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INTERNATIONAL STANDARD

colour inside

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

IEC 61000-4-3:2020-09(en)

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ELECTROMAGNETIC COMPATIBILITY (EMC) –

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

FOREWORD

International Standard IEC 61000-4-3 has been prepared by subcommittee 77B: High frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

It forms part 4-3 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107.

This fourth edition cancels and replaces the third edition published in 2006, Amendment 1:2007 and Amendment 2:2010. This edition constitutes a technical revision.

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

a) testing using multiple test signals has been described;

b) additional information on EUT and cable layout has been added;

c) the upper frequency limitation has been removed to take account of new services;

d) the characterization of the field as well as the checking of power amplifier linearity of the immunity chain are specified.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
77B/830/FDIS	77B/825/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

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

A list of all parts in the IEC 61000 series, published under the general title *Electromagnetic compatibility (EMC)*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

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

Part 1: General

General considerations (introduction, fundamental principles)

Definitions, terminology

Part 2: Environment

Description of the environment

Classification of the environment

Compatibility levels

Part 3: Limits

Emission limits

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

Part 4: Testing and measurement techniques

Measurement techniques

Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines

Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

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

This part 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

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 document 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 RF electromagnetic fields from RF sources not in close proximity to the EUT. The test environment is specified in Clause 6.

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.

NOTE 2 Immunity testing against RF sources in close proximity to the EUT is defined in IEC 61000-4-39.

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

NOTE 3 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 in this basic document have the primary objective of establishing an adequate reproducibility of testing configuration and repeatability of test results at various test facilities.

This document is an independent test method. It is not possible to use other test methods as substitutes for claiming compliance with this document.

2 Normative references

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

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

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-161 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
amplitude modulation
AM
modulation in which the amplitude of a periodic carrier is a given function, generally linear, of the instantaneous values of the modulating signal

[SOURCE: IEC 60050-702:2016, 702-06-17]

3.1.2
anechoic chamber
shielded enclosure which is lined with radio-frequency absorbers to reduce reflections from the internal surfaces

3.1.3
fully anechoic chamber
shielded enclosure whose internal surfaces are totally lined with anechoic material

3.1.4
semi-anechoic chamber
shielded enclosure in which all surfaces except the metal floor are covered with material that absorbs electromagnetic energy (i.e. RF absorber) in the frequency range of interest

3.1.5
modified semi-anechoic chamber
semi-anechoic chamber which has additional absorbers installed on the ground plane

3.1.6
antenna
that part of a radio transmitting or receiving system which is designed to provide the required coupling between a transmitter or a receiver and the medium in which the radio wave propagates

Note 1 to entry: In practice, the terminals of the antenna or the points to be considered as the interface between the antenna and the transmitter or receiver should be specified.

Note 2 to entry: If a transmitter or receiver is connected to its antenna by a feed line, the antenna may be considered to be a transducer between the guided waves of the feed line and the radiated waves in space.

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

3.1.7
balun
device for transforming an unbalanced voltage to a balanced voltage or vice versa

[SOURCE: IEC 60050-161:1990 161-04-34]

3.1.8
common mode absorption device
CMAD
device that may be applied on cables leaving the test area in radiated immunity tests to damp resonances on cables

3.1.9
continuous wave
CW
sinusoidal electromagnetic wave, the successive oscillations of which are identical under steady-state conditions, which can be interrupted or modulated to convey information

3.1.10
electromagnetic wave
wave characterized by the propagation of a time-varying electromagnetic field

Note 1 to entry: An electromagnetic wave is produced by variations of electric charges or of electric currents

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

3.1.11
far field
that region of the electromagnetic field of an antenna wherein the predominant components of the field are those which represent a propagation of energy and wherein the angular field distribution is essentially independent of the distance from the antenna

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

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

[SOURCE: IEC 60050-712:1992, 712-02-02, modified – the word "region" has been removed from the term]

3.1.12
field strength
magnitude of the electromagnetic field at a given point

[SOURCE: IEC 60050-705:1995, 705-08-31, modified – the rest of the definition after "given point" has been deleted.]

3.1.13
frequency band
continuous set of frequencies lying between two specified limiting frequencies

Note 1 to entry: A frequency band is characterized by two values which define its position in the frequency spectrum, for instance its lower and upper limiting frequencies.

[SOURCE: IEC 60050-702:1992, 702-01-02]

3.1.14
full illumination method
test method in which the EUT being tested fits completely within the uniform field area (UFA)

Note 1 to entry: This test method may be applied for all test frequencies.

3.1.15
human body-mounted equipment
equipment which is intended for use when attached to or held in close proximity to the human body.

Note 1 to entry: 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.

3.1.16
intentional RF emitting device
device which radiates (transmits) an electromagnetic field intentionally

EXAMPLE: Digital mobile telephones and other radio devices.

3.1.17
intermodulation
interaction in non-linear device or transmission medium between the spectral components of the input signal or signals producing new spectral components having frequencies equal to linear combination with integral coefficients of the frequencies of the input spectral components

Note 1 to entry: Intermodulation can result from a single non-sinusoidal input signal or from several sinusoidal or non-sinusoidal input signals applied to the same or to different inputs

[SOURCE: IEC 60050-161:2017, 161-06-20]

3.1.18
isotropic field probe
field sensor, whose detection properties are independent of direction of propagation and polarization of an electromagnetic wave

[SOURCE: IEC 60050-731:1991, 731-03-08, modified – wording modified to apply to field probe.]

3.1.19
maximum RMS value
highest short-term RMS value of a modulated RF signal during an observation time of one modulation period

Note 1 to entry: The short-term RMS is evaluated over a single carrier cycle. For example, in Figure 1 b), the maximum RMS voltage is: $U_{\text{maximum rms}} = U_{\text{p-p}}/(2 \times \sqrt{2}) = 1{,}8$ V

3.1.20
modulation factor
in linear amplitude modulation, the ratio, generally expressed as a percentage, of the difference between the maximum and minimum amplitudes of the modulated signal to the sum of these amplitudes, expressed as:

$$m = 100 \times \frac{U_{\text{p-p,max}} - U_{\text{p-p,min}}}{U_{\text{p-p,max}} + U_{\text{p-p,min}}}$$

SEE Table 2 and Figure 1.

[SOURCE: IEC 60050-702:1992, 702-06-19, modified – the formula has been added and the note removed.]

3.1.21
non-constant envelope modulation
RF modulation scheme in which the amplitude of the carrier wave varies slowly in time compared with the period of the carrier itself

EXAMPLE Conventional amplitude modulation and time division multiple access (TDMA).

3.1.22
partial illumination method
test method used when the EUT face cannot be illuminated at once using a single UFA

3.1.23
polarization
orientation of the electric field vector of a radiated field

3.1.24
reference ground plane
RGP
flat conductive surface that is at the same electric potential as the reference ground, which is used as a common reference, and which contributes to a reproducible parasitic capacitance with the surroundings of the equipment under test (EUT)

[SOURCE: IEC 60050-161:2014, 161-04-36, modified – notes have been deleted.]

3.1.25
shielded enclosure
screened room
mesh or sheet metallic housing designed expressly for the purpose of separating electromagnetically the internal and the external environment

[SOURCE: IEC 60050-161:1990, 161-04-37]

3.1.26
time division multiple access
TDMA
multiple access technique in which the various terminals having access to a link are allotted separate recurrent time intervals for transmission

[SOURCE: IEC 60050-725:1994, 725-14-12]

3.1.27
transceiver
transmitter-receiver
combination in a single unit of a radio transmitter and a radio receiver employing common circuit components and usually the same antenna for both transmitting and receiving

[SOURCE: IEC 60050-713:1998, 713-08-02, modified – the note has been deleted.]

3.1.28
uniform field area
UFA
vertical plane in which field strength variations are acceptably small

SEE: 6.3.

3.2 Abbreviated terms

AE	Auxillary equipment
AM	Amplitude modulation
CMAD	Common-mode absorption device
CW	Continuous wave
DECT	Digital enhanced cordless telecommunications
EM	Electromagnetic
ERP	Effective radiated power
EUT	Equipment under test
GSM	Groupe Special Mobile, later renamed to: Global System for Mobile Communications

IMD	Intermodulation distortion
ISM	Industrial, scientific, medical
LTE	Long-term evolution (name for family of wireless radio transmissions)
MU	Measurement uncertainty
OFDM	Orthogonal frequency division multiplexing
PA	Power amplifier
PM	Power meter
PVC	Polyvinylchloride
RF	Radio frequency
RBW	Resolution bandwidth
RGP	Reference ground plane
RMS	Root mean square
SDH	Synchronous digital hierarchy
TDMA	Time division multiple access
TV	Television
UFA	Uniform field area
UMTS	Universal mobile telecommunications system
VRC	voltage reflection coefficient
VSWR	Voltage standing wave ratio
Wi-Fi	Name of wireless transmission service
WiMAX	Name of wireless transmission service

4 General

Electronic equipment can, in some manner, be affected by electromagnetic radiation. This radiation is frequently generated by various sources, such as small hand-held radio transceivers, fixed-station radio and television transmitters, vehicle radio transmitters and industrial electromagnetic sources. Many of these services use modulation techniques with a non-constant envelope.

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

In this document, the electromagnetic environment is characterized 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 and frequency ranges

5.1 Selection of test level

The test levels are given in Table 1.

Table 1 – Test levels

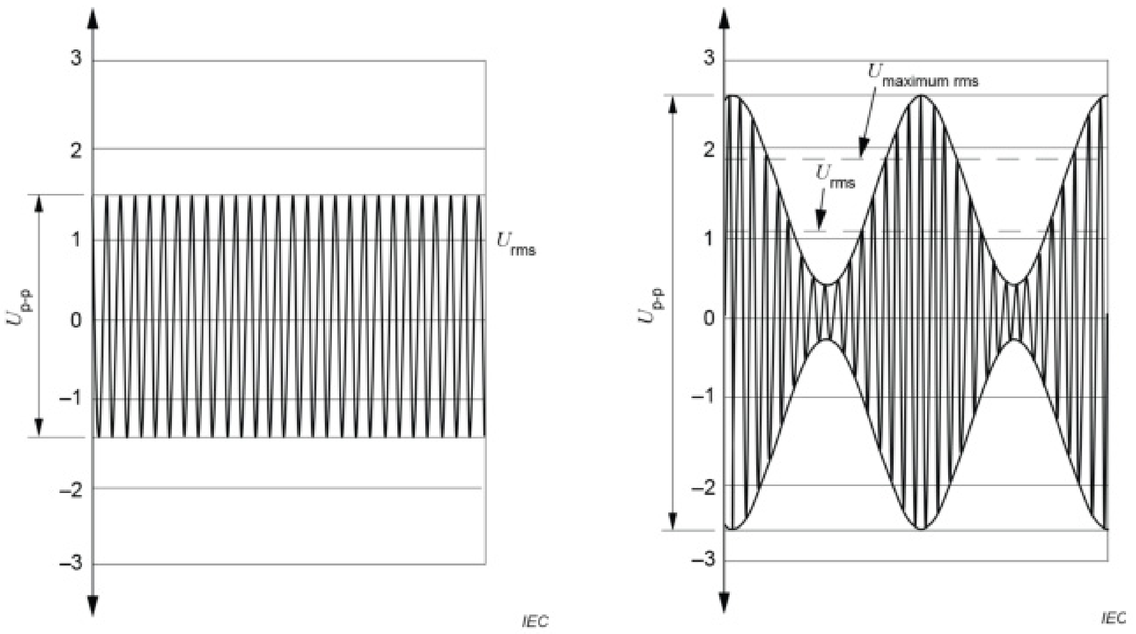
Level	Test field strength V/m
1	1
2	3
3	10
4	30
x	Special
x can be any level, above, below or in between the others. The level shall be specified in the product standard.	

This document does not suggest that a single test level is applicable over the entire frequency range. The product committees shall select the frequency range(s) to be tested as well as the appropriate test level(s). See Annex E giving guidance for product committees on the selection of test levels.

The test field strength column in Table 1 gives values of the unmodulated carrier signal. For testing of equipment, this carrier signal is amplitude modulated with a 1 kHz sine wave to simulate actual threats (see Figure 1 and Table 2). Details of how the test is performed are given in Clause 8.

Table 2 – Amplitude modulation characteristics at output of signal generator

Amplitude modulation	Internal or external, m = (80 ± 10) %, as measured on the output of the signal generator. With modulation factor m: $m = 100 \times \frac{U_{\text{p-p,max}} - U_{\text{p-p,min}}}{U_{\text{p-p,max}} + U_{\text{p-p,min}}}$ 1 kHz ± 0,1 kHz sine wave



a) Unmodulated RF signal

$$U_{rms,a} = 1\ V$$

$$U_{p\text{-}p,a} = U_{rms,a} \times \sqrt{2} \times 2 = 2{,}82\ V$$

b) Modulated RF signal 80 % AM

$$U_{p\text{-}p.max} = U_{p\text{-}p,a} \times \frac{100+m}{100} = 5{,}09\ V$$

$$U_{p\text{-}p.min} = U_{p\text{-}p,a} \times \frac{100-m}{m} = 0{,}57\ V$$

$$U_{rms,b} = U_{rms,a} \times \sqrt{1+\frac{\left(\frac{m}{100}\right)^2}{2}} = 1{,}15\ V$$

Figure 1 – Definition of the 80 % amplitude modulated (AM) test signal and the waveshapes occurring

Product committees may select alternative modulation schemes for equipment under test (see Annex A).

5.2 Test frequency ranges

This document defines testing in the frequency range above 80 MHz, limited only by the capability of the test instrumentation.

See Annex F for more information on the selection of frequency ranges and test methods defined in other basic standards, as well as the application of this document below 80 MHz.

The frequencies or frequency ranges to be selected for testing by product committees may be limited to those where intentional RF emitting devices actually operate.

Product committees can require a specific test level and type of modulation (as alternative to 80 % AM).

If the product is intended to conform only to the requirements of particular countries, testing may be reduced to cover just the specific frequency bands allocated to digital mobile telephones and other intentional RF emitting devices in those countries.

NOTE IEC TR 61000-2-5 and CISPR TR 31 contain information about frequencies and power levels known to be allocated to specific radio services.

6 Test equipment

6.1 Test instrumentation

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 needed to damp reflections.
– 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 as a minimum being capable of amplitude modulation as specified in Table 2.

  The use of low-pass or band-pass filters can be necessary to avoid problems caused by harmonics.
– Power amplifiers: to amplify the signal (unmodulated and modulated) and provide antenna drive to the necessary field level.
– Field generating antennas: biconical, log periodic, horn, combination of antennas or any other linearly polarized antenna system capable of satisfying frequency requirements (see Annex B).
– Isotropic field sensor: with adequate frequency range and sensitivity to measure the generated field strength (see Annex K about the calibration method for E-field probes).
– Power measurement device for the forward power: a directional coupler and a power meter may be used, or a forward power detector or monitor could be inserted between amplifier and antenna.
– Associated equipment to record the power levels: necessary for the required field strength and to control the generation of that level for testing.

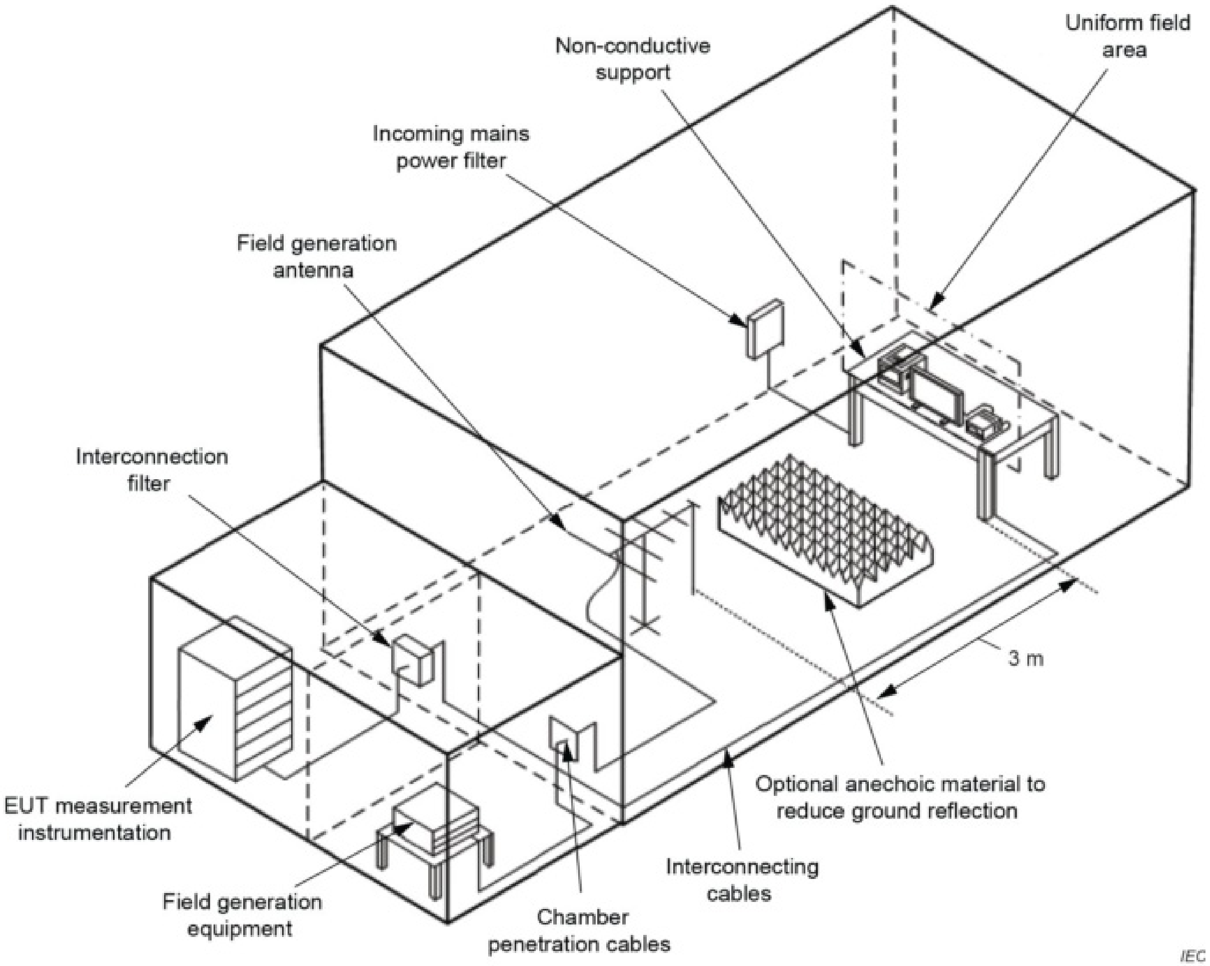
Care shall be taken to ensure adequate immunity of the test instrumentation. For the measurement uncertainty due to test instrumentation see Annex J.

