BRITISH STANDARD

BS EN 62233:2008

Incorporating corrigendum August 2008

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

ICS 17.220.20; 97.030

British Standards

National foreword

This British Standard is the UK implementation of EN 62233:2008, incorporating corrigendum August 2008. It is derived by from IEC 62233:2005. It supersedes BS EN 50366:2003, which will be withdrawn on 1 December 2012.

The CENELEC common modifications have been implemented at the appropriate places in the text. The start and finish of each common modification is indicated in the text by tags C〉 〈C.

The UK participation in its preparation was entrusted to Technical Committee CPL/61, Safety of household and similar electrical appliances.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was
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EUROPEAN STANDARD
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EN 62233

April 2008

ICS 97.030

Supersedes EN 50366:2003 + A1:2006
Incorporating corrigendum August 2008

English version

Measurement methods for electromagnetic fields of household appliances and similar apparatus with regard to human exposure
(IEC 62233:2005, modified)

Méthodes de mesures des champs
électromagnétiques des appareils
électrodomestiques et similaires
en relation avec l'exposition humaine
(CEI 62233:2005, modifiée)

Verfahren zur Messung
der elektromagnetischen Felder
von Haushaltgeräten und ähnlichen
Elektrogeräten im Hinblick
auf die Sicherheit von Personen
in elektromagnetischen Feldern
(IEC 62233:2005, modifiziert)

This European Standard was approved by CENELEC on 2007-12-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

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

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CENELEC
European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Ref. No. EN 62233:2008 E

Foreword

The text of the International Standard IEC 62233:2005, prepared by IEC TC 106, Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure, together with common modifications prepared by a Joint Editing Group of the Technical Committee CENELEC TC 61, Safety of household and similar electrical appliances, and CENELEC TC 106X, Electromagnetic fields in the human environment, was submitted to the Unique Acceptance Procedure and was approved by CENELEC as EN 62233 on 2007-12-01.

This European Standard supersedes EN 50366:2003 + A1:2006, to which it is technically equivalent.

The following dates are applicable:

- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2008-12-01
- latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2012-12-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 62233:2005 was approved by CENELEC as a European Standard with agreed common modifications.

CONTENTS

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.

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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.

[C]NOTE The methods are not suitable for comparing the fields of different appliances.[C]

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 Ⓒ*Text deleted*Ⓒ

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}

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[2] To be published.

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

C〉 3.2.Z1
operator distance
distance between the surface of the appliance and the closest point of the head or torso of the operator 〈C

4 Choice of test method C〉*Text deleted* 〈C

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.

C〉 *Text deleted* 〈C

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 } simplified ~ 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 cm^2 in each direction. The reference sensor consist of three mutually perpendicular concentric coils with a measuring area of 100 cm^2 ± 5 cm^2 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 cm^2 ± 0,3 cm^2 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. C〉*Text deleted*〈C

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.

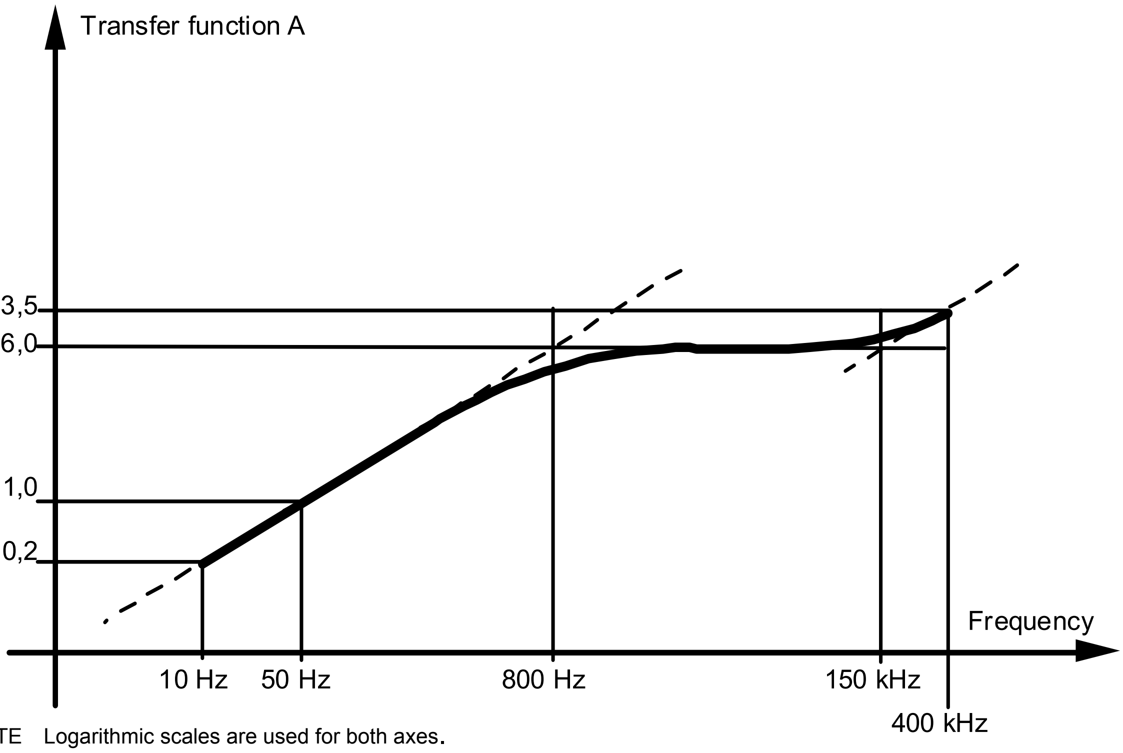
During the final measurement the sensor should remain stationary.

5.5.2 Time domain evaluation

C〉 This is the reference method and is used in case of doubt.

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 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.〈C

} The transfer function is to be established using a first order filter and shall have the characteristics shown in Figure Z1.



NOTE Logarithmic scales are used for both axes.

Figure Z1 - Transfer function

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 Z2.

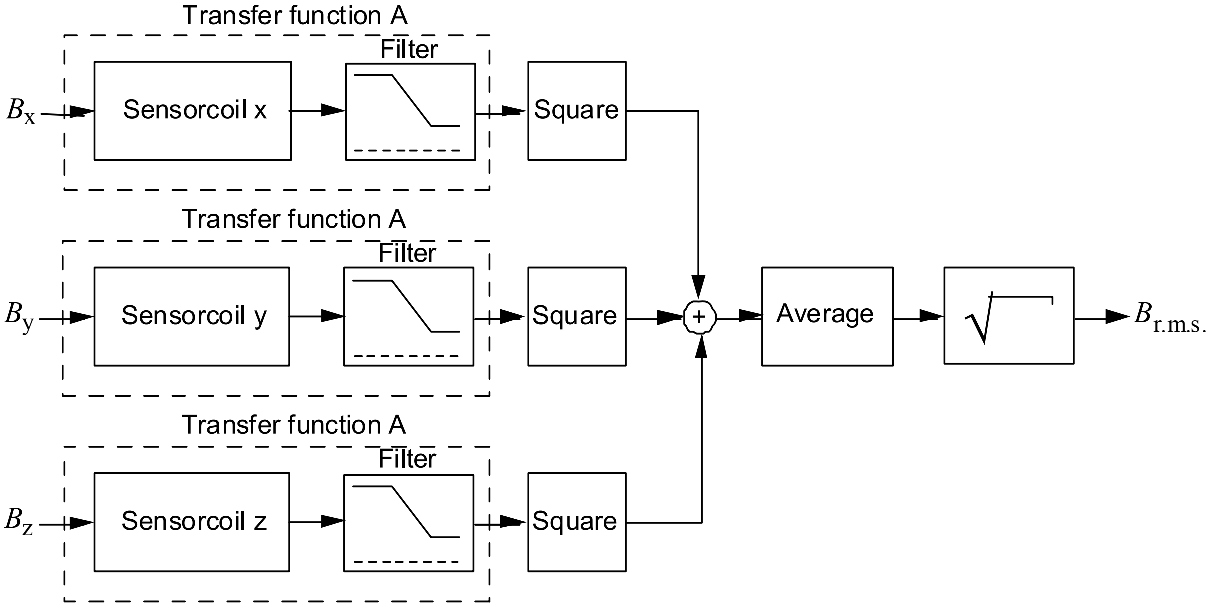


Figure Z2 - Schematic diagram of the reference method

NOTE 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. 〈C

[C⟩ 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 localized fields, this has to be performed after taking the coupling factor $a_c(r_1)$ given in Annex C into account. The final weighted result, W, can be derived as follows:

$$W_n = \frac{B_{r.m.s.}}{B_{RL}}$$

or applying the coupling factor $a_c(r_1)$

$$W_{nc} = a_c(r_1).W_n$$

where

W_n weighted result for one measurement;

$B_{r.m.s}$ 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. ⟨C]

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 $B(j)$.

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

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:

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

or applying the coupling factor *$a_c(r_1)$*:

$$W_{\text{nc}} = a_{\text{c}}(r_1) \cdot W_{\text{n}} \tag{6}$$

NOTE Coupling factor can be independent of frequency, for details see Annex C

$B(j)$: magnetic flux density at the order of j frequency line of the measured spectrum

$B_{\text{RL}}(j)$: reference level of the magnetic flux density at the order of j frequency.

$a_{\text{c}}(r_1)$: coupling factor according to Annex C or Table D.3.

W_{n}: weighted result for one measurement.

W_{nc}: weighted result for one measurement taking the coupling of the inhomogeneous field into account by applying $a_{\text{c}}(r_1)$

The determined weighted W shall not exceed the value 1.

C〉*Text deleted* 〈C

NOTE A pure summation always results in an overestimation of the exposure and for broadband fields consisting of higher frequencies harmonic components or noise, the limitation based on summation formula is very conservative because the amplitudes are not in the same phase. With most measurement equipment the relative phases are not measured (for example if a spectrum analyser is used), but an rms summation of frequency components can be undertaken. This will usually give a more realistic outcome than neglecting phase completely.

C〉5.5.4 Simplified test methods

Appliances that are constructed so that they can only produce magnetic fields at mains frequency and its harmonics need only be tested in the frequency range below 2 kHz.

Appliances are considered to meet the requirements of this standard when all the following conditions are fulfilled:

- the currents, including the harmonic currents, generating the magnetic fields are known;
- all harmonic currents with amplitudes higher than 10 % of the amplitude of the mains frequency decrease continuously over the frequency range;
- the magnetic flux density measured at mains frequency is less than 50 % of the reference level specified for the mains frequency;
- the magnetic flux density measured during a broadband measurement over the frequency range, with the mains frequency suppressed, is less than 15 % of the reference level specified for the mains frequency.

NOTE An active notch filter is a suitable means for suppressing the mains frequency. If the conditions are not fulfilled another measurement according to the reference method is recommended.

Appliances that are constructed so that they only produce very weak magnetic fields, when the mains frequency is dominating, are considered to meet the requirements of this standard when all the following conditions are fulfilled:

- the currents, including the harmonic currents, generating the magnetic fields are known;
- all harmonic currents with amplitudes higher than 10 % of the amplitude of the mains frequency decrease continuously over the frequency range;
- the magnetic flux density measured over the whole frequency range is less than 30 % of the reference level specified for the mains frequency. 〈C

5.6 Measurement uncertainty

The maximum overall measurement uncertainty shall not exceed 25 % of the limit. Guidance to assess uncertainty is provided in IEC 61786.

NOTE 1 The total measurement uncertainty can comprise aspects such as sensor position, operating conditions, noise background or the signal exceeding the dynamic range of the measuring instrument.

