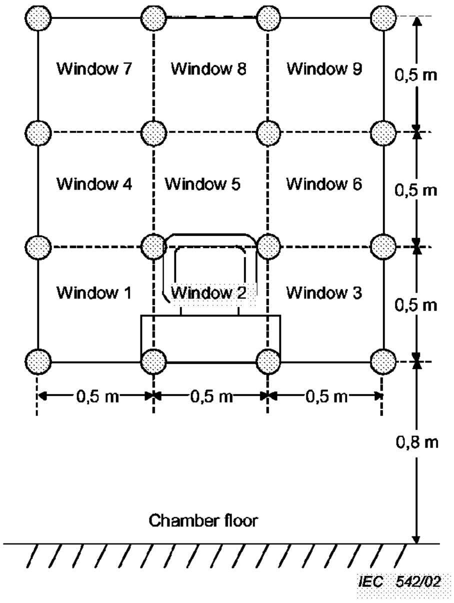
q) forward power and the field strength being known, the necessary forward power for the required test field strength can be calculated (for example if, at a given point, 80 W gives 9 V/m, then 8,9 W is needed for 3 V/m). The calculation shall be recorded;

r) repeat steps a) to e) for both horizontal and vertical polarizations.

The antennas and cables used to verify the field uniformity 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 J.1 and J.2).

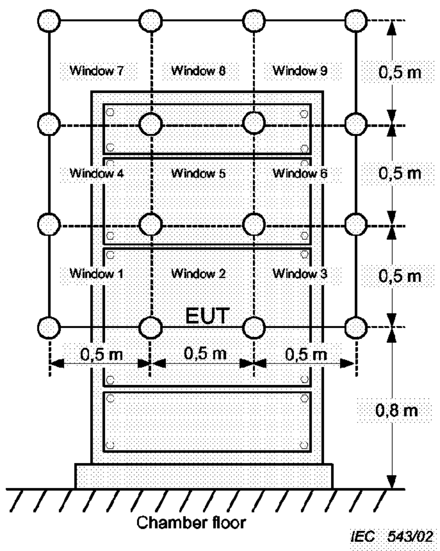


Concept of windows

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 J.1A – Example of division of the calibration area into 0,5 m × 0,5 m windows 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 J.1B – Example of division of the calibration area into 0,5 m × 0,5 m windows for floor-standing equipment

