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English version

Household and similar electrical appliances – Electromagnetic fields – Methods for evaluation and measurement

Appareils électrodomestiques et analogues – Champs électromagnétiques – Méthodes d'évaluation et de mesure

Elektrische Geräte für den Hausgebrauch und ähnliche Zwecke – Elektromagnetische Felder – Verfahren zur Bewertung und Messung

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CENELEC

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

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Foreword

A proposal for a standard dealing with the evaluation and measurement of electromagnetic fields around household and similar electrical appliances was prepared by a joint group of experts representing TC 61, Safety of household and similar electrical appliances, and TC 106X, Electromagnetic fields in the human environment. Document CLC/TC 61(Sec)1292, was circulated under the enquiry procedure in October 2000. The results of the enquiry were discussed during the Delft meeting in May 2001, when it was decided to prepare a new draft. This new draft, document CLCL/TC 61(Sec)1335, was discussed during the Paris meeting in November 2001, when it was decided to submit a new draft to the Unique Acceptance Procedure.

This draft was circulated in April 2002 and was approved by CENELEC as EN 50366 on 2003-02-01.

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)	2004-02-01
- date on which national standards conflicting with the EN have to be withdrawn	(dow)	2006-02-01

This European Standard has been prepared under mandate M/305 given to CENELEC by the European Commission and the European Free Trade Association and supports the principal objectives of the Low Voltage Directive 73/23/EEC.

Annexes A and C are normative and annexes B, D, E and F are informative.

NOTE Words in **bold** in the text are defined in Clause 3. When a definition concerns an adjective, the adjective and the associated noun are also in bold.

Contents

INTRODUCTION

This standard establishes a suitable evaluation method for determining the electromagnetic fields in the space around household and similar electrical appliances and defines standardized operating conditions and **measuring distances**. It provides a method to show compliance with the European Council Recommendation 1999/519/EC concerning human exposure to electromagnetic fields.

NOTE 1 The fact that magnetic fields in the surrounding space of a household appliance are non-homogeneous has to be taken into account. For household appliances, magnetic flux densities are at their highest on the appliance surfaces and decrease with increasing distance r from the appliance surface by at least $1/r$.

For evaluating the risk of magnetic flux densities the $1/r$ reduction in magnitude represents a worst-case assumption. The magnetic flux density is obtained by:

$$B(r) = \frac{c}{r + r_0}$$

where

$B(r)$	is the magnetic flux density,
c	is a constant,
r	is the distance from the appliance surface,
r_0	is the distance between the field source and the appliance surface.

NOTE 2 The reference levels of the recommendation are derived for homogeneous fields and for whole-body exposure to larger field sources, such as high voltage transmission lines. The magnetic fields surrounding household appliances are restricted to small parts of the body, e.g. hands and limbs.

It has been assumed in the drafting of this European Standard that the execution of its provisions is entrusted to appropriately qualified and experienced persons.

1 Scope

This European Standard deals with electromagnetic fields and defines methods for evaluating the electric field and the magnetic field for frequencies up to 300 GHz around household and similar electrical appliances.

The methods also apply to appliances not intended for normal household use, but which nevertheless may be accessible to the general public, such as appliances intended to be used by laymen in shops, in light industry and on farms.

NOTE The methods are not suitable for comparing the fields from different appliances.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 60335 series, Household and similar electrical appliances - Safety

3 Definitions

For the purpose of this standard the following definitions apply.

3.1
basic restriction
restriction, based on established health effects, of exposure to time-varying electric fields and magnetic fields

3.2
reference level
r.m.s. value of the magnetic field strength of homogeneous fields, derived from the **basic restriction**, to which a person may be exposed without adverse effects

3.3
measuring distance
distance between the surface of the appliance and the closest point of the sensor surface

3.4
operator distance
distance between the surface of the appliance and the closest point of the head or torso of the operator

3.5
hot spot
localized area of high magnetic field due to irregularities of the field distribution

3.6
coupling factor
factor taking into account the irregularities of the magnetic fields around appliances and the dimensions of a part of the human body

4 Measuring methods

4.1 Electric fields

In general, there is no need to evaluate electric fields around household appliances. For most appliances, the electric field strength can be deemed to comply with the **reference levels** without testing. If electric fields are found to be relevant, a test method will be established.

4.2 Magnetic fields

4.2.1 Frequency range

The frequency range considered is from 10 Hz to 400 kHz .

NOTE 1 The methods of measurement for frequencies from 0 Hz up to 10 Hz are under consideration.

The frequency range evaluated shall cover all frequencies of magnetic fields produced by an appliance, including a sufficient number of harmonics. If this is not feasible in one measurement, the weighted results of each measured frequency range shall be added.

In the frequency range above 400 kHz, appliances are deemed to comply without testing.

NOTE 2 The operating frequency of microwave ovens is covered by EN 60335-2-25 or EN 60335-2-90.

4.2.2 Measuring distances, sensor locations and operating conditions

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

4.2.3 Magnetic field sensor

Measurement values of magnetic flux density are averaged over an area of 100 cm² in each direction. The reference sensor consists 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 is not to 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 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.

4.2.4 Measuring procedures for magnetic fields

Appliances have at least one independent magnetic field source, each of which generates a fundamental frequency and possibly harmonics.

The magnetic flux density is measured using the procedure in 4.2.4.1. For appliances producing only line spectra, the procedure described in 4.2.4.2 may be applied instead. The simplified procedure in 4.2.4.3 may be used for appliances producing magnetic fields at mains frequency and its harmonics only.

The magnetic flux density is measured using a suitable instrument. In case of doubt, the reference sensor specified in 4.2.3 is used.

Transient magnetic fields with a duration of less then 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 2 s.

