IEC 61000-4-3

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

AMENDMENT 1
AMENDEMENT 1

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

**Compatibilité électromagnétique (CEM) –
Partie 4-3: Techniques d'essai et de mesure – Essai d'immunité aux champs électromagnétiques rayonnés aux fréquences radioélectriques**

IEC 61000-4-3 A1:2007

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FOREWORD

This amendment has been prepared by subcommittee 77B: High frequency phenomena of IEC technical committee 77: Electromagnetic compatibility.

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

FDIS	Report on voting
77B/546/FDIS	77B/556/RVD

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

The committee has decided that the contents of this amendment and the base publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,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

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CONTENTS

Add, to the existing list of annexes, the following new title:

Annex I (informative) Calibration method for E-field probes

Page 25

Add, at the end of the sixth dashed item (beginning with "– An isotropic field sensor"), the following new sentence:

Annex I provides a calibration method for E-field probes.

Page 111

Add the following new annex:

Annex I
(informative)

Calibration method for E-field probes

I.1 Overview

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

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

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

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

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

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

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

I.2 Probe calibration requirements

I.2.1 General

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

I.2.2 Calibration frequency range

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

I.2.3 Frequency steps

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

80 MHz to 1 GHz:

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

80, 100, 150, 200,…, 950, 1 000 MHz

1 GHz to 6 GHz:

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

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

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

I.2.4 Field strength

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

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

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

Table I.1 – Calibration field strength level

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

I.3 Requirements for calibration instrumentation

I.3.1 Harmonics and spurious signals

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

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

Calibration laboratories shall perform a measurement to validate that the harmonic and/or spurious signals from the amplifier satisfy the requirements for all measurement setups. This may be done by connecting a spectrum analyzer to Port 3 of the directional coupler (replacing the power meter sensor with the spectrum analyzer input – see Figure I.2).

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

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

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

I.3.2 Linearity check for probe

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

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

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

Table I.2 – Example for the probe linearity check

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

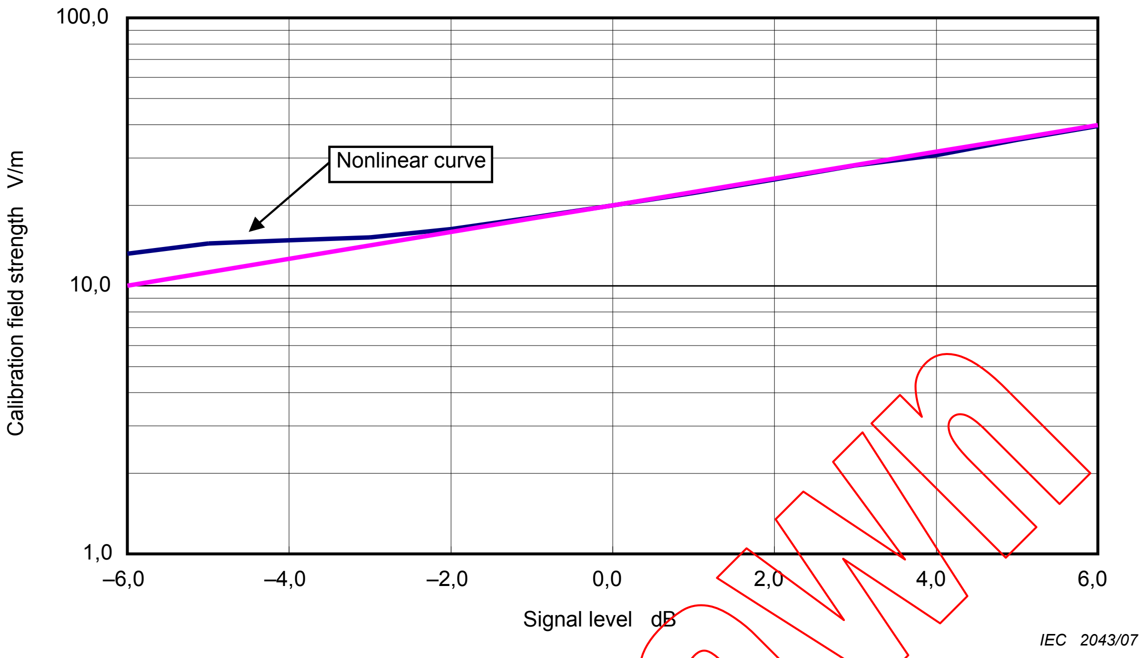

Figure I.1 – Example of linearity for probe

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

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

The equations (as given in [2]) were derived using aperture integration, by assuming that no reflection occurs at the aperture of the horn and that the field incident on the aperture is a 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.

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.

