IEC 61786-1

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INTERNATIONAL STANDARD

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HORIZONTAL STANDARD
NORME HORIZONTALE

Measurement of DC magnetic, AC magnetic and AC electric fields from 1 Hz to 100 kHz with regard to exposure of human beings – Part 1: Requirements for measuring instruments

Mesure de champs magnétiques continus et de champs magnétiques et électriques alternatifs dans la plage de fréquences de 1 Hz à 100 kHz dans leur rapport à l'exposition humaine – Partie 1: Exigences applicables aux instruments de mesure

IEC 61786-1:2013

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

MEASUREMENT OF DC MAGNETIC, AC MAGNETIC AND AC ELECTRIC FIELDS FROM 1 Hz TO 100 kHz WITH REGARD TO EXPOSURE OF HUMAN BEINGS –

Part 1: Requirements for measuring instruments

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International Standard IEC 61786-1 has been prepared by IEC technical committee 106: Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure.

The first editions of IEC 61786-1 and IEC 61786-2 replace IEC 61786:1998. Part 1 deals with measuring instruments, and Part 2 deals with measurement procedures. The content of the standard was revised in order to give up-to-date and practical information to the user.

It has the status of a horizontal standard in accordance with IEC Guide 108.

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

FDIS	Report on voting
106/292/FDIS	106/298/RVD

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

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

A list of all parts of the IEC 61786 series, published under the general title *Measurement of DC magnetic fields and AC magnetic and electric fields from 1 Hz to 100 kHz with regard to exposure of human beings,* can be found on the IEC website.

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
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MEASUREMENT OF DC MAGNETIC, AC MAGNETIC AND AC ELECTRIC FIELDS FROM 1 Hz TO 100 kHz WITH REGARD TO EXPOSURE OF HUMAN BEINGS –

Part 1: Requirements for measuring instruments

1 Scope

This part of IEC 61786 provides guidance for measuring instruments used to measure the field strength of quasi-static magnetic and electric fields that have a frequency content in the range 1 Hz to 100 kHz and with DC magnetic fields to evaluate the exposure levels of the human body to these fields.

Sources of fields include devices that operate at power frequencies and produce power frequency and power frequency harmonic fields, as well as devices that produce fields within the frequency range of this document, including devices that produce static fields, and the earth's static magnetic field. The magnitude ranges covered by this standard are 0,1 µT to 200 mT in AC (1 µT to 10 T in DC) and 1 V/m to 50 kV/m for magnetic fields and electric fields, respectively.

When measurements outside this range are performed, most of the provisions of this standard will still apply, but special attention should be paid to specified uncertainty and calibration procedures.

Specifically, this standard

- defines terminology;
- identifies requirements on field meter specifications;
- indicates methods of calibration;
- defines requirements on instrumentation uncertainty;
- describes general characteristics of fields;
- describes operational principles of instrumentation.

NOTE Measurement methods that achieve defined goals pertaining to assessment of human exposure are described in IEC 61786-2

Sources of uncertainty during calibration are also identified. In regard to electric field measurements, this standard considers only the measurement of the unperturbed electric field strength at a point in free space (i.e. the electric field prior to the introduction of the field meter and operator) or above conducting surfaces.

This horizontal standard is primarily intended for use by technical committees in the preparation of standards in accordance with the principles laid down in IEC Guide 108.

One of the responsibilities of a technical committee is, wherever applicable, to make use of horizontal standards in the preparation of its publications. The contents of this horizontal standard will not apply unless specifically referred to or included in the relevant publications.

2 Normative references

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

IEC 61000-3-2, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

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

IEC 61000-4-4, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

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

IEC 61000-4-8, *Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test*

CISPR 11, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*

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

Guide 108, *Guidelines for ensuring the coherency of IEC publications – Application of horizontal standards*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE 1 Internationally accepted SI-units are used throughout the standard.

NOTE 2 For other units, see Annex G.

NOTE 3 Throughout this standard, the words "magnetic flux density" and "magnetic field" will be considered synonymous.