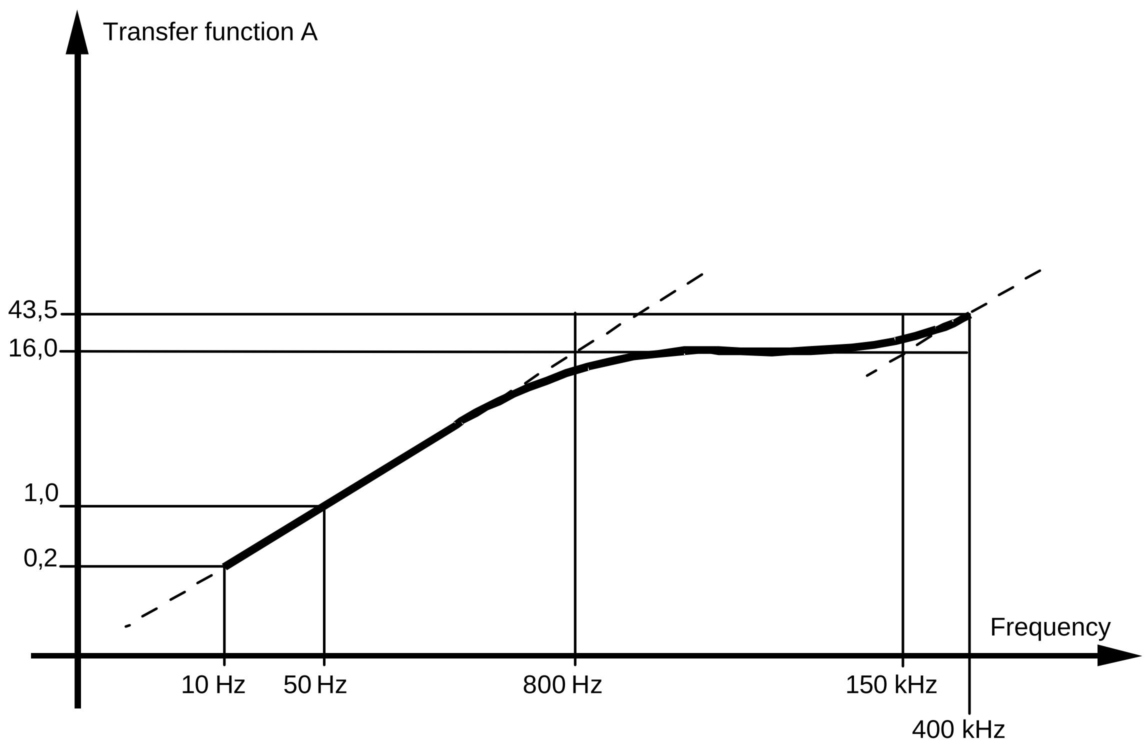
The magnetic flux density is determined by using an averaging time of 1 s.

4.2.4.1 Time domain evaluation

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

Independent of the type of signal, a time domain measurement of the value of the magnetic flux density can be carried out. For fields having several frequencies, the frequency characteristic of the transfer function takes into account the frequency dependency of the **reference levels**.

The transfer function is to be established using a first order filter and shall have the characteristics shown in Figure 1.



NOTE Logarithmic scales are used for both axes.

Figure 1 - Transfer function

The following sequence is used for the measurements:

– separate measurement of each coil signal;
– weighting of the signal by the transfer function;
– squaring the signals;
– adding the squared signals;
– averaging the sum of the squared signals;
– obtaining the square root of the average.

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

This procedure is shown schematically in Figure 2.

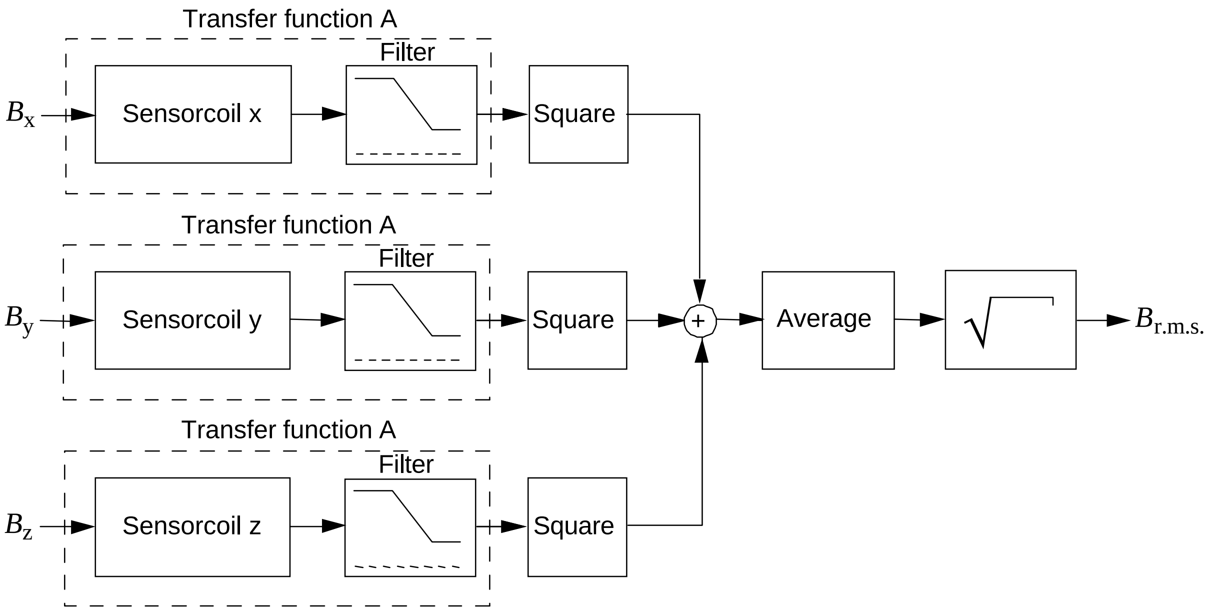


Figure 2 - Schematic diagram of the reference method

The measured value shall not exceed the **reference level** of the magnetic flux density at 50 Hz. However, if this level is exceeded, the value is recalculated taking into account the **coupling factor** $a_c(r_1)$ given in Annex A.

The weighted result is obtained from the following formula:

$$W = \frac{a_c(r_1)B_{r.m.s.}}{B_{RL}}$$

where

W is the weighted result;

$B_{r.m.s.}$ is the r.m.s. value of the magnetic flux density;

B_{RL} is the **reference level** of the magnetic flux density at 50 Hz;

$a_c(r_1)$ is the **coupling factor**.

The value W shall not exceed 1.

4.2.4.2 Line spectrum evaluation

This method may be used when there are only line spectra, for example magnetic fields having a fundamental frequency of 50 Hz and some harmonics.

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:

– separate measurement of each coil signal;
– Fourier transformation for each coil signal to obtain the estimated spectrum;
– vector addition of all three spectra for each discrete frequency.

NOTE If the frequency steps of the Fourier transformation are comparatively large, e.g. in the order of 10 %, an additional calculation of the discrete spectral lines may be necessary.

