

INTERNATIONAL STANDARD



BASIC EMC PUBLICATION

**Electromagnetic compatibility (EMC) –
Part 4-9: Testing and measurement techniques – **Pulse** **Impulse** magnetic field
immunity test**



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BASIC EMC PUBLICATION

**Electromagnetic compatibility (EMC) –
Part 4-9: Testing and measurement techniques – Pulse Impulse magnetic field
immunity test**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –**Part 4-9: Testing and measurement techniques –
Impulse magnetic field immunity test**

FOREWORD

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International Standard IEC 61000-4-9 has been prepared by subcommittee 77B: High frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

It forms Part 4-9 of the IEC 61000 series. It has the status of a basic EMC publication in accordance with IEC Guide 107.

This second edition cancels and replaces the first edition published in 1993 and Amendment 1:2000. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) new Annex B on induction coil field distribution;
- b) new Annex D on measurement uncertainty;
- c) new Annex E on mathematical modeling of surge waveform;
- d) new Annex F on characteristics using two standard induction coils;
- e) new Annex G on 3D numerical simulations;
- f) coil factor calculation and calibration using current measurement have been addressed in this edition.

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

CDV	Report on voting
77B/728/CDV	77B/745A/RVC

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

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

A list of all parts in the IEC 61000 series, published under the general title *Electromagnetic compatibility (EMC)*, can be found on the IEC website.

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

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- withdrawn,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

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INTRODUCTION

IEC 61000 is published in separate parts according to the following structure:

Part 1: General

General considerations (introduction, fundamental principles)
Definitions, terminology

Part 2: Environment

Description of the environment
Classification of the environment
Compatibility levels

Part 3: Limits

Emission limits
Immunity limits (insofar as they do not fall under the responsibility of the product committees)

Part 4: Testing and measurement techniques

Measurement techniques
Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines
Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

Each part is further subdivided into several parts, published either as international standards or as technical specifications or technical reports, some of which have already been published as sections. Others will be published with the part number followed by a dash and a second number identifying the subdivision (example: IEC 61000-6-1).

~~These standards and reports will be published in chronological order and numbered accordingly.~~

This part is an international standard which gives immunity requirements and test procedures related to "pulse magnetic field".

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-9: Testing and measurement techniques – ~~Pulse~~ Impulse magnetic field immunity test

1 Scope and object

This part of IEC 61000 ~~relates to~~ specifies the immunity requirements, test methods, and range of recommended test levels for equipment, ~~only under operational conditions~~, subjected to ~~pulse~~ impulse magnetic disturbances mainly ~~related to~~ encountered in:

- industrial installations,
- power plants,
- railway installations,
- medium voltage and high voltage sub-stations.

The applicability of this standard to equipment installed in different locations is determined by the presence of the phenomenon, as specified in Clause 4.

This standard does not consider disturbances due to capacitive or inductive coupling in cables or other parts of the field installation. Other IEC standards dealing with conducted disturbances cover these aspects.

The object of this standard is to establish a common ~~and reproducible basis~~ reference for evaluating the ~~performance~~ immunity of electrical and electronic equipment ~~for household, commercial and industrial applications~~ when subjected to ~~pulse~~ impulse magnetic fields. The test method documented in this part of IEC 61000 describes a consistent method to assess the immunity of an equipment or system against a defined phenomenon.

NOTE As described in IEC Guide 107, this is a basic EMC publication for use by product committees of the IEC. As also stated in Guide 107, the IEC product committees are responsible for determining whether this immunity test standard is applied or not, and if applied, they are responsible for determining the appropriate test levels and performance criteria. TC 77 and its sub-committees are prepared to co-operate with product committees in the evaluation of the value of particular immunity test levels for their products.

This standard defines:

- ~~recommended~~ a range of test levels;
- test equipment;
- test setups;
- test procedures.

The task of the described laboratory test is to find the reaction of the equipment under test (EUT) under specified operational conditions to impulse magnetic fields caused by switching and lightning effects.

2 Normative references

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

IEC 60050 (all parts), *International Electrotechnical Vocabulary (IEV)* (available at www.electropedia.org)

~~IEC 60060-2:1973, High-voltage test techniques — Part 2: Test procedures~~

~~IEC 60068-1:1988, Environmental testing — Part 1: General and guidance~~

~~IEC 60469-1:1987, Pulse techniques and apparatus — Part 1: Pulse terms and definitions~~

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

~~The following definitions and terms are used in this standard and apply to the restricted field of magnetic disturbances; not all of them are included in IEC 60050(161) [IEV].~~

For the purposes of this document, the terms and definitions given in IEC 60050 as well as the following apply.

3.1.1 calibration

set of operations which establishes, by reference to standards, the relationship which exists, under specified conditions, between an indication and a result of a measurement

Note 1 to entry: This term is based on the "uncertainty" approach.

Note 2 to entry: The relationship between the indications and the results of measurement can be expressed, in principle, by a calibration diagram.

[SOURCE: IEC 60050-311:2001, 311-01-09]

3.1.2 combination wave generator CWG

generator with 1,2/50 µs open-circuit voltage waveform and 8/20 µs short-circuit current waveform

Note 1 to entry: This definition is abbreviated from the equivalent definition in IEC 61000-4-5.

Note 2 to entry: This note applies to the French language only.

3.1.3 duration

T_d

<surge current for 8/20 µs> virtual parameter defined as the time interval between the instant at which the surge current rises to 0,5 of its peak value, and then falls to 0,5 of its peak value (T_w), multiplied by 1,18

$$T_d = 1,18 \times T_w$$

SEE: Figure 2.

3.1.4 front time

T_f

<surge current> virtual parameter defined as 1,25 times the interval T_f between the instants when the impulse is 10 % and 90 % of the peak value

SEE: Figure 2.

3.1.5 immunity

ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance

[SOURCE: IEC 60050-161:1990, 161-01-20]

3.1.6 induction coil

conductor loop of defined shape and dimensions, in which a current flows, generating a magnetic field of defined ~~constancy in its plane and in the enclosed volume~~ uniformity in a defined volume

3.1.7 induction coil factor

ratio between the magnetic field strength generated by an induction coil of given dimensions and the corresponding current value

Note 1 to entry: The field is that measured at the centre of the coil plane, without the EUT.

3.1.8 proximity method

method of application of the magnetic field to the EUT, where a small induction coil is moved along the side of the EUT in order to detect particularly sensitive areas

3.1.9 reference ground plane ~~(GRP)~~

flat conductive surface whose potential is used as a common reference ~~for the magnetic field generator and the auxiliary equipment (the ground plane can be used to close the loop of the induction coil, as in figure 5)~~
[IEV 161-04-36, modified]

3.1.10 rise time

T_r

interval of time between the instants at which the instantaneous value of an impulse first reaches 10 % value and then 90 % value

SEE: Figure 2.

3.1.11 surge

transient wave of electrical current, voltage or power propagating along a line or a circuit and characterized by a rapid increase followed by a slower decrease

3.1.12 system

set of interdependent elements constituted to achieve a given objective by performing a specified function

Note 1 to entry: The system is considered to be separated from the environment and other external systems by an imaginary surface which cuts the links between them and the considered system. Through these links, the system is affected by the environment, is acted upon by the external systems, or acts itself on the environment or the external systems.

3.1.13 transient, adjective and noun

pertaining to or designating a phenomenon or a quantity which varies between two consecutive steady states during a time interval short compared to the time scale of interest

[SOURCE: IEC 60050-161:1990, 161-02-01]

3.1.14

verification

set of operations which is used to check the test equipment system (e.g. the test generator and its interconnecting cables) to demonstrate that the test system is functioning

Note 1 to entry: The methods used for verification may be different from those used for calibration.

Note 2 to entry: For the purposes of this basic EMC standard this definition is different from the definition given in IEC 60050-311:2001, 311-01-13.

4.4

immersion method

~~method of application of the magnetic field to the EUT, which is placed in the centre of an induction coil (figure 1)~~

4.7

decoupling network, back filter

~~electrical circuit intended to avoid reciprocal influence with other equipment not submitted to the magnetic field test~~

3.2 Abbreviated terms

AE	Auxiliary equipment
CDN	Coupling/decoupling network
CWG	Combination wave generator
EFT/B	Electrical fast transient/burst
EMC	Electromagnetic compatibility
ESD	Electrostatic discharge
EUT	Equipment under test
MU	Measurement uncertainty
RGP	Reference ground plane

4 General

The magnetic fields to which equipment is subjected may influence the reliable operation of equipment and systems.

The following tests are intended to demonstrate the immunity of equipment when subjected to impulse magnetic fields related to the specific location and installation condition of the equipment (e.g. proximity of equipment to the disturbance source).

Pulse magnetic fields are generated by lightning ~~strokes~~ strikes on buildings and other metal structures including aerial masts, earth conductors and earth networks and by initial faults transients in low, medium and high voltage electrical systems.

In high voltage sub-stations, ~~a pulse~~ an impulse magnetic field may also be generated by the switching of high voltage bus-bars and lines by circuit breakers.

The test is mainly applicable to electronic equipment to be installed in electrical generation and distribution plants as well as in ~~telecontrol~~ their control centres. It is not relevant for distribution network equipment (e.g. transformers, power lines).

Product committees may consider other ~~possible~~ applications.

~~The test field waveform is that of the standard current pulse, waveform 6,4/16 µs.~~

~~NOTE The waveform 6,4/16 µs according to IEC 60469-1 corresponds to the 8/20 µs of IEC 60060-2.~~

5 Test levels

The preferred range of test levels is given in Table 1.

Table 1 – Test levels

Level	Pulse magnetic field strength
	A/m (peak)
1	not applicable
2	not applicable
3	100
4	300
5	1000
X ^a	special

NOTE The magnetic field strength is expressed in A/m; 1 A/m corresponds to a free space ~~induction~~ magnetic flux density of 1,26 µT.

a "n.a." = not applicable.
"x" ~~is an open~~ can be any level, above, below or in between the others.
The level ~~can be given in the product~~ shall be specified in the dedicated equipment specification.

~~Information on the selection of the test levels is given in Annex C.~~

~~Information on actual levels is given in annex D.~~

The test levels shall be selected according to the installation conditions. Classes of installation are given in Annex C.