6.2 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 with radio communications. In addition, since most test equipment used to collect data is sensitive to the 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 is adequately isolated from 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.

Further guidance on the use of anechoic chambers is given in Annex C.



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

Figure 2 – Example of suitable test facility

6.3 Uniform field area (UFA)

6.3.1 Characteristics of the UFA

This document uses the concept of a uniform field area (UFA, see Figure 3 and Figure 4), which is a vertical plane of the field in which variations are within limits specified below. The methods given in 6.3.2 and 6.3.3 are used to demonstrate the capability of the test facility and the test equipment to generate the uniform field for testing. Data for setting the required field strength for the immunity test is obtained and is used to test all EUTs.

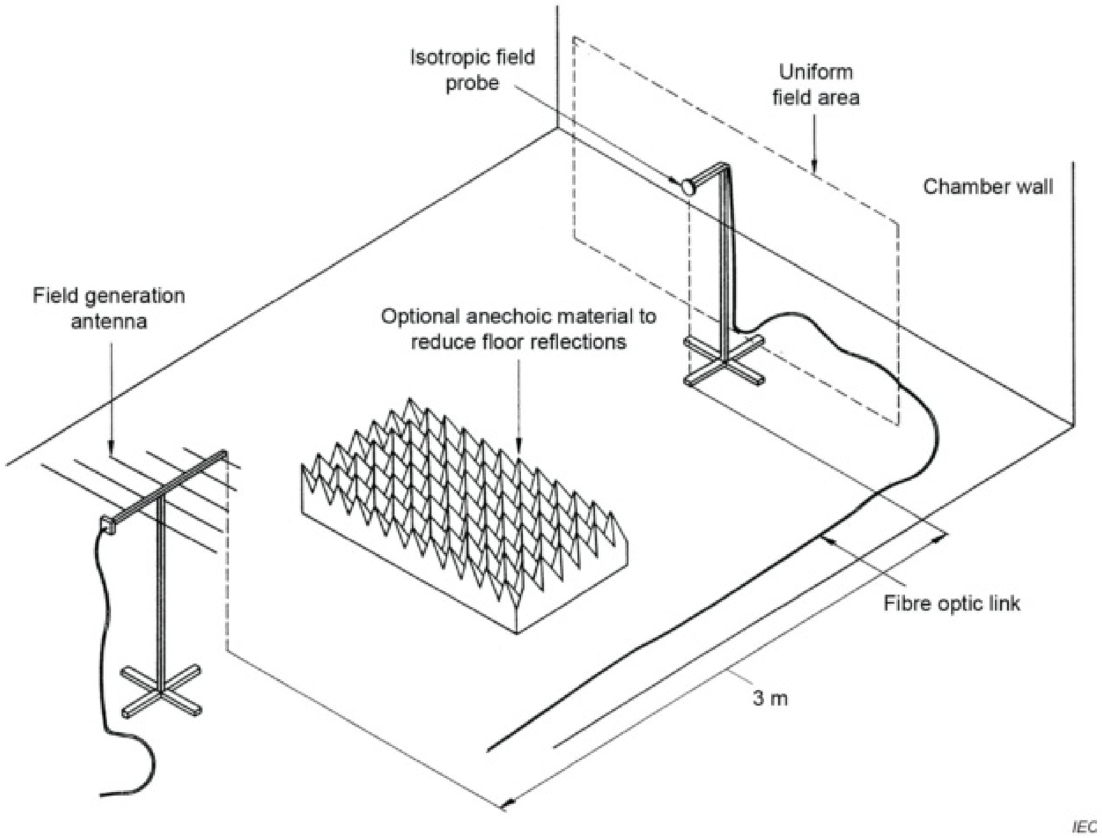


Figure 3 – Level setting setup

The uniform field level setting 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 actual test field strength E_{T} can be different from the level setting field strength E_{L} provided that the linearity of the system can be demonstrated (see 6.3.2 or 6.3.3 and Annex D). The level setting is valid as long as the setup of the test instrumentation used remains unchanged for testing. Since even small displacements can significantly affect the field, it is important, especially at high frequencies, that the position of test instrumentation such as antennas, absorbers, cables, etc., is recorded.

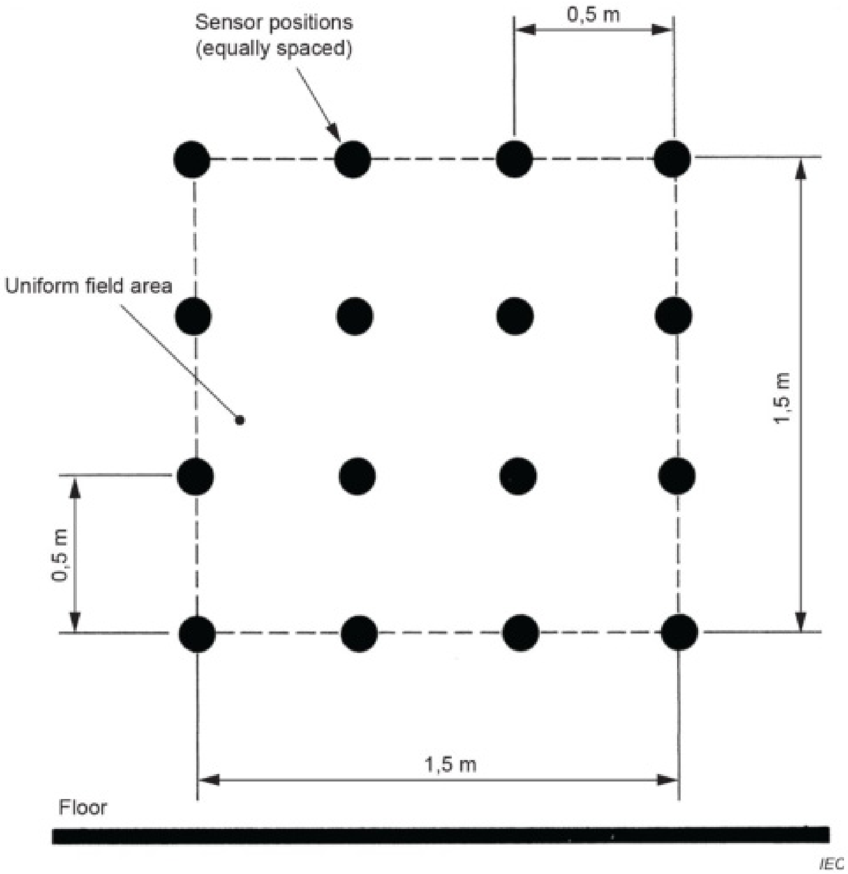


Figure 4 – Dimensions of sixteen-point uniform field area

The lower edge of the UFA can be at any height, if the criteria in 6.3.1 can be met. It is the intention that the EUT is fully illuminated by the field. However, it is difficult to establish a UFA close to a metallic floor, therefore fully illumination might not be possible for all EUTs. See Clause 7 for details.

It is intended that the full field level setting process 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 distance between the transmitting antenna and the UFA shall be such that the UFA requirements can be met. A distance of 3 m between the antenna and the UFA is preferred (see Figure 3). The minimum distance shall be 1 m. This distance is measured from the centre of a biconical antenna, or from the front tip of a log periodic or combination antenna, or from the front edge of horn or double ridge wave guide antenna. The distance used shall be recorded and shall be the same distance adopted for the test.

The preferred dimension for the UFA is 1,5 m × 1,5 m, however, if the EUT and its cabling (see 7.4) can be fully illuminated with a smaller UFA, a smaller UFA is allowed down to 0,5 m × 0,5 m minimum. For the minimum UFA of 0,5 m × 0,5 m, a fifth grid point is placed in the centre of the UFA. See Figure 5.

NOTE 1 Sampling with closer grid spacing over a portion of the UFA could be used to verify the homogenous nature of the field distribution.

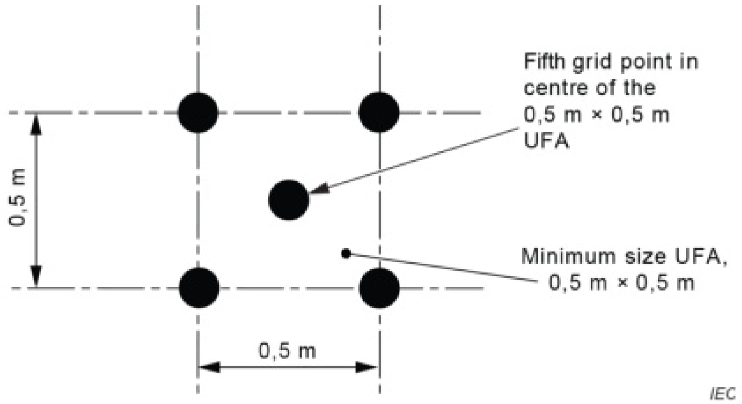


Figure 5 – Minimum UFA size having a fifth grid point in the centre

It is difficult to establish a UFA close to a metallic floor. Additional absorbing material can reduce or solve this problem (see Figure 2).

For the purpose of level setting, 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 0 dB to +6 dB of the nominal value for not less than 75 % of all grid points (e.g. if at least twelve of the sixteen 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 five grid points shall lie within the specified tolerance.

A UFA does not need to be a square as long as it can be constructed from 0,5 m × 0,5 m square elements. The UFA shape selected is used up to at least 1 GHz.

NOTE 2 At different frequencies, different measuring points can 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 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 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 test performed with a 0 dB to +6 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 a UFA with sufficient dimensions (preferred method) cannot be realised, then the area to be occupied by the EUT, and above the lower edge of the UFA, may be illuminated in a series of tests ("partial illumination"), using either method below:

– a characterization 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,
– 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.

Each of the antenna positions requires a full field level setting. It is not intended to illuminate the portion of a EUT that extends below the lower edge of the UFA (i.e. floor standing equipment). Additionally characterization of the field in the area below the UFA may be recorded. See 7.3.

Table 3 demonstrates the concepts of full illumination and partial illumination as well as where and how they can be applied.

The preferred method for all frequencies is full illumination. If full illumination cannot be used, one or more of the frequency-dependent alternative methods can be applied.

Table 3 – Requirements for uniform field area for application of full illumination and partial illumination

<table>
<tr><th>Requirements for UFA / Frequency range</th><th>Full illumination: the EUT and its cabling (see 7.4) fits completely within the UFA

(preferred method)</th><th>Partial illumination: the EUT and its cabling (see 7.4) does not fit completely within the UFA</th></tr>
<tr><td>Up to at least 1 GHz</td><td rowspan="2">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; 1,5 m × 1,5 m; 1,5 m × 2,0 m; 2,0 m × 2,0 m, etc).
Characterization in 0,5 m × 0,5 m grid steps.
At least 75 % of measured points within specifications if UFA is larger than 0,5 m × 0,5 m.
100 % (all five points) shall be in specifications if a UFA of only 0,5 m × 0,5 m is used.</td><td>Minimum UFA size 1,5 m × 1,5 m.
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).
Characterization in 0,5 m × 0,5 m grid steps.
75 % of measured points within specifications.</td></tr>
<tr><td>Above 1 GHz</td><td>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; 1,5 m × 1,5 m; 1,5 m × 2,0 m; 2,0 m × 2,0 m, etc).
Characterization in 0,5 m × 0,5 m grid steps.
At least 75 % of measured points within specifications if UFA is larger than 0,5 m × 0,5 m.
100 % (all five points) shall be in specifications if a UFA of only 0,5 m × 0,5 m is used.</td></tr>
</table>

Generally, the characterization of the field in anechoic and semi-anechoic chambers can be performed using the test setup shown in Figure 6.

The characterization shall always be performed with an unmodulated carrier for both horizontal and vertical polarizations in accordance with the steps given below. It is required to ensure that the amplifiers can reproduce the modulation within the linearity requirements during testing (see 6.3.2 or 6.3.3 and Annex D). For 80 % AM, the level setting process is performed with a field strength at least 1,8 times as high as the field strength to be applied to the EUT. Denote this level setting field strength by E_{L}. E_{L} is the value which is applicable only to the field level setting. The test field strength E_{T} shall not exceed $E_{\mathrm{L}}/1,8$.

NOTE 3 Other methods to ensure avoiding saturation can be used (see Annex D for further information).

If modulations other than 80 % AM are used, a suitable saturation check should be performed based upon the peak power of the modulated signal.

Two different characterization methods are described below using an 1,5 m × 1,5 m UFA (sixteen grid points) as an example. These methods are considered as giving the same field uniformity and test level setting.

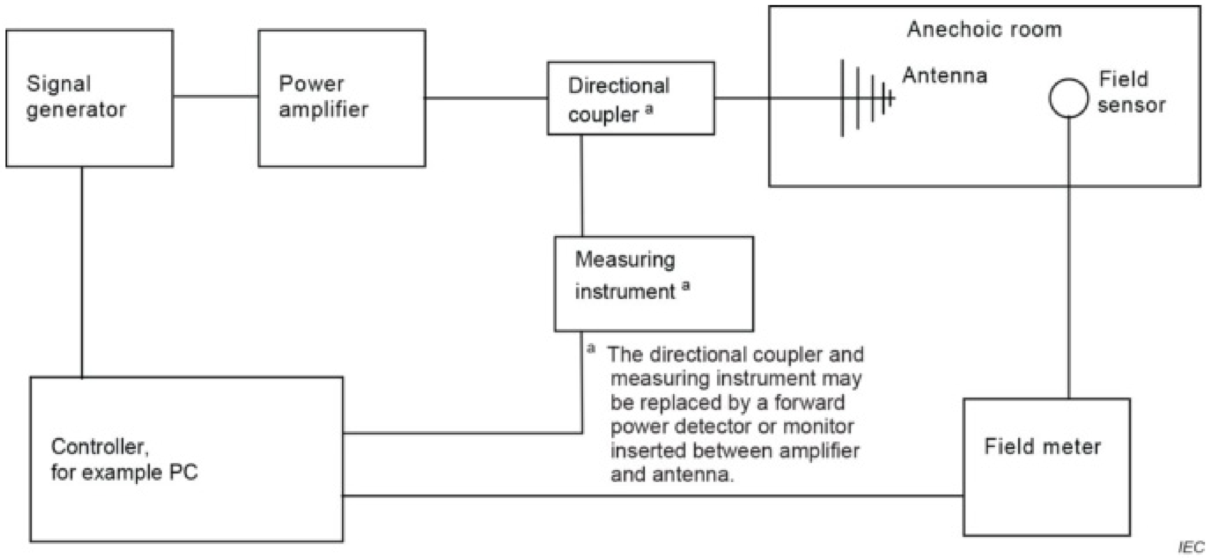


Figure 6 – Measuring setup

6.3.2 Constant field strength level setting method

The constant field strength of the uniform field shall be:

- established at each particular frequency. The particular frequencies are determined by using the frequency step described in 8.4
- established at each of the points of the UFA, one after the other (see Figure 4);
- established by adjusting the forward power accordingly.
- measured via a calibrated field sensor.

The forward power necessary to establish the field strength chosen shall be measured in accordance with Figure 6 and is to be recorded in dBm for the sixteen points.

Procedure to be followed at both horizontal and vertical polarizations:

a) Position the sensor at one of the sixteen 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).

NOTE 1 To lower the uncertainty of the field measurement, the probe is oriented in the same manner at each of the grid points as it was oriented during the probe calibration.

b) Adjust the forward power to the field generating antenna so that the field strength obtained (with field probe correction factors for frequency applied) is equal to the level setting field strength E_{L}. Record the forward power reading.

c) Increase the frequency using the step size given in Clause 8.

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 the maximum frequency of the test range (for example 1 GHz).

e) Repeat steps a) to d) for each point in the grid.

At each frequency:

1) Sort the sixteen forward power readings into ascending order.

2) Start at the highest value and check if at least the eleven readings below this value (75 % of grid points) are within the tolerance of –6 dB to 0 dB of that value.

3) 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 in this example of a sixteen-point UFA, there are only five possibilities for each frequency).

4) Stop the procedure if at least twelve power readings (75 % of grid points) are within 6 dB. Take from these numbers the position where the maximum forward power was obtained as the reference. Record this value. Denote this forward power by P_L.