3.1 Meters

3.1.1
measuring instrument
device intended to be used to make measurements, alone or in conjunction with supplementary devices

[SOURCE: IEC 60050-300:2001, 311-03-01]

3.1.2
field meter
meter designed to measure electric, magnetic and electromagnetic fields

Note 1 to entry: Field meters usually consist of three parts: the probe, the detector circuit and the display.

3.1.3
probe
input device of a measuring instrument, generally made as a separate unit and connected to it by means of a flexible cable, which transmits the measurand in a suitable form

Note 1 to entry: A probe can be composed of one or several sensors.

[SOURCE: IEC 60050-300:2001, 313-09-11, modified – a note to entry has been added.]

3.1.4
detector
device for discerning the existence or variations of waves, oscillations or signals, usually for extracting information conveyed.

EXAMPLES Peak detector, rms detector

[SOURCE: IEC 60050-702:1992, 702-09-39, modified – the examples are different.]

3.1.5
free-body meter
meter that measures the unperturbed electric field strength at a point above the ground and is supported in space without conductive contact to ground

3.1.6
fluxgate magnetometer
instrument designed to measure magnetic fields by making use of the non-linear magnetic characteristics of a probe or sensing element that has a ferromagnetic core

3.1.7
ground reference meter
meter that measures the electric field at or close to the surface of the ground, frequently implemented by measuring the induced current or charge oscillating between an isolated electrode and ground.

Note 1 to entry: The isolated electrode is usually a plate located at ground level or slightly above the ground surface.

3.1.8
survey meter
lightweight battery-operated meter that gives a real time read-out and that can be held conveniently by hand in order to conduct survey type measurements in different locations

3.1.9
coil probe
magnetic flux density sensor comprised of a coil of wire that produces an induced voltage proportional to the time derivative of the magnetic field

3.1.10
Hall effect probe
magnetic flux density sensor containing an element exhibiting the Hall effect to produce a voltage proportional to the magnetic flux density

3.2 Meter characteristics

3.2.1
crest factor
ratio of the maximum absolute value of an alternating quantity to its root-mean-square value

[SOURCE: IEC 60050-103:2009, 103-14-57, modified – the original term was "peak factor" and the note has been deleted.]

3.2.2
crosstalk
the appearance of undesired energy in a channel, owing to the presence of a signal in another channel, caused by, for example induction, conduction or non-linearity

[SOURCE: IEC 60050-722:1992, 722-15-03]

3.2.3
frequency response
for a linear time-invariant system with a sinusoidal input variable in steady state the ratio of the phasor of the output variable to the phasor of the corresponding input variable, represented as a function of the angular frequency ω

[SOURCE: IEC 60050-351:2006, 351-24-33, modified – the note in the original has been deleted.]

3.2.4
isotropy of the probe
a measure of the degree to which the response of a field probe is independent of the polarization and direction of propagation of the incident field

3.2.5
pass-band
frequency band throughout which the attenuation is less than a specified value

[SOURCE: IEC 60050-151:2001, 151-13-52]

3.2.6
root-mean-square value
rms value

1) for n quantities x_1, x_2,..x_n, positive square root of the mean value of their squares:

$$X_q = \left[\frac{1}{n} \left(x_1^2 + x_2^2 + \ldots + x_n^2 \right) \right]^{1/2} \tag{1}$$

2) for a quantity *x* depending of a variable *t*, positive square root of the mean value of the square of the quantity taken over a given interval [t_0, t_0+T] of the variable

$$X_q = \left[\frac{1}{T} \int_{t_0}^{t_0+T} \left[x(t) \right]^2 dt \right]^{1/2} \tag{2}$$

Note 1 to entry: The rms value of a periodic quantity is usually taken over an integration interval the range of which is the period multiplied by a natural number

[SOURCE: IEC 60050-103:2009, 103-02-02, modified – the second note in the original definition has been deleted.]

3.3 Field characteristics

3.3.1
unperturbed field
field at a point that would exist in the absence of persons or movable objects

3.3.2

nearly uniform field
field in area where the resultant field over the cross-sectional area of the probe does not change more than 1%

3.3.3
quasi-static field

field that satisfies the condition $f << \frac{c}{l}$ (i.e. wavelength >> l), where f is the frequency of the field, c is the speed of light, and l is a characteristic dimension of the measurement geometry, e.g. the distance between the field source and the measurement point

Note 1 to entry: Power frequency magnetic and electric fields near power lines and appliances are examples of quasi-static fields.

