

Measurement methods for electromagnetic fields of household appliances and similar apparatus with regard to human exposure

ICS 97.030

National foreword

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with regard to human exposure**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**MEASUREMENT METHODS FOR ELECTROMAGNETIC FIELDS
OF HOUSEHOLD APPLIANCES AND SIMILAR APPARATUS
WITH REGARD TO HUMAN EXPOSURE**

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International Standard IEC 62233 has been prepared by IEC technical committee 106: Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure.

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

FDIS	Report on voting
106/99/FDIS	106/103/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.

The committee has decided that the contents of this 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- withdrawn;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.

INTRODUCTION

This standard establishes a suitable evaluation method for determining the electromagnetic fields in the space around the equipment mentioned in the scope, and defines standardized operating conditions and measuring distances.

This document is designed as one method for measurement and assessment of electromagnetic (EM) fields and their potential effect on the human body by reference to exposure standards. Existing exposure standards, e.g. ICNIRP'98 [11]¹⁾, IEEE C95.1-1999 [22] and IEEE C95.6-2002 [12], present rules for the exposure of humans to EM fields. The simplest and more practical levels [limits] with which to comply are limits (suitably time-averaged in some cases) on the electric (E) and magnetic (B) fields, measured in the absence of the human to be exposed to these fields. These limits are called maximum permissible exposure levels, IEEE-based levels, or reference levels (ICNIRP). Suitable definitions and specified measurement techniques are applied in any exposure compliance measurement or assessment. Compliance with maximum permissible exposure or reference levels is sufficient for positive assessment of meeting these levels as specified in the appropriate exposure standard.

This document addresses the additional measurement and calculation techniques which permit determination of compliance under one set of specified circumstance, without reference to time of exposure or actual exposure conditions. This document is not meant to supplant definitions and procedures specified in exposure standards but is aimed at supplementing the procedure already specified for compliance with exposure.

¹⁾ Figures in square brackets refer to the Bibliography.

MEASUREMENT METHODS FOR ELECTROMAGNETIC FIELDS OF HOUSEHOLD APPLIANCES AND SIMILAR APPARATUS WITH REGARD TO HUMAN EXPOSURE

1 Scope

This International Standard deals with electromagnetic fields up to 300 GHz and defines methods for evaluating the electric field strength and magnetic flux density around household and similar electrical appliances, including the conditions during testing as well as measuring distances and positions.

Appliances may incorporate motors, heating elements or their combination, may contain electric or electronic circuitry, and may be powered by the mains, by batteries, or by any other electrical power source.

Appliances include such equipment as household electrical appliances, electric tools and electric toys.

Appliances not intended for normal household use but which nevertheless may be approached by the public, or may be used by laymen, are within the scope of this standard.

This standard does not apply to:

- apparatus designed exclusively for heavy industrial purposes;
- apparatus intended to be part of the fixed electrical installation of buildings (such as fuses, circuit breakers, cables and switches);
- radio and television receivers, audio and video equipment, and electronic music instruments;
- medical electrical appliances;
- personal computers and similar equipment;
- radio transmitters;
- apparatus designed to be used exclusively in vehicles;

The fields of multifunction equipment which is subjected simultaneously to different clauses of this standard and/or other standards shall be assessed using the provisions of each clause/standard for the relevant functions in operation.

Abnormal operation of the appliances is not taken into consideration.

This standard includes specific elements to assess human exposure:

- definition of sensor;
- definition of measuring methods;
- definition of operating mode for appliance under test;
- definition of measuring distance and position.

The measurement methods specified are valid from 10 Hz to 400 kHz. In the frequency range above 400 kHz and below 10 Hz appliances in the scope of this standard are deemed to comply without testing unless otherwise specified in IEC 60335 series.

2 Normative references

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

IEC 60335 (all parts), *Safety of household and similar electrical appliances*

IEC 61786, *Measurement of low-frequency magnetic and electric fields with regard to exposure of human beings – Special requirements for instruments and guidance for measurements*

IEC 62311, *Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz – 300 GHz)²⁾*

CISPR 14-1, *Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus – Part 1: Emission*

3 Terms and definitions

For the purpose of this standard the following terms and definitions apply. Internationally accepted SI-units are used throughout the standard.

3.1 Physical quantities and units

Quantity	Symbol	Unit	Dimension
Conductivity	σ	Siemens per metre	S/m
Current density	J	Ampere per square metre	A/m ²
Electric field strength	E	Volt per metre	V/m
Frequency	f	Hertz	Hz
Magnetic field strength	H	Ampere per metre	A/m
Magnetic flux density	B	Tesla	T (Wb/m ² or Vs/m ²)

3.2 Terms and definitions

3.2.1

basic restriction (basic limitations)

restrictions on exposure to time-varying electric, magnetic and electromagnetic fields that are based on established biological effects and include a safety factor. The basic restriction for the current density is J_{BR} , the basic restriction for the internal electric field strength is E_{BR}

²⁾ To be published.