5) Confirm that the test system (e.g. the power amplifier) is not in saturation. Assuming that E_L has been chosen as 1,8 times E_T, perform the following procedure at each level setting frequency:

   i) decrease the output from the signal generator by 5,1 dB from the level needed to establish a forward power of P_L, as determined in the above steps (-5,1 dB is the same as E_L / 1,8);

   ii) record the new forward power delivered to the antenna;

   iii) subtract the forward power measured in step ii) from P_L. If the difference is between 3,1 dB and 7,1 dB, then the amplifier is considered to be sufficiently linear, and the test system is suitable for testing. Otherwise the test system is not suitable for testing.

NOTE 2 If at a specific frequency, the ratio between E_L and E_T is R (dB), where $R = 20 \log(E_L / E_T)$, then the test power $P_T = P_L - R$ (dB). The subscripts L and T refer to level setting and test, respectively.

NOTE 3 Step 5) describes how to check if the amplifier used is sufficiently linear. For more information refer to Annex D.

6.3.3 Constant power level setting 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 sixteen points one after the other (see Figure 4) using the step size given in 8.4 and 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 6, and noted. The same forward power shall be applied for all sixteen positions. The field strength created by this forward power is to be recorded at each of the sixteen points.

Procedure to be followed at both horizontal and vertical polarizations:

a) Position the sensor at one of the sixteen 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).

   NOTE 1 To lower the uncertainty of the field measurement, the probe is oriented in the same manner at each of the grid points as it was described in the probe calibration report.

b) Apply a forward power to the field generating antenna so that the field strength obtained (with field probe correction factors for frequency applied) equals E_L. Record the forward power and field strength readings.

c) Increase the frequency using the step size given in Clause 8.

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 the maximum frequency of the test range (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.

At each frequency:

1) Sort the sixteen field strength readings into ascending order.

2) Select one field strength as the reference and calculate the deviation from this reference for all other positions in decibels.
3) Start at the lowest value of the field strength and check if at least eleven (75 % of grid points) readings above this value are within the tolerance of 0 dB to +6 dB of that lowest value.
4) 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 in this example of a sixteen-point UFA, there are only five possibilities for each frequency).
5) Stop the procedure if at least twelve field strength values (75 % of grid points) are within 6 dB and take from these numbers the position where the minimum field strength was obtained as the reference.
6) Calculate the forward power necessary to create the required field strength in the reference position. Denote this forward power by P_L.
7) Confirm that the test system (e.g. the power amplifier) is not in saturation. Assuming that E_L has been chosen as 1,8 times E_T, perform the following procedure at each level setting frequency:
   i) decrease the output from the signal generator by 5,1 dB from the level needed to establish a forward power of P_L as determined in the above steps (−5,1 dB is the same as E_L / 1,8);
   ii) record the new forward power delivered to the antenna;
   iii) subtract the forward power measured in step ii) from P_L. If the difference is between 3,1 dB and 7,1 dB, then the amplifier is considered to be sufficiently linear, and the test system is suitable for testing. Otherwise the test system is not suitable for testing.

NOTE 2 If at a specific frequency, the ratio between E_L and E_T is R (dB), where $R = 20 \log(E_L/E_T)$, then the test power $P_T = P_L - R$ (dB). The subscripts L and T refer to level setting and test respectively.

NOTE 3 Step 7) describes how to check if the amplifier used is sufficiently linear. For more information refer to Annex D.

7 Test setup

7.1 General

All testing of equipment shall be performed in a configuration as close as possible to actual installation conditions. Wiring shall be consistent with the procedures stated in the instructions for use, and the equipment shall be in its housing with all covers and access panels in place, unless otherwise stated.

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. However, grounding of housing or case of the equipment shall be consistent with the recommendations stated in the instructions for use.

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

During the immunity test, the EUT shall have the face to be illuminated coincident with the UFA. Typical EUT setups are shown in Figure 7 and Figure 8a) and Figure 8b).

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.

At higher frequencies (e.g., above 1 GHz), tables or supports made from wood or glass reinforced plastic can be reflective. 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.

In order to have each EUT face coincident with the UFA, an adjustment of the EUT position may be necessary.

7.2 Arrangement of table-top equipment

The equipment to be tested is placed in the test facility on a non-conductive table within the UFA. The height of the non-conducting support should be (0,8 ± 0,05) m. This height is specified even if the UFA's lower edge starts at another height than 0,8 m.

The equipment is then connected to power and signal cables in accordance with relevant installation instructions.

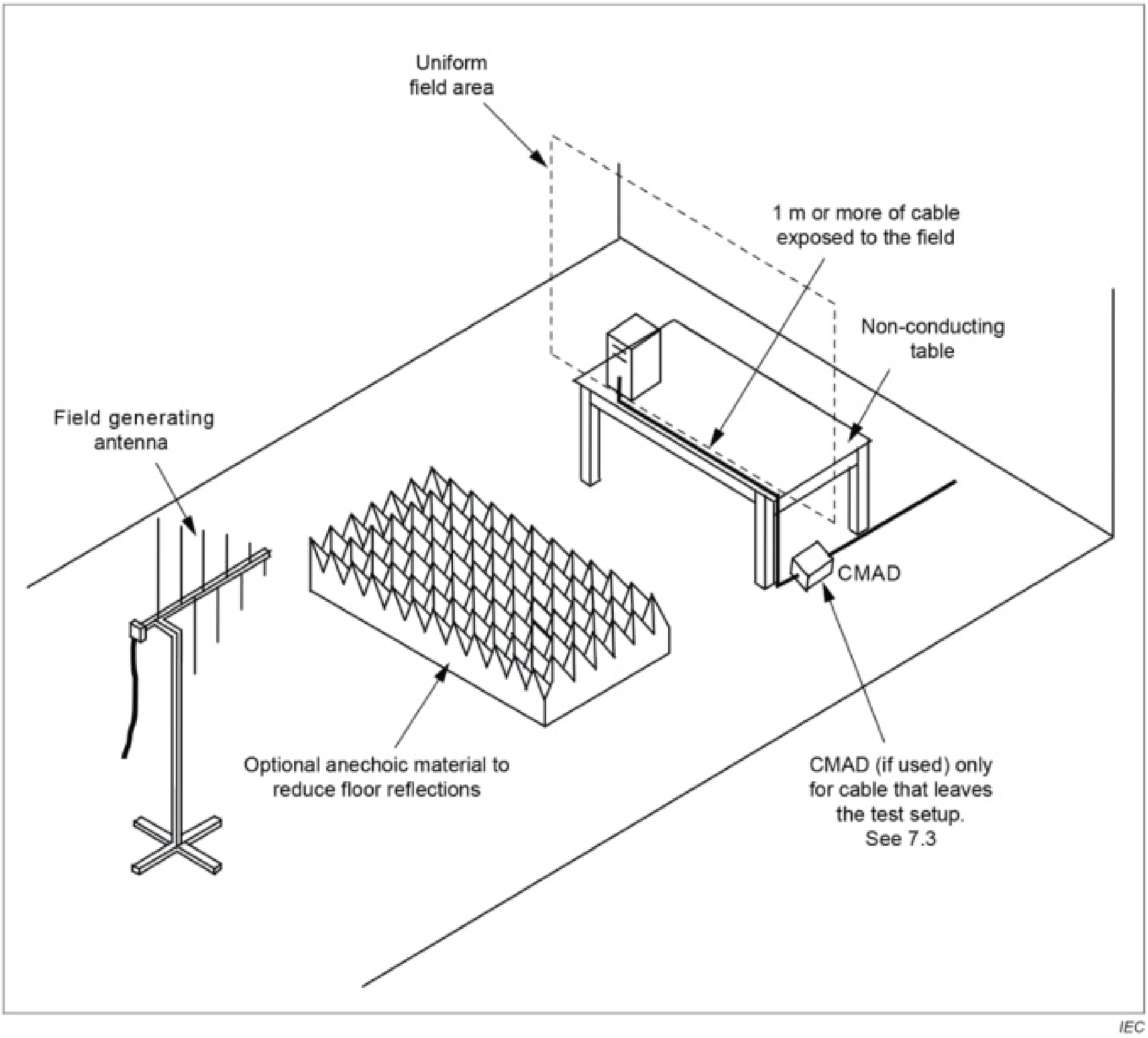
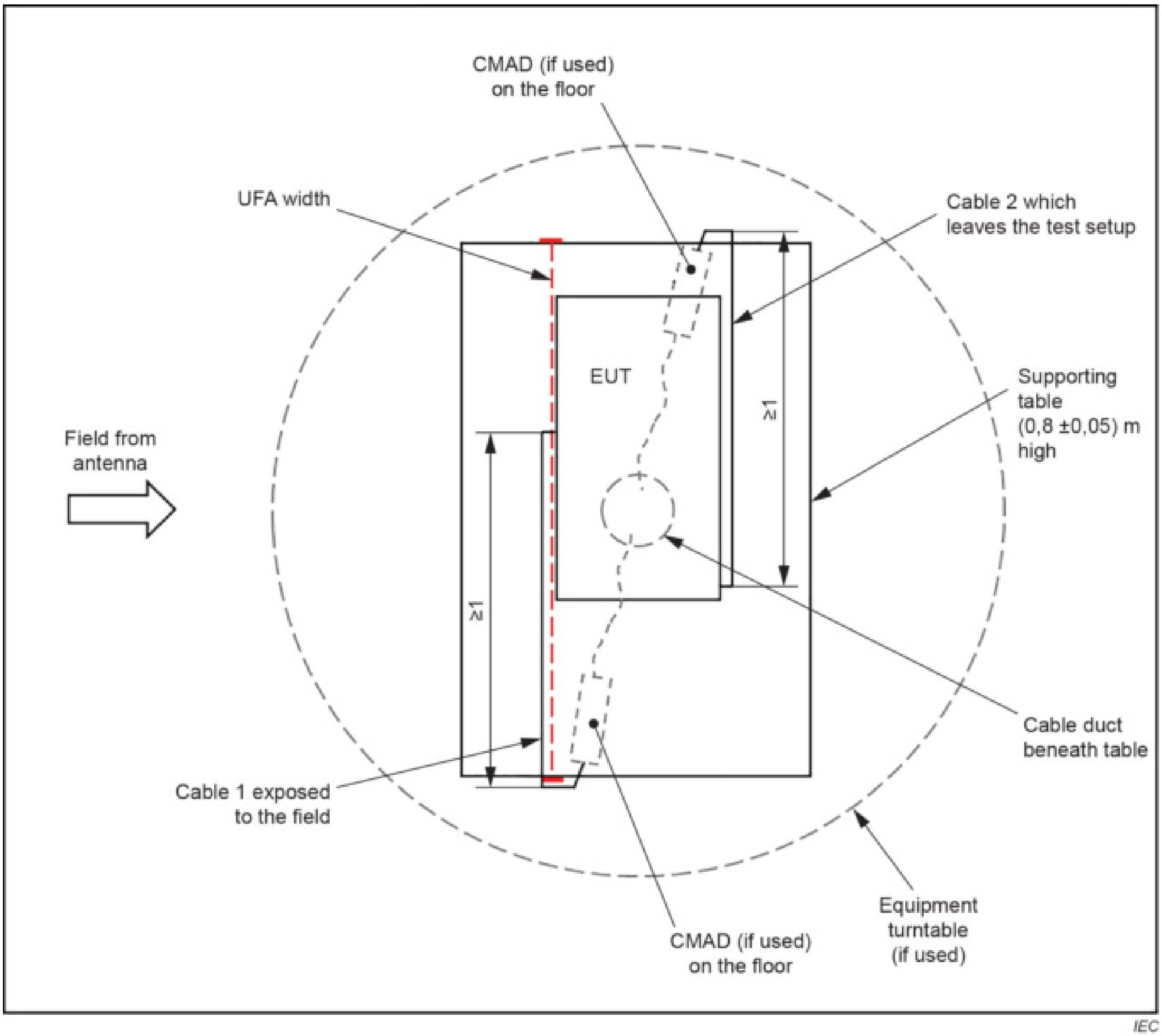
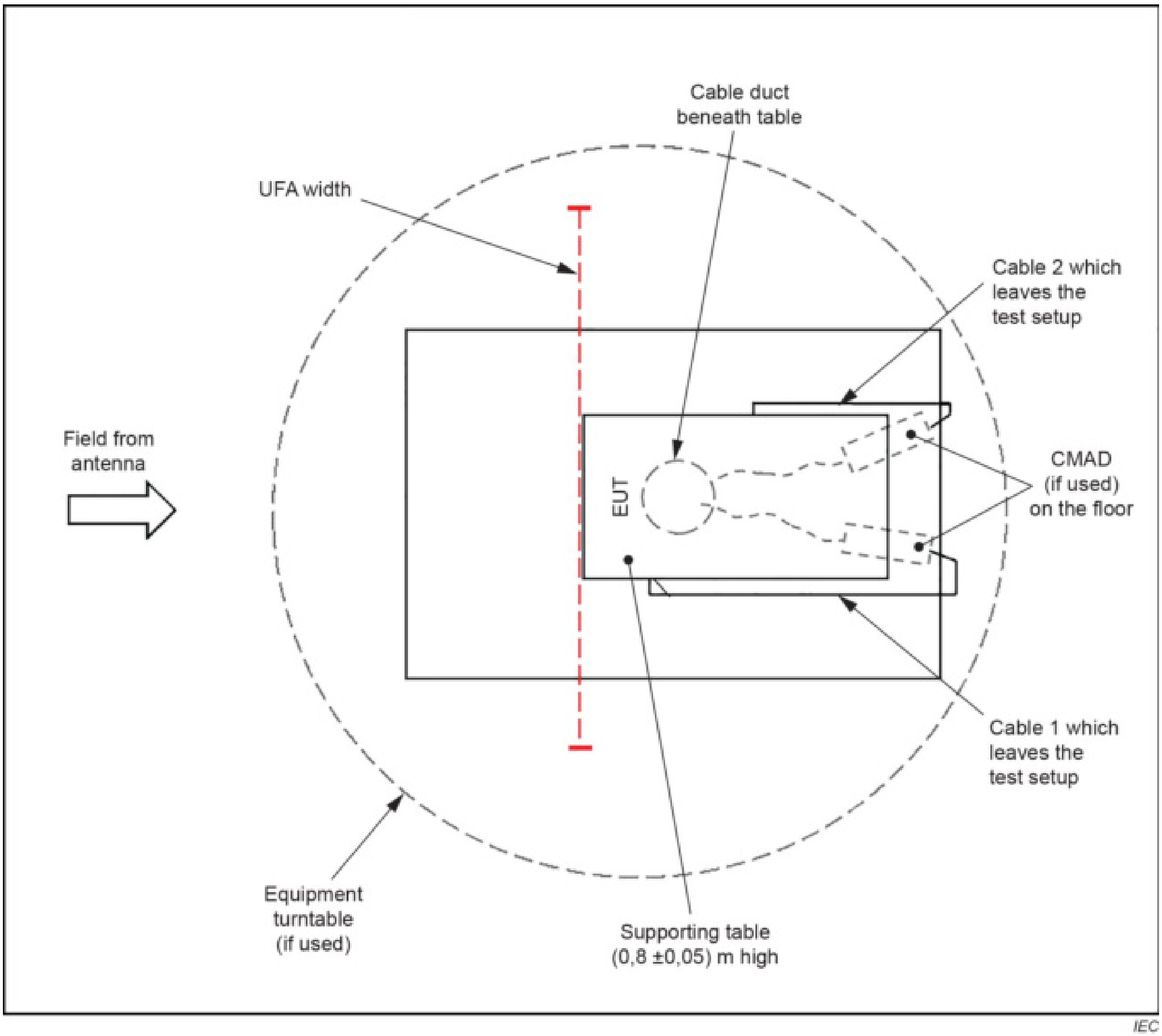


Figure 7 – Example of EUT setup and cable layout for table top EUT having a cable that leaves the test setup



NOTE 1 When the setup is turned 180°, Cable 2 becomes illuminated.

a) Example of EUT setup (top view) and cable layout for table top EUT having cable that leaves the test setup



NOTE 2 The cables and EUT position have been adjusted to align with the UFA.

NOTE 3 In this orientation no cables are intentionally illuminated by the field.

b) Example of the same EUT (top view) but in an alternative setup (EUT rotated 90° and different cable layout)

Figure 8 – Example of EUT setup (top view)

7.3 Arrangement of floor-standing equipment

Floor-standing equipment should be mounted on a non-conductive support 0,05 m, or more, above the floor in order to prevent accidental earthing of the EUT and distortion of the field. The support shall preferably be bulk non-conductive, rather than an insulating coating on a metallic structure.

Floor standing equipment should be positioned to maximize the area of the EUT placed within the UFA.

If due to its heavy weight or large physical size or for safety reasons, the equipment cannot be raised to the height of the UFA or removed from its delivery support (for example, a shipping pallet), this variation shall be recorded in the test report. If the EUT extends more than 0,5 m below the lower edge of the UFA, the magnitude of the field at a height of 50 % of the lower edge of the UFA (at all 0,5 m horizontally separated level setting points) shall be recorded and documented in the level setting record. The data at this height is not considered for the suitability of the test facility and for the level setting procedure.

NOTE Non-conductive rollers can be used as the support.

See Annex H for guidance on the placement of large and heavy EUTs.

The equipment is then connected to power and signal wires in accordance with relevant installation instructions.

7.4 Arrangement of wiring

Cables shall be connected to the EUT and arranged on the test site in accordance with the installation instructions and shall replicate typical installations and use as much as possible.