6 Test equipment

~~The test magnetic field is obtained by a current flowing in an induction coil; the application of the test field to the EUT is by the immersion method.~~

~~An example of application of the immersion method is given in figure 1.~~

~~The test equipment includes the current source (test generator), the induction coil and auxiliary test instrumentation.~~

6.1 Test generator

~~The generator, with the output waveform corresponding to the test magnetic field, shall be able to deliver the required current in the induction coils specified in 6.2.~~

~~The generator power capability shall therefore be dimensioned by taking into account the coil impedance; the inductance may range from 2,5 µH for the 1 m standard coil, to several µH (e.g. 6 µH) for a rectangular induction coil (1 m × 2,6 m, see 6.2).~~

~~The specifications of the generator are:~~

~~— current capability, determined by the maximum selected test level and induction coil factor (see 6.2.2 and annex A), ranging from 0,87 m⁻¹ (1 m standard coil for testing table top or~~

~~small equipment) to $0,66 \text{ m}^{-1}$ (rectangular induction coil, $1 \text{ m} \times 2,6 \text{ m}$, for testing floor-standing or large equipment);~~

- ~~— operability in short-circuit condition;~~
- ~~— low output terminal connected to the earth terminal (for connection to the safety earth of the laboratory);~~
- ~~— precautions to prevent the emission of large disturbances that may be injected in the power supply network or may influence the test results.~~

~~The characteristics and performances of the current source or test generator for the field considered in this standard are given in 6.1.1.~~

~~6.1.1 Characteristics and performances of the test generator~~

~~The test generator is a non-repetitive (single-shot) pulse current generator with characteristics as follows:~~

~~Specifications~~

~~Rise time: $6,4 \mu\text{s} \pm 30 \%$~~

~~Duration: $16 \mu\text{s} \pm 30 \%$~~

~~Output current range: 100 A to $1\,000 \text{ A}$, divided by the coil factor~~

~~Polarity: positive and negative~~

~~Phase relationship with the power frequency: synchronizable from 0° to 360° with 10° steps~~

~~Synchronization: triggerable by external signal~~

~~A standard current pulse generator, e.g. the surge hybrid generator (waveform $1,2/50$ $6,4/16 \mu\text{s}$), may be used.~~

~~NOTE The output current range for the standard coil is from 120 A to $1\,200 \text{ A}$ peak.~~

~~The waveform of the output current is given in figure 2.~~

~~The schematic circuit of the generator is given in figure 3.~~

~~6.1.2 Verification of the characteristics of the test generator~~

~~In order to compare the results for different test generators, the essential characteristics of the output current parameters shall be verified.~~

~~The output current shall be verified with the generator connected to the standard induction coil specified in 6.2.1 a); the connection shall be realized by twisted conductors or coaxial cable of up to 3 m length and suitable cross-section.~~

~~The emission of disturbances by the generator shall be verified (see 6.1).~~

~~The characteristics to be verified are:~~

- ~~— output current peak value;~~
- ~~— rise time;~~
- ~~— duration.~~

~~A $1,8 \text{ mm}$ wire diameter ($2,5 \text{ mm}^2$) should be used for the loop for short-circuit current operation; however, the mechanical rigidity should be taken into account.~~

~~The verifications shall be carried out with a current probe and oscilloscope or other equivalent measurement instrumentation with 10 MHz minimum bandwidth.~~

~~The accuracy of the measurements shall be $\pm 10\%$.~~

~~6.2 Induction coil~~

~~6.2.1 Characteristics of the induction coil~~

~~The induction coil, connected to the test generator previously defined (see 6.1.1), shall generate a field strength corresponding to the selected test level and the defined homogeneity.~~

~~The induction coil shall be made of copper, aluminium or any conductive non-magnetic material, of such cross-section and mechanical arrangement as to facilitate its stable positioning during the tests.~~

~~A same coil is suitable for the generation of the magnetic fields considered in this standard; it may be a "single turn" coil and shall have a suitable current capability, as may be necessary for the selected test level.~~

~~Multi-turn coils may be used in order to have a lower testing current.~~

~~The induction coil shall be adequately dimensioned to surround the EUT (three orthogonal positions).~~

~~Depending on the size of the EUT, induction coils of different dimensions may be used.~~

~~The dimensions recommended below are suitable for the generation of magnetic fields over the whole volume of the EUT's (table-top equipment or floor-standing equipment), with an acceptable variation of ± 3 dB.~~

~~The characteristics of induction coils in respect of the magnetic field distribution are given in annex B.~~

~~a) Induction coil for table-top equipment~~

- ~~— The induction coil of standard dimensions for testing small equipment (e.g. computer monitors, watt-hour meters, transmitters for process control, etc.) has a square (or circular) form with 1 m side (or diameter), made of a conductor of relatively small cross-section.~~
- ~~— The test volume of the standard square coil is 0,6 m $\times$ 0,6 m $\times$ 0,5 m (height).~~
- ~~— A double coil of standard size (Helmholtz coil) could be used in order to obtain a field homogeneity better than 3 dB or for testing larger EUT's.~~
- ~~— The double coil (Helmholtz coil) shall comprise of two or more series of turns, properly spaced (see figure 7, figure B.4, figure B.5).~~
- ~~— The test volume of a double standard size coil, 0,8 m spaced, for a 3 dB homogeneity is 0,6 m $\times$ 0,6 m $\times$ 1 m (height).~~
- ~~— For example, the Helmholtz coils, for a 0,2 dB inhomogeneity, have dimensions and separation distances as given in figure 7.~~

~~b) Induction coil for floor-standing equipment~~

- ~~— Induction coils shall be made according to the dimensions of the EUT and the different field polarizations.~~
- ~~— The coil shall be able to envelop the EUT; the coil dimensions shall be such as to give a minimum distance of coil conductors to EUT equal to 1/3 of the dimension of the EUT considered.~~

~~— The coils shall be made of conductors of relatively small cross-section.~~

~~NOTE Due to the possible large dimensions of EUT's, the coils may be made of "C" or "T" sections in order to have sufficient mechanical rigidity.~~

~~— The test volume is determined by the testing area of the coil (60 % × 60 % of each side) multiplied by a depth corresponding to 50 % of the shorter side of the coil.~~

~~6.2.2 Calibration of the induction coil, coil factor~~

~~In order to make it possible to compare the test results from different test equipment, the induction coils shall be calibrated in their operating condition, before conducting the test (without the EUT, in free space condition).~~

~~An induction coil of the correct dimensions for the EUT dimensions, shall be positioned at 1 m minimum distance from the wall of the laboratory and any magnetic material, by using insulating supports, and shall be connected to the test generator as prescribed in 6.1.2.~~

~~Appropriate magnetic field sensors (B.W. > 10 MHz), with dynamics and frequency response corresponding to the pulse field, shall be used to verify the magnetic field strength generated by the induction coil.~~

~~The field sensor shall be positioned at the centre of the induction coil (without the EUT) and with suitable orientation to detect the maximum value of the field.~~

~~The current in the induction coil shall be adjusted to obtain the field strength specified by the test level.~~

~~The calibration shall be carried out at power frequency: the current value that generates a given field strength shall be used for the pulse test of the present standard.~~

~~The calibration procedure shall be carried out with the test generator and induction coil.~~

~~The coil factor is determined (and verified) by the above procedure.~~

~~The coil factor gives the current value to be injected in the coil to obtain the required test magnetic field (H/I).~~

~~Information on the measurement of the test magnetic field is given in annex A.~~

~~6.3 Test and auxiliary instrumentation~~

~~6.3.1 Test instrumentation~~

~~The test instrumentation includes:~~

- ~~— current measuring system (sensors and instrument) for setting and measuring the current injected in the induction coil;~~
- ~~— termination networks, back filters, etc., on power supply, control and signal lines.~~

~~The termination network gives a defined impedance of 50 Ω to earth for all the external circuits connected to the EUT terminals. It may be represented by the line impedance stabilization network for power supply circuits, coupling/decoupling network, or resistor-capacitor series for input/output control and signal circuits. These networks shall be described in the test plan.~~

~~The termination networks, back filters, etc. shall be compatible with the operating signals.~~

~~Back filters shall be used in the connections to the simulator (see 6.3.2).~~

~~The current measuring system is a calibrated current probe or shunt; the transient current measurement instrumentation shall have a bandwidth of 10 MHz.~~

~~The accuracy of the measurement instrumentation shall be $\pm 10\%$.~~

~~6.3.2 Auxiliary instrumentation~~

~~The auxiliary instrumentation comprises a simulator and any other instrument necessary for the operation and verification of the EUT functional specifications.~~

6 Test instrumentation

6.1 General

The test system comprises the combination wave generator and the induction coil for a table-top test setup and, in addition, an RGP for a floor-standing test setup.

6.2 Combination wave generator

6.2.1 General

For this application, the combination wave generator is used as a current source.

NOTE The combination wave generator specified in this standard has identical wave shape definitions to the ones given in IEC 61000-4-5.

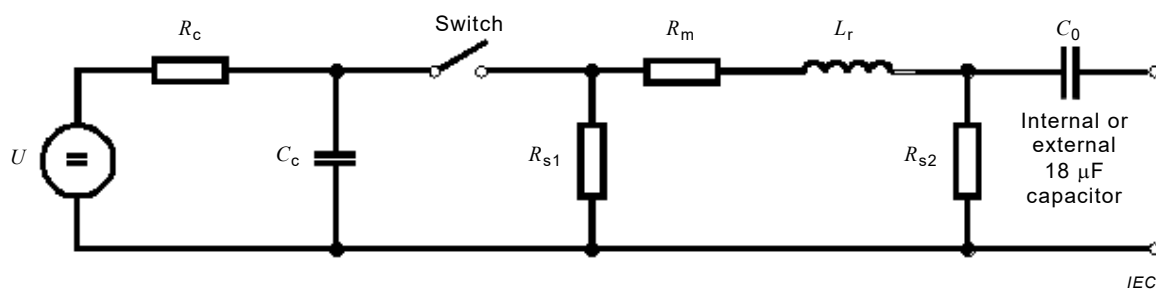
Therefore only the 8/20 μs waveform is relevant. The combination wave generator shall be able to deliver the required impulse current to the induction coils specified in 6.3.

The waveform is specified as a short-circuit current and therefore shall be measured without the induction coil connected.

This generator is intended to generate a surge having:

- a short-circuit current front time of 8 μs ;
- a short-circuit current duration of 20 μs .

A simplified circuit diagram of the generator is given in Figure 1. The values for the different components R_{S1} , R_{S2} , R_m , L_r , and C_c are selected so that the generator delivers an 8/20 μs current surge into a short-circuit.



Key

U	High-voltage source
R_c	Charging resistor
C_c	Energy storage capacitor
R_s	Impulse duration shaping resistors
R_m	Impedance matching resistor
L_r	Rise time shaping inductor
C_o	Internal or external 18 μ F capacitor

Figure 1 – Simplified circuit diagram of the combination wave generator

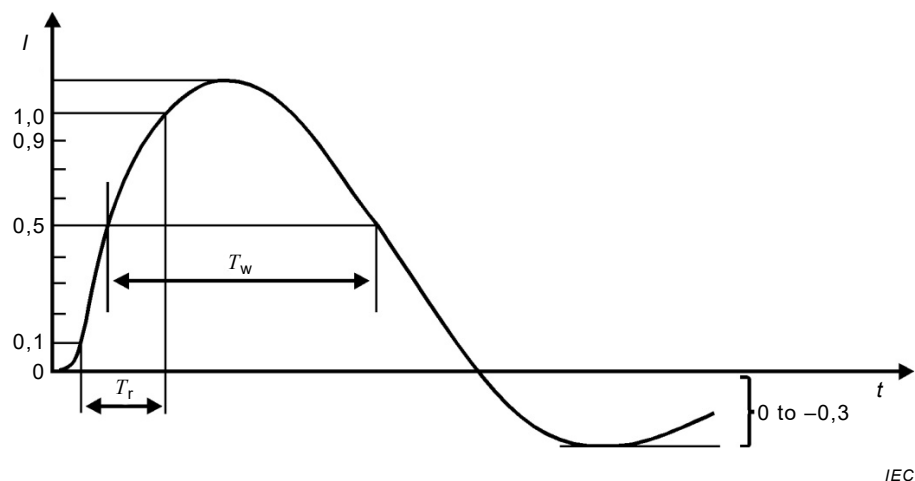
6.2.2 Performance characteristics of the generator

Polarity	positive and negative
Phase shifting	in a range between 0° to 360° relative to the phase angle of the a.c. line voltage to the EUT with a tolerance of $\pm 10^\circ$
Repetition rate	1 per minute or faster
Short-circuit peak output current	100 A to 1 000 A or the required test level divided by the coil factor
Waveform of the surge current	see Table 2 and Figure 2
Short-circuit peak output current tolerance	$\pm 10 \%$

Table 2 – Definitions of the waveform parameters 8/20 μ s

	Front time T_f μ s	Duration T_d μ s
Short-circuit current	$T_f = 1,25 \times T_r = 8 \pm 20 \%$	$T_d = 1,18 \times T_w = 20 \pm 20 \%$

A generator with floating output shall be used.