3.3.4
resultant field
field given by the expression

$$F_R = \sqrt{F_x^2 + F_y^2 + F_z^2} \quad (3)$$

where F_x, F_y, and F_z are the rms values of the three orthogonal field components,

or by the expression

$$F_R = \sqrt{F_{max}^2 + F_{min}^2} \quad (4)$$

where F_{max} and F_{min} are the rms values of the semi-major and semi-minor axes of the field ellipse, respectively.

Note 1 to entry: The resultant F_R is always $\geq F_{max}$. If the field is linearly polarized, F_{min} = 0 and $F_R = F_{max}$. If the field is circularly polarized, $F_{max} = F_{min}$ and $F_R \approx 1{,}41\ F_{max}$.

3.4 Measurements

3.4.1
correction factor
numerical factor by which the uncorrected result of a measurement is multiplied to compensate for a known error

Note 1 to entry: Since the known error cannot be determined perfectly, the compensation cannot be complete.

3.4.2
coverage factor
numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty

Note 1 to entry: For a quantity z described by a normal distribution with expectation μ_z and standard deviation σ, the interval $\mu_z \pm k\sigma$ encompasses 68,27 %, 95,45 % and 99,73 % of the distribution for a coverage factor k = 1, 2 and 3, respectively.

3.4.3
scale factor
factor by which the instrument reading is multiplied to obtain its input quantity

3.4.4
standard uncertainty
uncertainty of the result of a measurement expressed as a standard deviation

3.4.5
uncertainty of calibration
parameter, associated with the result of a calibration, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

Note 1 to entry: Uncertainty of calibration generally comprises many components. Some of these components may be estimated on the basis of the statistical distribution of the results of series of measurements, and can be characterized by experimental standard deviations. Estimates of other components can be based on experience or other information.

4 Symbols

a	=	radius of coil probe; radius of spherical electric field probe
$2a$, $2b$	=	side dimensions of rectangular coil
$\mathbf{B}$	=	magnetic flux density vector
B_0	=	amplitude of alternating magnetic field
B_R	=	resultant magnetic field
B_z	=	axial magnetic flux density
C	=	stray capacitance of coil probe
d	=	spacing of parallel plates; distance from electromagnetic field source; spacing of Helmholtz coils
$\mathbf{D}$	=	electric displacement vector
E	=	electric field strength
E_0	=	uniform electric field strength
F_{max}, F_{min}	=	rms values of semi-major and semi-minor axes of field ellipse
I	=	current to magnetic field coils
L	=	inductance of coil probe
N	=	number of turns of wire (magnetic field coil system)
Q	=	induced charge
r	=	distance between magnetic field source and measurement location; resistance of coil probe and leads
R	=	approximate input impedance of detector circuit (magnetic field meter); radius of Helmholtz coils
S	=	electrode surface area (electric field meter)
t	=	time
T	=	period of periodic signal
V	=	voltage
Z	=	impedance in current injection circuit
λ	=	wave length
ε_0	=	permittivity of free space
μ_0	=	permeability of free space
φ	=	magnetic flux
ω	=	angular frequency of alternating field

5 Instrumentation specifications

5.1 General

When measuring field in the context of assessment of human exposure, the following items are considered below:

– measurement of the resultant field strength;

– measurement of the unperturbed electric field.

NOTE 1 Other items may be required depending on the goal of the measurement.

The various types of instrumentation available for characterizing quasi-static magnetic fields are described in Clause D.1.

The various types of instrumentation available for characterizing static magnetic fields are described in Clause D.3

Several types of magnetic field meters are in common use, e.g. field meters with coil probes, meters with Hall-effect probes, and meters that combine two coils with a ferromagnetic core as in a fluxgate magnetometer.

NOTE 2 Hall effect probes respond to static as well as time-varying magnetic flux densities. Due to limited sensitivity and saturation problems sometimes encountered when attempting to measure small power frequency flux densities in the presence of the substantial static geomagnetic flux of the earth, Hall-effect probes have seldom been used to measure magnetic fields of a.c. power lines.