The magnetic flux density, B_f, is given by:

$$B_f = \sqrt{B_{xf}^2 + B_{yf}^2 + B_{zf}^2}$$

where

B_f is the magnetic flux density at frequency f;

B_{xf}, B_{yf} and B_{zf} are the individual flux densities of the three coils at any one frequency.

The weighted result is obtained from the sum of the frequency components using the following formula:

$$W = \sqrt{\sum_{1}^{n} \left(\frac{B_f}{B_{RLf}} \right)^2}$$

where

W is the weighted result;

B_{RLf} is the **reference level** of the magnetic flux density at frequency f obtained from Annex B;

n is the number of relevant frequencies (harmonics).

The value W shall not exceed 1. However, if this value is exceeded, the weighted result is multiplied by the relevant **coupling factor** $a_c(r_1)$ given in Annex A. The result shall not exceed 1.

4.2.4.3 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.

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.

4.3 Measurement uncertainty

4.3.1 Inaccuracies of measurement can give rise to errors in the calculated values of magnetic flux density and the weighted result. The total error on the final result shall not exceed 25 %.

NOTE 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.

4.3.2 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 1 This applies 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 2 This applies for measurements carried out by authorities for market surveillance purposes.

5 Test report

The test report shall include at least the following items:

– identification of the appliance;

– rated voltage of the appliance;

– the measuring method;

– **measuring distance,** sensor locations and operating conditions, unless specified in Annex A;

– the maximum magnetic flux density, weighted with the **coupling factor**, if applicable.

6 Compliance criteria

Appliances are deemed to comply with the **basic restriction** if the **reference levels** are not exceeded (see Annex B).

If a value exceeds the **reference level**, the **coupling factor** can be taken into account to show compliance with the **basic restriction**. The **coupling factor** has been determined to cover the worst case for the same type of appliances.

If necessary, the **coupling factor** can be recalculated in accordance with Annex C. This procedure has to be used for appliances not listed in Table A.1. An example for the determination of the **coupling factor** is given in Annex D.

If the value still exceeds the **reference level**, this does not necessarily mean that the **basic restriction** is exceeded. Calculation methods can be used to verify whether the **basic restriction** is fulfilled (see Annex F, under consideration).

Annex A
(normative)

Test conditions for the measurement of magnetic flux density

A.1 General

A.1.1 The measurements are carried out under the conditions specified in Table A.1, the appliance being positioned as in normal use. If the appliance is not listed in Table A.1, the measurement is made with the appliance operating as specified for normal operation in the EN 60335 series, the magnetic flux density being measured at **operator distance** around the appliance.

A.1.2 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.

A.1.3 The appliance is supplied at rated voltage and rated frequency, and operated as in normal use. If the rating includes 50 Hz, it is tested at 50 Hz.

Appliances having more than one rated voltage are tested at the highest rated voltage, unless the voltage range includes 230 V, in which case it is tested at 230 V. For multiphase appliances, the appliance is tested at 400 V.

A.1.4 Controls are adjusted to the highest setting, unless otherwise specified in Table A.1. However, pre-set controls are used in the intended position. The measurements are made while the appliance is energized.

A.1.5 Tests are carried out at an ambient temperature of 20 °C ± 5 °C.

A.2 Operating conditions for specific appliances

A.2.1 Appliances with accessories

Appliances having accessories are tested with the accessory that results in the highest load.

A.2.2 Battery operated appliances

Appliances supplied by battery are tested with the battery fully charged.

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

Type of appliance	Measuring distance r_1 cm	Sensor locations[a]	Operating conditions	Coupling factor a_c
Appliances not mentioned in the table	**Operator distance**	All surfaces	As specified in the relevant part of EN 60335	See Annex C
Air cleaners	50	All surfaces	Continuously	0,17
Air conditioners	50	Around	Continuously, lowest temperature setting	0,18
Battery chargers	50	All surfaces	Connected to a discharged battery having the highest capacity specified by the manufacturer	0,17
Blankets	0	Top	Spread out and laid on a sheet of thermal insulation	0,12
Blenders	50	Around	Continuously, no load	0,17
Citrus presses	50	Around	Continuously, no load	0,17
Clocks	50	Around	Continuously	0,17
Coffee makers	50	Around	As specified in 3.1.9 of EN 60335-2-15	0,17
Coffee mills	50	All surfaces	As specified in 3.1.9.108 of EN 60335-2-14	0,17
Convector heaters	50	Around	With highest output	0,17
Deep fat fryers	50	Around	As specified in 3.1.9 of EN 60335-2-13	0,17
Dental hygiene appliances	0	All surfaces	As specified in 3.1.9 of EN 60335-2-52	0,12
Depilators	0	Against cutter	Continuously, no load	0,12
Dishwashers	30	Top, front	Without dishes in the washing mode and drying mode	0,18
Egg boilers	50	Around	As specified in 3.1.9 of EN 60335-2-15	0,17
Facial sauna appliances	10	Top	Continuously	0,12
Fans	50	Front	Continuously	0,17
Fan heaters	50	Front	Continuously, highest heat setting	0,17
Floor polishers	50	All surfaces	Continuously without any mechanical load on the polishing brushes	0,18
Food processors	50	Around	Continuously without load, highest speed setting	0,17
Food warming cabinets	50	Front	Continuously without load, highest heat setting	0,17
Foot warmers	50	Top	Continuously without load, highest heat setting	0,17

Type of appliance	Measuring distance r_1 cm	Sensor locations[a]	Operating conditions	Coupling factor a_c
Gas ignitors	50	All surfaces	Continuously	0,17
Grills	50	Around	Continuously without load, highest heat setting	0,18
Hair clippers	0	Against cutter	Continuously without load	0,12
Hairdryers	10	All surfaces	Continuously, highest heat setting	0,12
Hand-guided tools	30	Around, unless the same side is always towards the user	No-load, highest speed setting	0,16
Hand-held tools	30	Around, unless the same side is always towards the user	No-load, highest speed setting. Tools not designed for continuous operation (e.g. power staplers): operating with the setting which has the greatest effect.	0,14
Heat pumps	50	Around	Continuously, highest temperature setting	0,18
Heating mats	50	Top	Spread out and laid on a sheet of thermal insulation	0,17
Heating pads	0	Top	Spread out and laid on a sheet of thermal insulation	0,12
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	0,18
Icecream makers	50	Around	Continuously without load, lowest temperature setting	0,17
Immersion heaters	50	Around	Heating element fully submerged	0,17
Induction hobs and hotplates			See A.4.	
Irons	50	All surfaces	As specified in 3.1.9 of EN 60335-2-3	0,17
Ironing machines	50	All surfaces	As specified in 3.1.9 of EN 60335-2-44	0,18
Juice extractors	50	Around	Continuously without load	0,17
Kettles	50	Around	Half-filled with water	0,17
Kitchen scales	50	Around	Continuously without load	0,17
Knives	50	All surfaces	Continuously without load	0,17
Massage appliances	0	Against the massage head	Continuously without load, highest speed se tting	0,12