Front time: $T_f = 1,25 \times T_r = 8 \mu s \pm 20 \%$

Duration: $T_d = 1,18 \times T_w = 20 \mu s \pm 20 \%$

NOTE 1 The value 1,25 is the reciprocal of the difference between the 0,9 and 0,1 thresholds.

NOTE 2 The value 1,18 is derived from empirical data.

**Figure 2 – Waveform of short-circuit current (8/20 μs)
at the output of the generator with the 18 μF capacitor in series**

6.2.3 Calibration of the generator

If a current transformer (probe) is used to measure short-circuit current, it should be selected so that saturation of the magnetic core does not take place. The lower (-3 dB) corner frequency of the probe should be less than 100 Hz. The calibration shall be carried out with a current probe and oscilloscope or other equivalent measurement instrumentation with a bandwidth of not less than 1 MHz. The calibration shall be performed for all test levels, which are applied for testing.

The characteristics of the generator shall be measured through an external capacitor of 18 μF in series with the output, under short-circuit conditions. If the 18 μF capacitor is implemented in the generator, no external 18 μF capacitor is required for calibration.

All performance characteristics stated in 6.2.2, with the exception of phase shifting, shall be met at the output of the generator.

6.3 Induction coil

6.3.1 Field distribution

For the two single-turn standard coils of 1 m $\times$ 1 m and 1 m $\times$ 2,6 m, the field distribution is known and shown in Annex B. Therefore, no field verification or field calibration is necessary; the current measurement as shown in Figure 3 is sufficient.

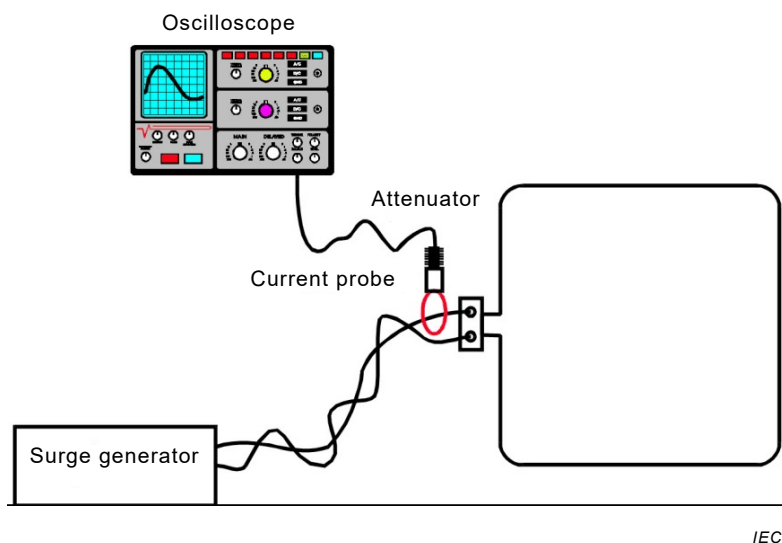


Figure 3 – Example of a current measurement of standard induction coils

Other coils of different dimensions may be used for an EUT which does not fit inside either of the two standard coils. In these cases, the field distribution shall be determined by measurement or calculation (see Annex A).

6.3.2 Characteristics of the standard induction coils of 1 m × 1 m and 1 m × 2,6 m

The standard induction coil shall be made of copper, aluminium or any conductive non-magnetic material, of such cross-section and mechanical arrangement as to facilitate its stable positioning during the tests.

The tolerance of the standard coils is ± 1 cm, measured between the centre lines (centre of the cross-section). The characteristics of induction coils with respect to the magnetic field distribution are given in Annex B.

6.4 Calibration of the test system

The essential characteristics of the test system shall be calibrated by a current measurement (see Figure 3).

The output current shall be verified with the generator connected to the standard induction coil specified in 6.2.1 for all applicable test levels. In order to comply with the specifications given in Table 3 and Table 4, an external capacitor (e.g. 18 μ F) in series may be required. The capacitor may be incorporated in the generator. The connection shall be realized by twisted conductors or a coaxial cable of up to 3 m length and of suitable cross-section.

The following specifications given in Table 3 and Table 4 shall be verified.

Table 3 – Specifications of the waveform time parameters of the test system

	Front time T_f	Duration T_d
System using 1 m × 1 m standard induction coil	$T_f = 1,25 \times T_r = 8 \mu s \begin{smallmatrix} +2,4 \\ -0,8 \end{smallmatrix} \mu s$	$T_d = 1,18 \times T_W = 20 \mu s \begin{smallmatrix} +6 \\ -2 \end{smallmatrix} \mu s$
System using 1 m × 2,6 m standard induction coil	$T_f = 1,25 \times T_r = 8 \mu s \begin{smallmatrix} +3,2 \\ -0,8 \end{smallmatrix} \mu s$	$T_d = 1,18 \times T_W = 20 \mu s \begin{smallmatrix} +8 \\ -2 \end{smallmatrix} \mu s$

Table 4 – Specifications of the waveform peak current of the test system

Test level	Peak current $I \pm 10\%$ A	
	System using 1 m × 1 m standard induction coil	System using 1 m × 2,6 m standard induction coil
1	not applicable	not applicable
2	not applicable	not applicable
3	111	152
4	333	453
5	1 111	1 515
X ^a	special/0,9	special/0,66
NOTE The values 0,9 and 0,66 are the calculated coil factors of standard induction coils as described in A.2.3 (see Annex A).		
^a "X" can be any level, above, below or in between the others. The level shall be specified in the dedicated equipment specification.		

If a current transformer (probe) is used to measure short-circuit current it should be selected so that saturation of the magnetic core does not take place. The lower (-3 dB) corner frequency of the probe should be less than 100 Hz. The calibration shall be carried out with a current probe and oscilloscope or other equivalent measurement instrumentation with a bandwidth of not less than 1 MHz.

7 Test setup

7.1 Test equipment

The following equipment is part of the test setup ~~comprises the following components:~~

- equipment under test (EUT);
- auxiliary equipment (AE) when required;
- cables (of specified type and length);
- combination wave generator (CWG) with an internal/external (e.g. 18 µF) capacitor;
- ~~— test generator;~~
- ~~— termination network, back filter.~~
- induction coil;
- reference ground plane ~~(GRP)~~ in case of testing floor standing equipment;

~~Precautions shall be taken if the test magnetic field may interfere with the test instrumentation and other sensitive equipment in the vicinity of the test set-up.~~

~~Examples of test set-ups are given in the following figures:~~

~~Figure 4: Example of test set-up for table-top equipment~~

~~Figure 5: Example of test set-up for floor-standing equipment~~

~~7.1 Ground (reference) plane~~

~~The ground plane (GRP) shall be placed in the laboratory; the EUT and auxiliary test equipment shall be placed on it and connected to it.~~

~~The ground plane shall be a non-magnetic metal sheet (copper or aluminium) of 0,25 mm thickness; other metals may be used but in this case they shall have 0,65 mm minimum thickness.~~

~~The minimum size of the ground plane is 1 m × 1 m.~~

~~The final size depends on the dimensions of the EUT.~~

~~The ground plane shall be connected to the safety earth system of the laboratory.~~

7.2 — Equipment under test

~~The equipment is configured and connected to satisfy its functional requirements. It shall be placed on the GRP with the interposition of a 0,1 m thickness insulating support (e.g. dry wood).~~

~~The equipment cabinets shall be connected to the safety earth directly on the GRP with a connection of minimum length via the earth terminal of the EUT.~~

~~The power supply, input and output circuits shall be connected to the sources of power supply, control and signals via the back filters.~~

~~The cables supplied or recommended by the equipment manufacturer shall be used. In absence of any recommendation, unshielded cables shall be adopted, of a type appropriate for the signals involved. All cables shall be exposed to the magnetic field for 1 m of their length.~~

~~The back filters shall be inserted in the circuits at 1 m cable lengths from the EUT and connected to the ground plane.~~

~~The input and output circuits, to the simulator, shall be provided with back filters in order to prevent interference to that equipment.~~

~~The communication lines (data lines) shall be connected to the EUT by the cables given in the technical specification or standard for this application. Each line, in the proximity of the EUT, shall be maintained at a distance of about 0,1 m from the GRP.~~

7.3 — Test generator

~~The test generator shall be placed at less than 3 m distance from the induction coil.~~

~~One terminal of the generator shall be connected to the ground plane.~~

7.4 — Induction coil

~~The induction coil, of the type specified in 6.2.1, shall enclose the EUT placed at its centre.~~

~~Different induction coils may be selected for testing in the different orthogonal directions, according to the general criteria specified in 6.2.1 a) and b).~~

~~Induction coils used in the vertical position (horizontal polarization of the field) can be bonded (at the foot of one vertical conductor) directly to the ground plane, which represents the low side of the coil, as a part of it. In this case, 0,1 m minimum distance from EUT to the ground plane is sufficient.~~

~~The induction coil shall be connected to the test generator in the same way as for the calibration procedure specified in 6.2.2.~~

~~The induction coil selected for the tests shall be specified in the test plan.~~

7.2 Verification of the test instrumentation

The purpose of verification is to ensure that the test setup is operating correctly. The test setup includes:

- the combination wave generator;
- the induction coil;
- the interconnection cables of the test equipment.

To verify that the system is functioning correctly, the following signal should be checked:

- surge impulse present at the induction coil terminals.

It is sufficient to verify that the surge is present at any level by using suitable measuring equipment (e.g. current probe, oscilloscope).

NOTE Test laboratories can define an internal control reference value assigned to this verification procedure.

7.3 Test setup for impulse magnetic field applied to a table-top EUT

Table-top EUTs shall be placed on a non-conductive table. The 1 m × 1 m induction coil may be used for testing EUTs with dimensions up to 0,6 m × 0,6 m × 0,5 m (L × W × H). The 1 m × 2,6 m induction coil may be used for testing EUTs with dimensions up to 0,6 m × 0,6 m × 2 m (L × W × H).

The induction coil shall be positioned in three orthogonal orientations.

When an EUT does not fit into the induction coil of 1 m × 2,6 m, either the proximity method (see 7.4) can be used or larger induction coils may be constructed to suit the dimensions of the EUT for different field orientation of the magnetic field.

NOTE If it is impractical to construct coils for very large equipment, the proximity method is the only suitable test method.

It is not necessary to maximize the impact of cables during this test. The proximity of the cables to the loop antenna can impact the results so the cables shall be routed to minimize this impact. The minimized cabling dimension shall be incorporated into the determination of the maximum size of EUT that can be tested.

An RGP is not required below the EUT (see Figure 4 below). The induction coil shall be kept at least 0,5 m from any conducting surfaces, for example the walls and floor of a shielded enclosure.

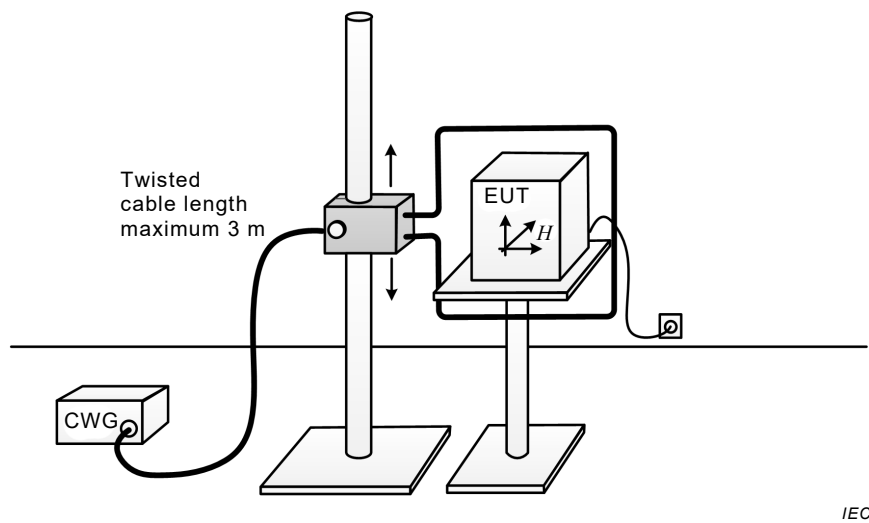


Figure 4 – Example of test setup for table-top equipment showing the vertical orthogonal plane

7.4 Test setup for impulse magnetic field applied to a floor standing EUT

The induction coil of standard dimensions for testing floor standing equipment (e.g. racks) has a rectangular shape of 1 m × 2,6 m with one short side which may be the RGP for large sized equipment. The 1 m × 1 m induction coil can be used for floor standing equipment with the maximum dimensions of 0,6 m × 0,6 m.