The 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 product specification requires a wiring length of less than or equal to 1 m, then the specified length shall be used. If the length specified is greater than 1 m, or is not specified, then the length of cable used shall be chosen in accordance with typical installation practices. Unless otherwise specified above, a minimum of 1 m of cable shall be exposed to the electromagnetic field in one orientation, either vertical or horizontal. Deviations from this (for example, heavy or rigid cables that cannot be manipulated) shall be stated in the test report. Cables routed orthogonally to the UFA cannot be expected to contribute to picking up signal from the field and, therefore, are not considered to contribute to the combined length of cable exposed to the field. The length of cable exposed to the field should be routed physically as close to the UFA as practical.

Excess length of cables interconnecting units of the EUT shall be bundled low-inductively in the approximate centre of the cable to form a bundle. Deviations from this (for example, heavy or rigid cables that cannot be manipulated) shall be stated in the test report.

Each cable does not need to be exposed to the field during the exposure of each face of the EUT. But each cable shall, at least during one of the EUT orientations, be positioned within the UFA, and thus exposed to the field. Cables not intentionally exposed to the field (in the current orientation) should be routed in a manner to reduce their coupling to the field. This may require repositioning of the cables for each exposure. For EUTs with large numbers of attached cables or where typical installation practices limit the ability to position cables within the UFA, attempts should be made to expose attached cables to the field.

See Annex G for guidance on suggested practices for cable layout, cable exposure to the applied electromagnetic field, and EUT setup.

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.

If cable decoupling is performed, CMADs may be used. The impedance and absorption properties of the CMAD are specified in CISPR 16-1-4. CMADs may be used to reduce the influence of cables outside the test area on the radiated immunity test results. If CMADs are used, the cable leaving the test area shall enter the CMAD at the point where it reaches the floor as shown in Figure 7. The CMAD shall always be placed flat on the floor. Each cable to be decoupled should be treated with a separate CMAD.

In order to avoid saturation, the current capability of the CMADs shall be taken into consideration, especially for high common mode current power cables (e.g. the output port of inverters).

If CMADs are used, the following applies:

- Decoupling may apply to any type of cable (e.g. power, telecommunication, and control).

- For a test setup with up to three cables leaving the test area, each cable should be decoupled with a CMAD.
- For a test setup with more than three cables leaving the test area, the power cable(s) shall be treated with CMADs as first priority (unless otherwise specified by a product committee). After this, CMADs for the remaining cables should be placed on the cables expected to contain the more sensitive signals. Up to three CMADs in total can be used. The cables on which the CMADs have been applied shall be documented in the test report.

See Annex G for more information about cable routing and CMADs.

7.5 Arrangement of human body-mounted equipment

Human body-mounted equipment (see 3.1.15) may be tested in the same manner as table top items. However, this can involve over-testing or under-testing because the characteristics of the human body are not taken into account during the level setting and testing processes. For this reason, product committees are encouraged to specify the use of a human body simulator with appropriate dielectric characteristics.

8 Test procedure

8.1 General

The test procedure includes:

– test level, frequency range(s) and test modulation;
– the verification of the laboratory reference conditions, including a pre-check of the generated field strength;
– the preliminary verification of the correct operation of the equipment;
– the execution of the test;
– the evaluation of the test results (see Clause 9).

8.2 Laboratory reference conditions

8.2.1 General

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 8.2.2 and 8.2.3.

8.2.2 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.

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

8.2.3 Electromagnetic conditions

The electromagnetic conditions of the laboratory shall allow for the correct operation of the EUT in order not to influence the test results.

8.3 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 should contain information about:

- 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;
- the frequency range, dwell time and frequency steps;
- the size, shape and height of the uniform field area;
- whether any partial illumination is used;
- the test level and modulation 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 Clause 8 are for the use of field generating antennas as defined in Clause 6.

The forward power P_T derived from P_L should be used as the reference parameter for establishing the test field strength. See NOTE 2 of 6.3.2 or 6.3.3 for details

Before testing, it shall be verified that the test equipment/system is operating properly. This can be done, for example, by measuring the field strength at one or more points within the UFA at one or more frequencies.

The EUT is initially placed with one face coincident with the UFA plane. The EUT face being illuminated shall be contained within the UFA unless partial illumination is being applied. See 6.3 regarding field level setting and use of partial illumination.

The frequency ranges to be considered are swept with the signal modulated in accordance with 5.1, pausing to adjust the RF signal level or to switch oscillators and antennas as necessary. Where the frequency range is swept incrementally, see 8.4 about the step size requirements.

The dwell time of the 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.

NOTE 1 The dwell time starts when the test condition has stabilized at each frequency.

In order to reduce test time, more than one frequency may be applied simultaneously (multiple signal testing) during a single dwell time, provided the linearity requirements of 6.3.2 step 5) or 6.3.3 step 7) are met on the aggregate signal. At each of the signal frequencies, the test levels shall be the ones resulting from the level setting procedure for testing with one frequency at a time. The same modulation is applied simultaneously to each signal. Intermodulation signals shall be treated like harmonics and checked to ensure they are not causing a significant effect (see Annex I regarding modulation effects and Clause 9 regarding the evaluation of the test result).

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 2 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.

The polarization of the field requires 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, special tools or devices to exercise the EUT during the exposure are recommended.

8.4 Step sizes

Where the frequency range is swept incrementally, the step size shall not exceed 1 % of the preceding frequency. This maximum step size applies to both the level setting procedures of 6.3.2, 6.3.3 and the execution of the test in 8.3.

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 evaluation of the test result shall be based on the performance of the EUT during the dwell time with the appropriate modulation applied.

EUT performance evaluation should be based on a single cause and effect basis. If multiple test signals were used during testing, care should be taken to ensure that any recorded performance degradation was caused by a single test signal and was not caused by the combination of multiple test signals. 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;
– 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;
– any additional information relevant to the EUT position with respect to the size and position of the UFA;
– any additional information relevant to the tolerance of the UFA, if required by 6.3.1;
– description and/or pictures of the cabling and equipment position and orientation;
– any deviations from this document.

Annex A
(informative)

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

A.1 Summary of available modulation methods

During the development of this document, 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, for example 1:8 duty cycle at 200 Hz for GSM, 1:24 duty cycle at 100 Hz for DECT portables, etc.;
– pulsed RF signal simulating exactly the characteristics of each system, for example 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);
– OFDM (orthogonal frequency division multiplexing) signal for broadcast and radio communication.

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

Table A.1 – Comparison of modulation methods

Signal type	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 remain the same. 2 It is not necessary to specify (and measure) the rise time of the TDMA pulse. 3 Used in this document 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 Demodulation in EUT produces a broadband audio response which shall be measured with a broadband level meter, thereby raising background noise. 3 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 The details of the modulation need to be varied to match each of the different systems (e.g. GSM, DECT, etc.). 2 Demodulation in EUT produces a broadband audio response which shall be measured with a broadband level meter, thereby raising background noise. 3 Necessary to specify the rise time.
OFDM	1 Good representation of digital modulation. 2 May reveal "unknown" failure mechanisms (sensitive to the large rate of change of the RF envelope).	1 The details of the OFDM parameters need to be varied to match each of the different radio services (e.g. LTE, DAB, DVB-T).

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 Table A.2 and Table 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 to 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 3.1.19) 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 1:24 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 3.1.19) 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 DC 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 1 800, 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 document 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 balun and two symmetric conical elements which provide a broad frequency range and can be used both for transmitting and receiving. 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 logarithmically spaced dipoles of different lengths connected to a transmission line.

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

B.3 Combination antennas

A log-periodic antenna and a biconical antenna can be combined. This combination can increase the frequency range and can cover the frequency range from below 80 MHz to some GHz using only one antenna. Such antennas may be named hybrid antennas or similar.

As the biconical element is usually positioned away from the tip of the log-periodic antenna, the distance between the dipole element and the EUT may be substantially larger than the tip of the hybrid antenna. Such antennas may require more power to the antenna to generate the RF field.

Two log-periodic antennas can also be combined in order to achieve higher gain. Such antennas may be named "stacked" antennas or similar.

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.

NOTE Higher gain antennas typically have smaller beam-width.

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 pyramids.

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. For chambers with ferrite absorbers, see Clause C.2. 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 level setting procedure. Additionally, tilting and raising of the field generating antenna can prevent direct illumination of absorbing material placed on the floor. This is especially important for the arrangement of floor-standing equipment, see also 7.3 and Annex H for guidance on the placement of large and heavy EUTs.

Uniformity can also be improved by placing the field generating antenna off the axis of the chamber (horizontally and vertically if necessary), such that any reflections are not symmetrical.

C.2 Use of ferrite-lined chambers at frequencies above 1 GHz

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

Anechoic chambers which use only ferrite as an absorber are designed for use at frequencies up to 1 GHz. The problem described below may occur, for example, in a small ferrite-lined anechoic chamber.

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).

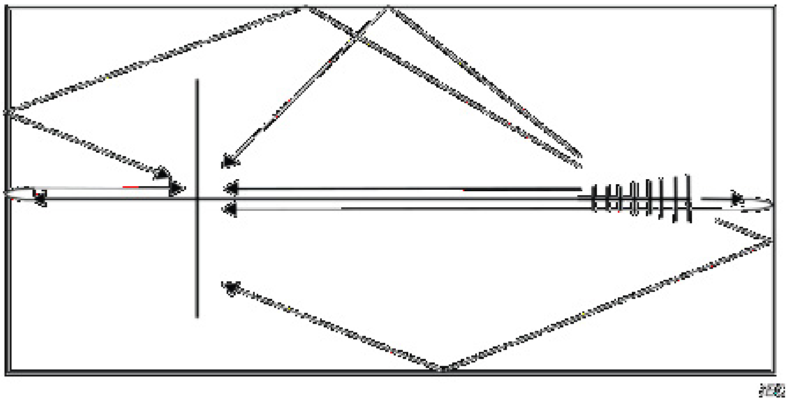


Figure C.1 – Multiple reflections in an existing small anechoic chamber

Especially for frequencies where the wavelength is shorter than 0,2 m, the reproducibility of the results can be very sensitive to the positioning of the field generating antenna and the field sensor or EUT.

C.2.2 Solutions to reduce reflections

The influence from reflections can be reduced in the following manner:

- 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).
- Attach carbon type anechoic material to the rear wall behind the EUT (seen from the field generating antenna) 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 Carbon loaded anechoic material can be specified to work together with the existing ferrite absorber material, in order 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).

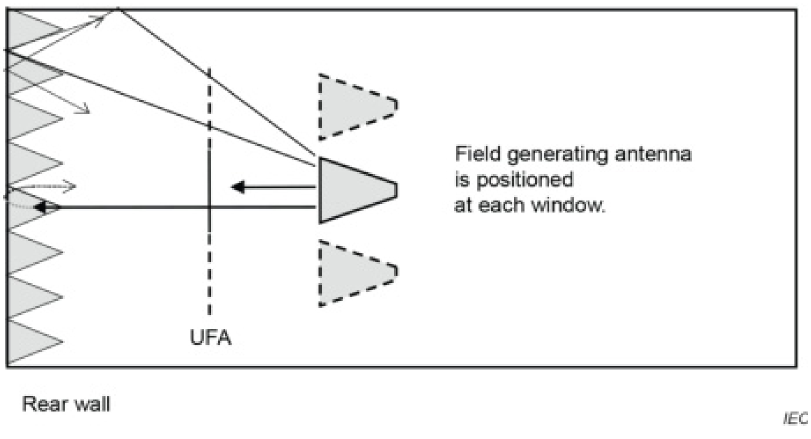


Figure C.2 – Most of the reflected waves are eliminated (applies for top and side view)

Annex D
(informative)

Amplifier compression and non-linearity

D.1 Objective of limiting amplifier distortion

Amplifier non-linearity can have a significant impact on the disturbance signal applied to the EUT. The goal is to keep amplifier non-linearity low enough to minimize the effect on the disturbance signal. Annex D is provided to assist test laboratories in understanding and limiting amplifier distortion.

D.2 Possible problems caused by harmonics and saturation

Operating an amplifier in saturation may result in the following scenarios:

a) The harmonics may contribute significantly to the measured values taken during UFA measurement. The field strength at the intended frequency is incorrectly measured, as the broadband field probe will measure the fundamental and its harmonics.

b) Harmonics may cause an EUT failure where the EUT is robust at the intended fundamental frequency but not robust at the harmonic frequency. The false failure would be recorded incorrectly and may lead to an incorrect redesign.

c) 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. Special low-pass or notch filters could be used to protect sensitive EUTs.

d) Saturation may be present without measurable harmonics. This occurs if the amplifier has a low-pass output filter which suppresses the harmonics and/or internal circuitry and combining technology may work to suppress the harmonics at the band edges. This situation may also lead to incorrect results.

   1) If this occurs during the UFA characterization, wrong level setting data will be derived as the assumption of linearity is used in the algorithm described in 6.3.2 or 6.3.3.

   2) During a test, this type of saturation will lead to an incorrect modulation factor and harmonics of the modulation frequency (usually 1 kHz).

D.3 Limiting the harmonic content in the field

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

For all frequencies where harmonics are produced at the output of the amplifier, the harmonics in the amplifier output signal should be low enough that the harmonics in the electric field are at least 6 dB less than the fundamental. This is considered adequate, with the exception of the scenario discussed in Clause D.2, item c).

Depending on the phase relationship between the fundamental signal and the harmonic signals, the field strength error could be 10 % or more of the fundamental field strength. 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.

However, an actual testing system consists of a standard signal generator, a power amplifier, an antenna and coax cables connecting those devices. It should be noted that 6 dB harmonics for a power amplifier could not be sufficient in some cases depending on the antenna factor value used.

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.

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 would be reduced by 20 %.

D.4 Effect of linearity characteristic on the immunity test

D.4.1 General

Issues which affect the result of the immunity test are the linearity characteristic of the amplifier, harmonics and saturation of the amplifier.

Amplifier linearity should be verified, thus ensuring that the amplifier used generates the correct field strength at the UFA field strength level or at lower calculated levels.

D.4.2 Evaluation method of the linearity characteristic

D.4.2.1 Evaluation level range

The linearity characteristic of the amplifier should be evaluated over the amplitude range of the amplifier that is used for testing. This shall include the minimum level including the decrease from modulation to the maximum level including the increase from modulation.

The maximum level is referred to as the maximum level of the CW signal to be measured increased by 5,1 dB to allow for the contribution of modulation.

When calculating different test field strength levels, based on the level setting results for one of the UFA points, the evaluation range of linearity shall be the minimum to maximum amplifier output used for the test. For example, if a 3 V/m test is performed using the data obtained from a 10 V/m UFA level setting, the evaluation range of linearity is defined as the power amplifier outputs required to achieve a field strength of 1,67 V/m to 18 V/m.

D.4.2.2 Evaluation process

It is important to use the actual test setup and instrumentation, such as antenna, anechoic chamber and the test system used for EUT test, for the evaluation of amplifier linearity. The test arrangement is shown in Figure D.1.

Amplifier linearity should be evaluated at least at the minimum, middle and maximum frequency in the available range of the amplifier. However, depending on the frequency response and the compression behaviour of the amplifier, a significantly more detailed analysis of the compression behaviour might be necessary. As a minimum, an amplifier with for example a frequency range of 80 MHz to 1 GHz should be evaluated at 80 MHz, 500 MHz and 1 GHz. If the frequency range of the amplifier is divided into several frequency bands, the evaluation should be applied for each frequency band.

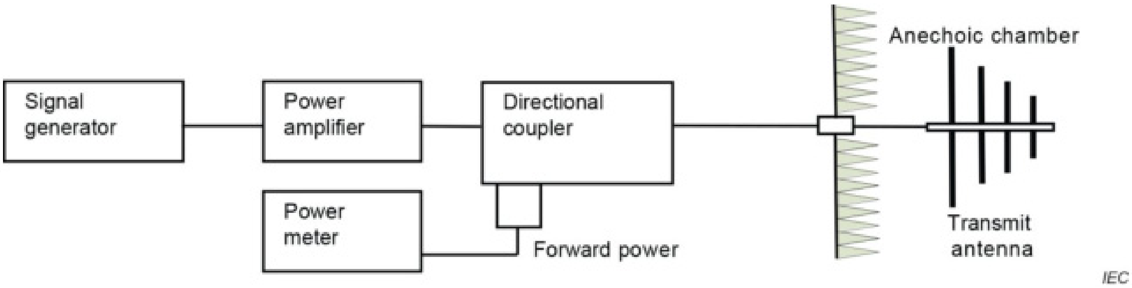


Figure D.1 – Amplifier linearity measurement setup

The linearity test shall be performed in accordance with the following procedure for each frequency as defined above.

1) Determine the signal generator setting necessary to generate both the minimum and maximum level (see D.4.2.1) for the appropriate test setup.
2) Set the signal generator to the minimum value determined in step 1) and record the output of the signal generator and the forward power of the amplifier.
3) Increase the setting of the signal generator by 1 dB and record the output of the signal generator and the forward power of the amplifier.
4) Repeat steps 2) to 3) until the maximum set value of the signal generator determined in step 1) is reached.

D.4.2.3 Linearity criteria

For the results obtained in D.4.2.2, the gain error over the level range of the measured amplifier output shall not exceed ±1 dB. See examples in Figure D.2 and Figure D.3.

If the measured data obtained following the process defined in D.4.2.2 meets the ±1 dB specification, then the amplifier, which the test laboratory uses, satisfies the linearity criterion.