Type of appliance	Measuring distance r_1 cm	Sensor locations[a]	Operating conditions	Coupling factor a_c
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.	0,16
Mixers	50	All surfaces	Continuously without load, highest speed setting	0,17
Oil filled radiators	50	Around	Continuously, highest heat setting	0,18
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.	0,18
Ranges	30	Top, front	Each function separately	0,18
Range hoods	30	Bottom, front	Controls at highest setting	0,18
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	50	Around	Half-filled with water, without lid and highest heat setting	0,17
Shavers	0	Against cutter	Continuously without load	0,12
Slicing machines	50	All surfaces	Continuously without load, highest speed setting	0,18
Solaria - parts touching the body - other parts	 0 30	 Around Around	 Continuously, highest settings Continuously, highest settings	 0,12 0,17
Spin extractors	30	Top, front	Continuously without load	0,16
Storage heaters	50	Around	Continuously, highest heat setting	0,18
Tea makers	50	Around	Continuously, no load	0,17
Toasters	50	Around	Without load, highest heat setting	0,17
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	0,14

Type of appliance	Measuring distance r_1 cm	Sensor locations[a]	Operating conditions	Coupling factor a_c
Transportable tools	30	Top and side towards the user	No-load, highest speed setting	0,16
Tumble dryers	30	Top, front	In the drying mode with textile material in form of pre-washed, double-hemmed cotton sheets having dimensions of approximately 0,7 m x 0,7 m and a mass between 140 g/m² and 175 g/m² in dry condition	0,18
Vacuum cleaners, handheld	50	All surfaces	As specified in 3.1.9 of EN 60335-2-2	0,18
Vacuum cleaners, body sling	0	All surfaces	As specified in 3.1.9 of EN 60335-2-2	0,12
Vacuum cleaners, others	50	Around	As specified in 3.1.9 of EN 60335-2-2	0,18
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	0,12
Water heaters	50	Around	Controls at highest setting, with water flowing, if necessary	0,17
Whirlpool baths - inside - outside	 0 30	 Around Around	 Continuously Continuously	 0,12 0,17

[a] The sensor is moved at the specified distance from the outside of the appliance. It is moved over an area to cover the surface of the appliance specified. When the sensor location is specified as “around”, the sensor is moved in a plane at a representative height around the appliance.

NOTE The **measuring distances** have been defined to protect against effects on central nervous system tissues in the head and trunk of the body (see Council Recommendation 1999/519/EC, annex II “Basic restrictions”, note 2).

A.3 Test conditions for induction hobs and hotplates

A.3.1 Measuring distances

For each cooking zone, the measurements are made along four vertical lines (A, B, C, D) at a distance of 30 cm from the edges of the appliance (see Figure A.1). 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 if the appliance is intended to be used when placed against a wall.