The RGP shall have a minimum thickness of 0,65 mm and a minimum size of 1 m × 1 m. The EUT shall be insulated from the RGP.

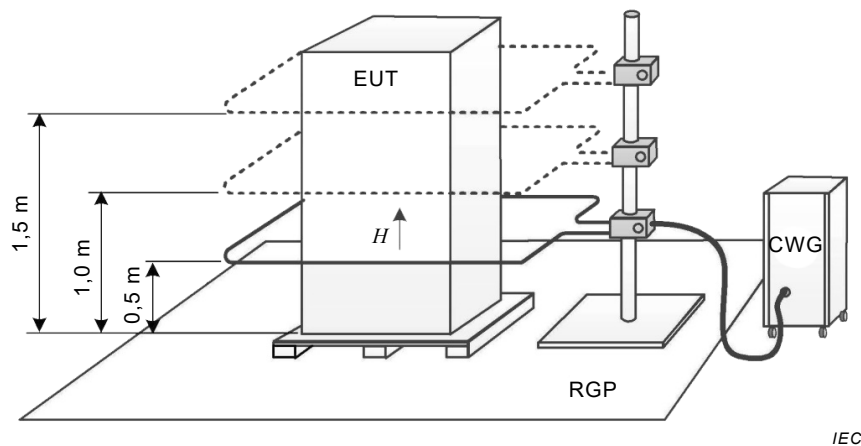


Figure 5 – Example of test setup for floor standing equipment showing the horizontal orthogonal plane

For floor standing equipment (e.g. cabinets) where the top of the EUT is greater than 0,75 m from the RGP, more than one position shall be tested. The distance between the positions shall be $(0,5 \pm 0,05)$ m. Figure 5 indicates that three positions have to be tested. In any case, the induction coil shown in Figure 5 shall not be placed below 0,5 m. Figure 6 shows an example for testing with a vertical orthogonal plane.

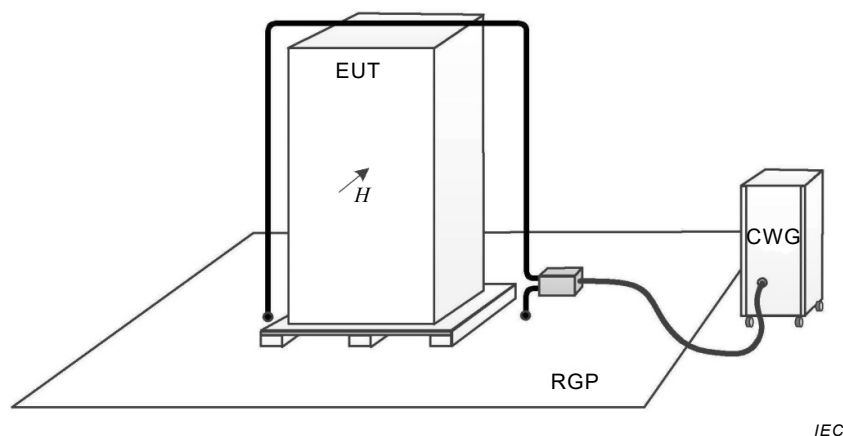


Figure 6 – Example of test setup for floor standing equipment showing the vertical orthogonal plane

The test volume of the rectangular coil is 0,6 m × 0,6 m × 2 m (L × W × H).

When an EUT does not fit into the rectangular coil of 1 m × 2,6 m, either the proximity method (see Figure 7 and 7.5 for more detailed information) can be used or larger induction coils may be constructed to suit the dimensions of the EUT for a different field orientation of the magnetic field (see Annex A).

If it is impractical to construct coils for very large equipment, the proximity method is the only suitable test method. Product committees may select either the proximity method or use a suitable coil.

It is not necessary to maximize the impact of cables during this test. The proximity of the cables to the loop antenna can impact the results so the cables shall be routed to minimize this impact. The minimized cabling dimension shall be incorporated into the determination of the maximum size of EUT that can be tested.

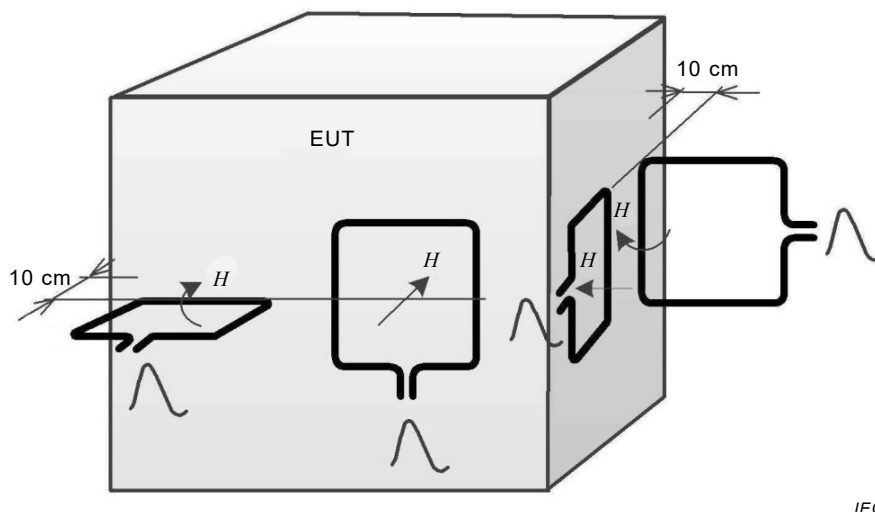


Figure 7 – Example of test setup using the proximity method

7.5 Test setup for impulse magnetic field applied in-situ

In-situ testing is generally the only practical test method available for large machinery or similar equipment. During in-situ testing, an RGP is normally not available. Therefore, the

proximity method may be the only practical test method without the RGP in place. Figure 7 gives an example for a test setup for in-situ testing. The 1 m × 1 m standard induction coil shall be used when examining EUTs using the proximity method. Furthermore it is necessary that the standard induction coil is isolated from the EUT. The distance between the standard induction coil and the EUT shall be (10 ± 1) cm.

NOTE The distance has been defined to ensure the same field strength as in the centre of the standard induction coil.

Testing of table top equipment according to 7.3 may also be performed but this is not the preferable test method.

8 Test procedure

8.1 General

The test procedure ~~shall~~ includes:

- the verification of the test instrumentation according to 7.2;
- ~~verification~~ the establishment of the laboratory reference conditions;
- ~~preliminary verification~~ the confirmation of the correct operation of the ~~equipment~~ EUT;
- ~~carrying out~~ the execution of the test;
- the evaluation of the test results (see Clause 9).

8.2 Laboratory reference conditions

~~In order to minimize the effect of environmental parameters on the test results, the test shall be carried out in climatic and electromagnetic reference conditions as specified in 8.1.1 and 8.1.2.~~

8.2.1 Climatic conditions

~~The tests shall be carried out in standard climatic conditions in accordance with IEC 68-1:~~

- ~~– temperature: 15 °C to 35 °C~~
- ~~– relative humidity: 25 % to 75 %~~
- ~~– atmospheric pressure: 86 kPa to 106 kPa~~

~~NOTE Any other value may be given in the product specifications.~~

Unless otherwise specified in generic, product family or product standards, the climatic conditions in the laboratory shall be within any limits specified for the operation of the EUT and the test equipment by their respective manufacturers.

Tests shall not be performed if the relative humidity is so high as to cause condensation on the EUT or the test equipment.

8.2.2 Electromagnetic conditions

The electromagnetic conditions of the laboratory shall be such as to guarantee the correct operation of the EUT so as not to influence the test results; ~~otherwise, the tests shall be carried out in a Faraday cage.~~

~~In particular, the electromagnetic field value of the laboratory shall be at least 20 dB lower than the selected test level.~~

8.3 ~~Carrying out~~ Execution of the test

~~The test shall be carried out on the basis of a test plan including verification of the performances of the EUT as defined in the technical specification.~~

~~The power supply, signal and other functional electrical quantities shall be applied within their rated range.~~

~~If the actual operating signals are not available, they may be simulated.~~

~~Preliminary verification of equipment performances shall be carried out prior to applying the test magnetic field.~~

~~The test magnetic field shall be applied by the immersion method to the EUT, previously set up as specified in 7.2.~~

~~The test level shall not exceed the product specification.~~

~~NOTE In order to detect the most susceptible side/positions of the EUT, mainly of a stationary type, the proximity method may be used for investigation purposes. This method is not to be used for certification. An example of application of the test field by proximity method is given in figure 6.~~

~~The test is performed by applying at least 5 pulses of positive and 5 pulses of negative polarity.~~

~~The time interval between pulses shall be no less than 10 s.~~

~~a) Table-top equipment~~

~~The equipment shall be subjected to the test magnetic field by using the induction coil of standard dimensions (1 m × 1 m) specified in 6.2.1 a) and shown in figure 4.~~

~~The induction coil shall then be rotated by 90° in order to expose the EUT to the test field with different orientations.~~

~~b) Floor-standing equipment~~

~~The equipment shall be subjected to the test magnetic field by using induction coils of suitable dimensions as specified in 6.2.1 b); the test shall be repeated by moving and shifting the induction coils, in order to test the whole volume of the EUT for each orthogonal direction.~~

~~The test shall be repeated with the coil shifted to different positions along the side of the EUT, in steps corresponding to 50 % of the shortest side of the coil.~~

~~NOTE The moving of the induction coil in steps corresponding to 50 % of the shortest side of the coil gives overlapping test fields.~~

~~The induction coil shall then be rotated by 90° in order to expose the EUT to the test field with different orientations and the same procedure.~~

Verification shall be performed. It is preferable to perform the verification prior to the test (see 7.2).

The test shall be performed according to a test plan which shall specify the test setup, including:

- test level;
- number of impulses (for each orthogonal orientation):
number of impulses unless otherwise specified by the relevant standard:
 - for d.c. powered EUT, five positive and five negative impulses;

- for single-phase a.c. powered EUT, 20 positive and 20 negative impulses without phase synchronization;
- for three-phase a.c. powered EUT, 20 positive and 20 negative impulses without phase synchronization;
- impulse repetition rate not less than one impulse per minute (product committees may specify this repetition rate);
- representative operating conditions of the EUT;
- three orthogonal orientations of the magnetic field in case of table-top equipment;
- three orientations of the magnetic field in case of floor standing equipment;
- locations of the induction coil relative to the EUT (test points).

For most products, phase synchronization may not be appropriate; therefore product committees should decide on the need of phase synchronization for their products.

NOTE 1 The application of tests with different phase angles may be more critical for equipment with inverter technology.

NOTE 2 Special safety considerations may be needed when using the generator's CDN output.