If the data do not meet the linearity specification, then D.4.2.4 shall apply.

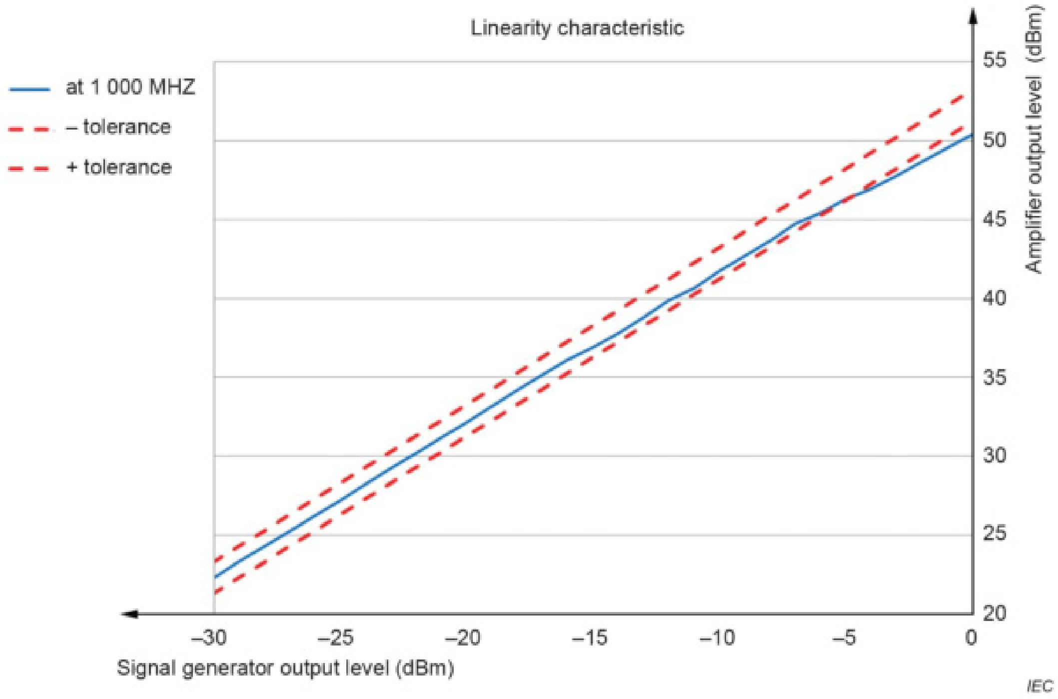


Figure D.2 – Example of linearity curve

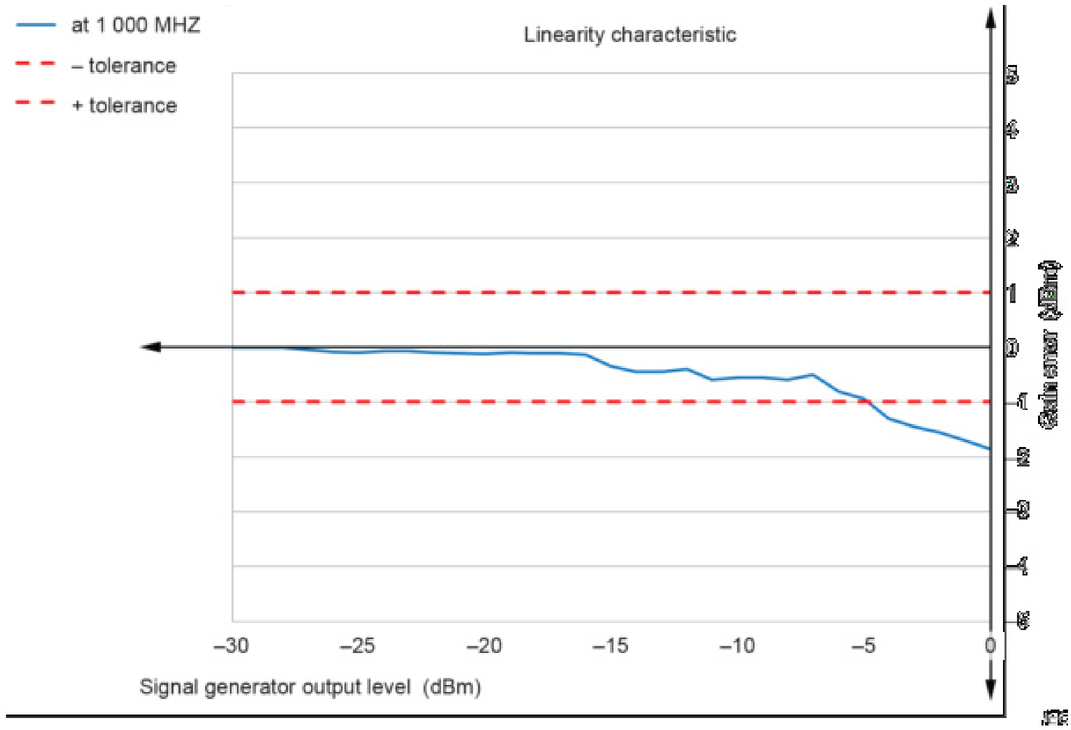


Figure D.3 – Example of gain deviation

NOTE Figure D.2 and Figure D.3 show an example defining the tolerance of ±1 dB based on the amplifier output at a single frequency. The signal generator output in this example is varied between a minimum level of −30 dBm and a maximum level of 0 dBm. In this example the amplifier exceeds the tolerance.

D.4.2.4 Immunity test when the amplifier linearity characteristic does not meet the criteria

If the evaluation performed in D.4.2.3 does not fulfil the criteria for linearity by ±1dB, it is necessary to adjust the forward power during the actual EUT test according to the following methods.

One method is to use a system with feedback, in which a power meter is used to monitor the output power from the power amplifier.

NOTE Care is taken to select equipment capable of measuring modulated signals.

Another method is for systems without a feedback, where the forward power level setting needs to be done at each desired test level.

Annex E
(informative)

Guidance for product committees on the selection of test levels

E.1 General

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

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

where

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

k is a constant, with a value of 7 (half wave dipole), 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.

NOTE IEC TR 61000-2-5 contains more detailed information about frequencies and power levels known to be allocated to specific radio services.

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.
- 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 and/or ISM equipment may be located close by.
- Class 4: Portable transceivers are in use at a distance of 0,2 m and 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.

If transmitters are used closer than 0,2 m from the EUT, a test according to IEC 61000-4-39 (see Annex F) should be taken into account.

NOTE IEC TR 61000-2-5 gives more detailed information about test levels to be applied for different electromagnetic environments taking into account also various kinds of communication services and frequency ranges.

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 Formula (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 performance criteria

Test level	Carrier field strength	Maximum RMS field strength	Protection distance for						Performance criteria [a]	
			GSM 8 W	GSM 2 W	DECT 0,25 W	LTE/UMTS 0,2 W	WiMAX 1,26 W	WI-FI 1 W	Example 1 [b]	Example 2 [c]
	V/m	V/m	m	m	m	m	m	m		
1	1	1,8	11	5,5	1,9	1,7	4,4	3,9	-	-
2	3	5,4	3,7	1,8	0,6	0,6	1,5	1,3	A	-
3	10	18	1,1	0,6	~0,2 [d]	~0,2 [d]	0,4	0,4	B	A
4	30	54	0,4	~0,2 [d]	~0,1 [d]	~0,1 [d]	~0,1 [d]	~0,1 [d]	-	B

[a] Defined performance criteria as defined by the relevant product committee.

[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 Formula (E.1) is not accurate. If transmitters are used closer than 0,2 m from the EUT, a test according to IEC 61000-4-39 (see Annex F) should be taken into account.

A performance class, see Clause 9.

B performance class, see Clause 9.

The following issues were considered when formulating Table E.1:

- For GSM/LTE hand held equipment, 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 usually much lower than maximum, except when used in areas with poor connection to the base station.
- Due to the attenuation by the presence of multiple indoor obstacles (walls, ceilings,...), compared to outdoor propagation conditions, the transmitting equipment usually adjusts their ERP (increased possibly to the maximum transmit power) for optimization of the communication link. This represents the worst-case situation from an EMC point of view, since most of potentially 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 Formula (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 Formula (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 in the order of ±6 dB.
- The protection distance according to Formula (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 Annex E are typical values which are rarely exceeded in the described locations. At some locations these values will be exceeded, for example radar installations, 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

The purpose of Annex F 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;
- the distance from the disturbing source to the EUT;
- the kind of the disturbing source, for example transmitters or inhomogeneous magnetic fields;
- the frequency of the disturbing source.

In total, at least six documents within the IEC 61000-4 series of basic standards can be used for testing equipment immunity to radio-frequency disturbances.

The documents differ by the disturbance phenomenon they simulate, or by the testing method.

This document and IEC 61000-4-6 form a set of documents that are intended to cover a full frequency range of 150 kHz and up. IEC 61000-4-6 specifies injection of radio-frequency test signals into the cabling of the EUT using suitable coupling devices. As a guideline, the transition is at 80 MHz, where the test with conducted RF disturbances stops, and the testing with radiated fields from an antenna starts.

This document has been optimized for frequencies above 80 MHz. The testing is performed using radiating antennas placed at a distance of at least 1 m from the EUT.

There is a range of frequencies, for which the test methods which appear in either document are useable. It is possible to use the test method defined in IEC 61000-4-6 up to 230 MHz. It is possible to use the test method defined in this document down to 26 MHz. Exposed cable lengths, test distance and UFA size may have to be increased for lower frequencies.

This document covers testing, where the intention is to simulate radio-frequency disturbance sources operated not in close proximity of the source. The testing distance is normally 3 m and is never lower than 1 m. Opposed to this is IEC 61000-4-39, which is optimized to simulate disturbance sources (magnetic or electromagnetic), where the radiated disturbance is caused by radio-frequency fields from devices used in close proximity. In this case, the frequency range is from 9 kHz to 6 GHz, and the testing distance is 10 cm or less.

Three further documents can be used for immunity testing with radio-frequency disturbances using various testing facilities and methods.

IEC 61000-4-22 provides a method of radiated immunity test performed in a fully anechoic (FAR) test chamber. The document could be considered similar, although not equivalent to, IEC 61000-4-3.

IEC 61000-4-20 is often used with small EUTs having no or very few cables. The testing facility is a TEM structure optimized for the purpose. The method may be applied from DC to several GHz.

IEC 61000-4-21 is very useful in case of large and complex EUTs to be tested at very high fields. The testing is performed in a reverberation test chamber, which utilizes reflections from the chamber as part of the testing method. The testing makes use of a statistical approach completely different from the deterministic approach adopted in this document. This method's usable frequency range is limited by the size and properties of the test facility.

Annex G
(informative)

Cable layout details

G.1 Intentions of EUT setup for radiated immunity test

In the final installation, the EUT and its attached cables will be subjected to exposure from electromagnetic field sources in the vicinity of the EUT. The field will induce signals into the attached cables and to the EUT itself. The intention of the test is to simulate both the induction/coupling of disturbance signals via the cables and the direct induction/coupling into the electronic circuits of the EUT.

To ensure that the cables are able to pick up signals from the field exposure, the cables shall be positioned such that each cable is not placed very close to other cables, and such that each cable is not placed close to metallic parts.

The coupling of the field to each EUT can be different for each face of the EUT. Consequently, the EUT units are exposed with a field from numerous directions, so each face of the EUT unit is in turn tested. This can require testing of up to six faces of the EUT cabinet/encapsulation. As the cables have been tested using at least one well specified configuration, it is not essential that the cabling is equally well defined when each EUT cabinet is turned into other orientations. When the cables are positioned well in order to pick up the field, they need in principle not to be re-routed, as the induction of signals via the cables has then been established.

G.2 Cable in the field

It is specified in the present document, that if possible, at least 1 m of each cable shall be placed exposed to the field. One meter is roughly equal to ¼ of the wavelength at the lower test frequency of 80 MHz (¼ wavelength = 93,75 cm). Induced signals are very easily picked up from the field by cables having a length of ¼ wavelength or more. At higher frequencies, the wavelength is smaller, and signal pickup occurs more easily. At approximately 300 MHz the cables may no longer be the dominant entry path for induced signals into the EUT, as also direct field penetration into the EUT plays a large role.

G.3 Cables leaving the test area

In 7.4, the use of common mode absorption devices (CMADs) on up to three cables leaving the EUT setup is suggested, but not mandatory. However, the test laboratory is encouraged to use the CMADs by placing one on each cable where the cables first meet the floor. The impedance and absorption properties of the CMAD are specified in CISPR 16-1-4.

In a typical situation the CMAD smoothes out the resonances. Product committees may take this into account in order to assess if the test level adopted is adequate to the specific situation.

G.4 Turning the EUT cabinets

The direct induction of electromagnetic field into the cabinet of the EUT is ensured by turning the EUT. This is essential, as sensitive electronic circuits may be subject to direct radiation into the circuit boards and sub-assemblies.

If the turning of the cabinets can be made without major rearrangements of the cabling, then each cabinet can be turned while the cabling is arranged as before. Rearrangement of the cabling each time an EUT is turned is not necessary if at least one configuration of the cable layout follows the cable routing rules described earlier. The test laboratory is free to arrange the test setup in, for example, rotational symmetry, so the EUT cabinet can be turned using an automatic turntable, or the arrangement can be made so the EUT cabinet(s) can be turned manually by hand during each partial scan as long as the overall rules for test setup layout are followed.

Annex H
(informative)

Examples of test setups for large and heavy EUTs

H.1 EUTs with bottom fed cables

Figure H.1 shows an example of how to arrange the test setup for equipment where signal and power cables are fed from the bottom. The EUT should be placed on the insulating pallet or other insulating support with a thickness of 0,05 m, or more. Non-conductive rollers, which are common on large and heavy EUTs, can be used. The large EUT cables are generally very thick and rigid and difficult to bend and not designed to be routed on the ground. Thus, exposing these types of cables is very difficult in practice. In real installations, these cables are shielded by the EUT enclosure and go directly underground. These underground cables do not need to be exposed to the electromagnetic field due to the nature of the actual installation.