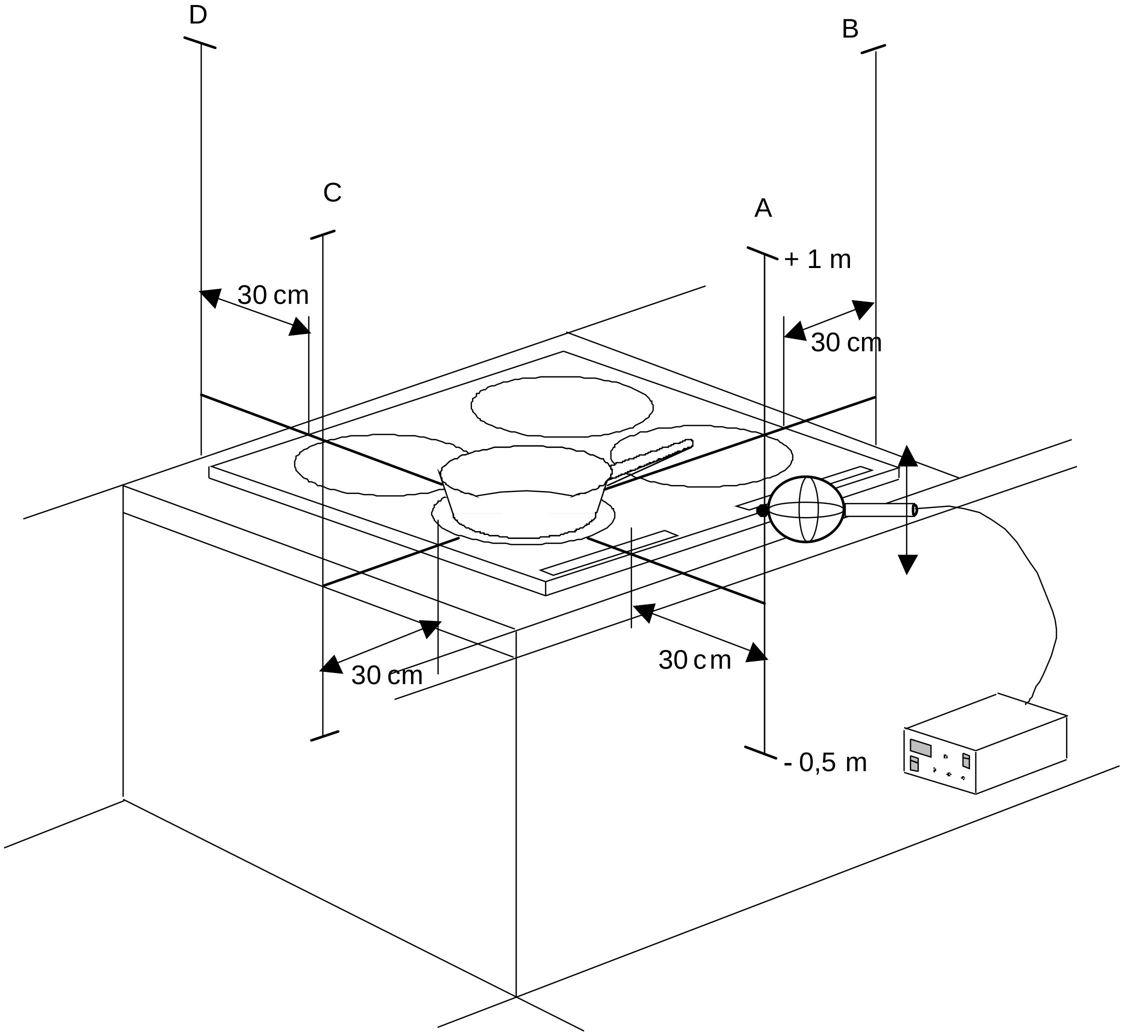
A.3.2 Operating mode

Enamelled steel vessels are filled to 50 % of their capacity with water and placed on each cooking zone in turn.

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 at the highest power input, the other cooking zones not being covered.

The measurements are made when the water boils. If the water does not boil, the measurement is made 1 min after the heating unit has been switched on.



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.1 – Measuring distances for induction hobs and hotplates

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.

Annex C
(normative)

Determination of coupling factors

Introduction

The **reference levels** B_{RL} given in the EU council recommendation (1999/519/EC) are defined for homogeneous fields. The strong inhomogeneity of the magnetic fields around appliances within this standard are considered by factors $a_c(r_1)$ that are listed in Annex A. They take the dimension of the part of body which is in the field into account as well.

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

$$B_{mc}(r_1) = a_c(r_1)\, B_m$$

C.1 Determination of coupling factors by calculation

The determination of the factor $a_c(r_1)$ is achieved in four steps:

Step 1 Evaluation of the extent of the hot spot

The magnetic flux density $B_m(r_0)$ is measured tangentially to the surface along the line of the lowest gradient starting at the **hot spot** $r_0 = 0$ m. The measurement stops at $r_0 = X$ m 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 measurement points is in the range of 5 mm to 10 mm.

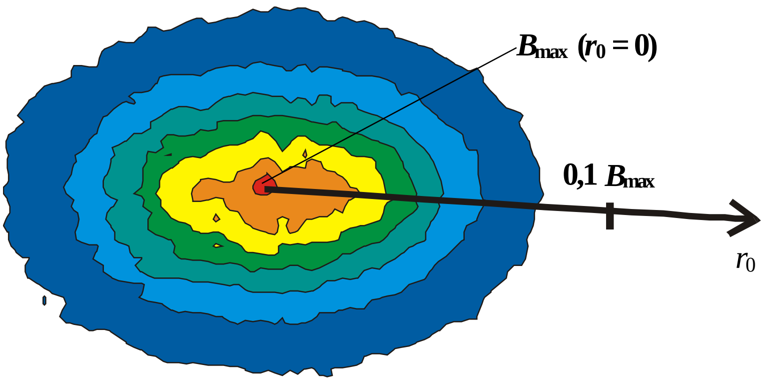


Figure C.1 – Hot spot

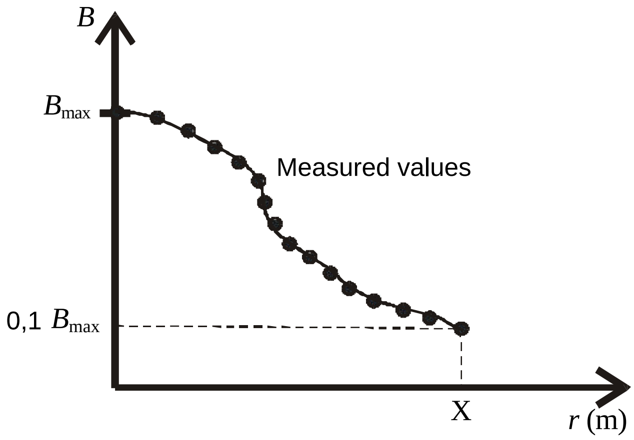


Figure C.2 – Gradient of magnetic flux density

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 field gradient. 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).

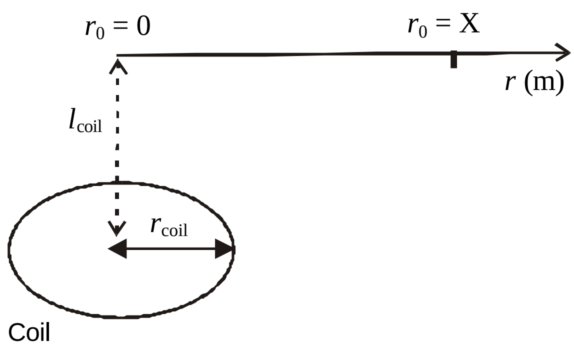


Figure C.3 – Equivalent coil position

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

The value G is calculated from the following formula:

$$G(r_{coil}, l_{coil}) = \int_{r_0=0}^{r_0=\mathrm{X\,m}} \frac{B_m(r_0)}{B_m(r_0 = 0\,\mathrm{m})} dr_0$$

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.

Table C.1 – Values of *G* for different coils

Distance l_{coil} mm	Radius r_{coil} mm						
	5	**10**	**20**	**30**	**50**	**70**	**100**
5	0,006 80						
10	0,009 27	0,013 54					
15	0,012 58	0,015 62					
20	0,016 14	0,018 48	0,027 03				
25	0,019 80	0,021 68	0,028 80				
30	0,023 51	0,025 11	0,031 17	0,040 51			
35	0,027 26	0,028 61	0,033 90	0,042 17			
40	0,031 02	0,032 22	0,036 89	0,044 29			
50	0,038 58	0,039 55	0,043 34	0,049 41	0,067 50		
70	0,053 78	0,054 48	0,057 18	0,061 64	0,075 35	0,094 44	
100	0,076 60	0,077 11	0,079 05	0,082 19	0,092 13	0,106 44	0,134 93
200	0,152 94	0,153 17	0,154 15	0,155 73	0,160 85	0,168 45	0,184 20
300	0,229 30	0,229 53	0,230 12	0,231 19	0,234 61	0,239 71	0,250 54

Step 3 Determination of factor *k*

Factor k represents the relationship between the equivalent coil and the human body and is given by the following formula.

$$k(r, r_{\text{coil}}, f, \bullet) = \frac{f}{50\,\text{Hz}} \cdot \frac{\bullet}{0{,}1\frac{\text{S}}{\text{m}}} \cdot \frac{J_{\text{max}}(r, r_{\text{coil}})}{B_{\text{max, sensor}}(r, r_{\text{coil}}, A_{\text{sensor}})}$$

where

r	is the distance between the equivalent coil and the human body, in mm,
J_{max}	is the human tissue current density, in A/m^2,
A_{sensor}	is the area of the sensor, in cm^2,
$B_{max, sensor}$	is the maximum magnetic field density in the sensor, in T,
σ	is the electric conductivity of the homogeneous model of the human body, in S/m.