9 Evaluation of test results ~~and test report~~

The test results shall be classified in terms of the loss of function or degradation of performance of the equipment under test, relative to a performance level defined by its manufacturer or the requestor of the test, or agreed between the manufacturer and the purchaser of the product. The recommended classification is as follows:

- a) normal performance within limits specified by the manufacturer, requestor or purchaser;
- b) temporary loss of function or degradation of performance which ceases after the disturbance ceases, and from which the equipment under test recovers its normal performance, without operator intervention;
- c) temporary loss of function or degradation of performance, the correction of which requires operator intervention;
- d) loss of function or degradation of performance which is not recoverable, owing to damage to hardware or software, or loss of data.

The manufacturer's specification may define effects on the EUT which may be considered insignificant, and therefore acceptable.

This classification may be used as a guide in formulating performance criteria, by committees responsible for generic, product and product-family standards, or as a framework for the agreement on performance criteria between the manufacturer and the purchaser, for example where no suitable generic, product or product-family standard exists.

~~This clause gives a guide for the evaluation of the test results and for the test report, related to this standard.~~

~~The variety and diversity of equipment and systems to be tested make the task of establishing the effects of this test on equipment and systems difficult.~~

~~The test results shall be classified on the basis of the operating conditions and the functional specifications of the equipment under test, as in the following, unless different specifications are given by product committees or product specifications:~~

- ~~1) normal performance within the specification limits;~~
- ~~2) temporary degradation or loss of function or performance which is self recoverable;~~

- ~~3) temporary degradation or loss of function or performance which requires operator intervention or system reset;~~
- ~~4) degradation or loss of function which is not recoverable due to damage of equipment(components) or software, or loss of data.~~

Equipment shall not become dangerous or unsafe as a result of the application of the tests ~~defined in this standard.~~

~~In the case of acceptance tests, the test program and the interpretation of the test results have to be described in the specific product standard.~~

~~As general rule, the test result is positive if the equipment shows its immunity, for all the period of application of the test, and at the end of the tests the EUT fulfils the functional requirements established in the technical specification.~~

~~The technical specification may define effects on the EUT, that may be considered insignificant and therefore acceptable.~~

~~For these conditions it shall be verified that the equipment is able to recover its operative capabilities by itself at the end of the test; the time interval during which the equipment has lost its functional capabilities shall be therefore recorded. —
These verifications are binding for the definitive evaluation of the test result.~~

~~The test report shall include the test conditions and the test results.~~

10 Test report

The test report shall contain all the information necessary to reproduce the test. In particular, the following shall be recorded:

- the items specified in the test plan required by Clause 8 of this standard;
- identification of the EUT and any associated equipment, for example, brand name, product type, serial number;
- identification of the test equipment, for example, brand name, product type, serial number;
- any special environmental conditions in which the test was performed, for example, shielded enclosure;
- any specific conditions necessary to enable the test to be performed;
- performance level defined by the manufacturer, requestor or purchaser;
- performance criterion specified in the generic, product or product-family standard;
- any effects on the EUT observed during or after the application of the test disturbance, and the duration for which these effects persist;
- the rationale for the pass/fail decision (based on the performance criterion specified in the generic, product or product-family standard, or agreed between the manufacturer and the purchaser);
- any specific conditions of use, for example cable length or type, shielding or grounding, or EUT operating conditions, which are required to achieve compliance;
- the induction coils selected for the tests;
- the position and orientation of the induction coil relative to EUT.

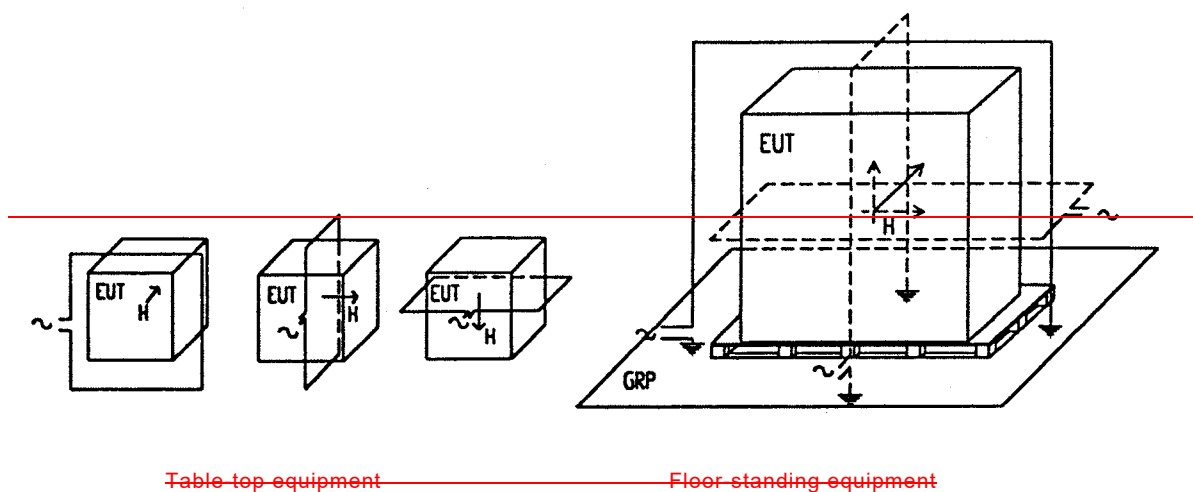


Figure 1 — Example of application of the test field by the immersion method

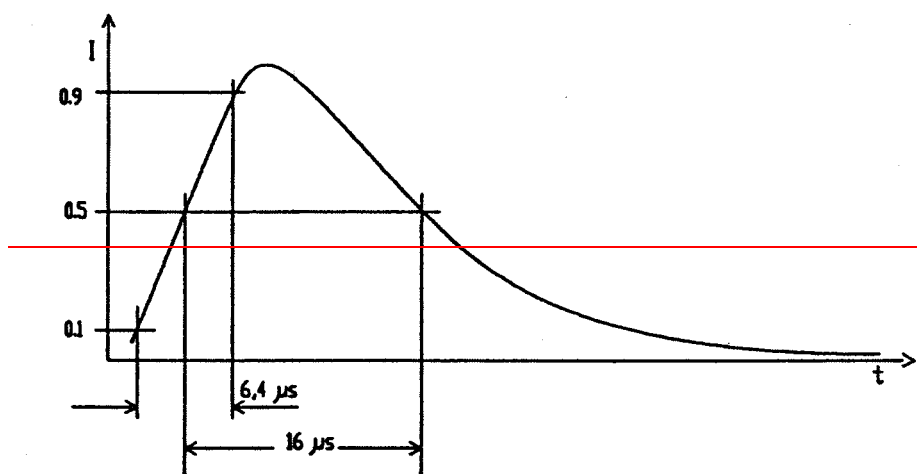
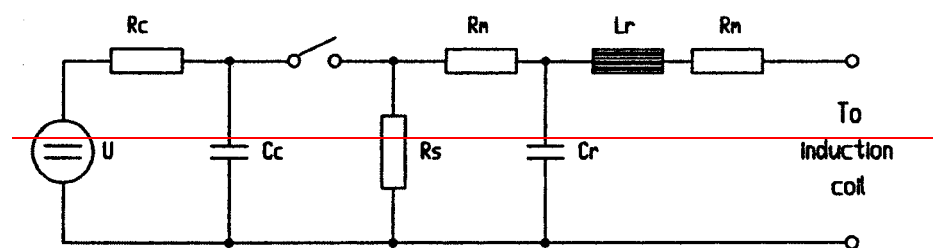


Figure 2 — Current waveform of the test generator for pulse magnetic field (6,4/16 μs)



U: High voltage source
 Rc: Charging resistor
 Cc: Energy storage capacitor
 Lr: Rise time shaping resistor
 Rm: Impedance matching resistor
 Rs1, Rs2: Pulse duration shaping resistors

Figure 3 — Schematic circuit of the test generator for pulse magnetic field (6,4/16 μs)

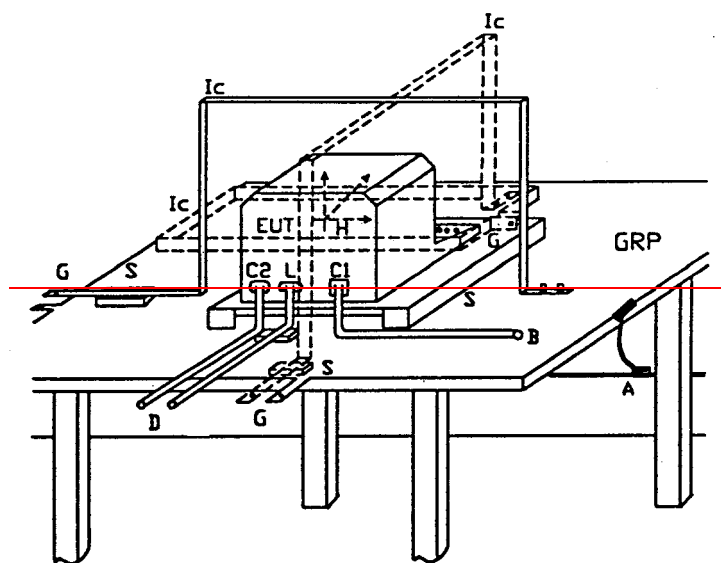


Figure 4 — Example of test set-up for table-top equipment

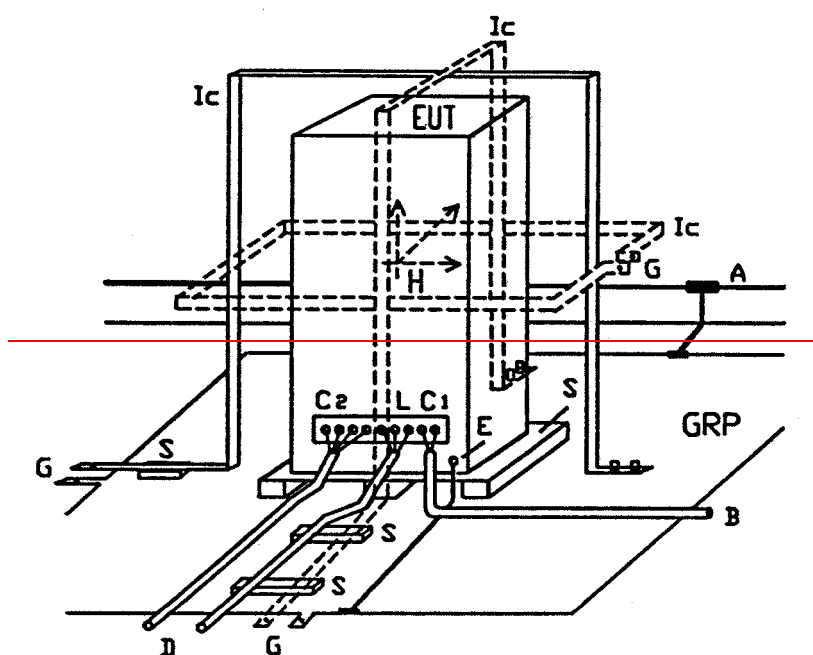


Figure 5 — Example of test set-up for floor-standing equipment

References common to figure 4 and figure 5

GRP: Ground plane	C1: Power supply circuit
A: Safety earth	C2: Signal circuit
S: Insulating support	L: Communication line
EUT: Equipment under test	B: To power supply source
Ic: Induction coil	D: To signal source, simulator
E: Earth terminal	G: To the test generator