Ⓒ〉*Note deleted*〈Ⓒ

When the result has to be compared with a limit, the measurement uncertainty shall be implemented as follows:

- to establish whether an appliance produces only fields below the limit, the measurement uncertainty has to be added to the result and the sum has to be compared with the limit;

  NOTE This applies e.g. for measurements carried out by the manufacturer.

- to establish whether an appliance produces fields over the limit, the measurement uncertainty has to be subtracted from the result and the difference has to be compared with the limit.

  NOTE This applies e.g. for measurements carried out by authorities for market surveillance purposes.

5.7 Test report

The test report shall include at least the following items:

- Identification of the appliance
- specification of the measuring equipment
- operating mode, measuring positions and measuring distance unless specified in Annex A
- rated voltage and frequency
- measuring method
- measured maximum value, weighted with the coupling factor if applicable

Ⓒ〉*Text deleted*〈Ⓒ

- measurement uncertainty, if the measured result is more than 75 % of the limit.

6 Evaluation of results

The requirements of this standard are fulfilled:

- if the measured values with measurement uncertainty taken into account (see 5.6) do not exceed the reference levels, or
- if a measured value exceeds the reference level the coupling factor can be taken into account to show that the basic restrictions are met. For specific apparatus the corresponding coupling factor $a_c(r_1)$ can be determined as described in Annex C, or
- if the value still exceeds the reference level when using the coupling factor, it does not necessarily follow that the basic restrictions will be exceeded. It shall be verified, e.g. by calculation methods, whether the basic restrictions are fulfilled or not.

NOTE For calculation methods, IEC 62226 can be used.

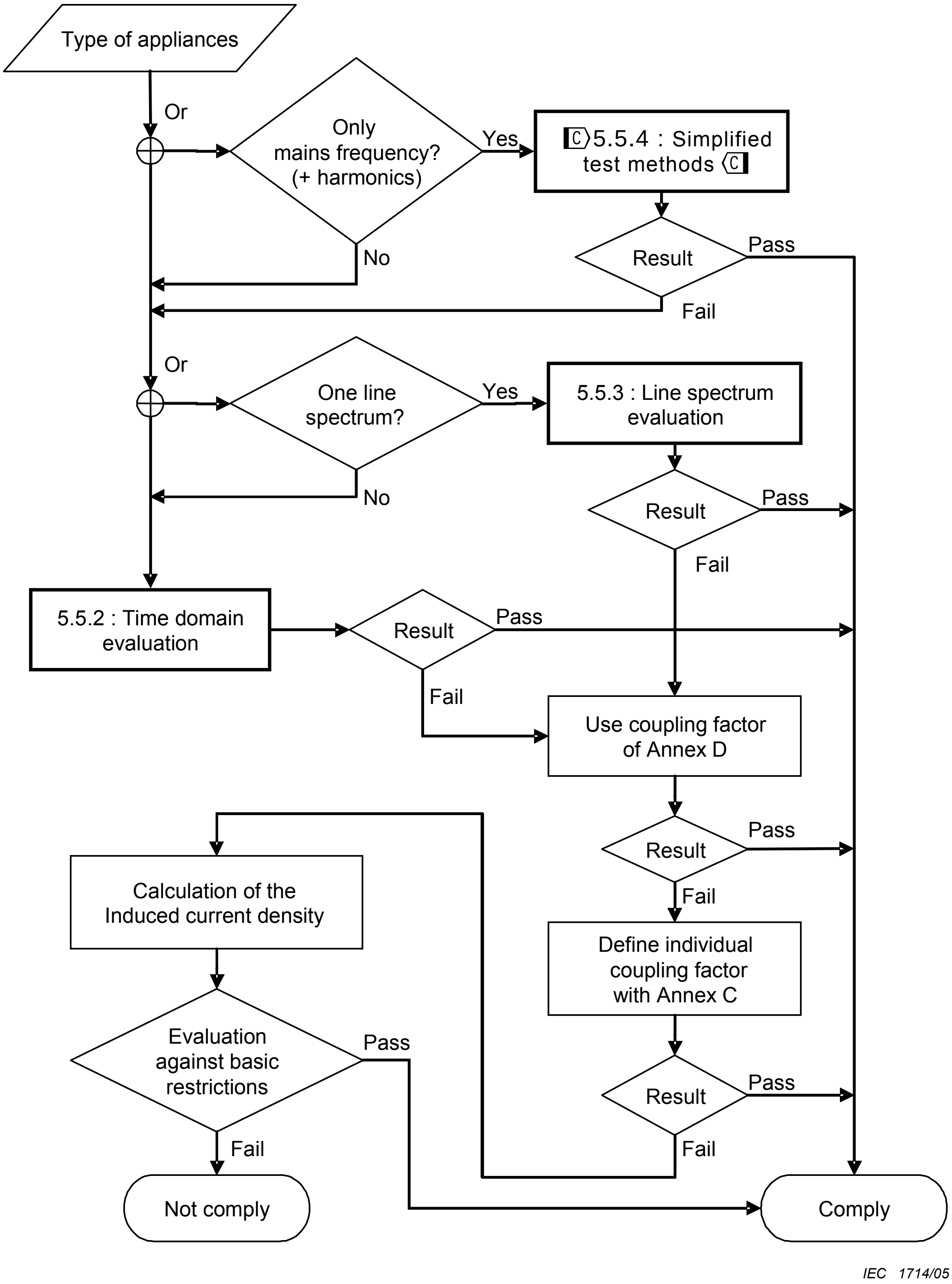
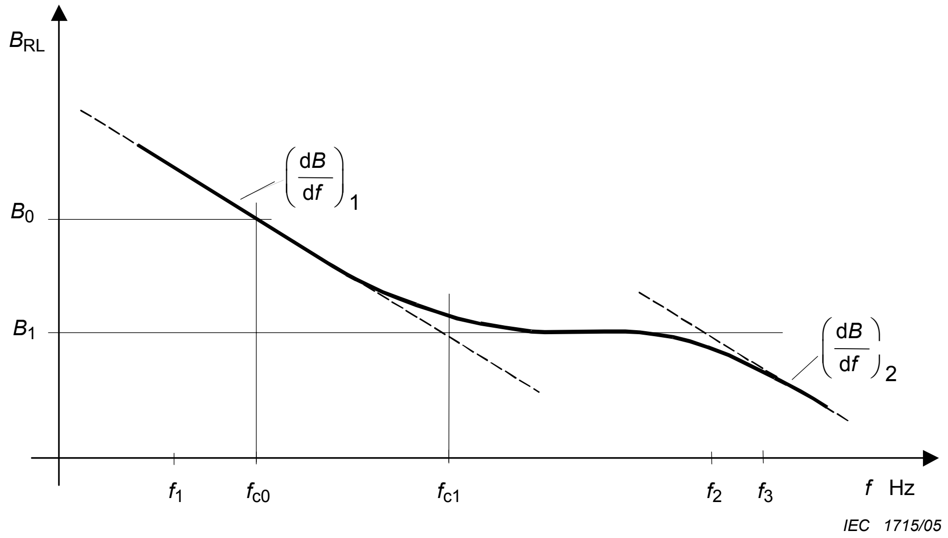
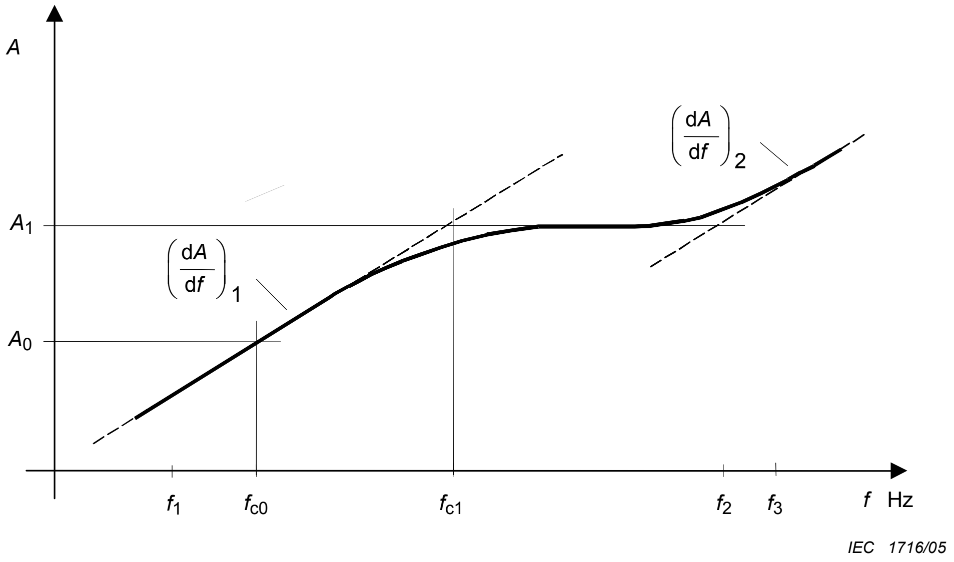


Figure 1 – Recommendations for the choice of the test method starting with the evaluation against the reference levels



$$\text{with } B(f_{C0}) = B_0,\ B(f_{C1}) = B_1 \text{ and the gradients } \left(\frac{dB}{df}\right)_n$$

Figure 2 – Example for dependency on frequency of the reference levels with smoothed edges



$$\text{With } A(f_{C0}) = A_0 = \frac{B_{RL}(f_{C0})}{B_0} = 1; \quad A(f_{C1}) = A_1 = \frac{B_{RL}(f_{C0})}{B_1}; \quad \left(\frac{dA}{df}\right)_n = \left[\left(\frac{dB}{df}\right)_n\right]^{-1}$$

Figure 3 – Example for a transfer function *A* corresponding to the reference level of Figure 2

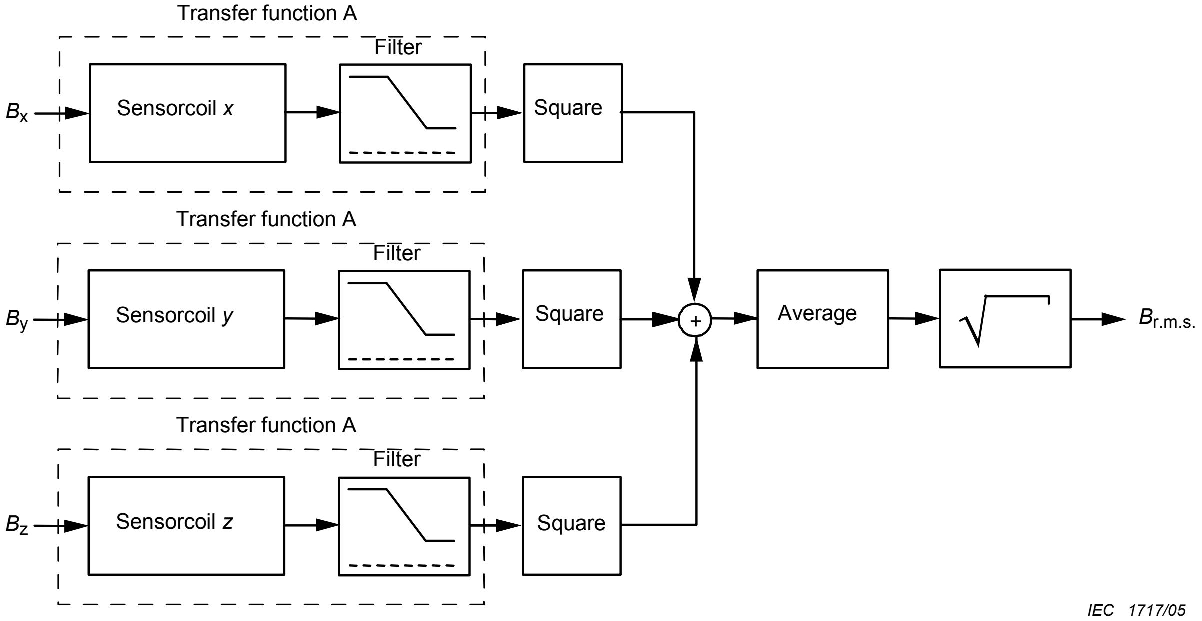


Figure 4 – Schematic diagram of the reference method

Annex A

(normative)

Test conditions for the measurement of magnetic flux density

A.1 General

The measurements are carried out under the conditions specified in Table A.1, the appliance being positioned as in normal use.