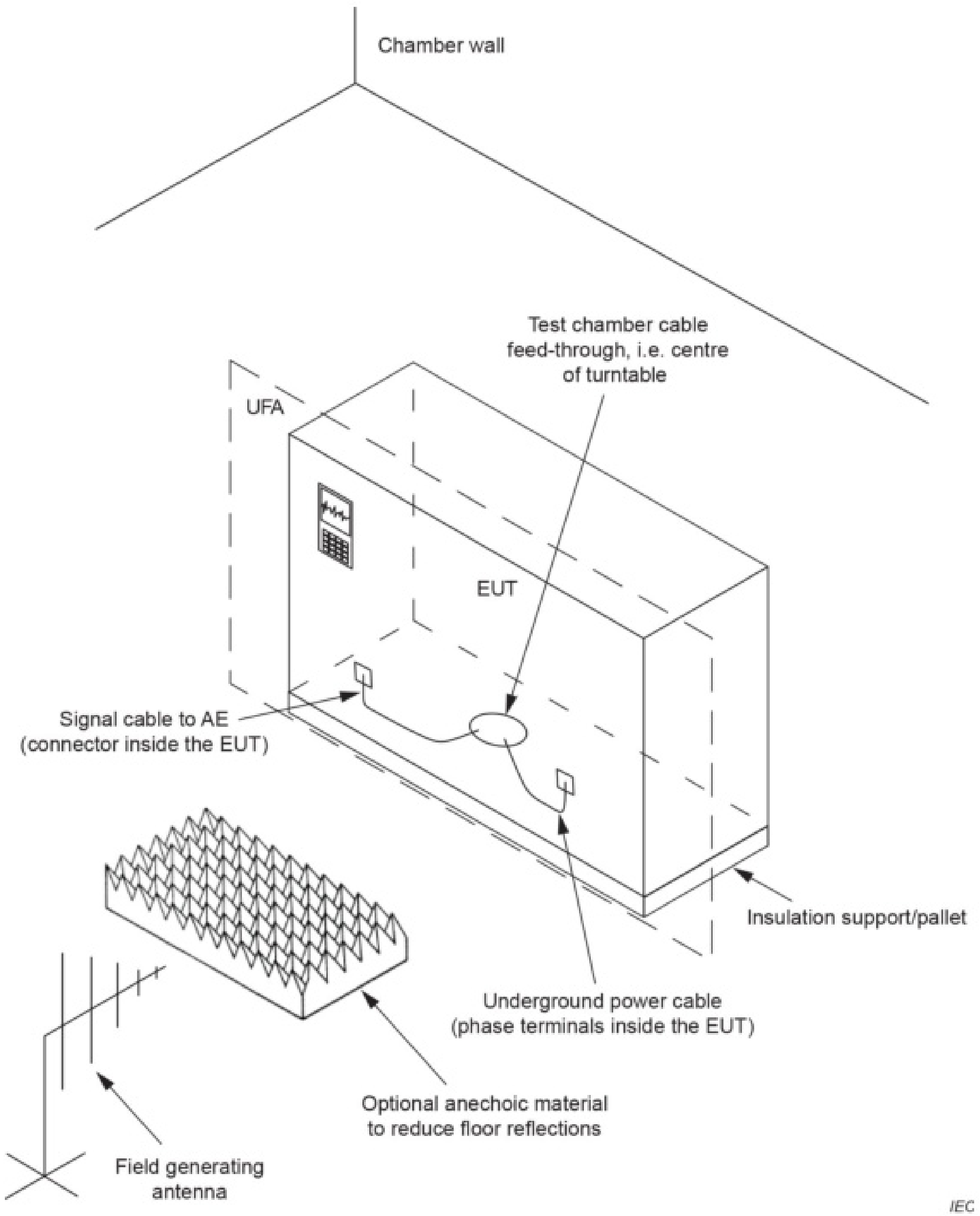
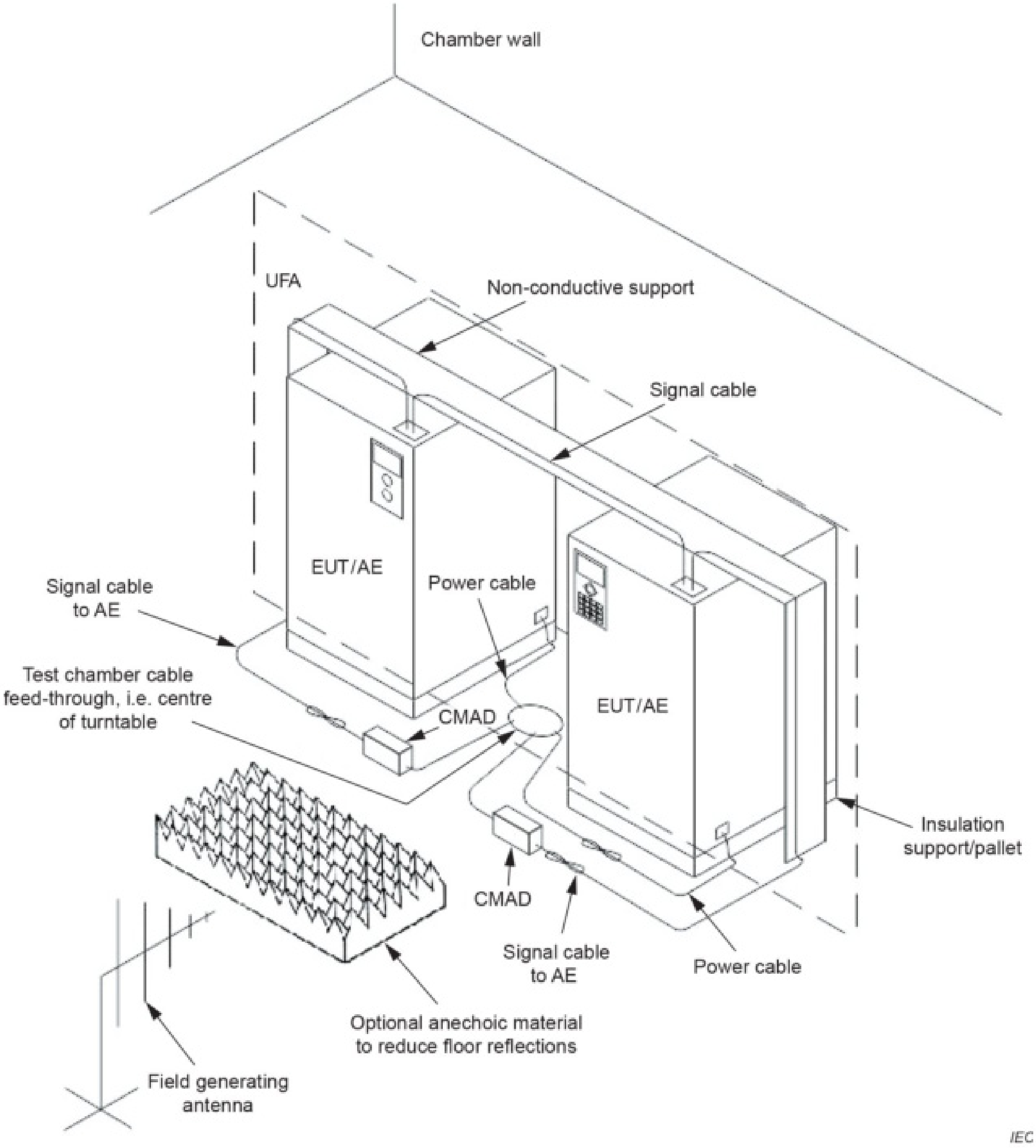


Figure H.1 – Example of a test setup for EUT with bottom fed underground cables (CMADs not shown)

H.2 EUTs with overhead cables

Figure H.2 shows an example of signal and power cables setup, where signal cables have been routed overhead due to actual installation method, for example with network server products. If conductive or shielded cable trays are specified as part of the installation of an EUT, these should also be used for the test setup. If possible, excess length of cables interconnecting units of the EUT should be bundled low-inductively in the approximate centre of the cable

If the EUT is too large to fit into the UFA window, the single UFA window should be moved after each test along the EUT in a way that the EUT, including overhead cables, will be totally covered by the UFAs.



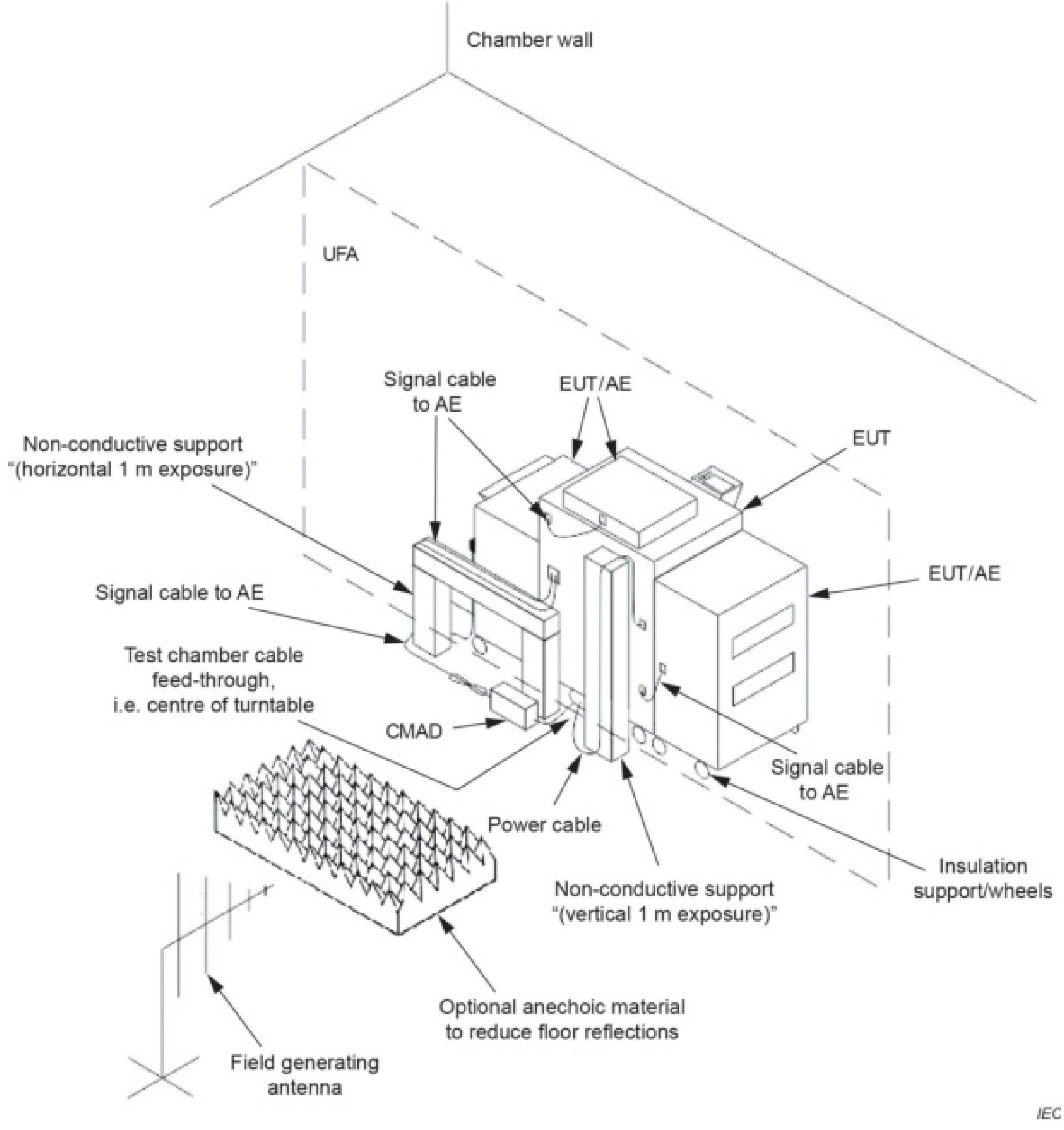
NOTE 1 The UFA matches the size of the EUT with cables.

NOTE 2 Power cables are too large for CMAD

Figure H.2 – Example of a test setup for EUTs with overhead cables

H.3 EUTs with multiple cables and AEs

Figure H.3 shows an example of a signal and power cables setup, which contains several different lengths and types of cables between multiple AEs, for example a floor-standing multi-functional printer. Only long enough cables should be exposed to the EM field for 1 m horizontal or vertical polarization. In case of short, fixed length cables between the EUT and AEs, it may not be possible to expose cables in accordance with this recommendation. They should, instead, be arranged according to the user manual. Not specified, long cables should be arranged as shown in Figure H.3 using non-conductive support to achieve vertical and/or horizontal exposure. If possible, excess length of cables connecting units of the EUT should be bundled low-inductively in the approximate centre of the cable.



NOTE Power cables are too large for the CMAD.

Figure H.3 – Example of a setup of EUTs with multiple cables and AEs

H.4 Large EUTs with side fed cables and multiple UFA windows

Figure H.4 shows an example of a large EUT with a side fed cable, which needs to be covered by multiple UFA windows. The single UFA window should be moved after each test along the EUT in a way that the EUT, including external side fed cables, will be totally covered by the UFAs. The antenna and optional anechoic material should be moved as shown in Figure H.4 until the whole EUT has been covered by the UFA windows. If possible, excess length of cables interconnecting units of the EUT should be bundled low-inductively in the approximate centre of the cable.

NOTE To apply multiple UFA windows, the methods given in 6.3.1 are applicable.

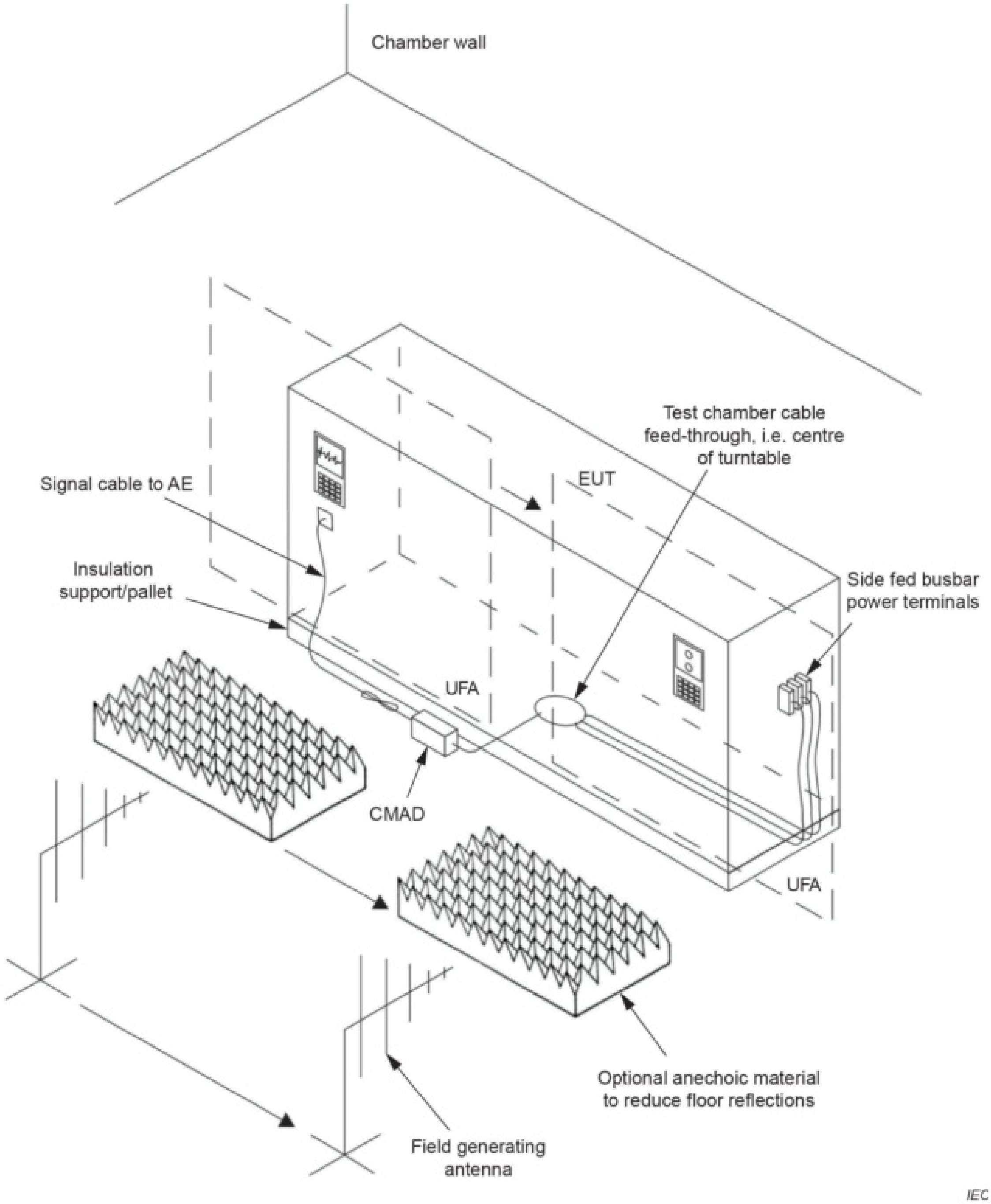


Figure H.4 – Large EUTs with side fed cables and multiple UFAs

Annex I
(informative)

Testing with multiple signals

I.1 General

Annex I provides information related to testing EUTs with multiple signals during one dwell cycle in order to reduce the overall test time. It provides information related to: the intermodulation effects created by multiple signals, the power required to generate multiple signals, the level setting requirements, linearity and harmonic checks, and EUT performance criteria with multiple signals.

I.2 Intermodulation

Intermodulation may be generated in a system with nonlinearities. The intermodulation between each frequency component will form additional signals at frequencies that are not just at harmonic frequencies (integer multiples) of either, but also at the sum and difference frequencies of the original frequencies and at multiples of those sum and difference frequencies.

The result of this intermodulation is the creation of unwanted signals in the form of sidebands (centred around fundamental and harmonic frequencies).

Care shall be taken to ensure that these unwanted signals do not significantly affect the quality of the susceptibility test. To this end, these unwanted signals can be treated as harmonics and should be at least −6 dB compared to the intended test signal in the field.

This can be seen in the graph in Figure I.1 and mathematically represented as follows:

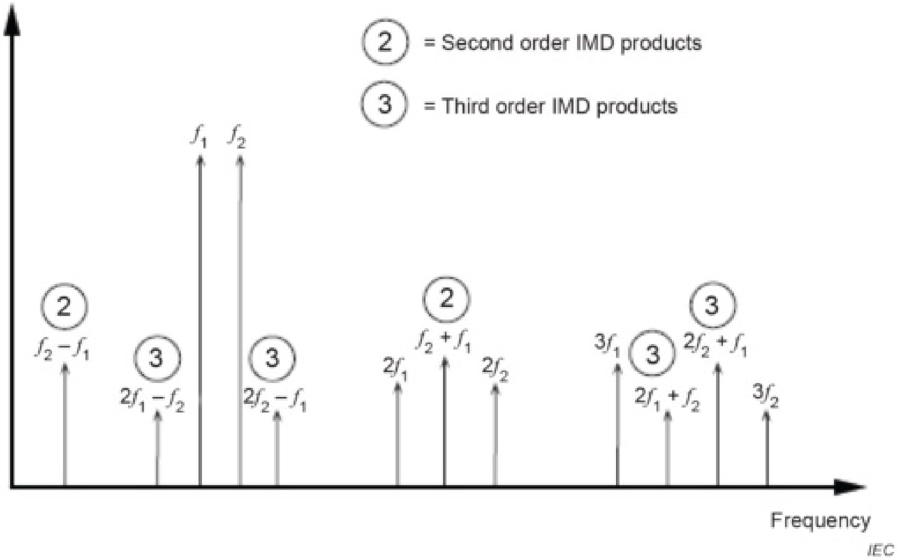


Figure I.1 – Test frequencies f_1 and f_2 and intermodulation frequencies of the second and third order

$$v_{Out} = a_1 v_i + a_2 v_i^2 + a_3 v_i^3 + \cdots \quad (I.1)$$

where a_1, a_2 and a_3 are transfer functions for the first, second and third order harmonics, with:

$$v_i(t) = \cos(2\pi f_1 t) + \cos(2\pi f_2 t) \quad \text{(I.2)}$$

The higher order voltages are calculated using Formulae (I.3) and (I.4):

$$v_i(t)^2 = \frac{1}{2}(1+\cos(4\pi f_1 t)) + \left[\cos(2\pi(f_1 - f_2)t) + \cos(2\pi(f_1 + f_2)t)\right] + \frac{1}{2}(1+\cos(4\pi f_2 t)) \quad \text{(I.3)}$$

and:

$$v_i(t)^3 = \left(\frac{3}{4}+\frac{3}{2}\right)\cos 2\pi f_1 t + \left(\frac{3}{4}+\frac{3}{2}\right)\cos 2\pi f_2 t + \frac{3}{4}(\cos(4\pi f_1 t - 2\pi f_2 t) + \cos(4\pi f_1 t + 2\pi f_2 t)) + \frac{3}{4}(\cos(4\pi f_2 t - 2\pi f_1 t) + \cos(4\pi f_2 t + 2\pi f_1 t)) + \frac{1}{4}\cos(6\pi f_1 t) + \frac{1}{4}\cos(6\pi f_2 t) \quad \text{(I.4)}$$

I.3 Power requirements

The power required to generate multiple signals can be defined in both peak and average terms. If each signal has the same power, then the following formulae apply:

$$P_{MSAVG} = P_{SSAVG} \cdot N \quad \text{(I.5)}$$

$$P_{MSPK} = P_{SSPK} \cdot N^2 \quad \text{(I.6)}$$

where:

P_{MSAVG} is the average power of multiple signals;

P_{MSPK} is the peak power of multiple signals;

P_{SSAVG} is the average power of a single signal;

P_{SSPK} is the peak power of a single signal;

N is the number of signals.