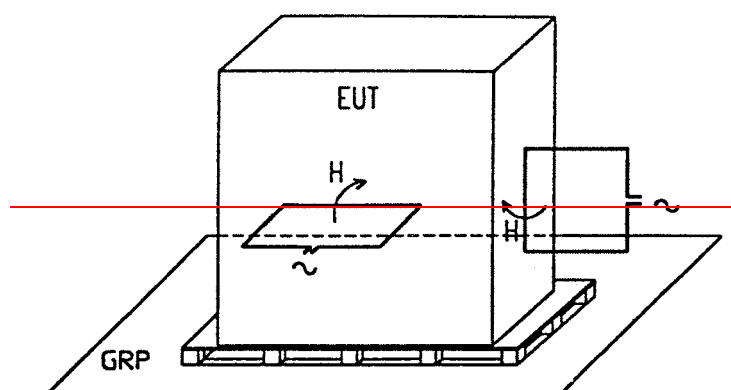
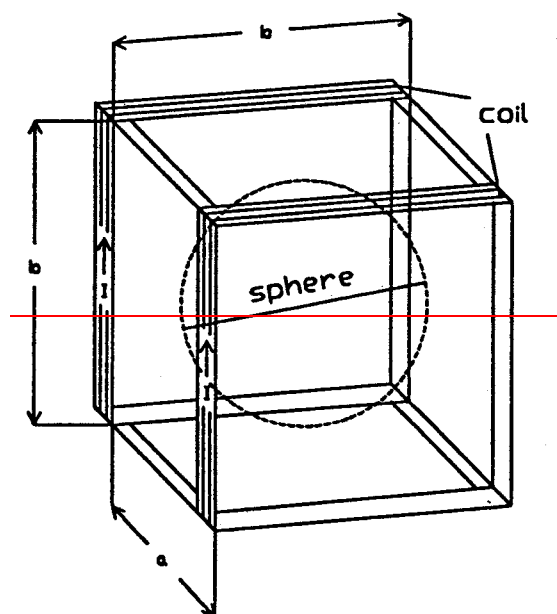


Figure 6 – Example of investigation of susceptibility to magnetic field by the proximity method



n : Number of turns in each coil — a : Separation of the coils

b : Side of the coils (m) — I : Current value (A)

H : Magnetic field strength (A/m) — $H: 1,22 \times n/b \times I$

(with $a = b/2,5$ the non-homogeneity of the magnetic field strength is $\pm 0,2$ dB)

Figure 7 – Illustration of Helmholtz coils

Annex A (~~normative~~ informative)

Characteristics of non standard induction coils~~-calibration method~~

A.1 General

When an EUT does not fit into standard induction coils, either the proximity method may be used or non standard induction coils may be used. Non standard coils are constructed to accommodate the dimensions of the EUT for the different orientations of the magnetic field.

Note that larger induction coils give repeatable results, but it may not be practical to construct very large coils. The maximum dimensions of non standard induction coils are determined by whether the waveform requirements of the 1 m × 2,6 m coil can be achieved. The proximity method may give useful but not necessarily reproducible results.

NOTE Due to the possible large dimensions of EUTs, the coils can be made of "C" or "T" cross-sectional shape in order to have sufficient mechanical rigidity.

A.2 Determination of the coil factor

A.2.1 General

The induction coil factor shall be determined by measurement or calculation. The coil factor is used to calculate the current in the induction coil to obtain the required magnetic field strength in the centre of the induction coil.

A.2.2 Coil factor measurement

A.2.2.1 General

In order to compare the test results from different coils, the induction coil factor shall be measured in a free space condition without an EUT.

A magnetic field sensor of adequate sensitivity shall be used to measure the magnetic field strength H generated by the induction coil.

The field sensor should be positioned at the centre of the induction coil and with suitable orientation to detect the maximum value of the field. The current I in the induction coil shall be measured and adjusted to obtain a field strength within the measurement range of the magnetic field sensor. The coil factor, k_{CF} , is obtained as $k_{CF} = H/I$.

A.2.2.2 Coil factor measurement for table-top equipment

The following procedure should be carried out:

The induction coil shall be positioned at a minimum of 1 m from conductive or magnetic structures. Insulating material may be used to support the induction coil. The induction coil is connected to an a.c. source. The measurement can be carried out at any frequency (e.g. 50 Hz or 60 Hz).

A.2.2.3 Coil factor measurement for floor standing equipment

The following procedure should be carried out:

The induction coil should be positioned on the RGP, which may form one side of the coil. Except for the RGP, all other conductive or magnetic structures shall be at least 1 m from the coil. Insulating material may be used to support the induction coil. The induction coil shall be connected to an a.c. source. The measurement shall be carried out at power frequency.

A.2.3 Coil factor calculation

The coil factor can be calculated from the geometrical dimensions of the induction coil. For a single-turn, rectangular induction coil having sides $a + b$ and c (see Figure A.1), the coil factor k_{CF} is given by

$$k_{CF}(P) = \frac{H(P)}{I} = \frac{1}{4\pi} \left[\frac{4a/c + c/a}{\sqrt{a^2 + (c/2)^2}} + \frac{4b/c + c/b}{\sqrt{b^2 + (c/2)^2}} \right] \quad (\text{A.1})$$

where $H(P)$ is the magnetic field at point P and I is the induction coil current. Equation (A.1) is valid, when the largest dimension of the cross-section of the coil inductor is small compared to the shortest side of the induction coil. For a square induction coil with side c and if P is at the centre of the coil, then $a = b = c/2$. If P is at the centre of a rectangular coil, then $a = b$. If the RGP is the bottom side of the coil, then equation (A.1) is still valid taking into account the image of the actual (physical) coil. In this case, if P is at the centre of the physical coil, then the k_{CF} of the coil formed by the physical coil plus its image is given by equation (A.1) with $b = 3 \times a$.

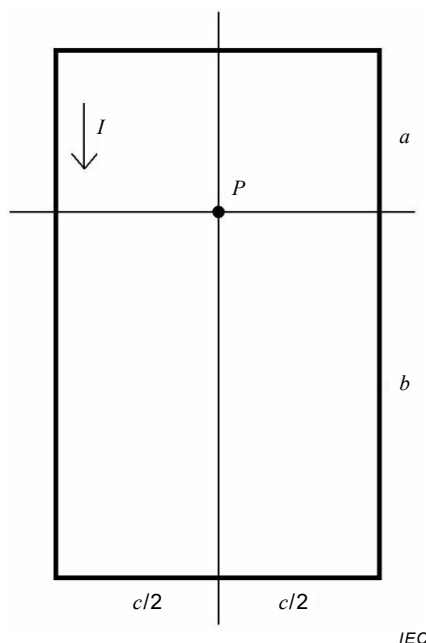


Figure A.1 – Rectangular induction coil with sides $a + b$ and c

A.3 Magnetic field measurement

~~The magnetic field test is related to free space condition, without the EUT and at 1 m minimum distance from the laboratory walls and any magnetic material.~~

The field measurement mentioned in A.2.2.1 is also applicable for large non standard induction coils. The measurement of the magnetic field may be done with a measurement system comprising ~~wide band~~ calibrated sensors ~~(10 MHz minimum bandwidth, available in the market)~~ and recording instruments e.g. transient recorders or storage oscilloscopes, for example a "Hall effect" or multi-turn loop sensors with a diameter of at least one order of

magnitude smaller than the induction coil and a power frequency narrow band instrument. The maximum EUT volume is limited by the +3 dB isoline in the x - y plane and by the ± 3 dB isolines in the x - z plane.

A.2 Calibration of the induction coil

~~The calibration shall be carried out by injecting the calibration current at power frequency in the induction coil and measuring the magnetic field by sensors placed at its geometrical centre.~~

~~Proper orientation of the sensor shall be selected in order to obtain the maximum value.~~

~~The "induction coil factor" shall be determined for each induction coil as the ratio "field strength/current of injection" (H/A).~~

~~The "coil factor", determined at a.c. current, is not related to the current waveform, because it is a characteristic parameter of the induction coil; it is therefore applicable for the evaluation of magnetic field at power frequency and other frequencies defined in this standard.~~

~~For standard dimension coil, the coil factor is determined by the manufacturer of the coil, and can be verified by laboratory measurements before carrying out the tests.~~

A.4 Verification of non standard induction coils

The measurement may be carried out by injecting the power frequency current into the induction coil and measuring the magnetic field using sensors placed at the geometrical centre of the coil as shown in Figure A.2.

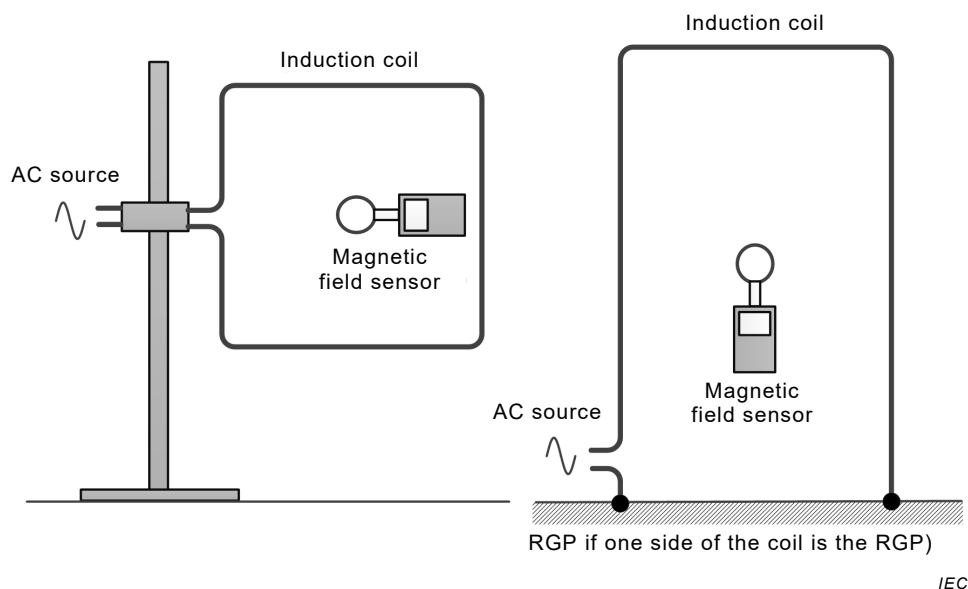


Figure A.2 – Example of verification setup for non standard induction coils

The induction coil factor can be calculated from equation (A.1) if the largest cross-section dimension of the coil inductor is not more than 0,02 of the shortest side of the coil.

If one side of the coil is the RGP, an additional source of uncertainty is the finite size of the RGP. This can be evaluated through the relative deviation between the coil factors calculated assuming the presence and absence of an infinite size RGP.

Annex B (normative)

Characteristics of the induction coils

B.1 General

This annex considers the problems of generation of the test magnetic fields.

In the first stage, both the immersion and proximity methods were considered.

In order to know the limits of application of such methods, some questions have been emphasized.

In the following the reasons for the values are explained.

B.2 Induction coil requirements

The requirement of the induction coil is "3 dB tolerance of the test field in the volume of the EUT"; this tolerance has been considered a reasonable technical compromise in respect of a test characterized by severity levels in 10 dB steps, due to practical limits in the generation of constant field over a wide range of volumes.

The constancy of the field is a requirement limited to a single direction, orthogonal to the coil plane. The field in different directions is obtainable in successive test steps by rotating the induction coil.

B.3 Induction coil characteristics

The characteristics of induction coils of different dimensions suitable for testing *table-top equipment* or *floor-standing equipment* are given in diagrams showing:

- profile of the field generated by a square induction coil (1 m side) in its plane (see figure B.1);
- 3 dB area of the field generated by a square induction coil (1 m side) in its plane (see figure B.2);
- 3 dB area of the field generated by a square induction coil (1 m side) in the mean orthogonal plane (component orthogonal to the plane of the coil) (see figure B.3);
- 3 dB area of the field generated by two square induction coils (1 m side) 0,6 m spaced, in the mean orthogonal plane (component orthogonal to the plane of the coils) (see figure B.4);
- 3 dB area of the field generated by two square induction coils (1 m side) 0,8 m spaced, in the mean orthogonal plane (component orthogonal to the plane of the coils) (see figure B.5);
- 3 dB area of the field generated by a rectangular induction coil (1 m × 2,6 m) in its plane (see figure B.6);
- 3 dB area of the field generated by a rectangular induction coil (1 m × 2,6 m) in its plane (ground plane as a side of the induction coil) (see figure B.7);
- 3 dB area of the field generated by a rectangular induction coil (1 m × 2,6 m), with ground plane, in the mean orthogonal plane (component orthogonal to the plane of the coil) (see figure B.8).