NOTE 2 For inhomogeneous fields, the highest field values occur on the surface of the human body. The electric conductivity of the surface of the human body is 0,1 S/m.

The distance r is obtained from the following formula, where r_1 is the **measuring distance** specified in Table A.1, expressed in millimetres.

$$r = r_1 + l_{\text{coil}}$$

The values of factor k at a frequency of 50 Hz are given in Table C.2 for the whole human body. They have been established using the human body and magnetic field models described in Annex E and comparing the measured results with those obtained when using the reference sensor described in 4.2.3

Table C.2 – Values of factor *k* at 50 Hz for the whole human body

Distance *r* mm	**Radius r_{coil}** mm						
	5	**10**	**20**	**30**	**50**	**70**	**100**
100	2,273 21	2,331 38	2,285 02	2,248 22	2,223 67	2,161 36	2,126 68
200	2,264 14	2,335 35	2,287 48	2,263 64	2,280 81	2,283 15	2,350 54
300	2,533 36	2,657 96	2,565 52	2,526 81	2,531 92	2,515 92	2,567 71
400	2,780 04	2,931 19	2,818 14	2,770 68	2,775 99	2,751 17	2,795 75
500	3,011 08	3,173 58	3,057 15	2,997 82	2,990 69	2,948 71	2,991 95
600		3,360 43		3,074 84			
700		3,541 33		3,193 45			
1 000		3,997 64		3,522 02			

Step 4 Calculation of the coupling factor

The **coupling factor** $a_c(r)$ is determined from the following formula:

$$a_c(r) = k \cdot \frac{B_{RL}(f)}{J_{BR}(f)}$$

where

B_{RL} is the **reference level** at frequency f,

J_{BR} is the **basic restriction** at the same frequency.

The relationship between the **reference level** and the **basic restriction** is shown in Table C.3.

Table C.3 – Relationship between the reference level and the basic restriction for various frequencies

Frequency range	$\frac{B_{RL}(f)}{J_{BR}(f)} \left[\frac{T}{A/m^2}\right]$
> 0 Hz – 1 Hz	5
1 Hz – 4 Hz	$5 / f$
4 Hz – 8 Hz	$20 / f^2$
8 Hz – 25 Hz	$2{,}5 / f$
0,025 kHz – 0,8 kHz	$2{,}5 / f$
0,8 kHz - 1 kHz	$3{,}175 \times 10^{-3}$
1 kHz – 100 kHz	$3{,}175 / f$
NOTE The frequency f is in Hz.	

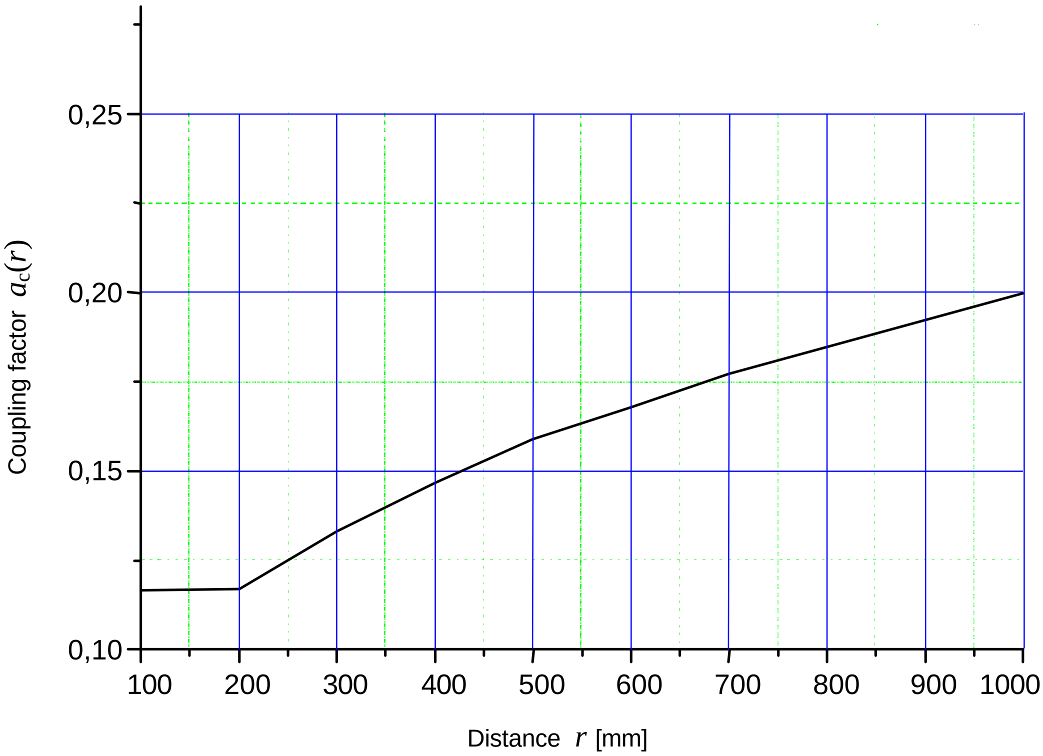
If 50 Hz is used as the basis for the evalution, e.g. using the measurement procedures according to 4.2.4.1 or 4.2.4.2, the **coupling factor** $a_c(r)$ can be calculated from the following formula:

$$a_c(r) = k \cdot 50 \times 10^{-3} \ \frac{T}{A/m^2}$$

C.2 Graphical evaluation of coupling factors

The **coupling factor** can be determined from Figure C.4. This method provides an approximate value for the **coupling factor** assuming that the radius of the equivalent coil (r_{coil}) is 10 mm, which is the worst case.