[1] Figures in square brackets refer to the reference documents in Clause I.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, which again would result in large measurement uncertainties in the calibration.

I.4 Field probe calibration in anechoic chambers

I.4.1 Calibration environments

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

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

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

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

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

I.4.2 Validation of anechoic chambers for field probe calibration

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

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

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

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

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

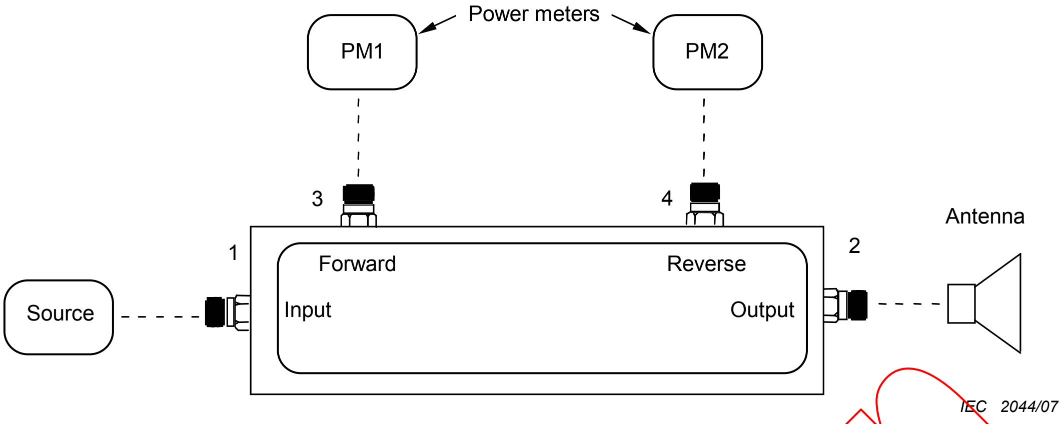

Figure I.2 – Setup for measuring net power to a transmitting device

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

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

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

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

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:

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

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

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

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

The net power delivered to the transmitting device is then:

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

I.4.2.2 Establishing a standard field using horn antennas

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

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

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

I.4.2.3 Chamber validation test frequency range and frequency steps

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

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

I.4.2.4 Chamber validation procedure

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

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

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

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

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

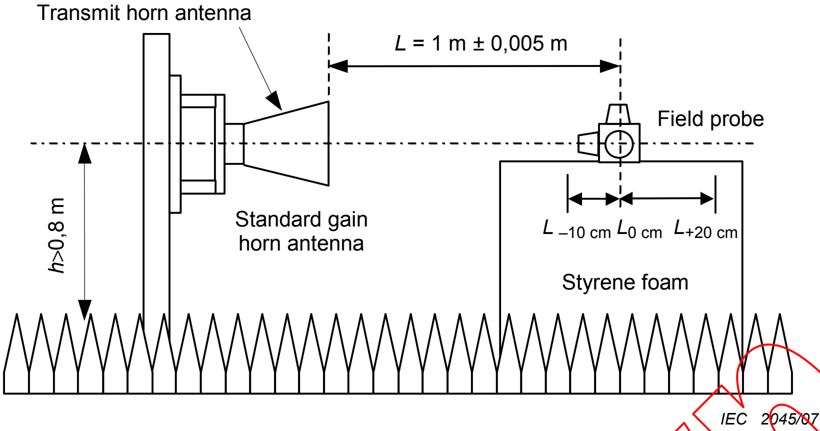

Figure I.3 – Test setup for chamber validation test

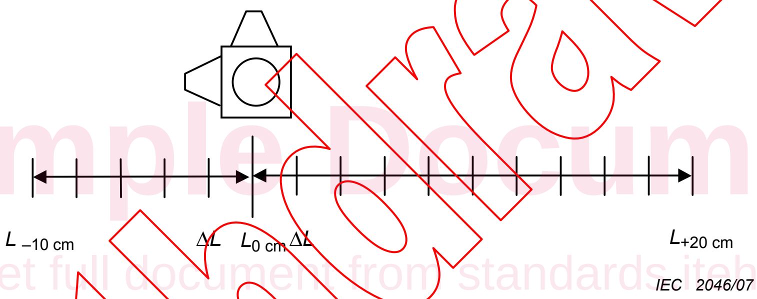

Figure I.4 – Detail for measurement position ΔL

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

The positions will be L-10 cm, L-8 cm, L-6 cm, …,L_0, 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 certain field strength (e.g. 20 V/m) at 1 m distance is applied for all probe positions. With the transmit antenna and field probe both vertically polarized, the probe readings for all positions at all frequencies are recorded. The test is repeated with antenna and probe horizontally polarized.

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

I.4.2.5 VSWR acceptance criteria

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

a) Calculation of the field strength