3.2.2

coupling factor

$a_c(r_1)$

factor taking into account the irregularities of the fields around the appliances, the measuring area of the sensor and the dimension of the trunk or head of the operator at measuring distance r_1 (refer to 3.2.6)

3.2.3

Fourier transformation

mathematical procedure that derives a frequency function from a time function (see IEC 101-13-09)

3.2.4

fast Fourier transformation

FFT

speed optimised Fourier transform

3.2.5

hot spot

a localized area with a maximum field strength due to inhomogeneity of the field distribution

3.2.6

measuring distance

r_1

shortest distance from the surface of the appliance to the closest point of the sensor surface (see Annex A)

3.2.7

measuring positions

3.2.7.1

around

the sensor is moved all around the appliance at a constant distance of its surface and where persons are expected

NOTE See Figure A.2.

3.2.7.2

top

the sensor is moved along a surface at the specified constant distance from the top surface of the appliance

NOTE See Figure A.1.

3.2.7.3

front

the sensor is moved along a surface at the specified distance from the front of the appliance

NOTE See Figure A.1.

3.2.8

reference level

maximum permissible exposure level

B_{RL}

field level derived from the basic restrictions under worst case assumptions (e.g. exposure to homogeneous field)

NOTE The reference levels may be exceeded providing that the basic restrictions are met.

3.2.9**response time**

time required for a field-measuring instrument to reach some specified percentage of the final value after being placed in the field to be measured

3.2.10**Weighted result** **W**

final result of the measurement, taking the frequency dependent reference level into account

4 Choice of test method and limit sets

An appropriate limit set has to be chosen.

For all appliances, independent of the spectrum of the produced fields, the procedure in 5.5.2 is applicable. This is the reference method, which has to be used in case of dispute.

In case where maximum permissible exposure levels or reference levels are exceeded, in any particular situation of fields, human body position or measurement configuration, the determination of compliance with basic restrictions has to be taken into account.

The procedure in 5.5.3 may be applied for appliances producing a line spectrum composed of only one fundamental line and their harmonics lines.

For appliances producing significant fields only on the mains frequency and its harmonics, if any, one of the alternative test methods in 5.5.4 may be used.

Equipment where the full working cycle is less than 1 s shall be measured according to IEC 62311 for pulsed fields; however operating conditions, measuring distances and coupling factor are given in this standard.

A step by step procedure can be applied, from the easiest methods to the more complicated ones, see the flow diagram in Figure 1.

5 Measuring methods**5.1 Electric fields**

The measurement method is under consideration.

If appliances, with their internal transformer or electronic circuit, are working at voltage lower than 1 000 V, they are deemed to comply without testing.

5.2 Frequency range

The frequency range considered is from 10 Hz to 400 kHz. See Scope (Clause 1).

If it is not feasible to cover the frequency range in one measurement, the weighted results of each measured frequency range shall be added.

5.3 Measuring distances, positions and operating mode

The **measuring distances**, sensor locations and operating conditions are specified in Annex A.

The configuration and mode of operation during measurement shall be noted in the test report.

5.4 Magnetic field sensor

Measurement values of flux density are averaged over an area of 100 cm² in each direction. The reference sensor consist of three mutually perpendicular concentric coils with a measuring area of 100 cm² ± 5 cm² to provide isotropic sensitivity. The outside diameter of the reference sensor shall not exceed 13 cm.

For the determination of **coupling factors**, as specified in Annex C, an isotropic sensor having a measuring area of 3 cm² ± 0,3 cm² is used.

NOTE 1 It is permissible to use a single direction sensor (not isotropic) in combination with an appropriate summation method.

NOTE 2 The final value of the magnetic flux density is the vector addition of the values measured in each direction. This ensures that the measured value is independent of the direction of the magnetic field vector.

5.5 Measuring procedures for magnetic fields

5.5.1 General

The measuring signal shall be evaluated dependent on the frequency. Taking independent field sources into account, the highest measured value shall be taken.

Transient magnetic fields with a duration of less than 200 ms, e.g. during switching events, are disregarded.

If a switching action occurs during the measurements, the measurement has to be repeated.

The measuring equipment is to have a maximum noise level of 5 % of the limit value. Any measured value below the maximum noise level is disregarded.

The background level is to be less than 5 % of the limit value.

The response time for the measuring equipment to reach 90 % of the final value is not to exceed 1 s.

The magnetic flux density is determined by using an averaging time of 1 s.

Shorter sampling times may be used if the source is shown to be constant over a period greater than 1 s for 10 Hz – 400 kHz signals.

During the final measurement the sensor should remain stationary.

5.5.2 Time domain evaluation

Independent of the type of the signal, a time domain measurement of the value of the magnetic flux density can be carried out. For fields with several frequency components, the dependency on the frequency of the reference levels is taken into account by implementing a transfer function *A* which is inverse of the reference level expressed as a function of the frequency.