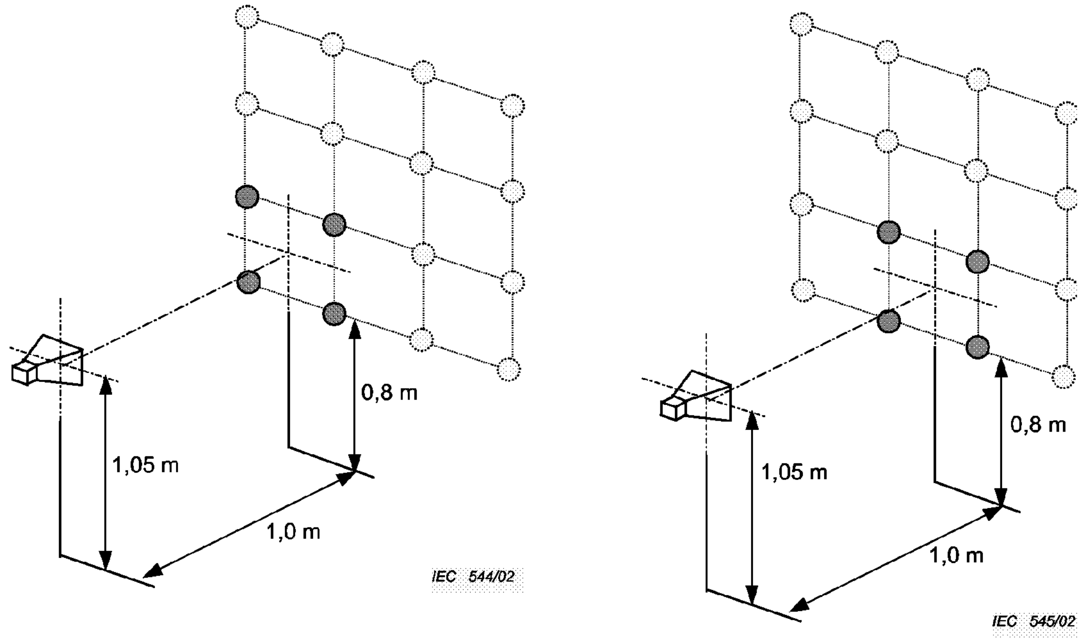


Figure J.2 – Example of illumination of successive windows

Annex K
(informative)

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

K.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 the test laboratories in understanding and limiting amplifier saturation effects.

K.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 probably 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 (spurious) 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.

A1 K.3 Options for controlling amplifier non-linearity

K.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 (note exceptional scenario K.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.

K.3.2 Measuring the harmonic content of the field

The harmonic content of the field can 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.

For situations in which a low pass filter suppresses harmonics of a saturated amplifier it is suggested under no circumstances (for example worst frequency, maximal 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. A1

A1 K.4 Examples for the calibration procedures showing the equivalence of both methods

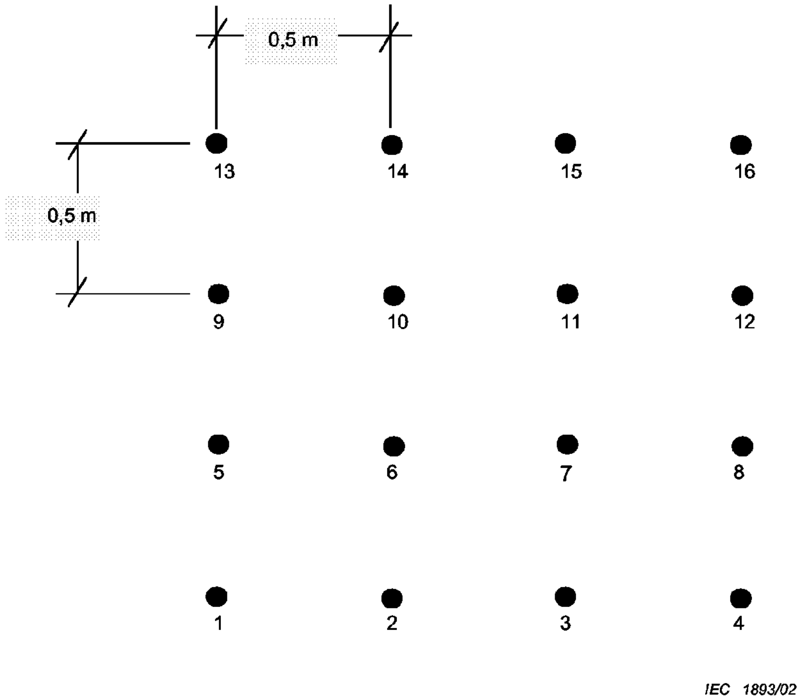


Figure K.1 – Measuring positions of the uniform area

Figure K.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.

K.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 V/m (as an example) the following forward power values shown in table K.1 have been measured at one particular frequency using the measuring set up according to figure 7. A1

A1

Table K.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 K.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 $^{-0}_{+6}$ 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).

K.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 K.3 have been recorded at one particular frequency using the measuring set up according to figure 7. A1

A1⟩

Table K.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	–10
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 K.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 ${}^{-0}_{+6}$ 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 dBm + 20 log (6 V/m/3 V/m) = 33 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). ⟨A1

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

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

Publication	Year	Title	EN/HD	Year
IEC 60050-161	1990	International Electrotechnical Vocabulary (IEV) - Chapter 161: Electromagnetic compatibility	-	-
IEC 61000-4-6	1996	Electromagnetic compatibility (EMC) Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields	EN 61000-4-6	1996

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