[C⟩*Text deleted*⟨C]

A.1.1 [C⟩Operating conditions, if not specified in Table A.1⟨C]

a) Maximum setting.

b) The operating condition as specified in the relevant CISPR 14-1 series or without load, if possible.

Manufacturer's specifications regarding short time operation have to be taken into account.

The running-in time is not specified but, prior to testing, the appliance is operated for a sufficient period to ensure that the conditions of operation are typical of those during normal use.

The appliances shall be operated as in normal use from a supply which provides the rated voltage ±2 % and the rated frequency ±2 % of the appliance.

If a voltage range and/or a frequency range are indicated, then the supply voltage and/or frequency shall be the nominal voltage and/or frequency of the country or region in which the appliance is intended to be used.

[C⟩ Controls are adjusted to the highest setting. However, pre-set controls are used in the intended position. The measurements are made while the appliance is energized.⟨C]

Tests are carried out at an ambient temperature of 25 °C ± 10 °C.

A.1.2 [C⟩Measuring distance, if not specified in Table A.1⟨C]

a) The appliance used in contact with the relevant parts of the body: 0 cm.

b) Other appliances: 30 cm.

A.1.3 [C⟩Sensor location, if not specified in Table A.1⟨C]

a) Appliance in contact with the relevant parts of the body: toward user (contact side).

b) Un-transportable large appliance: front (operating side) and the other sides to which persons can access (see Figure A.1).

c) Other appliances: around (see Figure A.2).

A.2 Measuring distances, sensor location and operating conditions for specific appliances

A.2.1 Multifunction equipment

Multifunction equipment, which is subjected simultaneously to different clauses of this standard, shall be tested with each function operated separately, if this can be achieved without modifying the equipment internally.

For equipment for which it is not practical to test with each function operated separately, or where the separation of a particular function would result in the equipment being unable to fulfil its primary function, the equipment shall be operated with the minimum number of functions needed to operate.

A.2.2 Battery operated equipment

If the appliance can be connected to the mains it shall be tested operating in each permitted mode. When operating with power from the battery, the battery shall be fully charged prior to start the test.

A.2.3 Measuring distance and sensor location

C〉 NOTE The measuring distances in Table A.1 have been defined based upon the expected location of the operator during normal operation, to protect against effects on central nervous system tissues in the head and trunk of the body.

Table A.1 - Measuring distances, sensor locations, operating conditions and coupling factors

Type of appliance	Measuring distance r_1 cm	Sensor locations	Operating conditions	Coupling factor $a_c(r_1)$ σ = 0,1 S/m 8 Hz .. 800 Hz [a]
Appliances not mentioned in the table	Operator distance	All surfaces	As specified in EN 55014-1	See Annex C
Air cleaners	30	All surfaces	Continuously	0,17
Air conditioners	30	Around	Continuously. When cooling lowest temperature setting. When heating highest temperature setting	0,18
Battery chargers (including inductive)	30	All surfaces	Charging a discharged battery having the highest capacity specified by the manufacturer	0,15
Blankets	0	Top	Spread out and laid on a sheet of thermal insulation	0,19
Blenders	30	Around	Continuously, no load	0,16
Citrus presses	30	Around	Continuously, no load	0,15
Clocks	30	Around	Continuously	0,15
Coffee makers	30	Around	As specified in 3.1.9 of EN 60335-2-15	0,16
Coffee mills	30	All surfaces	As specified in 3.1.9.108 of EN 60335-2-14	0,15
Convector heaters	30	Around	With highest output	0,20
Deep fat fryers	30	Around	As specified in 3.1.9 of EN 60335-2-13	0,16
Dental hygiene appliances	0	All surfaces	As specified in 3.1.9 of EN 60335-2-52	0,19
Depilators	0	Against cutter	Continuously, no load	0,30
Dishwashers	30	Top, front	Without dishes in the washing mode and drying mode	0,18
Egg boilers	30	Around	As specified in 3.1.9 of EN 60335-2-15	0,15
Electric and electronic controls for track sets	30	All surfaces	Continuously	0,17
Facial sauna appliances	10	Top	Continuously	0,12
Fans	30	Front	Continuously	0,16
Fan heaters	30	Front	Continuously, highest heat setting	0,16

〈C

Type of appliance	Measuring distance r_1 cm	Sensor locations	Operating conditions	Coupling factor $a_c(r_1)$ $\sigma = 0,1$ S/m 8 Hz .. 800 Hz [a]
Floor polishers	30	All surfaces	Continuously without any mechanical load on the polishing brushes	0,19
Food processors	30	Around	Continuously without load, highest speed setting	0,17
Food warming cabinets	30	Front	Continuously without load, highest heat setting	0,15
Foot warmers	30	Top	Continuously without load, highest heat setting	0,15
Gas heating appliances, wall mounted	30	Front, left and right side	Continuously, highest heat setting with pump in operation	0,16
Gas heating appliances, floor standing	30	Front, left and right side	Continuously, highest heat setting with pump in operation	0,20
Gas igniters	30	All surfaces	Continuously	0,15
Grills	30	Around	Continuously without load, highest heat setting	0,16
Hair clippers	0	Against cutter	Continuously without load	0,30
Hairdryers	10	All surfaces	Continuously, highest heat setting	0,12
Heat pumps	30	Around	Continuously. When cooling lowest temperature setting. When heating highest temperature setting	0,17
Heating mats	30	Top	Spread out and laid on a sheet of thermal insulation	0,15
Heating pads	0	Top	Spread out and laid on a sheet of thermal insulation	0,14
Hobs	30	Top, front	As specified in 3.1.9 of EN 60335-2-6 but with highest setting, each heating unit separately	0,18
Hotplates	30	Around	As specified in 3.1.9 of EN 60335-2-9 but with highest setting, each heating unit separately	0,17
Icecream makers	30	Around	Continuously without load, lowest temperature setting	0,18
Immersion heaters	30	Around	Heating element fully submerged	0,16
Induction hobs and hotplates	See A.3.1	See A.3.1	See A.3.2.	
Irons	30	All surfaces	As specified in 3.1.9 of EN 60335-2-3	0,15
Ironing machines	30	All surfaces	As specified in 3.1.9 of EN 60335-2-44	0,19
Juice extractors	30	Around	Continuously without load	0,17
Kettles	30	Around	Half-filled with water	0,17
Kitchen scales	30	Around	Continuously without load	0,14
Knives	30	All surfaces	Continuously without load	0,16

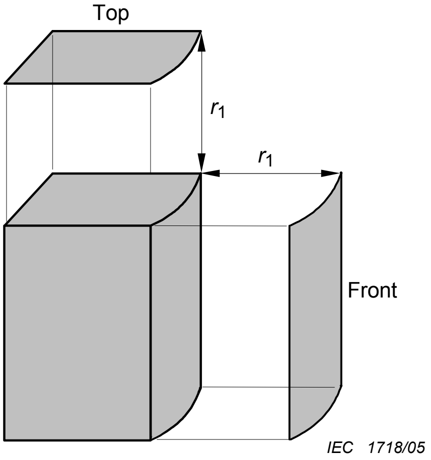
C〉

Type of appliance	Measuring distance r_1 cm	Sensor locations	Operating conditions	Coupling factor $a_c(r_1)$ σ = 0,1 S/m 8 Hz .. 800 Hz [a]
Massage appliances	0	Against the massage head	Continuously without load, highest speed setting	0,21
Microwave ovens	30	Top, front	Continuously with highest microwave power setting. Conventional heating elements, if available, are operated simultaneously at their highest setting. The load is 1 l of tap water, placed in the centre of the shelf. The water container is made of electrically non-conductive material such as glass or plastic.	0,17
Mixers	30	All surfaces	Continuously without load, highest speed setting	0,16
Oil filled radiators	30	Around	Continuously, highest heat setting	0,20
Ovens	30	Top, front	Oven empty with door closed, thermostat being at the highest setting. Also in the cleaning mode, if available, as described in the instructions for use.	0,20
Ranges	30	Top, front	Each function separately	0,20
Range hoods	30	Bottom, front	Controls at highest setting	0,19
Refrigeration appliances	30	Top, front	Continuously with the door closed. The thermostat is adjusted to lowest temperature setting. The cabinet is empty. The measurement is made after steady conditions have been reached but with active cooling in all compartments.	0,18
Rice cookers	30	Around	Half-filled with water, without lid and highest heat setting	0,16
Shavers	0	Against cutter	Continuously without load	0,30
Slicing machines	30	All surfaces	Continuously without load, highest speed setting	0,17
Solaria				
- parts touching the body	0	Around	Continuously, highest settings	0,18
- other parts	30	Around	Continuously, highest settings	0,20
Spin extractors	30	Top, front	Continuously without load	0,18
Storage heaters	30	Around	Continuously, highest heat setting	0,20
Tea makers	30	Around	Continuously, no load	0,16
Toasters	30	Around	Without load, highest heat setting	0,16
Tools, hand-guided	30	Around, unless the same side is always towards the user	No-load, all settings e.g. speed set to maximum.	0,15
Tools, hand-held	30	Around, unless the same side is always towards the user	No-load, all settings e.g. speed set to maximum.	0,15

〈C

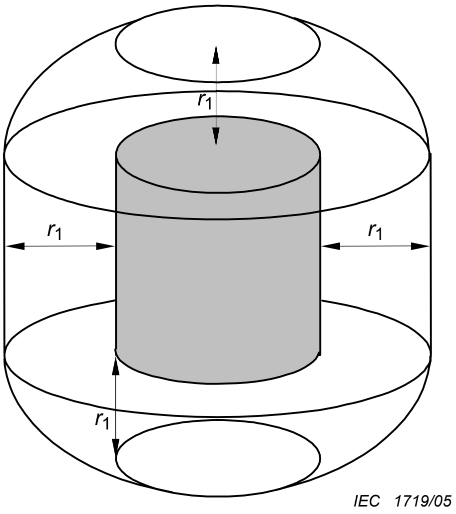
Type of appliance	**Measuring distance** r_1 cm	**Sensor locations**	**Operating conditions**	**Coupling factor** $a_c(r_1)$ σ **= 0,1 S/m** **8 Hz .. 800 Hz** [a]
Tools, transportable	30	Top and side towards the user	No-load, all settings e.g. speed set to maximum.	0,16
Tools with heating elements	30	Around, unless the same side is always towards the user	Highest temperature setting. Glue guns with glue stick in working position	0,15
Tumble dryers	30	Top, front	Drum filled with textile material having a mass in the dry condition of 50 % of the maximum load. The textile material consists of pre-washed double-hemmed cotton sheets approximately 70 cm ×70 cm cm having a mass between 140 g/m² and 170 g/m² in the dry condition. The material is soaked with water of a mass of 60 % of that of the textile material.	0,18
Vacuum cleaners, handheld	30	All surfaces	As specified in 3.1.9 of EN 60335-2-2	0,16
Vacuum cleaners, body sling	0	All surfaces	As specified in 3.1.9 of EN 60335-2-2	0,13
Vacuum cleaners, others	30	Around	As specified in 3.1.9 of EN 60335-2-2	0,16
Washing machines and washer dryers	30	Top, front	Without textiles, in the spinning mode at highest speed	0,18
Water-bed heaters	10	Top	Spread out and laid on a sheet of thermal insulation	0,14
Water heaters	30	Around	Controls at highest setting, with water flowing, if necessary	0,17
Whirlpool baths - inside - outside	 0 30	 Around Around	 Continuously Continuously	 0,18 0,20

[a] The worst case coupling factors have been calculated for frequencies up to 800 Hz. For fundamental operating frequencies greater than 800 Hz and lower than 150 kHz, the coupling factor is $a_c(r_1)$ x 1,25.