In order to eliminate all distortion, the peak power could be used to calculate the number of signals that can be generated by a given amplifier. However, since the individual signals differ in frequency, their relative phase is always changing. The peak power level is only reached when all of the signals are in phase. This is a relatively short-lived occurrence and most of the time the average power is a better estimate.

When the average power is used and the peak power cannot be reached, distortion (intermodulation) results. In general, this distortion can be minimized by only using amplifiers within their linear operating limits.

The amplifier power required is determined by the level setting requirements as well as the linearity and harmonics requirements.

I.4 Level setting requirements

The level setting procedures of 6.3.2 and 6.3.3 require the use of isotropic field probes which are not frequency selective and cannot parse out and measure multiple signals. Therefore, the level setting procedures should be carried out using single frequencies.

In order to use multiple signals, a secondary level setting procedure will need to be performed. This can be done using different kind of test equipment, for example multiple signal sources or vector signal generators and frequency selective power measurement equipment (signal analyser, spectrum analyser, network analyser, receiver, etc.). However, independent of the choice of test equipment it is important that intermodulation and amplifier saturation effects are respected. The level setting procedure will use the results of 6.3.2 and 6.3.3 (power required by frequency to ensure the test level with AM) to determine how many signals can be combined into a test set without saturating the amplifier and introducing too much distortion. The linearity and harmonics checks of 6.3.2 step 5) and 6.3.3 step 7), and Annex D should be performed on all present signals within a test set, simultaneously, with each new signal addition until one or both of the checks fail. This is the maximum number of signals that can be used together.

I.5 Linearity and harmonics checks

The linearity check procedure defined in 6.3.2 step 5) and 6.3.3 step 7) should be used on each test set of signals as an aggregate. The signal generator drive level to each of the individual signals in the test set should be reduced simultaneously by 5,1 dB. With all test signals still present but reduced, each individual output signal should be measured and checked to be at least reduced by 3,1 dB.

The harmonics check procedure defined in Annex D should be modified to include all non-fundamental frequencies (harmonics, intermodulation products, spurious, etc). These non-fundamental signals can be measured in power to be delivered to the antenna, or field strength directly with the use of a receive antenna. Power measurements, however, should be corrected for antenna gain to relate them to the field. All non-fundamental signals should be at least −6 dB compared to the intended test signal in the field.

NOTE High power low-pass filters can be used on each amplifier output to limit the harmonics and intermodulation product content to within the amplifier's and/or measurement equipment's (directional coupler, signal/spectrum analyser) upper operating bandwidth.

I.6 EUT performance criteria with multiple signals

Testing with more than one signal during a dwell time exposes the EUT to more energy than required by this document. This overexposure could cause an EUT to lose function or experience a degradation of performance that would not be caused by illumination by a single frequency.

Since the requirements of this document are for single frequency testing, retesting the product using the individual frequencies of the set that caused the degradation is necessary. The results of the individual frequencies test take precedence.

Annex J
(informative)

Measurement uncertainty due to test instrumentation

J.1 General

Annex J gives information related to the measurement uncertainty (MU) of the test level setting according to the particular needs of the test method contained in the main body of the document. Further information can be found in [1, 2][1].

Annex J shows an example of how an uncertainty budget can be prepared based upon level setting. Other parameters of the disturbance quantity such as the modulation frequency, modulation depth, and the harmonics produced by the amplifier, may also need to be considered in an appropriate way by the test laboratory. The methodology shown in Annex J 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 6.3.2 step a) and 6.3.3 step a) of this document.

J.2.2 MU contributors of the measurand

The following influence diagram (see Figure J.1) gives an example of influences upon the level setting. It applies to both the level setting 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 Table J.1 and Table J.2. As a minimum, the contributions listed in Table J.1 and Table 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.

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1 Numbers in square brackets refer to the reference documents in Clause J.4.

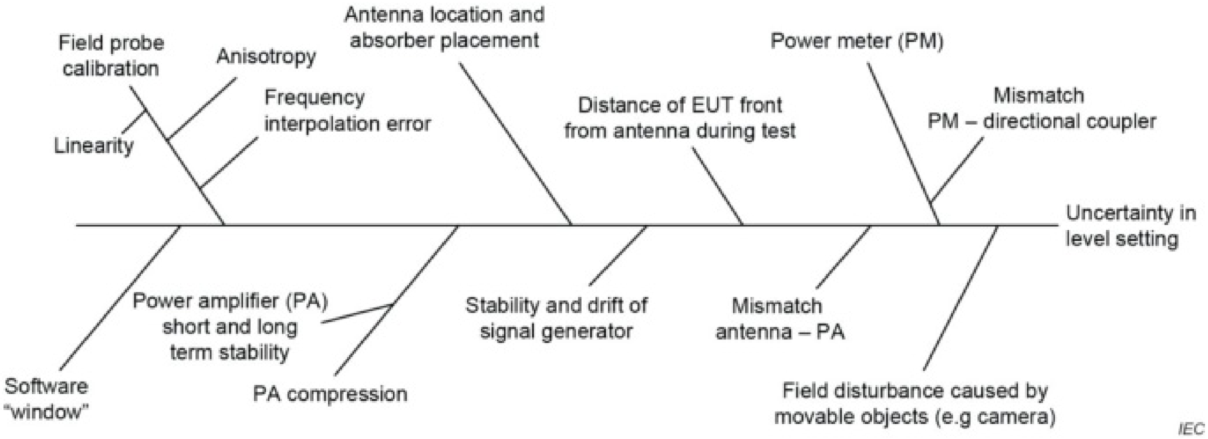

Figure J.1 – Example of influences upon level setting

J.2.3 Calculation examples for expanded uncertainty

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

In this document, 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 the MU. Examples include those that are compensated by level control of the amplifier output power or that remain unchanged between the level setting 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.

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

Table J.1 – Level setting process

Symbol	Uncertainty source X_i	$U(x_i)$ dB	Distribution	Divisor	$u(x_i)$ dB	c_i	$u_i(y)$ dB	$u_i(y)^2$
FP	Field probe calibration	1,7	normal k = 2	2	0,85	1	0,85	0,72
PM_c	Power meter	0,3	rect	1,73	0,17	1	0,17	0,03
PA_c	PA rapid gain variation	0,2	rect	1,73	0,12	1	0,12	0,01
SW_c	SW levelling precision	0,6	rect	1,73	0,35	1	0,35	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**

Table J.2 – Test process

Symbol	Uncertainty source X_i	$U(x_i)$ dB	Distribution	Divisor	$u(x_i)$ dB	c_i	$u_i(y)$ dB	$u_i(y)^2$
CAL	Level setting process	1,88	normal k = 2	2,00	0,94	1	0,94	0,89
AL	Antenna location variation and absorber placement	0,38	k = 1	1	0,38	1	0,38	0,14
PM_t [a]	Power meter	0,3	rect	1,73	0,17	1	0,17	0,03
PA_t	PA rapid gain variation	0,2	rect	1,73	0,12	1	0,12	0,01
SW_t	SW levelling precision	0,6	rect	1,73	0,35	1	0,35	0,12
SG	Signal generator stability	0,13	rect	1,73	0,08	1	0,08	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 level setting 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 includes 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 upper and lower tolerance around the target value for level setting during the level setting process. These tolerances can usually be adjusted by the test laboratory. The software window is the upper and lower tolerance around the target value.

CAL is the expanded uncertainty associated with the level setting 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 level setting 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 6). In this case, the uncertainties of the signal generator and power amplifier have to be reviewed.

PA_t includes the uncertainty derived from rapid gain variation of the power amplifier after the steady status has been reached.

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 TR 61000-1-6, *Electromagnetic compatibility (EMC) – Part 1-6: General – Guide to the assessment of measurement uncertainty*

[2] UKAS, M3003, Edition 4, 2019, *The Expression of Uncertainty and Confidence in Measurement*, free download on www.ukas.com

[3] ISO/IEC Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

Annex K
(informative)

Calibration method for E-field probes

K.1 Overview

E-field probes with broad frequency range and large dynamic response are extensively used in the level setting 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.

Currently, probe calibration results can 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.

Annex K provides relevant information on calibration of probes to be used in IEC 61000-4-3.

During the level setting procedure given in 6.3 the E-field probes are subject to relatively low field strength, for example 1 V/m to 30 V/m. Calibration of the E-field probes shall take the intended frequency and dynamic ranges into consideration.

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, and many variables have to be taken into account.

In this frequency range, 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.

Annex K therefore concentrates on improving the probe calibration procedures with horn antennas in anechoic chambers in which a comprehensive calibration procedure is depicted.

K.2 Probe calibration requirements

K.2.1 General

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

K.2.2 Calibration frequency range

The frequency range shall be at least the frequency range required by the tests.

K.2.3 Frequency steps

To be able to better compare test results between different calibration laboratories, it is advisable to use the set of fixed frequencies given below for the calibration. The use of fewer or different frequencies shall be technically justified.

- 80 MHz to 1 GHz:

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

80 MHz, 100 MHz, 150 MHz, 200 MHz,..., 950 MHz, 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 MHz, 1 200 MHz, 1 400 MHz,..., 5 800 MHz, 6 000 MHz

- Above 6 GHz:

Under consideration

NOTE It is not intended to measure a probe at 1 GHz twice.

K.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 characterization is carried out at a 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 K.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 K.3.3.

NOTE The calibration is performed using CW signals without modulation.

Table K.1 – Calibration field strength level

Test level	Calibration field strength
1	2 V/m
2	6 V/m
3	20 V/m
4	60 V/m
X	Y V/m
X,Y is an open calibration level which can be higher or lower than one of the other levels 1 to 4. This level may be given in the product specification or test laboratory.	

K.3 Requirements for calibration instrumentation

K.3.1 General

Subclauses K.3.2 to K.3.4 specify the requirements for the instrumentation necessary to perform the field sensor calibration.

K.3.2 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 field probe 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 analyser which is connected to the amplifier output through an attenuator, or through a directional coupler.

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

NOTE 1 The antenna can have additional influence on harmonic content and might be checked separately.

NOTE 2 An attenuator can be used to ensure that the power level does not exceed the maximum allowable input power of the spectrum analyser.

The frequency span shall cover at least the third harmonic of the actual calibration 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).

K.3.3 Linearity check for probe

The linearity of the probe which is used for the chamber validation according to K.4.2.6 shall be within ±0,5 dB from an ideal linear response in the required dynamic range (see Figure K.1). Linearity shall be confirmed by a calibration certificate 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 actual use of the 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, for example 1 dB. Table K.2 shows an example of the field strength levels to be checked for a 20 V/m application.

Table K.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

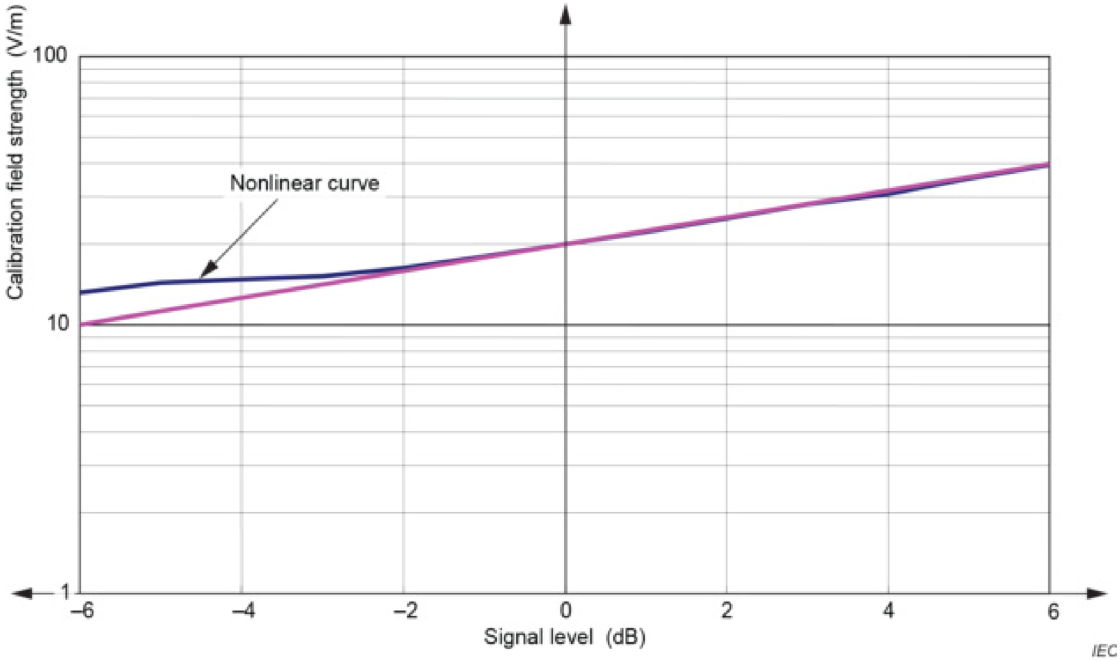

Figure K.1 – Example of linearity for probe

K.3.4 Determination of the gain of the standard horn antennas

The far field gain of the standard horn antennas can be determined fairly accurately (less than 0,1 dB of uncertainties have been reported in [1][2]). 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. Therefore, field probes are typically calibrated in the near field region of the transmitting antennas. The near field gain of standard gain horn antennas has been determined by using equations such as those described in [2]. The gain is computed based on the physical dimensions of a standard horn, and by assuming a quadratic phase distribution at the horn aperture.

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 TE_{10} 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 ±0,5 dB, but can be larger. The gain determined in this manner is inadequate for use in performing the chamber VSWR test and subsequent probe calibrations.

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.

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2 Numbers in square brackets refer to the reference documents in Clause K.6.

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, especially with larger probes or with probes with metallic scattering surfaces, which again would result in large measurement uncertainties in the calibration.

K.4 Field probe calibration in anechoic chambers

K.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 K.4.2.1.

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

NOTE At lower frequencies, such as 80 MHz to several hundred MHz, the use of an anechoic chamber might not be practical and result in larger uncertainties. Therefore, at these lower frequencies other methods such as TEM waveguides can be used to have better uncertainties.

Alternatively, the electric field can be established using a transfer probe (see K.5.5). The system and the environment used for probe calibration shall meet the following requirements.

K.4.2 Validation of anechoic chambers for field probe calibration

K.4.2.1 General

The probe calibration measurements assume a free space environment. A chamber VSWR test using a calibrated reference 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 Annex K 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 can 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.

K.4.2.2 Measuring net power to a transmitting device using directional couplers

Net power delivered to a transmitting device can be measured with a four-port bi-directional coupler, or two three-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 K.2.

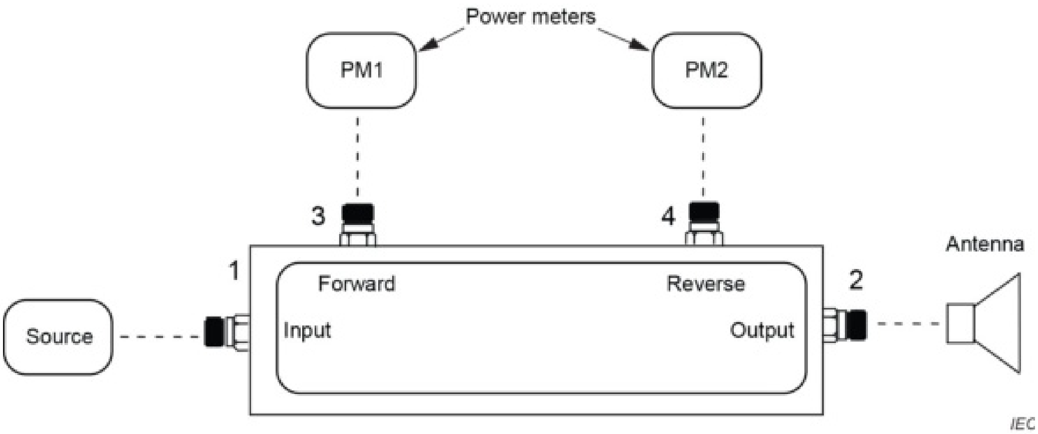

Figure K.2 – Setup for measuring net power to a transmitting device

The forward coupling, reverse coupling and transmission coupling are defined in the following formulae in the case where each port is connected to 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 mainly affected by the directivity of the coupler and by its matching impedance. 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.

The net power delivered to the transmitting device is then:

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

K.4.2.3 Establishing a standard field using horn antennas

The gain of the horn antenna is determined by the methods described in K.3.4. 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 η_0 = 377 Ω for free space, P_{net} (in W) is the net power determined by the method described in K.4.2.2, g is the numeric gain of the antenna determined by K.3.4 and d (in m) is the distance from the antenna aperture.