NOTE This method has been used for the determination of the **coupling factors** in Table A.1



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

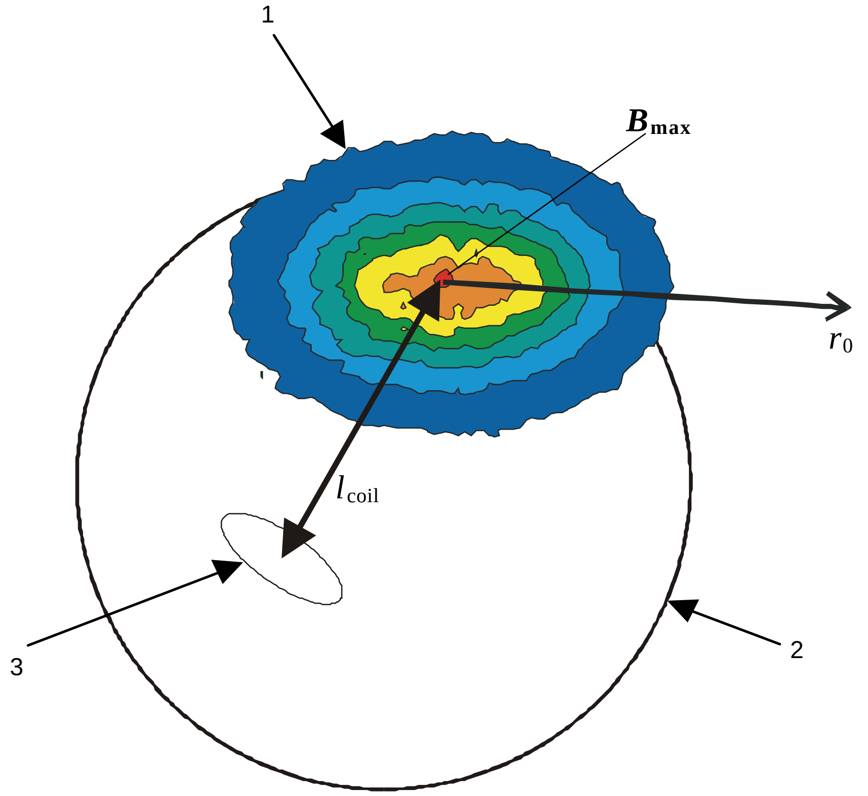
Figure C.4 - Coupling factors for different distances

Annex D
(informative)

An example of calculating the coupling factor

As stated in C.1, the determination of the **coupling factor** $a_c(r)$ is achieved in four steps.

Step 1 Evaluation of the extent of the hot spot



1 Measurement on a tangential plane around the **hot spot**

2 Model of a household appliance as a sphere

3 Coil

Figure D.1 - Measurement of the magnetic flux density

Step 2 Determination of the equivalent coil

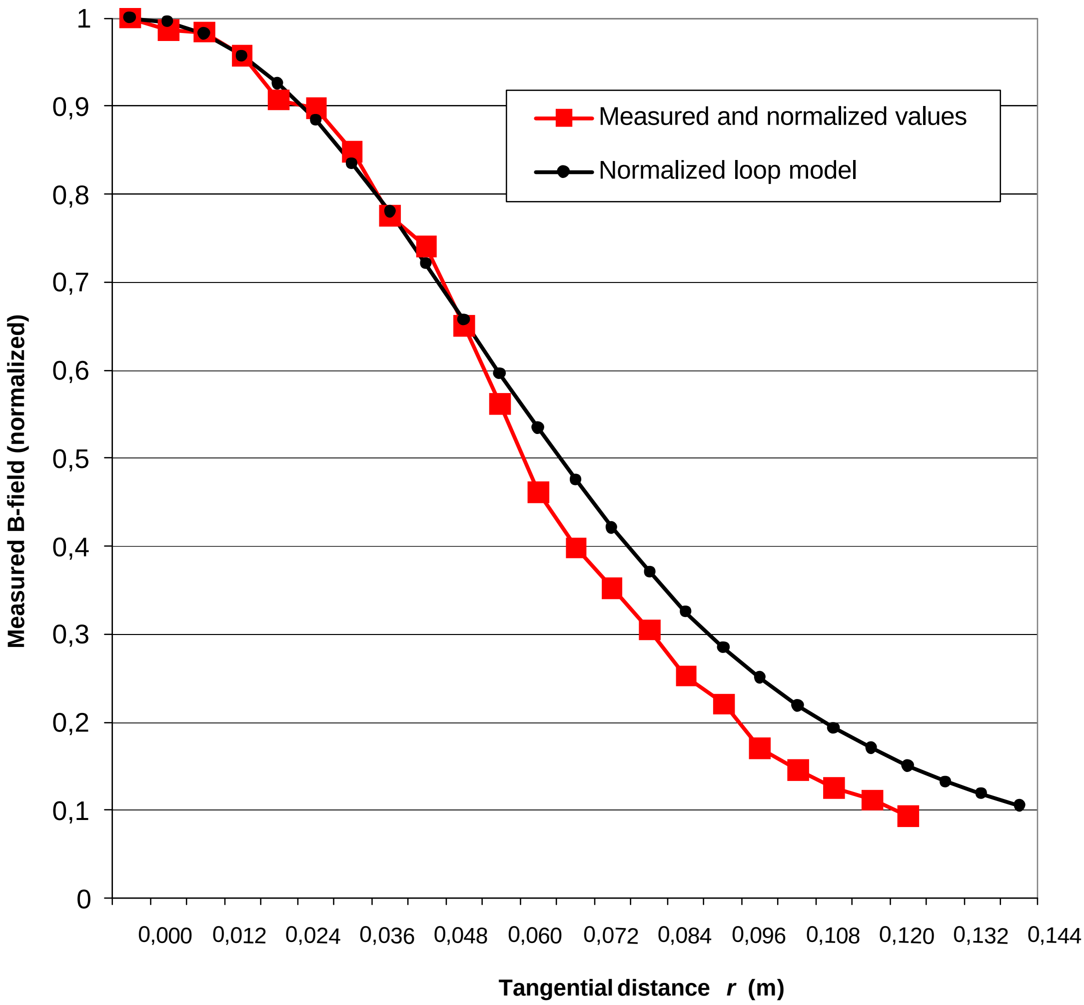


Figure D.2 - Normalized field distribution along the tangential distance *r*

An integration of the normalized measured flux density results in a value G = 0,071 66 (m).