The sensor is moved on a surface at the distance r_1, from the top / front of the appliance

Figure A.1 – Measuring position: top / front (see 3.2.7)



The sensor is moved all around the appliance, where people have access, at the distance r_1, perpendicular of its surface

Figure A.2 – Measuring position: around (see 3.2.7)

A.3 Test conditions for induction hobs and hotplates

A.3.1 Measuring distances

For each cooking zone measurements are made along four vertical lines (A, B, C, D) at a distance of 30 cm from the edges of the appliance to the surface of the sensor (see Figure A.3). The measurements are made up to 1 m above the cooking zone and 0,5 m below it. The measurement is not made at the rear of the appliance (line D) if it is intended to be used when placed against a wall.

A.3.2 Operating mode

An enamelled steel cooking vessel, approximately half filled with tap water is placed centrally on the cooking zone to be measured.

The smallest vessel recommended in the instructions for use is used. If no recommendations are provided, the smallest standard vessel that covers the marked cooking zone is used. The bottom diameters of standard cooking vessels are: 110 mm, 145 mm, 180 mm, 210 mm and 300 mm.

The induction heating units are operated in turn, the other cooking zones not being covered.

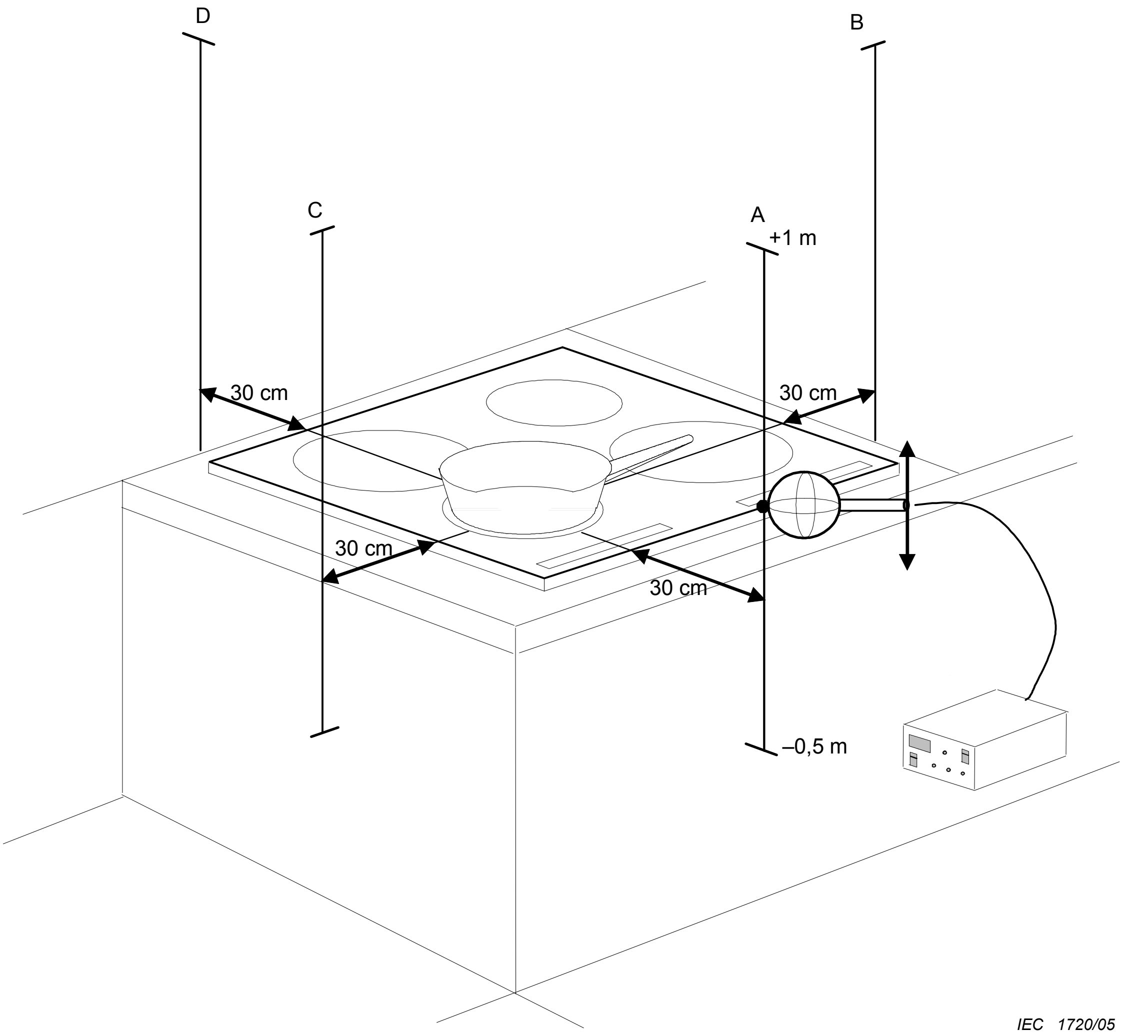
Energy controller settings shall be set to maximum.

The measurements are made after stable operating conditions are reached.

[C⟩ NOTE Z1 Stable operating conditions are reached after the water starts to boil and when the magnetic field or the power on the mains supply is stabilized. ⟨C]

If no stable conditions can be reached, an appropriated observation time (e.g. 30 s) should be defined to be sure to get the max. value at fluctuating field sources.

NOTE Because of sharing power between induction heating units, the highest and continuous magnetic field is obtained when each heating units are operated separately.



Lines A, B, C and D indicate the measuring positions.

This figure shows the front left hand induction heating element of a 4-zone hob in operation.

Figure A.3 – Measuring distances for induction hobs and hotplates

[C⟩ Annex B

(informative)

Basic restrictions and reference levels

The following basic restrictions and reference levels of 1999/519/EC apply.

Table B.1 - Basic restrictions for electric, magnetic and electromagnetic fields (0 Hz to 300 GHz)

Frequency range	Magnetic flux density mT	Current density mA/m² r.m.s.	Whole body average SAR W/kg	Localized SAR (head and trunk) W/kg	Localized SAR (limbs) W/kg	Power density, S W/m²
0 Hz	40					
> 0 - 1 Hz		8				
1 - 4 Hz		8/*f*				
4 - 1 000 Hz		2				
1 000 Hz - 100 kHz		*f*/500				
100 kHz - 10 MHz		*f*/500	0,08	2	4	
10 MHz - 10 GHz			0,08	2	4	
10 - 300 GHz						10
f is the frequency in Hz.						

Table B.2 - Reference levels for electric, magnetic and electromagnetic fields (0 Hz to 300 GHz, unperturbed r.m.s. values)

Frequency range	E-field strength V/m	H-field strength A/m	B-field μT	Equivalent plane wave power density S eq W/m²
0 Hz - 1 Hz	-	$3{,}2 \times 10^4$	4×10^4	-
1 Hz - 8 Hz	10 000	$3{,}2 \times 10^4 / f^2$	$4 \times 10^4 / f^2$	-
8 Hz - 25 Hz	10 000	4 000/*f*	5 000/*f*	-
0,025 kHz - 0,8 kHz	250/*f*	4/*f*	5/*f*	-
0,8 kHz - 3 kHz	250/*f*	5	6,25	-
3 kHz - 150 kHz	87	5	6,25	-
0,15 MHz - 1 MHz	87	0,73/*f*	0,92/*f*	-
1 MHz - 10 MHz	$87/f^{1/2}$	0,73/*f*	0,92/*f*	-
10 MHz - 400 MHz	28	0,073	0,092	2
400 MHz - 2 000 MHz	$1{,}375\ f^{1/2}$	$0{,}003\,7\ f^{1/2}$	$0{,}004\,6\ f^{1/2}$	*f*/200
2 GHz - 300 GHz	61	0,16	0,20	10
f is as indicated in the frequency range column.				

NOTE These limits do not apply for the protection of workers against exposure to electromagnetic fields. ⟨C]

B.2 IEEE standard [12]

Table B.3 – Basic limitations for general public exposure applying to various regions of the body up to 3 kHz – Excerpts

Exposed tissue	f_e Hz	E_O V/m-r.m.s
Brain	20	5,89 x 10^{-3}
Heart	167	0,943
Hands, wrists, feet & ankles	3 350	2,10
Other tissue	3 350	0,701

Interpretation of Table as follows:

$E_i = E_o$ for $f \le f_e$; $E_i = E_o(f / f_e)$ for $f \ge f_e$.

In addition to the listed restrictions, exposure of the head and torso to magnetic fields below 10 Hz shall be restricted to a peak value of 167 mT for the general public, and 500 mT in the controlled environment.

Table B.4 – Magnetic field limits for general public exposure: exposure of head and torso – Excerpts

Frequency range Hz	B mT-r.m.s	H A/m-r.m.s
< 0,153	118	9,39x10^4
0,153 - 20	18,1/f	1,44x10^4/f
20 - 759	0,904	719
759 – 3 000	687/f	5,47x10^5/f
3 000 - 100 kHz		164

Limits for frequencies above 3 kHz are included to demonstrate consistency with IEEE standards above 3 kHz (IEEE, 1991).

Annex C
(normative)

Determination of coupling factors

C.1 The determination of the coupling factors by calculation

The reference levels B_{RL} given in Annex B are defined for homogeneous fields. The strong inhomogeneity of the magnetic fields around appliances within this standard are considered by factors $a_c(r_1)$. They take the dimension of the part of body which is in the field into account as well.

The procedure is applicable to concentrated sources only. The field distribution from the hot spot with B_{max} to 0,1 B_{max} shall be continuous.

The corrected measuring value $B_{mc}(r_1)$, which is compared with the reference level B_{RL}, is obtained from the measured value B_m by

$$\mathbf{B_{mc}(r_1) = a_c(r_1)\ B_m} \text{ and } W_{nc} = a_c\ (r_1)\cdot W_n \tag{C.1}$$

The determination of the factor $a_c(r_1)$ is achieved in four steps, based on the fundamental of the operating frequency:

- **Step 1 Evaluation of the extent of the hot spot**

The magnetic flux density $B(r_0)$ is measured tangentially to the surface along the line of the lowest gradient starting at the hot spot $r_0 = 0$. The measurement stops at $r_0 = X$ where the flux density decreases to 10 % of the maximum value of the hot spot, as shown in Figures C.1 and C.2. The distance between measuring points is in the range of 0,5 cm to 1 cm.

NOTE 1 The assessment of a coupling factor can be done narrow banded, i.e. in the operating frequency.