The various types of instrumentation available for characterizing quasi-static electric fields are described in Clause E.1. The following two types of electric field meters are considered in this standard:

a) the free-body meter;

b) the ground reference meter.

Sufficient information shall be provided with the instrumentation, including instrument specifications and a clearly written instruction manual, to enable users to determine compliance with this standard, to aid them in the proper operation of the field meter, and to assess the usefulness of the device for the user's application. The instrument specifications that shall be provided and/or satisfied are given below.

5.2 Measurement uncertainty

The measurement uncertainty of the measuring instrument shall be specified by the manufacturer of the instrument. The measurement uncertainty shall be determined following the ISO/IEC Guide 98-3. The uncertainty shall be specified as an extended measurement uncertainty using a coverage factor of 2. The uncertainty is valid after available correction factors are applied. The uncertainty shall contain all components which are relevant when the instrument is used in a nearly uniform field. Such components may be calibration uncertainty, frequency response, deviations of the gain in different measurement range settings, isotropy of the probe, internal noise sources, non-linearity, stability, temperature response and humidity response. The uncertainty of the instrument does not include effects due to the handling of the instrument like positioning the probe in a non-uniform field or the influence of the measuring person on the field to be measured. Such components must be taken into account as additional uncertainties in the measurement report.

NOTE 1 At power frequency, the uncertainty of measuring instrument is usually 10 % or better.

NOTE 2 Examples of guidelines on the treatment of calibration uncertainties are given in Annex B.

5.3 Magnitude range

The magnitude range over which the instrument operates within the specified uncertainty shall be clearly indicated.

5.4 Pass-band

Broadband measuring instruments in the AC range always have a lower and an upper cut off frequency, which define a pass band. Normally the pass band limits are defined by the minus 3 dB point of the frequency response. The nominal frequency response of an instrument can be described as the frequency response of a system with a high pass filter and a low pass filter connected in series. The filter types and the filter orders should be specified (e.g. 3rd order Butterworth high pass and 5th order Butterworth low pass). The nominal frequency response of the instrument is normally not treated as a source of measurement uncertainty because the band limiting effect of the filters is a desired property of the instrument if broadband measurements are made. In frequency selective measurements (e.g. FFT) the band limiting effect of the filters is not desired and the nominal frequency response should be automatically corrected. The measurement uncertainty of an instrument due to manufacturing tolerances is normally greater at the band limits compared to medium frequencies. Therefore the measurement uncertainty of an instrument is often specified also and sometimes only in a restricted frequency range. This range is not as broad as the pass band but should be still broad enough to cover all frequencies of interest. In the restricted frequency range the influence of the nominal frequency response shall be negligible.

5.5 Operating temperature and humidity ranges

The temperature and relative humidity ranges over which the instrument operates within the specified uncertainty shall be at least -10 °C to 45 °C and 5 % to 95 %, respectively. Sudden temperature changes that can lead to condensation in the instrument should be avoided.

Electric field measurement may be perturbed if the relative humidity is more than 70 % due to condensation effect on the probe and support [2] [1]. Since the effect of humidity depends on the field meter, the ability of the field meter to work correctly under those conditions should be checked before measurement (see Annex F).

5.6 Power supplies

The use of measurement equipment that is operating on internal battery power is recommended.

If batteries are used, provision should be made to indicate whether the battery condition is adequate for proper operation of the field meter. Instruments used to record personal exposure should be capable of at least 8 h operation within their rated uncertainty before replacement or recharging of the batteries becomes necessary.

If rechargeable batteries are used it is recommended that the instrumentation is not operated while connected to the charging station. When such connections are necessary, it should be demonstrated that stray fields from the battery charger, conducted disturbances from the mains voltage and electromagnetic coupling via the connecting leads (to the battery charger) do not affect the measurement (see 5.9).

There shall be no wire connections to electric field free-body meters.

If batteries with ferromagnetic jackets are used in exposure meters, care must be exercised that the jackets do not significantly influence readings by the instrument (see IEC 61786-2 for more details about source of measurement uncertainty).

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1 Numbers in square brackets refer to the Bibliography.