Step 3 Determination of factor *k*

Knowing the value of G, the radius r_{coil} of the equivalent coil can be determined (see Table C.1). In this example l_{coil} is assumed to be 70 mm. From Table C.1, for l_{coil} = 70 mm, the value of G closest to the value determined in step 2 is 0,075 35 m, which gives r_{coil} = 50 mm. This coil is represented by the curve of the normalized loop model in Figure D.2 and is shown to be a good approximation.

The factor k can now be determined for the whole body. From Table C.2, for r =100 mm (the value closest to 70 mm, as determined above) and r_{coil} = 50 mm, factor k = 2,223 67.

Step 4 Calculation of the coupling factor

In this example, the measurement procedure according to 4.2.4.1 was used. The **coupling factor** $a_c(r)$ is

$$a_c(r) = k \cdot 50 \times 10^{-3} \ \frac{\mathrm{T}}{\mathrm{A/m^2}}$$

Therefore $a_c(r)$ = 2,223 67 x 50 x 10^{-3} = 0,111 83

Annex E
(informative)

Representation of the human body and magnetic field

Figure E.1 shows the dimensions of the homogeneous model for the human body that was used to obtain the values in Annex C. The three-dimensional model shows the point of origin for the calculations.

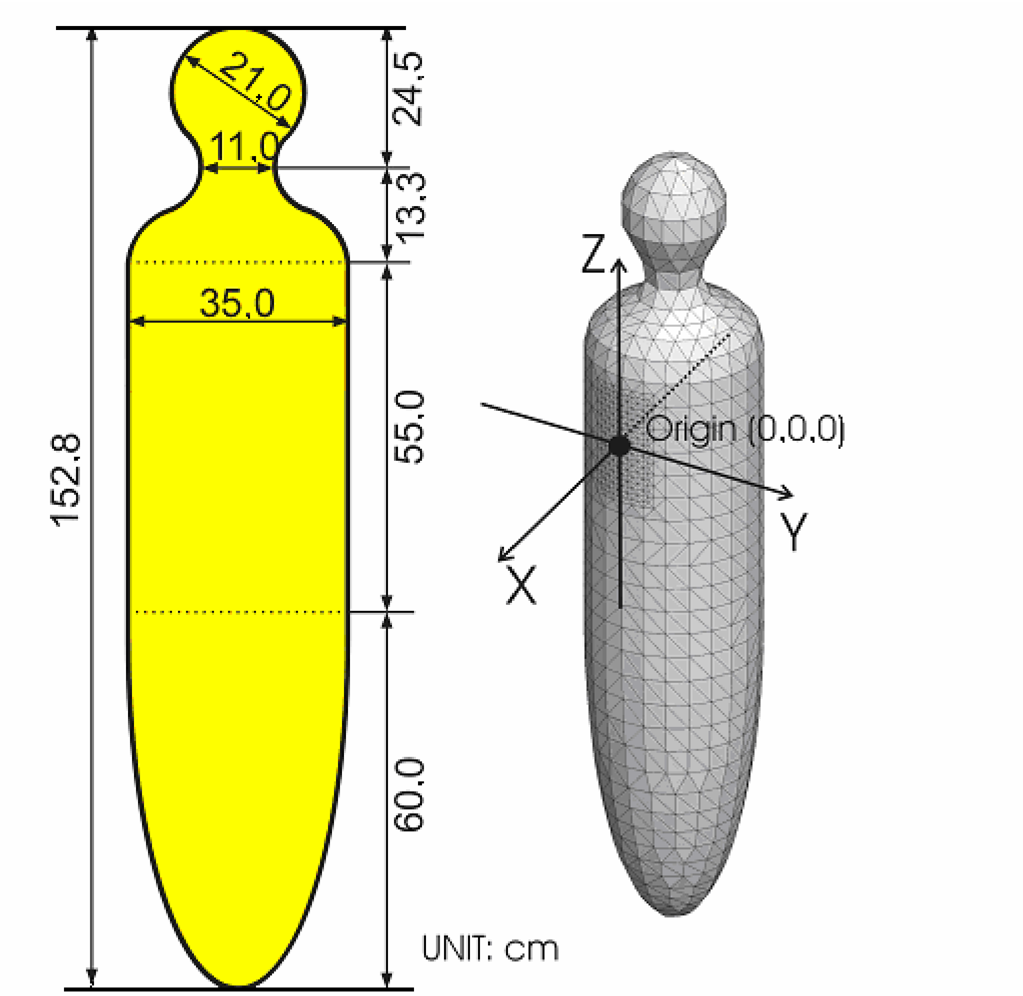


Figure E.1 - Numerical model of the human body

The magnetic field is non uniform and can be represented by a circular current loop, which was used as a basis for the calculations in Annex C.

Current loops having different diameters were positioned at a distance *r* from the numerical model and orientated to provide the worst case. See Figure E.2.

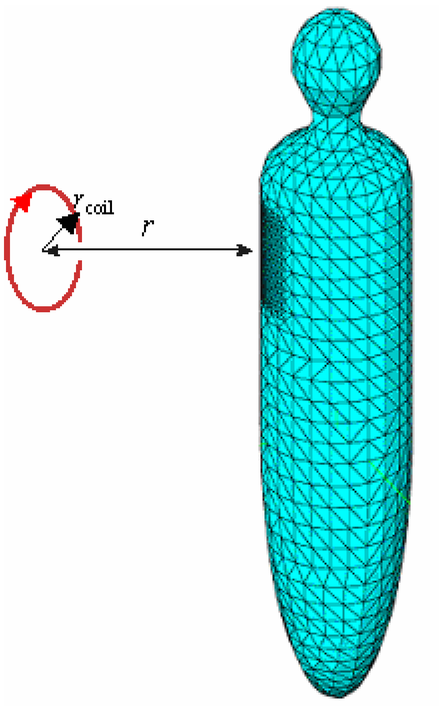


Figure E.2 - Position of magnetic field source in relation to the model

The factor k used in Annex C gives the relationship between the maximum induced electric current density J_{max} inside the numerical model and the maximum magnetic flux density measured at the same position.

NOTE For the determination of the factor k the Method of Moments (MoM) technique was used.

Annex F
(informative)

Calculation method of current densities for comparison with the basic restriction

A full calculation method is under consideration.

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