NOTE 2 It is recommended to use a small sensor, e.g. the sensor with 3 cm^2 measuring area defined in 5.4.

$$\frac{B\ (r_0 = X)}{B\ (r_0 = 0)} = 0{,}1 \tag{C.2}$$

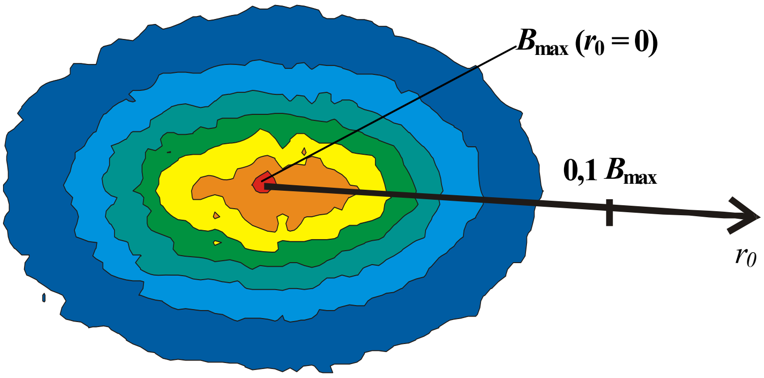


Figure C.1 – Hot spot

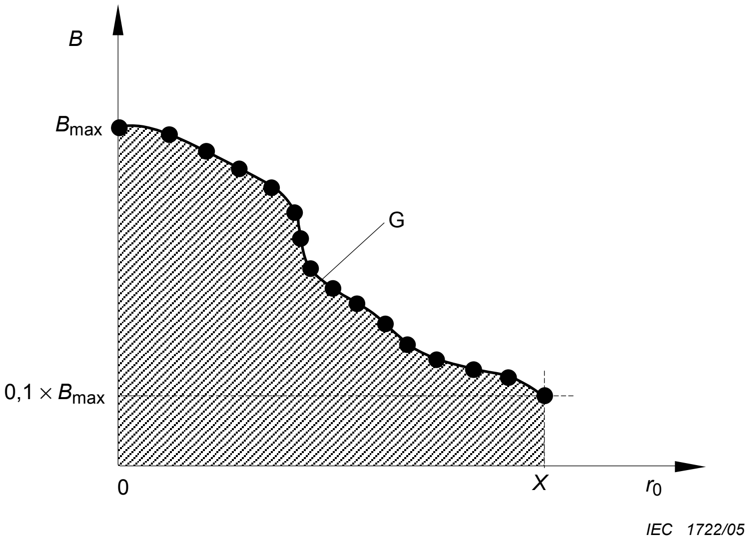


Figure C.2 – Gradient of flux density and integral *G*

- **Step 2 Determination of the equivalent coil**

The measurement results from step 1 are used to determine the radius of an equivalent coil which gives a similar integral *G*. For further calculations it is assumed that this coil is positioned at a distance l_{coil} from the **hot spot**, corresponding to the location of the magnetic field source inside the appliance (see Figure C.3).

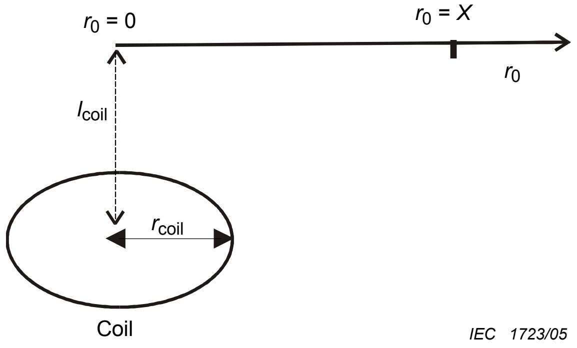


Figure C.3 – Equivalent coil position

An integration of the normalized measured flux density results in a single value *G* and this can then be used to determine the radius r_{coil} of the equivalent coil (Table C.1). Linear interpolation is used to obtain other values of r_{coil} which shall not exceed l_{coil}.

NOTE 1 For small appliances, the magnetic field source is assumed to be at the centre of the appliance. For larger appliances, the location of each magnetic field source is determined by examination of the appliance.

NOTE 2 The procedure is applicable only for concentrated sources. The field distribution from the hot spot with $B_{\max}$ to 0,1 $B_{\max}$ shall be continuous.

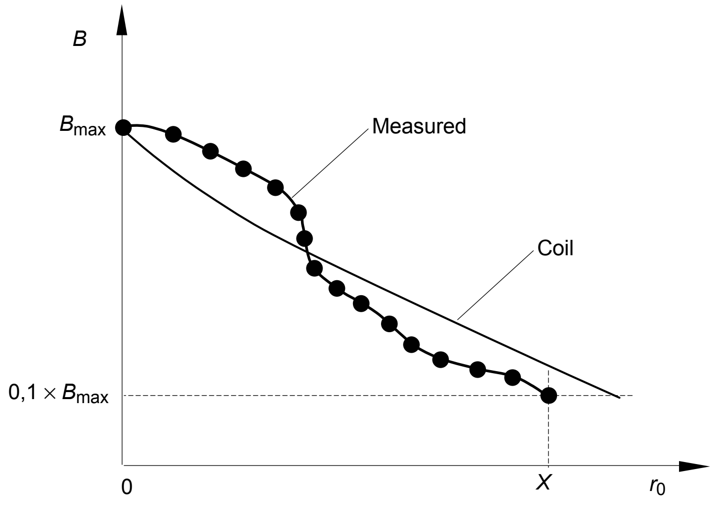
The value *G* is calculated from the following formula:

$$G(r_{\text{coil}}, l_{\text{coil}}) = \int_{r_0=0}^{r_0=X} \frac{B\ (r_0)}{B\ (r_0=0)} dr_0 \qquad \text{(C.3)}$$

Table C.1 – Value G [m] of different coils

Distance	**Radius r_{coil} (mm)**					
l_{coil} (mm)	**10**	**20**	**30**	**50**	**70**	**100**
10	0,013 54					
15	0,015 62					
20	0,018 48	0,027 03				
25	0,021 68	0,028 80				
30	0,025 11	0,031 17	0,040 51			
35	0,028 61	0,033 90	0,042 17			
40	0,032 22	0,036 89	0,044 29			
50	0,039 55	0,043 34	0,049 41	0,067 50		
70	0,054 48	0,057 18	0,061 64	0,075 35	0,094 44	
100	0,077 11	0,079 05	0,082 19	0,092 13	0,106 44	0,134 93
200	0,153 17	0,154 15	0,155 73	0,160 85	0,168 45	0,184 20
300	0,229 53	0,230 12	0,231 19	0,234 61	0,239 71	0,250 54

NOTE To get the coil which covers the worst case condition , the smallest coil radius for the given value *G* should be chosen.



IEC 1724/05

Figure C.4 – Gradients of flux density and coil

Step 3 Determination of factor *k*

The coil radius r_{coil} is used to determine the factor $k(r, r_{\text{coil}}, f, \sigma)$ between the equivalent source (coil) and the human body in the distance r.

$$r = r_1 + l_{\text{coil}} \tag{C.4}$$

r_1: is the measuring distance (see 3.2.6)

l_{coil}: is the inside distance from the equivalent coil to the surface

NOTE Addition must be made in the same unit.

$$k(r, r_{\text{coil}}, f, \sigma) = \frac{J_{\max}(r, r_{\text{coil}}, f, \sigma)}{B_{\max,\text{sensor}}(r, r_{\text{coil}}, A_{\text{sensor}})} \tag{C.5}$$

$J_{\max}$: is the highest current density in the body

A_{sensor}: is the measuring area of the sensor

The factor k, which is frequency dependant, depends on the distance r between coil and the human body as well as the electric conductivity σ of the homogeneous model of the human body and the size of the sensor. The dependence on the frequency can be compensated by rescaling to the **reference level** instead of to the **basic restriction (see step 4)**.

For inhomogeneous fields, the value of σ is 0,1 S/m since the highest field values occur on the surface of the human body (see D.2.2). The following calculations are based on this value using the reference sensor described in 5.4. Table C.2 lists the values of factor k for the whole human body.

Table C.2 – Value of factor $k[\frac{A/m^2}{T}]$ at 50 Hz for the whole human body

Distance *r*	**Radius r_{coil}** mm					
cm	**10**	**20**	**30**	**50**	**70**	**100**
1	21,354	15,326	8,929	5,060	3,760	3,523
5	4,172	3,937	3,696	3,180	2,858	2,546
10	2,791	2,735	2,696	2,660	2,534	2,411
20	2,456	2,374	2,369	2,404	2,398	2,488
30	2,801	2,735	2,714	2,778	2,687	2,744
40	3,070	2,969	2,933	3,042	2,865	2,916
50	3,271	3,137	3,086	3,251	2,989	3,040
60	3,437	3,271	3,206	3,429	3,079	3,134
70	3,588	3,388	3,311	3,595	3,156	3,216
100	3,940	3,659	3,601	4,022	3,570	3,604

NOTE 1 The factors k are determined by applying the coil as a source with the appropriate numerical model for the human body as described in D.2. It is applicable only for the region close to the source and not for homogenous fields.

NOTE 2 The radius r_{coil} which is larger dimension than the distance r can not be determined by the procedure in Annex C.

Factors k for other frequencies f and conductivity's σ can be calculated from the values in Table C.2 by

$$k^{*}(r, r_{\text{coil}}) = \frac{f}{50\,\text{Hz}} \cdot \frac{\sigma}{0{,}1\,\frac{\text{S}}{\text{m}}} \cdot k \tag{C.6}$$

- **Step 4 Calculation of the coupling factor**

[C〉 The coupling factor $a_c(r)$ is the result of the re-scaled factor *k* and can be determined as followed:

$$a_c(r,r_{coil},f,\sigma) = k(r,r_{coil},f,\sigma)\cdot\frac{B_{RL}(f)}{J_{BR}(f)} \qquad (C.7)$$

NOTE 1 The term $B_{RL}(f)/J_{BR}(f)$ is proportional $1/f$ from 8 Hz up to 800 Hz and from 1 kHz to 100 kHz. In consequence the factor $a_c(r)$ is frequency independent within these ranges (see Figure C.5).

In case of measuring according to 5.5.2 and 5.5.3 a f_{C0} equivalent is used. Therefore the coupling factor $a_c(r)$ evaluates to:

$$a_c(r,r_{coil},f_{c0},\sigma) = k(r,r_{coil},f_{c0},\sigma)\cdot\frac{B_{RL}(f_{c0})}{J_{BR}(f_{c0})} \qquad (C.8)$$

NOTE 2 The coupling factor $a_c\,(r_1)$ can be determined from Figure C.5 using equation C.4.