K.4.2.4 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 K.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, for example 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.

K.4.2.5 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 K.4.2.8 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 K.3 and Figure K.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 K.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 positioned in the centre of the horn antenna face.

Dimensions in centimetres

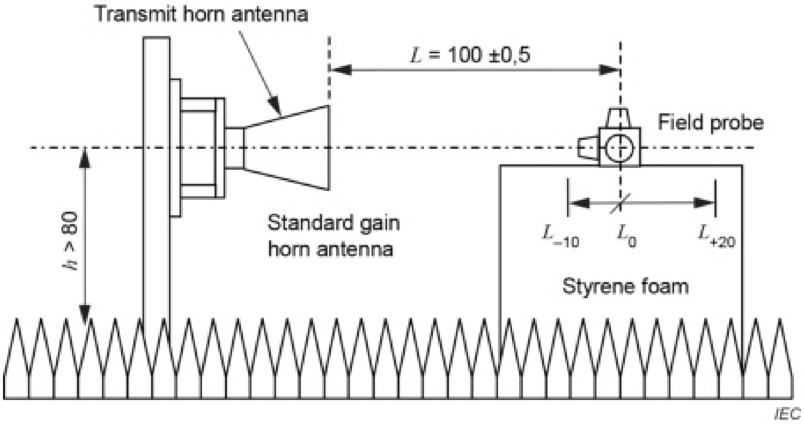

Figure K.3 – Test setup for chamber validation test

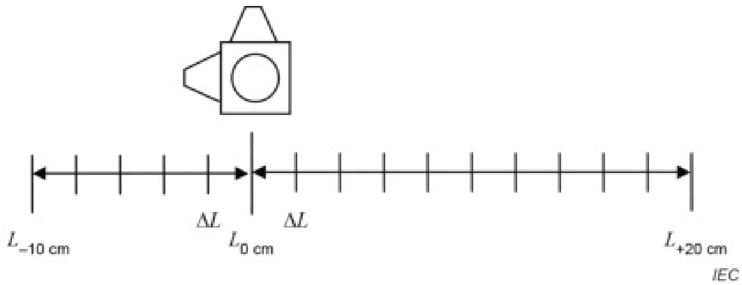

Figure K.4 – Detail for measurement position ΔL

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

The positions will be $L_{-10\ cm}$, $L_{-8\ cm}$, $L_{-6\ cm}$, …, $L_{0\ cm}$, $L_{+2\ cm}$, $L_{+4\ cm}$, …, $L_{+20\ cm}$, ΔL = 2 cm.

If the probe is placed in the near field of the transmitting horn antenna (distance < 2 D^2/λ, 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 a 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 K.4.2.6.

K.4.2.6 VSWR acceptance criteria

VSWR measurement results shall be compared by using the following procedure. For the calculation of the field strength, refer to K.4.2.3.

a) Calculation of the field strength

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.

– The 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.

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 (see Figure K.5).

– 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.

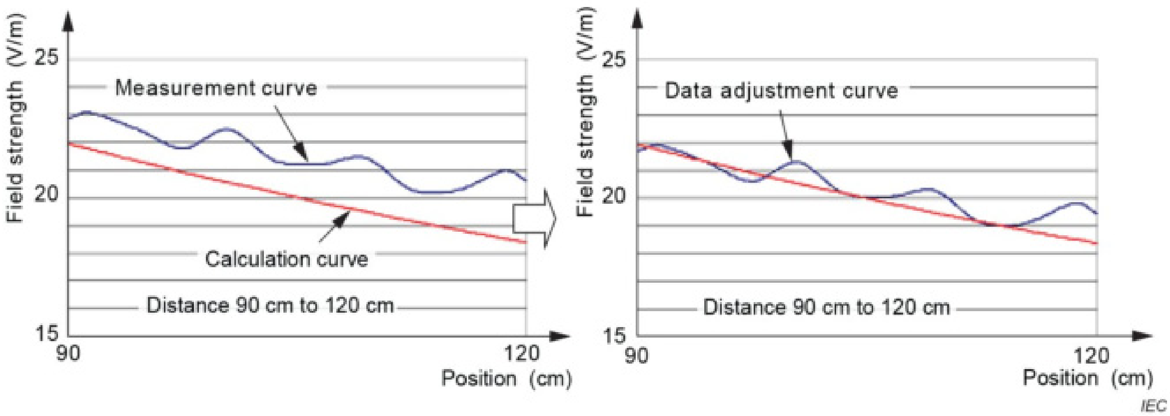

Figure K.5 – Example of data adjustment

c) Comparison of measurement data and calculation data

When the data difference in the calculation curve and measurement curve exceeds ±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).

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

K.4.2.7 Probe fixture validation

The probe fixture can 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 K.4.2.7 shall be performed for any new probe fixtures to be used.

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 structure shall be as non-intrusive as possible, and at least 50 cm away from the probe sensor part. Support structures in front (between the antenna and the probe) or behind the probe shall be avoided.

b) Generate a standard field that is within the dynamic range of the probe and position 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 a) and b). Record probe readings for all orientations.

d) Remove the reference fixture and replace it with the calibration fixture to be qualified. Repeat steps b) and c).

e) Compare results from steps c) and d). The difference between the readings with the two fixtures for the same probe orientation shall be less than ±0,5 dB.

K.4.2.8 Alternative chamber validation procedure

This alternative chamber validation procedure is applicable when the validation procedure of K.4.2.5 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.

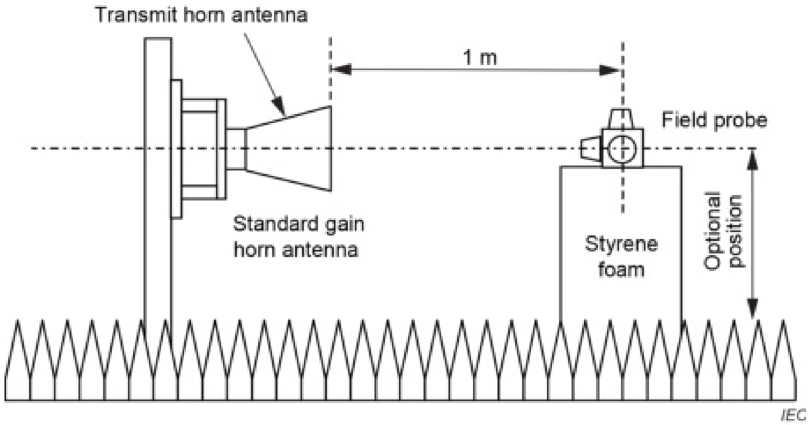

Figure K.6 – Example of the test layout for antenna and probe

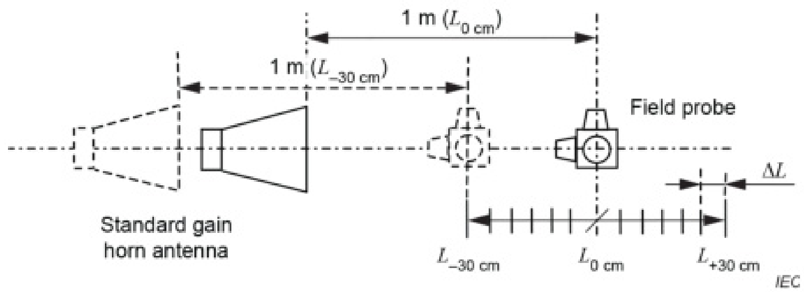

Figure K.7 – Test setup for chamber validation test

The setup is illustrated in Figure K.6 and Figure K.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 K.4.2.7).

The positions will be $L_{-30\ cm}$, $L_{-25\ cm}$, $L_{-20\ cm}$, …, $L_{0\ cm}$, $L_{+5\ cm}$, $L_{+10\ cm}$, …, $L_{+30\ cm}$, ΔL = 5 cm.

A constant field, for example 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 twenty-six independent probe readings (thirteen positions, and two polarizations, see Figure K.8). The maximum spread of the readings at each frequency shall be less than ±0,5 dB.

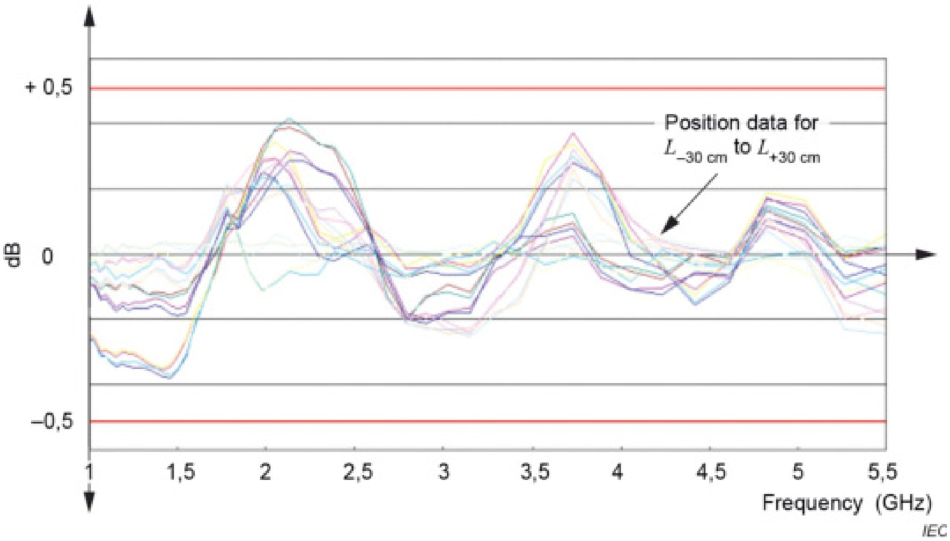

Figure K.8 – Example of alternative chamber validation data

K.4.3 Probe calibration procedure

K.4.3.1 General

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 ±0,5 dB from the ideal. If adjustments are made, the calibration laboratory should report the response both before and after adjustment.

The linearity check process should be applicable to the probe to be calibrated. For the influences of linearity on the calibration system, refer to K.3.3.

NOTE When it is not possible to adjust the probe, any non-linearity is compensated for by the user when carrying out the level setting procedures.

For the probe calibration, a measurement system/environment which satisfies the requirement of Clause K.4 shall be used.

K.4.3.2 Probe calibration setup

A fixture that is not fully qualified according to K.4.2.7 can result in large measurement uncertainties. Therefore, the probe fixture validated according to K.4.2.7 shall be used.

The calibration of the field probe should be done according preferably to the manufacturer's specification regarding the probe orientation, in order to achieve the best performances in terms of isotropy and probe response. This orientation shall also be used in the test laboratory to limit the effect of anisotropy. 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 Figure K.9 and Figure K.10.

Dimensions in metres

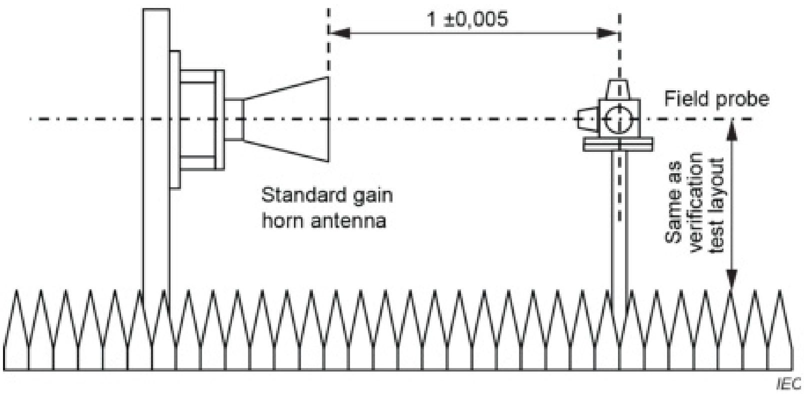

Figure K.9 – Field probe calibration layout

Dimensions in metres

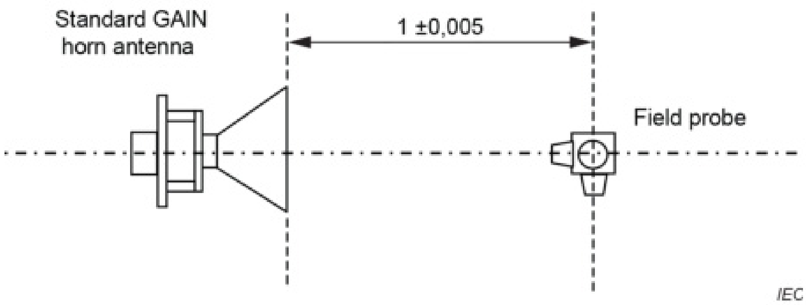

Figure K.10 – Field probe calibration layout (top view)

K.4.3.3 Calibration report

The measurement results obtained based on K.4.3.2 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 guidance for probe calibration measurement uncertainty.

K.5 Other probe calibration environments and methods

K.5.1 General

Clause K.5 describes the environment requirement for other calibration sites, for example TEM waveguides, 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.

K.5.2 Field probe calibration using TEM cells

A 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 the methods described in IEC 61000-4-20:2010, 5.2. The upper frequency of a TEM cell is typically a few hundred MHz. The field at the centre of a TEM cell between the septum and the top or bottom plate is calculated from:

$$E = \frac{\sqrt{Z_0 P_{\text{net}}}}{h} \text{ (V/m)}, \qquad \text{(K.1)}$$

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 K.4.2.2, and 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, for example 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.

K.5.3 Field probe calibration using waveguide chambers

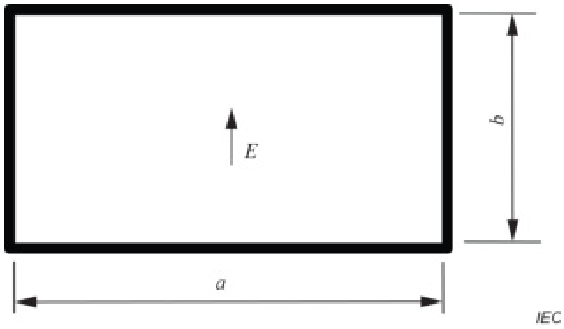

Figure K.11 – Cross-sectional view of a waveguide chamber

Calibration labs shall ensure that waveguide chambers operate in their dominant TE_{10} 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 (see Figure K.11) with inner dimensions of a (m) × b (m) ($a > b$), the cut-off frequency of the dominant TE_{10} mode is:

$$(f_c)_{10} = \frac{1}{2a\sqrt{\mu\varepsilon}} \qquad \text{(K.2)}$$

where μ and ε are the permeability and permittivity of the waveguide media. For air-filled waveguides, $\mu = \mu_0 = 400\pi$ nHm^{-1} and $\varepsilon = \varepsilon_0 = 8{,}854$ pFm^{-1}. The cut-off frequency for an air-filled waveguide chamber is:

$$(f_c)_{10} = \frac{150}{a} \text{ MHz.} \qquad \text{(K.3)}$$

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

$$E = \sqrt{\frac{2\eta_0 P_{net}}{ab\sqrt{1-\left((f_c)_{10}/f\right)^2}}} \text{ (V/m),} \qquad \text{(K.4)}$$

where f (in MHz) is the frequency of operation, η_0 = 377 Ω for the air-filled waveguide, P_{net} (in W) is the net power delivered to the waveguide and is determined by the method described in K.4.2.2. 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].

K.5.4 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].

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

K.5.5 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 K.5.2 or K.5.3. 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, i.e. it 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.

To have acceptable uncertainties, the following conditions shall be 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.

K.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

[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

Bibliography

IEC 60050-702, *International Electrotechnical Vocabulary – Part 702: Oscillations, signals and related devices*

IEC 60050-705, *International Electrotechnical Vocabulary – Part 705: Radio wave propagation*

IEC 60050-712, *International Electrotechnical Vocabulary – Part 712: Antennas*

IEC 60050-713, *International Electrotechnical Vocabulary – Part 713: Radiocommunications: transmitters, receivers, networks and operation*

IEC 60050-725, *International Electrotechnical Vocabulary – Chapter 725: Space radiocommunications*

IEC 60050-731, *International Electrotechnical Vocabulary (IEV) – Part 731: Optical fibre communication*

IEC TR 61000-2-5, *Electromagnetic compatibility (EMC) – Part 2-5: Environment – Description and classification of electromagnetic environments*

IEC 61000-4 (all parts), *Electromagnetic compatibility (EMC) – Part 4-X: Testing and measurement techniques*

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

IEC 61000-4-20:2010, *Electromagnetic compatibility (EMC) – Part 4-20: Testing and measurement techniques – Emission and immunity testing in transverse electromagnetic (TEM) waveguides*

IEC 61000-4-21, *Electromagnetic compatibility (EMC) – Part 4-21: Testing and measurement techniques – Reverberation chamber test methods*

IEC 61000-4-22, *Electromagnetic compatibility (EMC) – Part 4-22: Testing and measurement techniques – Radiated emissions and immunity measurements in fully anechoic rooms (FARs)*

IEC 61000-4-39, *Electromagnetic compatibility (EMC) – Part 4-39: Testing and measurement techniques – Radiated fields in close proximity – Immunity test*

IEC GUIDE 107, *Electromagnetic compatibility – Guide to the drafting of electromagnetic compatibility publications*

CISPR 16-1-4, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-4: Radio disturbance and immunity measuring apparatus – Antennas and test sites for radiated disturbance measurements*

CISPR TR 31, *Database on the characteristics of radio services*

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