Figure 2 shows an example of the frequency dependency of the reference levels.

The transfer function A is the inverse of the reference level B_{RL} and normalized on B_0 . The normalization shall be done at the frequency f_{C0} .

NOTE 1 It is recommended to use the mains frequency for the normalisation (e.g. $f_{C0} = 50$ Hz or 60 Hz)

The transfer function A is to be established using a first order filter. The Figure 3 shows an example of the characteristics of a transfer function.

The general formula of the transfer function is:

$$A(f) = \frac{B_{RL}(f_{C0})}{B_{RL}(f)} \quad (1)$$

The starting point of the transfer function shall be $f_1 = 10$ Hz. The ending point of the transfer function shall be $f_n = 400$ kHz.

NOTE 2 Examples for numerical values of transfer functions see Tables D.1 and D.2

The following sequence is used for the measurements:

- perform a separate measurement of each coil signal;
- apply a weighting to each signal using the transfer function;
- square the weighted signals;
- add the squared signals;
- average the sum;
- obtain the square root of the average.

The result is the weighted r.m.s. value of the magnetic flux density.

This procedure is shown schematically in Figure 4.

NOTE 3 The transfer function A (dashed line in Figure 4) contains the coils with their differentiating characteristics and a low-pass filter with "lag-lead element" to provide the necessary integration. The result is a signal which is directly proportional to $B(t)$ and is rated by the transfer function A shown in Figure 3. The corner frequencies of the "lag-lead element" are the same as in the transfer function in Figure 3.

NOTE 4 Different ways that the transfer function can be applied to a time domain signal include: analog filter in an electronic circuit, pre-programmed DSP chip, a signal analyser, or a digital computer calculation with a spreadsheet package or a custom-written program.

NOTE 5 For many appliances in the power frequency range of 50/60 Hz and their harmonics and limit sets that have field intensity limits effectively independent of frequency over the range of interest, this method can be applied without transfer function. This is for example possible for the IEEE C95.6-2002 Safety Standard that has a constant maximum permissible exposure (MPE) for magnetic flux density in the frequency range from 20 Hz to 759 Hz. In this case a pure RMS measurement can be performed in the frequency range of interest and the measurement result can be directly compared with the limits (e.g. MPE).

The actual measured value shall be compared directly with the reference level B_{RL} of the flux density at 50 Hz. With appliances with highly localised fields, this has to be performed after taking the coupling factor $a_c(r_1)$ given in Annex C into account. B_{RL} at f_{C0} must be used. The final weighted result, W , can be derived as follows:

$$W_n = \frac{B_{rms}}{B_{RL}} \quad (2)$$

or applying the coupling factor $a_c(r_1)$

$$W_{nc} = a_c(r_1) \cdot W_n \quad (3)$$

where

- W_n : weighted result for one measurement
- B_{rms} : r.m.s. value of the magnetic flux density
- B_{RL} : reference level of the magnetic flux density at f_{C0}
- $a_c(r_1)$: coupling factor according to Annex C or Table D.3.
- W_{nc} : weighted result for one measurement taking the coupling of the inhomogeneous field into account by applying $a_c(r_1)$

The determined weighted result W shall not exceed the value 1

5.5.3 Line spectrum evaluation

This method may be used when there is only a line spectrum, for example for magnetic fields having a fundamental frequency 50 Hz and some harmonics. See Clause 4.

The magnetic flux density is measured at each relevant frequency. This can be achieved by recording the time signal of the flux density and using a Fourier transformation for evaluating the spectral components.

The following sequence is used for the measurements:

- perform a separate measurement of each coil signal (x, y, z);
- integrate the signals to get a value which is directly proportional to $B(t)$;
- perform a discrete Fourier transform for each coil to obtain the estimated discrete magnitude spectrum $B(i)$ representing r.m.s values at the discrete frequencies $f(i) = i / T0$. ($T0$ = observation time);
- find the local maxima with $B(j)$ at frequency $f(j)$ by interpolating the discrete spectrum $B(i)$;
- perform a vector addition of all three directions for every discrete spectral line $B(j)$.

$$B(j) = \sqrt{B_x^2(j) + B_y^2(j) + B_z^2(j)} \quad (4)$$

NOTE The last two operations of the algorithm can be interchanged by using Equation (4) with $B(i)$ instead of $B(j)$.

Result is the amount of the magnetic flux density for each detected frequency.

To compare the measured values with limits, the reference level $B_{RL}(j)$ must be used. For appliances with highly localised fields the coupling factor $a_c(r_1)$ given in Annex C can be taken into account. For fields with several frequency proportions the calculation of a frequency weighted sum is necessary.

The weighted result is obtained from the following formula:

$$W_n = \sqrt{\sum_{j=1}^n \left(\frac{B(j)}{B_{RL}(j)} \right)^2} \quad (5)$$