Example for the re-scaling applying 1999/519/EC at f = 50Hz and σ = 0,1 S/m for the whole body and a coil of r_{Coil} = 10 mm in a distance r = 50 cm.

$$a_c(r = 50\,\text{cm}, r_{coil} = 10\,\text{mm}, f = 50\,\text{Hz}, \sigma = 0.1\,\text{S/m}) =$$

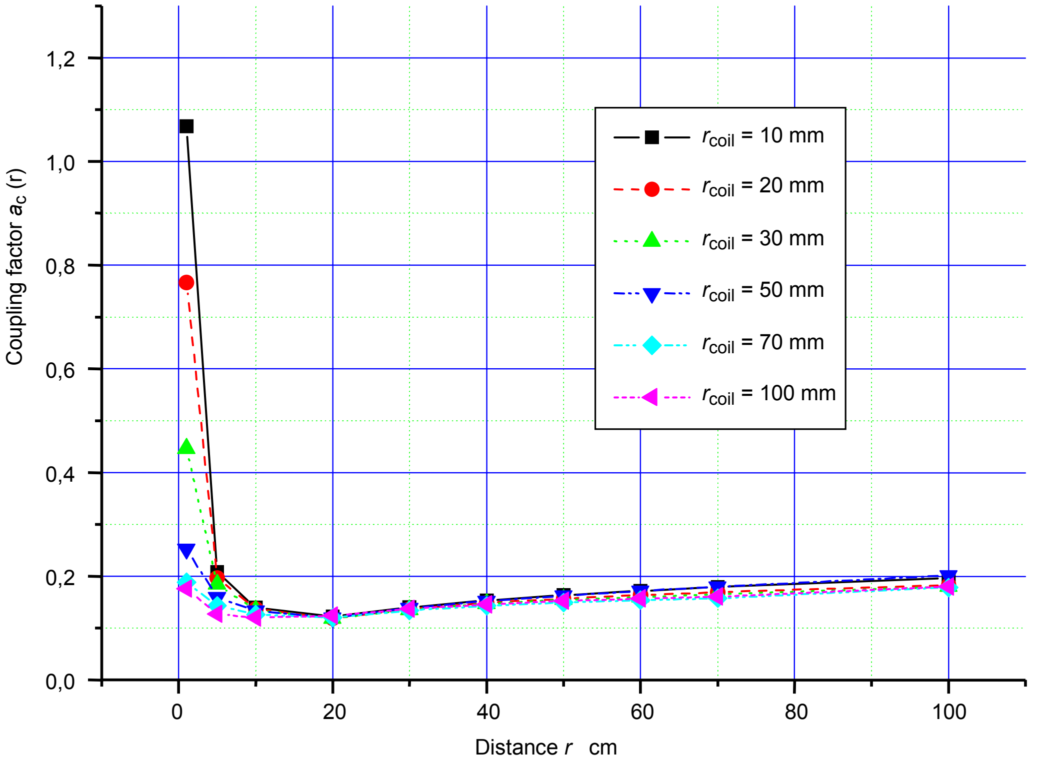
$$k(r = 50\,\text{cm}, r_{coil} = 10\,\text{mm}, f = 50\,\text{Hz}, \sigma = 0.1\,\text{S/m})\cdot\frac{B_{RL}(f = 50\,\text{Hz})}{J_{BR}(f = 50\,\text{Hz})} =$$

$$3.271\frac{A/m^2}{T}\,\frac{100\mu T}{2\,mA/m^2} = 0.1635$$

〈C]

C.2 Graphical evaluation of coupling factors

[C〉 The coupling factor can be determined from Figure C.5 using equation (C.4). This method provides a value for the coupling factor depending on the radius of the equivalent coil. 〈C]



IEC 1725/05

Figure C.5 – Coupling factor $a_C(r)$ with 0,1 S/m, A_{sensor}=100 cm^2, for the whole human body (re-scaled using ICNIRP limits)

Distance $r = r_1 + l_{coil}$, where r_1 is the measuring distance specified in Table A.1.

Annex D
(informative)

Examples using the limits of Annex B

D.1 Transfer function

The ICNIRP reference level $B_{RL}(f)$ for the general public exposure can be used to calculate the transfer function as follows:(example for a 50 Hz normalization point)

Table D.1 – Transfer function with ICNIRP general public exposure

$(f_1 = 10\text{ Hz}) \le f \le (f_{C1} = 800\text{ Hz})$	$A(f) = \frac{B_{RL}(f_{C0} = 50\text{ Hz})}{B_{RL}(f)} = \frac{{}^{5000}\!/_{50}\,\mu\text{T}}{{}^{5000}\!/_{f}\,\mu\text{T}} = \frac{f}{50\text{ Hz}}$
$(f_{C1} = 800\text{ Hz}) \le f \le (f_2 = 150\text{ kHz})$	$A(f) = \frac{B_{RL}(f_{C0} = 50\text{ Hz})}{B_{RL}(\text{f})} = \frac{{}^{5\,000}\!/_{50}\,\mu\text{T}}{6{,}25\,\mu\text{T}} = 16$
$(f_2 = 150\text{ kHz}) \le f \le (f_{n=3} = 400\text{ kHz})$	$A(f) = \frac{B_{RL}(f_{C0} = 50\text{ Hz})}{B_{RL}(f)} = \frac{{}^{5000}\!/_{50}\,\mu\text{T}}{{}^{920\,000}\!/_{f}\,\mu\text{T}} = \frac{f}{9{,}2\text{ kHz}}$

The IEEE magnetic maximum permissible exposure levels (see 3.2.8) for general public (exposure of head and torso) $B_{RL}(f)$ can be used to calculate the transfer function as follows:(example for a 60 Hz normalization point).

Table D.2 – Transfer function with IEEE general public exposure

$(f_1 = 10\text{ Hz}) \le f \le (f_{C1} = 20\text{ Hz})$	$A(\text{f}) = \frac{B_{RL}(f_{C0} = 60\text{ Hz})}{B_{RL}(f)} = \frac{0{,}904\text{ mT}}{{}^{18{,}1}\!/_{f}\text{ mT}} = \frac{f}{20\text{ Hz}}$
$(f_{C1} = 20\text{ Hz}) \le f \le (f_2 = 759\text{ Hz})$	$A(\text{f}) = \frac{B_{RL}(f_{C0} = 60\text{ Hz})}{B_{RL}(f)} = \frac{0{,}904\text{ mT}}{0{,}904\text{ mT}} = 1$
$(f_2 = 759\text{ Hz}) \le f \le (f_3 = 3{,}35\text{ kHz})$	$A(f) = \frac{B_{RL}(f_{C0} = 60\text{ Hz})}{B_{RL}(f)} = \frac{0{,}904\text{ mT}}{{}^{687}\!/_{f}\text{ mT}} = \frac{f}{759\text{Hz}}$
$(f_3 = 3{,}35\text{ kHz}) \le f \le (f_4 = 100\text{ kHz})$	$A(\text{f}) = \frac{B_{RL}(\text{f}_{C0} = 60\text{ Hz})}{B_{RL}(f)} = \frac{0{,}904\text{ mT}}{0{,}205\text{ mT}} = 4{,}41$
$(f_4 = 100\text{ kHz}) \le f \le (f_{n=5} = 400\text{ kHz})$	$A(f) = \frac{B_{RL}(f_{C0} = 60\text{ Hz})}{B_{RL}(f)} = \frac{0{,}904\text{ mT}}{{}^{205}\!/_{f}\text{ T}} = \frac{f}{22{,}68\text{ kHz}}$
NOTE All frequencies f used above in Hz.	

D.2 Coupling factors

Table D.3 – Coupling factor $a_c(r_1)$

Type of appliance	Measuring distance r_1	Coupling factor $a_c(r_1)$ ICNIRP	Coupling factor $a_c(r_1)$ IEEE (60 Hz)
Small	0 cm	1,00	0,330
Large	0 cm	0,15	0,048
Small	10 cm	0,14	0,043
Large	10 cm	0,16	0,051
Small	30 cm	0,14	0,043
Large	30 cm	0,18	0,056

Small: The field source is situated directly under the housing inside of the appliance.

Large: The field source has a distance between 10 cm and 40 cm from the surface of the housing inside the appliance.

NOTE 1 Worst case assumption, calculated by taking formula C.7 for the whole body.

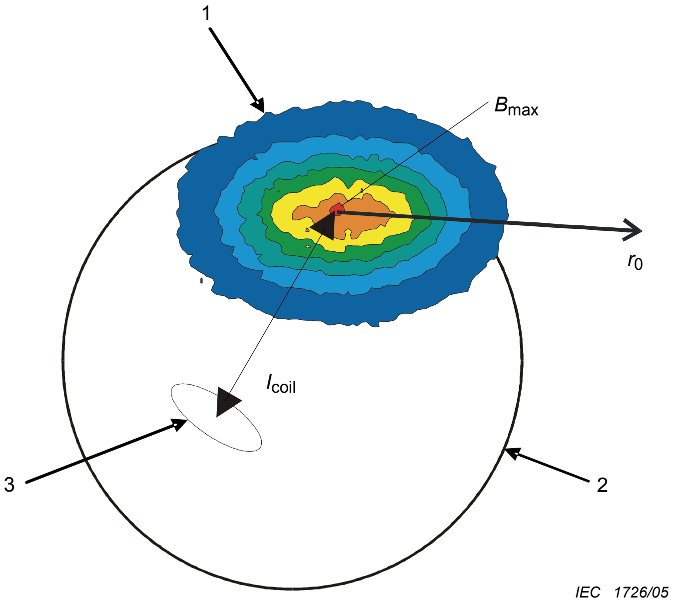
NOTE 2 The lower factors for IEEE, although the reference level is approximately 10 times higher than with ICNIRP, has its reason in the 35 times higher basic restriction for other tissue. The procedure calculates back to the basic restrictions.

D.3 Example for determining the coupling factor

As stated in Annex C, the determination of the **coupling factor** $a_c(r)$ is achieved in four steps.

- **Step 1 Evaluation of the extent of the hot spot**

The Figure D.1 illustrates the measurement procedure and Figure D.2 the result of a measurement.

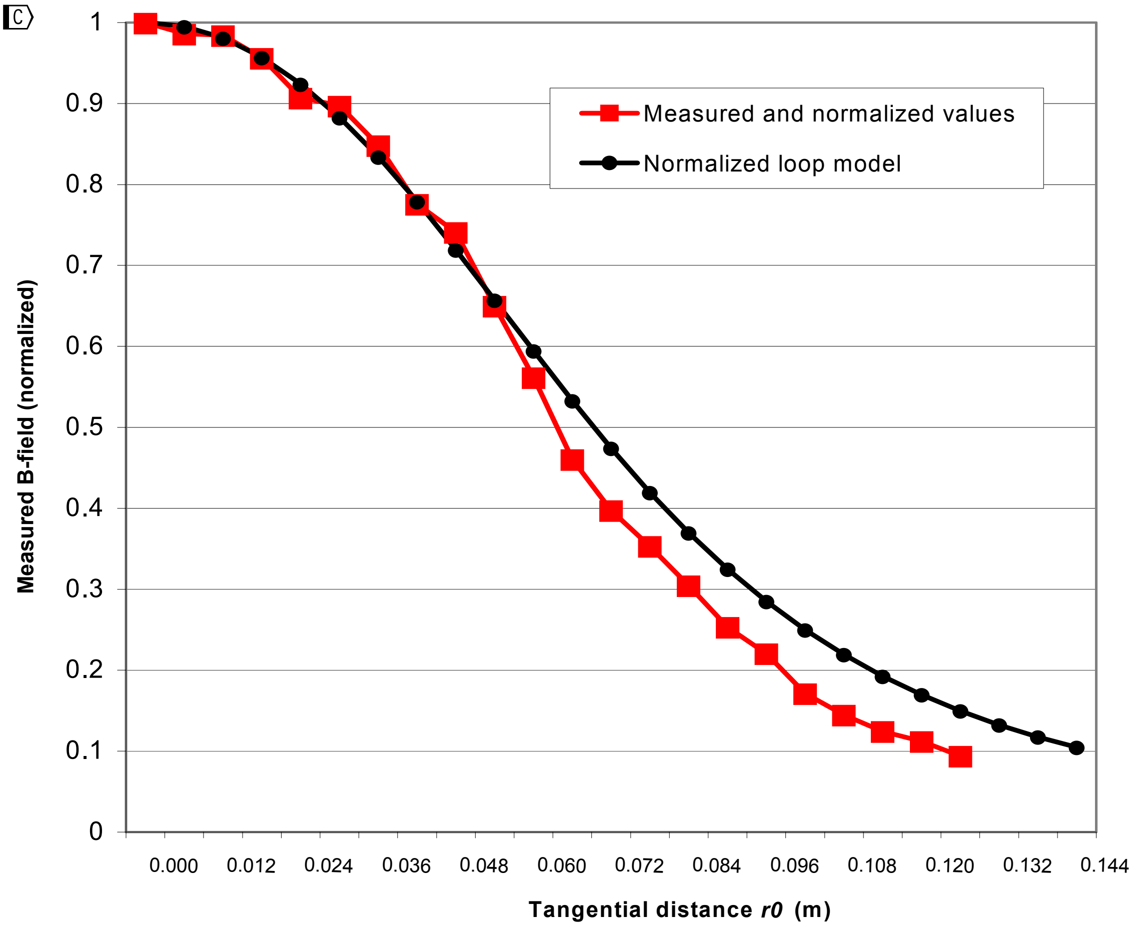


1	Measurement on a tangential plane around the hot spot
2	Model of a household appliance as a sphere
3	Coil as an equivalent field source

Figure D.1 – Measurement of the magnetic flux

- **Step 2 Determination of the equivalent coil**

⟦C⟩



⟨C⟧

Figure D.2 – Normalized field distribution along the tangential distance r_0

An integration of the normalized measured flux density along the axis (curve with squares in Figure D.2 above) results in a value G = 0,07166 [m].