~~In the selection of the form, arrangement and dimensions of the test coil, the following points have been considered:~~

- ~~— the 3 dB area, inside and outside the induction coil, is related to the shape and dimensions of the induction coil;~~
- ~~— for a given field strength, driving current value, power and energy of the test generator are proportional to the dimensions of the induction coil.~~

~~B.4 Summary of characteristics of induction coils~~

~~On the basis of the data on the field distribution of coils with different sizes and in view of adopting the test method given in this standard to different classes of equipment, the conclusions that can be drawn are as follows:~~

- ~~— single square coil, 1 m side: testing volume 0,6 m × 0,6 m × 0,5 m high (0,2 m minimum distance from EUT to the coil);~~
- ~~— double square coils, 1 m side, 0,6 spaced: testing volume 0,6 × 0,6 × 1 m high (0,2 m minimum distance from EUT to the coil); increasing of the separation of the coils up to 0,8 m, extends the maximum high of testable EUT (see the 3 dB area, in the mean orthogonal plane) up to 1,2 m.~~
- ~~— single rectangular coil, 1 m × 2,6 m: testing volume 0,6 m × 0,6 m × 2 m high (0,2 and 0,3 m minimum distance from EUT to the coil, respectively for the horizontal and vertical dimensions of EUT); if the induction coil is bonded to the GRP, a 0,1 m distance from it is sufficient.~~

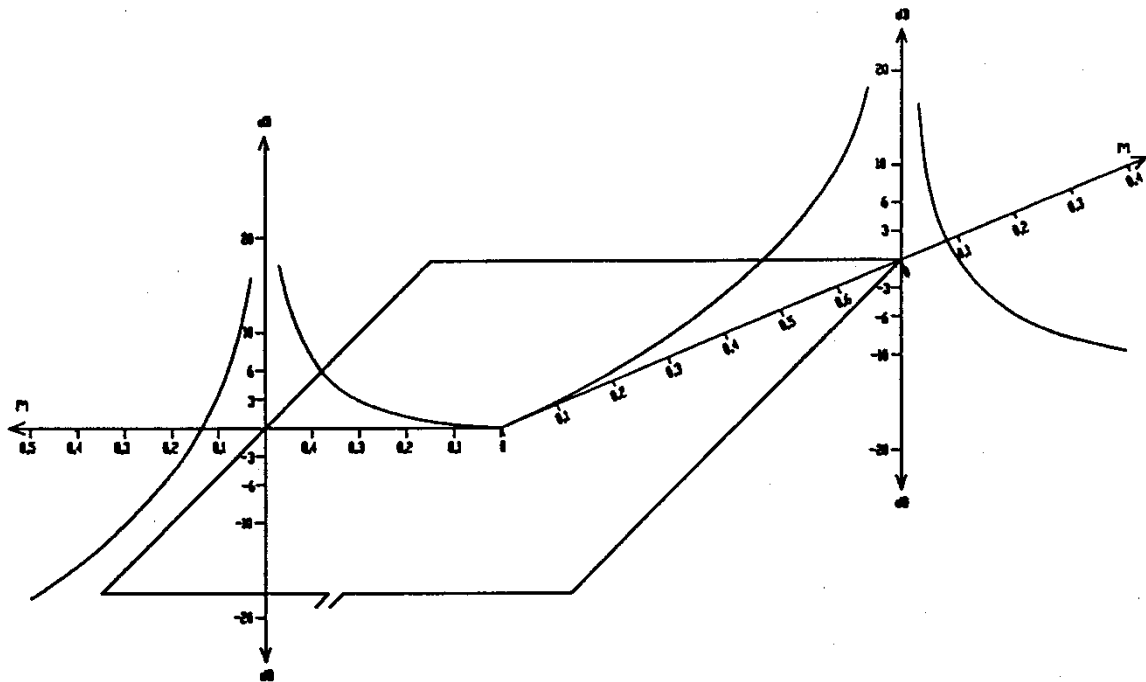


Figure B.1 — Characteristics of the field generated by a square induction coil (1 m side) in its plane

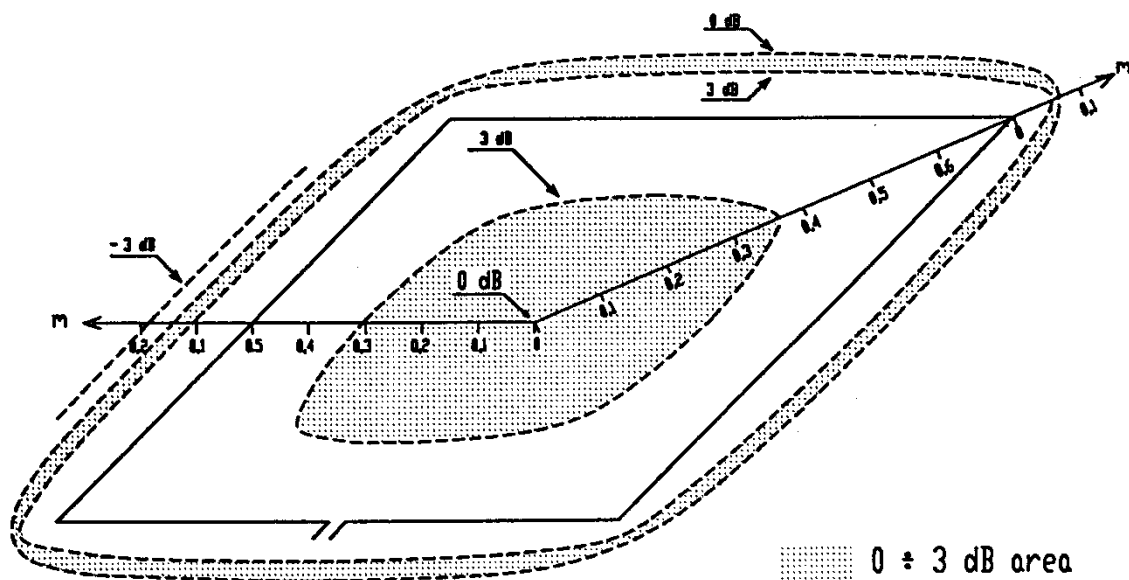


Figure B.2 — 3 dB area of the field generated by a square induction coil (1 m side) in its plane

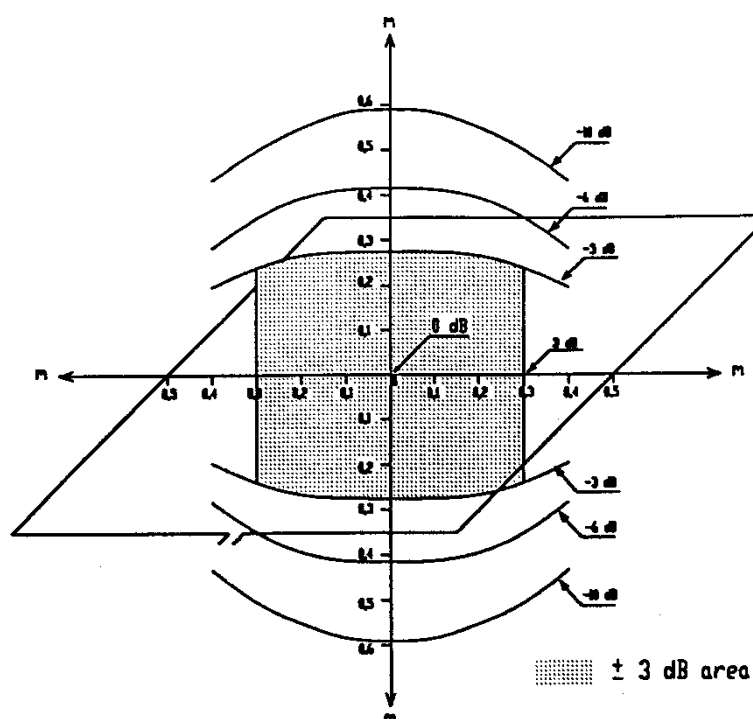


Figure B.3 — 3 dB area of the field generated by a square induction coil (1 m side) in the mean orthogonal plane (component orthogonal to the plane of the coil)

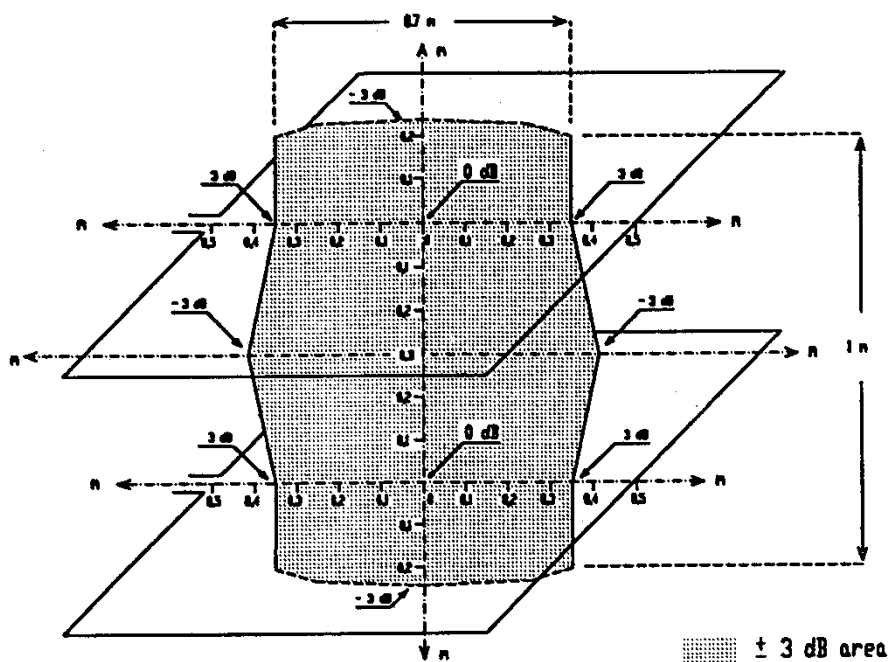


Figure B.4 — 3 dB area of the field generated by two square induction coils (1 m side) 0.6 m spaced, in the mean orthogonal plane (component orthogonal to the plane of the coils)

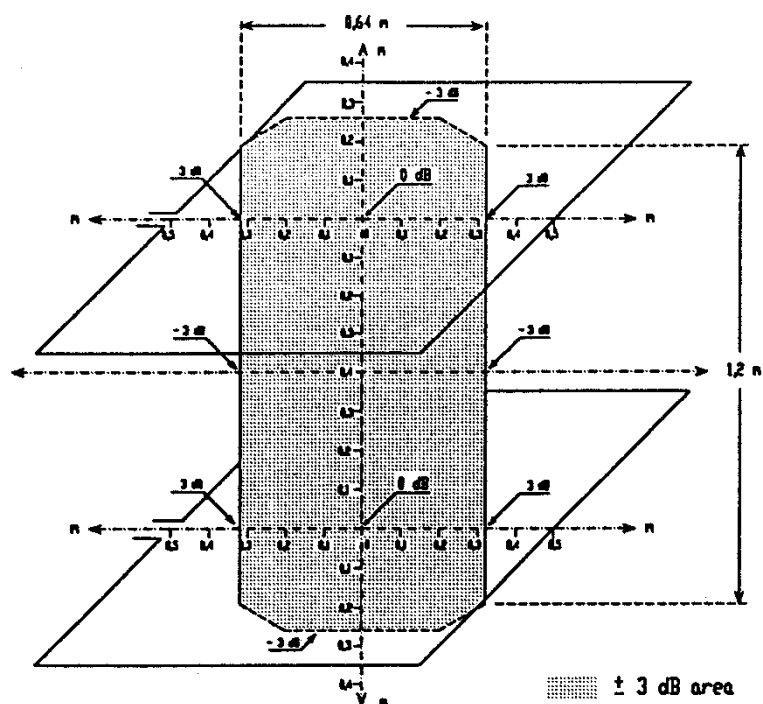


Figure B.5 — 3 dB area of the field generated by two square induction coils (1 m side) 0,8 m spaced, in the mean orthogonal plane (component orthogonal to the plane of the coils)