- **Step 3 Determination of factor *k***

⟦C⟩ With the value of G from step 2 ⟨C⟧, the radius r_{coil} of the equivalent coil can be determined (Table C.1). For this step it is important to know the distance l_{coil} , which depends on the size of the measured household appliance. In this example l_{coil} = 70 mm is a good approximation. Looking in Table C.1 in the row for l_{coil} = 70 mm, one will determine in the column r_{coil} = 50 mm the factor to G = 0,07535 [m], which is closest to the exact value G = 0,07166 [m] in this row. The curve with circles in above Figure D.2 represents the mentioned coil. As you can see this coil is a good approximation.

The factor k can now be determined e.g. for r_1 = 0 by looking in Table C.2 at r = 7 cm, r_{coil} = 50 mm, dependent on the desired model. For the whole body the nearest value is for r = 5 cm: k = 3,180 (with σ = 0,1 S/m, A_{sensor} = 100 cm^2).

- **Step 4 Calculation of the coupling factor**

In case of measuring according to 5.5.2 and 5.5.3, a 50 Hz equivalent is used and the appropriate assessment has already been done. Therefore the coupling factor $a_c(r)$ for σ = 0,1 evaluates to:

$$a_c(r,\sigma) = k(r, f = 50\ \text{Hz}, \sigma) \cdot 50 \times 10^{-3}\ \frac{\text{T}}{\text{A/m}^2} \qquad \text{(D.1)}$$

This results in a coupling factor: $a_c(r)$ = 0,159 for the whole body.

In case of searching the coupling factor $a_c(r)$ for a $\sigma \neq 0{,}1$ S/m the factor has to be multiplied by $\dfrac{\sigma}{0{,}1\frac{\mathrm{S}}{\mathrm{m}}}$.

Example to determine the coupling factor for σ = 0,3 S/m (for the whole body):

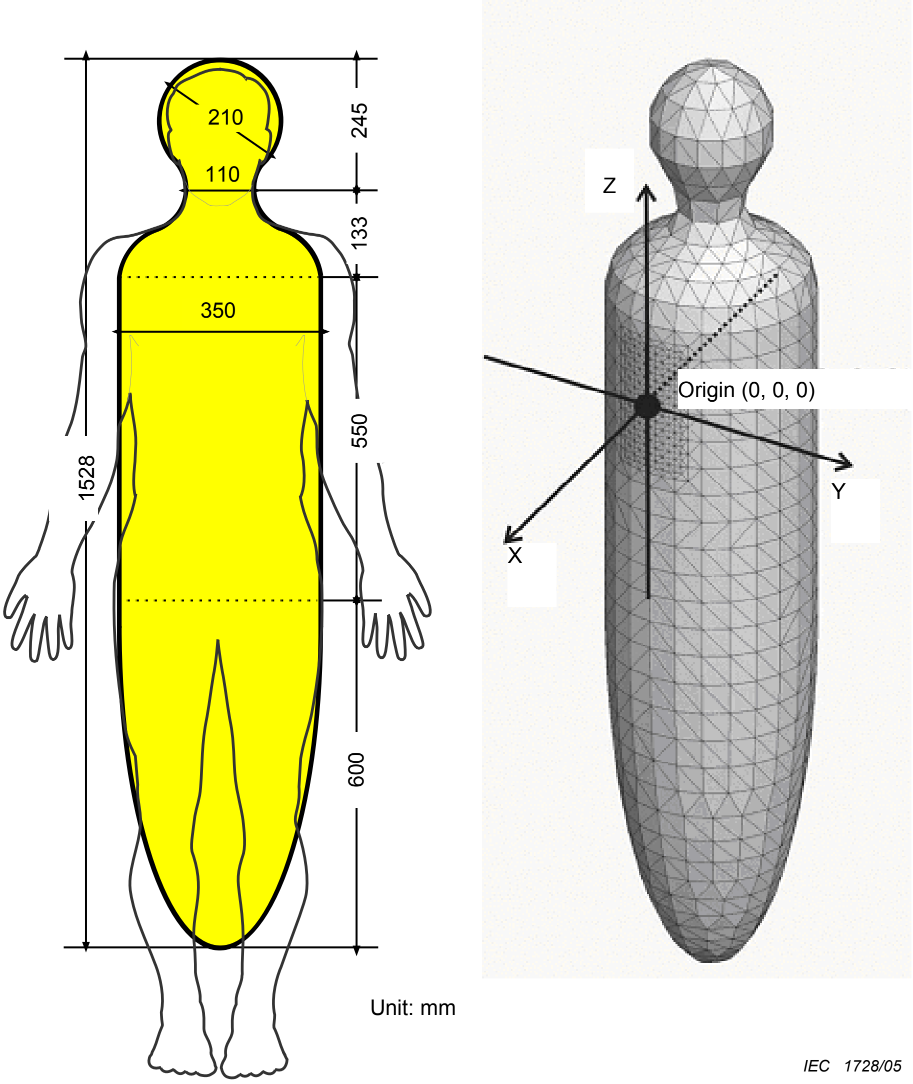
$$a_c(r)_{\sigma = 0{,}3\ \mathrm{S/m}} = 0{,}159 \cdot \frac{0{,}3\frac{\mathrm{S}}{\mathrm{m}}}{0{,}1\frac{\mathrm{S}}{\mathrm{m}}} = 0{,}477$$

D.4 Additional explanation about the determination of the coupling factor

D.4.1 Numerical models for the homogeneous human body

Figure D.3 shows the dimensions of the used numerical models for the homogeneous human body for the calculation of the **coupling factors**. The part at the bottom is half of an ellipse with the lowest turning-point at the shinbone and with the axis 350 mm/1 200 mm. The part in the middle is a cylinder with a diameter of 350 mm and for the head and shoulders the details are shown in Figure D.4.

C〉NOTE Based on the German Standard DIN 33 402, Part 2, 1986.〈C



IEC 1728/05

Figure D.3 – Numerical model of a homogenous human body

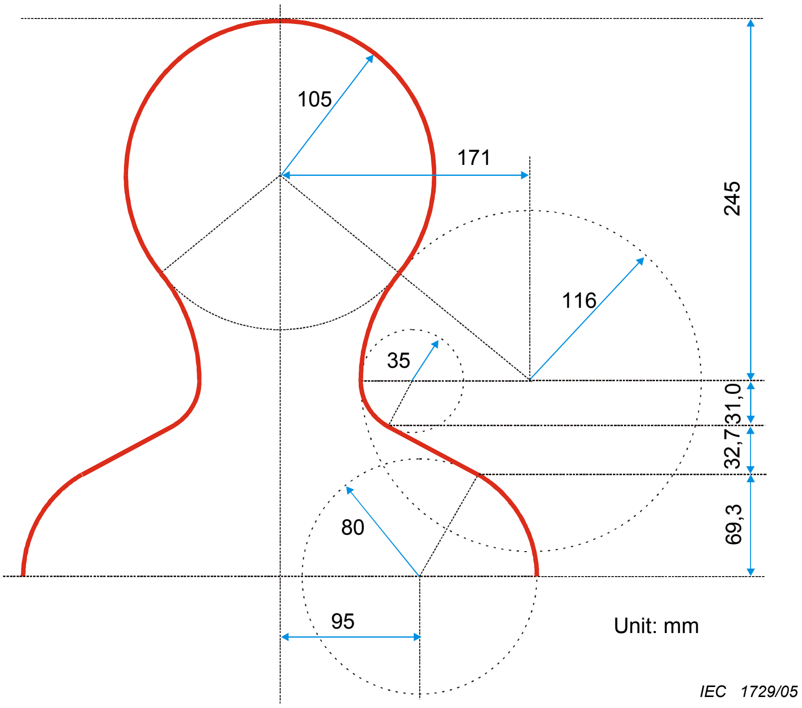


Figure D.4 – Details of the construction of the head and shoulders

D.4.2 Different sources of non-uniform magnetic fields and calculation of the factor *k*

The following list of sources for non-uniform magnetic fields cannot be complete but it gives an overview:

- circular current loops;
- rectangular current loops;
- single line currents;
- circular current coils;
- elementary dipoles.

However, only circular current loops were used as sources to calculate the coupling factors. Therefore, current loops of different diameter were positioned in a worst-case manner towards the numerical models. This is illustrated in Figure D.5.

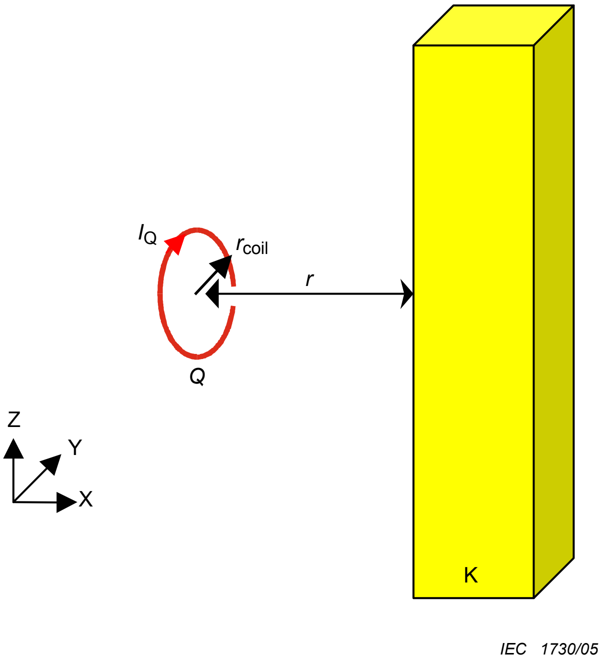


Figure D.5 – Position of source Q against model K

For a numerical calculation, the electric conductivity σ(*f*) of human body tissue must be taken into account for the frequency *f*. Finally, the electric current density *J* inside a human body model can be evaluated by applying Ohm's law:

$$J(r,f,\sigma) = \sigma(f).E_1(r,f) \qquad \text{(D.2)}$$

The factor *k* gives the relation between the maximum induced electric current density $J_{max}(r)$ inside the numerical model and the maximum magnetic flux density measured at the same position of the model. The source current I_Q can be chosen arbitrarily but should be equal for the calculation of J_{max} and $B_{max,sensor}$. The evaluation of the factor *k* depends therefore on the sensor used. For an arbitrary sensor area of A_{sensor} the averaged magnetic flux density through it has to be calculated. The maximum $B_{max,\ sensor}$ has to be taken. Since the frequency *f* and the conductivity *σ* are linearly connected to the factor *k* it can be calculated as follows:

$$k(r,f,\sigma) = \frac{J_{max}(r,f,\sigma)}{B_{max,\,sensor}(r,A_{sensor})} = \frac{\sigma\, E_{i,max}(r,f)}{B_{max,\,sensor}(r,A_{sensor})} \qquad \text{(D.3)}$$

For the conductivity of the homogenous body model in a homogenous field, *σ* = 0,2 S/m may be chosen. However, the strong inhomogeneity of the field distribution near appliances leads to a very modest penetration into the body and makes it possible to use σ = 0,1 S/m as well.

NOTE The conductivity of 0,1 S/m near the surface of the body has been calculated with a mixture of body conductivities.

Detailed values for the conductivity *σ* have been determined [9].

[C〉 *Text deleted* 〈C]

For the determination of the factor *k* in Annex C the method of moments (MoM) [5] as numerical technique was used.

- EXAMPLE 1

For a circular coil with radius r_{Coil} = 20 mm in a distance r = 10 cm and a source current I_{Q} = 100 A the result is for the **body model** (σ = 0,1 S/m and f = 50 Hz) the induced electric current density J_{max} = 14,956 µA/m^2. The averaged magnetic flux density for a 100 cm^2 sensor is calculated to $B_{\text{max,sensor = 100cm2}}$ = 5,46835 µT. The factor *k* therefore calculates to

$$k(r=10\,\text{cm}, f=50\ \text{Hz}, \sigma=0{,}1\frac{\text{S}}{\text{m}}) = \frac{14{,}956\ \frac{\mu\text{A}}{\text{m}^2}}{5{,}4683\ \mu\text{T}} = 2{,}735\,\frac{\text{A/m}^2}{\text{T}} \qquad \text{(D.5)}$$

(see Table C.2; the factor *k* for r = 10 cm and r_{coil} = 20 mm).

[C〉 *Text deleted* 〈C]

D.4.3 Calculation of the induced electric current density

Any numerical method and any field calculation software package that is suitable for the models and procedures described in sections D.2.1 and D.2.2 may be used. Generally applied methods are:

- BEM (boundary element method);
- FDFD (finite difference frequency domain);
- FDTD (finite difference time domain);
- FEM (finite element method);
- FIT (finite integration technique);
- MoM (method of moments);
- SPFD (scalar potential finite difference);
- IP (impedance method).

If using RF software codes, the application of a frequency scaling method [4] is possible: For any magnetic source, the calculation can be carried out at a higher frequency *f'* (≤0,5 MHz to guarantee the quasi-stationary character of the field). For this calculation, the electric conductivity $\sigma(f)$ of tissue must be taken into account for the frequency *f* (not *f'*). This calculation yields the electric field strength *E'* at the frequency *f'*. Now, by scaling the electric field strength due to

$$\vec{E}(\vec{r}) = f/f' \cdot \vec{\text{E}}'(\vec{r}) \qquad \text{(D.8)}$$

the values for the frequency of interest (*f*) can be determined. Finally, the electric current density can be evaluated by applying Ohm’s law:

$$J(\vec{r}) = \sigma(f) \cdot E(\vec{r}) \qquad \text{(D.9)}$$

Bibliography

[1] RUOSS, H-O., SPREITZER, W., NISHIZAWA, S., MESSY, S. and KLAR, M. Efficient determination of current densities induced in the human body from measured low-frequency inhomogeneous magnetic fields. *Microwave and Optical Technology Letters*, May 20, 2001, vol. 29, no. 4, pp. 211-213.

[2] NISHIZAWA, S., SPREITZER, W., RUOSS, H-O., LANDSTORFER, F. and HASHIMOTO, O. Equivalent source model for electrical appliances emitting low frequency magnetic fields. *Proceeding of 31th European Microwave Conference 2001*, September 2001,Vol.3, pp.117-120.

[3] KAMPET, U. and HILLER, W. Measurement of magnetic flux densities in the space around household appliances. In: *Proceedings of NIR 99*, Nichtionisierende Strahlung, 31. Jahrestagung des Fachverbandes für Strahlenschutz, Köln, 1999, vol. II, pp. 885-891.

[4] FURSE, CM and GANDHI, OP. Calculation of electric fields and currents induced in a millimeter-resolution human model at 60Hz using the FDTD method. *Bioelectromagnetics*, 1998, vol. 19, pp. 293-299.

[5] JAKOBUS, U. *Erweiterte Momentenmethode zur Behandlung kompliziert aufgebauter und elektrisch grosser elektromagnetischer Streuprobleme*. Fortschrittsberichte VDI, Reihe 21, Nr.171, 1995, VDI Verlag, Duesseldorf.

[6] Programm EMPIRE, http://www.imst.de/

[7] SHEWCHUCK, JR. *An introduction to the conjugate gradient method without the agonizing pain*. School of Computer Science, Carnegie Mellon University, Pittsburgh, 1994

[8] RUOß, H-O. and KAMPET, U. Numerical calculation of current densities induced in the human body caused by low frequency inhomogeneous magnetic sources. *Kleinheubacher Berichte 2001*, Band 144, pp. 155-162.

[9] Italian National Research Council; Institute for Applied Physics: *Calculation of the Dielectric Properties of Body Tissues in the frequency range 10 Hz - 100 GHz.* Florence (Italy), 1997-2002; http://sparc10.iroe.fi.cnr.it/tissprop/htmlclie/htmlclie.htm#atsftag

[10] FEKO: EM Software & System, www.feko.co.za

[11] ICNIRP. Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz). *Health Phys.*, 1998, vol. 41, no. 4, pp. 449-522

[12] IEEE C95.6:2002, *IEEE Standard for Safety Levels With Respect to Human Exposure to Electromagnetic Fields, 0 - 3 kHz*

[13] BIPM, IEC, IFCC, ISO, IUPAC, IUPAP and OIML:1995, *Guide to the Expression of Uncertainty in Measurement*, ISBN 92-67-10188-9.

[14] NIS 81, *The Treatment of Uncertainty in EMC Measurements.* United Kingdom Accreditation Service, Teddington, Middlesex, UK, Ed. 1, 1994

[15] 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*

[16] ORCUTT, Neil and GANDHI, OM P. A 3-D Impedance Method to Calculate Power Deposition in Biological Bodies Subjected to Time Varying Magnetic Fields. *IEEE Transactions on Biomedical Engineering*, August 1988, Vol. 35, No. 8.

[17] GANDHI, OM P., DEFORD, John F. and KANAI, Hiroshi. Impedance Method for Calculation of Power Deposition Patterns in Magnetically induced Hyperthermia. *IEEE Transactions on Biomedical Engineering*, October 1984, Vol. BME 31, No. 10.

[18] DAWSON, T. W., CAPUTA, K. and STUCHLY, M. A. Numerical evaluation of 60 Hz magnetic induction in the human body in complex occupational environments. *Physics in Medicine & Biology*, April 1999, Vol. 44 (4), pp. 1025-1040.

[19] NISHIZAWA, Shinichiro, LANDSTORFER, Friedrich (University of Stuttgart, Germany) and HASHIMOTO, Osamu (Aoyama Gakuin University, Japan). *Study of the magnetic field properties around household appliances using magnetic source models as prescribed by the CENELEC standard EN50366.* Submitted in IEIEC Tokyo Japan**.**

[20] NISHIZAWA, S., RUOSS, H–O., LANDSTORFER, F. and HASHIMOTO, O. Numerical study on an equivalent source model for inhomogeneous magnetic field dosimetry in the low-frequency range. *IEEE Transaction on Biomedical Engineering*, Vol. 51, No. 4, April 2004.

[21] NISHIZAWA, Shinichiro, LANDSTORFER, Friedrich, and HASHIMOTO, Osamu Dosimetric study of induction heater using the coil source model prescribed by the EN50366. *Proceeding of 3rd International Workshop on Biological Effects of Electromagnetic Fields*, Volume 2, (October 2004), pp.894-903.

[22] IEEE C95.1:1999, *IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz*

[23] CEI 62226-1, *Exposition aux champs électriques ou magnétiques à basse et moyenne fréquence – Méthodes de calcul des densités de courant induit et des champs électriques induits dans le corps humain – Partie 1 : Généralités*

[24] CEI 62226-2-1, *Exposition aux champs électriques ou magnétiques à basse et moyenne fréquence – Méthodes de calcul des densités de courant induit et des champs électriques induits dans le corps humain – Partie 2-1: Exposition à des champs magnétiques – Modèles 2D*

[16] ORCUTT, Neil and GANDHI, OM P. A 3-D Impedance Method to Calculate Power Deposition in Biological Bodies Subjected to Time Varying Magnetic Fields. *IEEE Transactions on Biomedical Engineering*, August 1988, Vol. 35, No. 8.

[17] GANDHI, OM P., DEFORD, John F. and KANAI, Hiroshi. Impedance Method for Calculation of Power Deposition Patterns in Magnetically induced Hyperthermia. *IEEE Transactions on Biomedical Engineering*, October 1984, Vol. BME 31, No. 10.

[18] DAWSON, T. W., CAPUTA, K. and STUCHLY, M. A. Numerical evaluation of 60 Hz magnetic induction in the human body in complex occupational environments. *Physics in Medicine & Biology*, April 1999, Vol. 44 (4), pp. 1025-1040.

[19] NISHIZAWA, Shinichiro, LANDSTORFER, Friedrich (University of Stuttgart, Germany) and HASHIMOTO, Osamu (Aoyama Gakuin University, Japan). *Study of the magnetic field properties around household appliances using magnetic source models as prescribed by the CENELEC standard EN50366.* Submitted in IEIEC Tokyo Japan**.**

[20] NISHIZAWA, S., RUOSS, H–O., LANDSTORFER, F. and HASHIMOTO, O. Numerical study on an equivalent source model for inhomogeneous magnetic field dosimetry in the low-frequency range. *IEEE Transaction on Biomedical Engineering*, Vol. 51, No. 4, April 2004.

[21] NISHIZAWA, Shinichiro, LANDSTORFER, Friedrich, and HASHIMOTO, Osamu Dosimetric study of induction heater using the coil source model prescribed by the EN50366. *Proceeding of 3rd International Workshop on Biological Effects of Electromagnetic Fields*, Volume 2, (October 2004), pp.894-903.

[22] IEEE C95.1:1999, *IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz*

[23] IEC 62226-1, *Exposure to electric and magnetic fields in the low and intermediate frequency range – Methods for calculating the current density and internal electric field induced in the human body – Part 1: General*

[24] IEC 62226-2-1, *Exposure to electric and magnetic fields in the low and intermediate frequency range – Methods for calculating the current density and internal electric field induced in the human body – Part 2-1: Exposure to magnetic fields – 2D models*

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

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

Publication	Year	Title	EN/HD	Year
IEC 60335 (mod)	Series	Household and similar electrical appliances – Safety	EN 60335	Series
IEC 61786	– [1]	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 (mod)	– [1]	Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz – 300 GHz)	EN 62311	2008 [2]
CISPR 14-1	– [1]	Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus – Part 1: Emission	EN 55014-1	2006 [2]

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[1] Undated reference.

[2] Valid edition at date of issue.

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