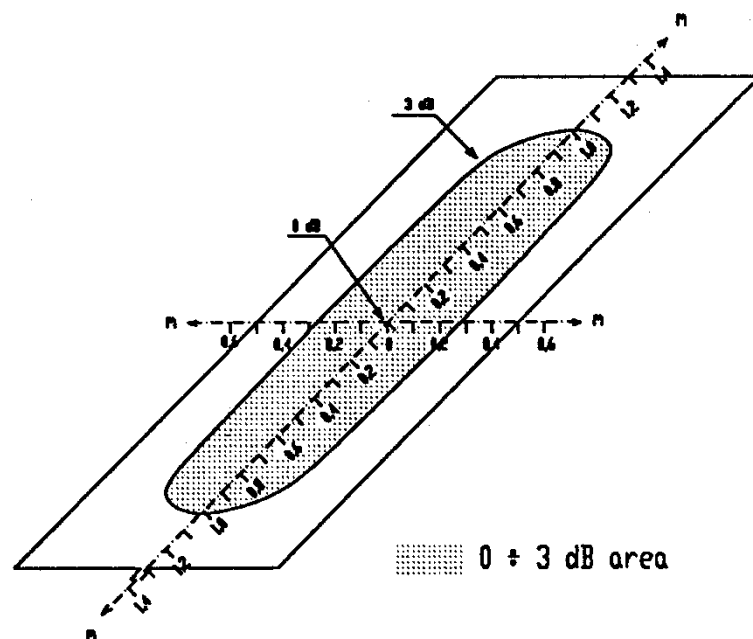


Figure B.6 — 3 dB area of the field generated by a rectangular induction coil (1 m × 2,6 m) in its plane

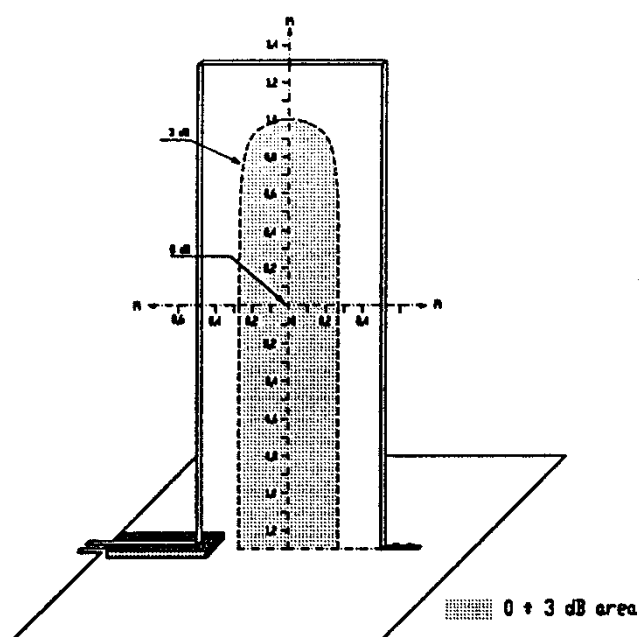


Figure B.7 — 3 dB area of the field generated by a rectangular induction coil (1 m × 2,6 m) in its plane (ground plane as a side of the induction coil)

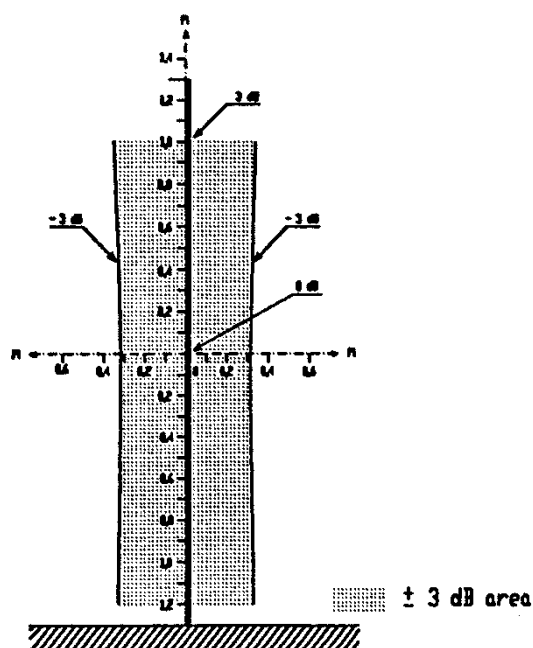


Figure B.8 — 3 dB area of the field generated by a rectangular induction coil (1 m × 2,6 m) with ground plane, in the mean orthogonal plane (component orthogonal to the plane of the coil)

Annex B

(informative)

Information on the field distribution of standard induction coils

B.1 General

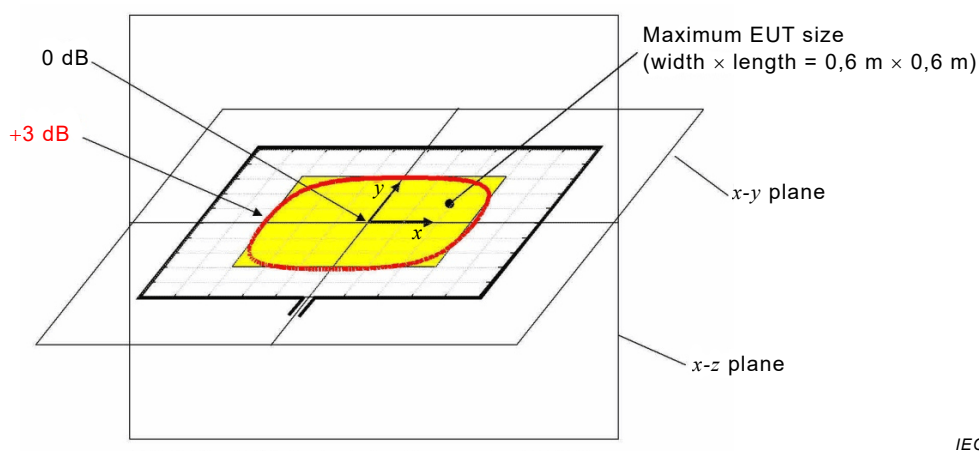
Annex B gives information on the maximum size of an EUT and its location in the standard induction coils. The maximum EUT volume is limited by the +3 dB isoline in the x - y plane and by the ± 3 dB isolines in the x - z plane.

The inductance for the single turn standard $1\text{ m} \times 1\text{ m}$ coil is approximately $2,5\text{ }\mu\text{H}$ and for the $1\text{ m} \times 2,6\text{ m}$ standard coil is approximately $6\text{ }\mu\text{H}$.

For the field computations the finite cross-section of the loop conductors are neglected (thin wire approximation).

B.2 1 m × 1 m induction coil

The +3 dB and -3 dB isolines for the magnetic field strength (magnitude) are shown in Figure B.1 for the x - y plane and in Figure B.2 for the x - z plane. The maximum EUT size is width $\times$ length $\times$ height = 0,6 m $\times$ 0,6 m $\times$ 0,5 m..



NOTE The -3 dB isoline is not shown because it is outside the loop

Figure B.1 – +3 dB isoline for the magnetic field strength (magnitude) in the x - y plane for the 1 m $\times$ 1 m induction coil

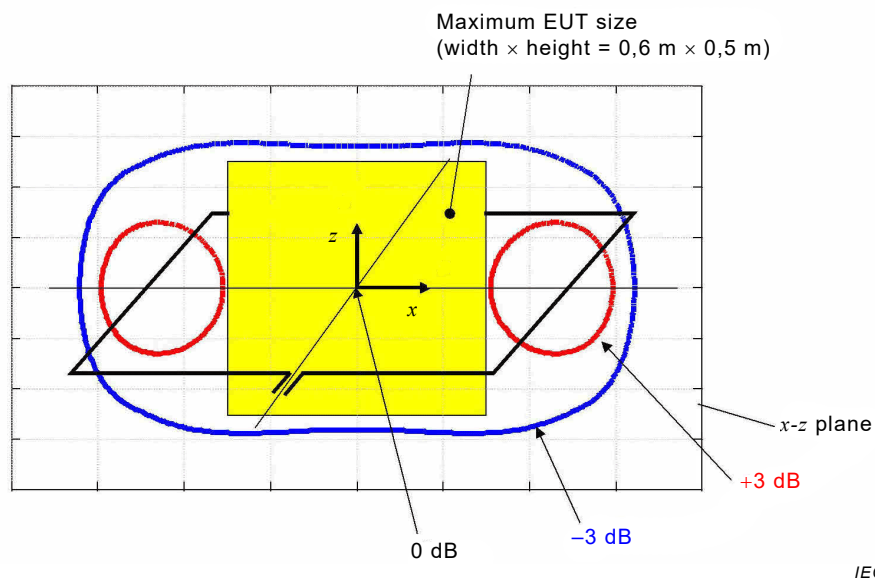
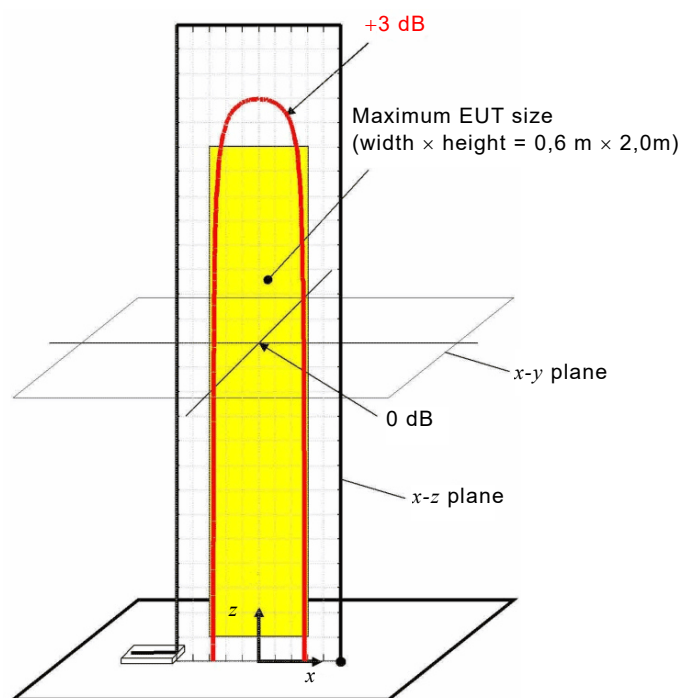


Figure B.2 – +3 dB and –3 dB isolines for the magnetic field strength (magnitude) in the x - z plane for the 1 m × 1 m induction coil

B.3 1 m × 2,6 m induction coil with reference ground plane

The +3 dB and -3 dB isolines for the magnetic field strength (magnitude) are shown in Figure B.3 for the x - z plane and in Figure B.4 for the x - y plane. The maximum EUT size is width × length × height = 0,6 m × 0,6 m × 2 m.

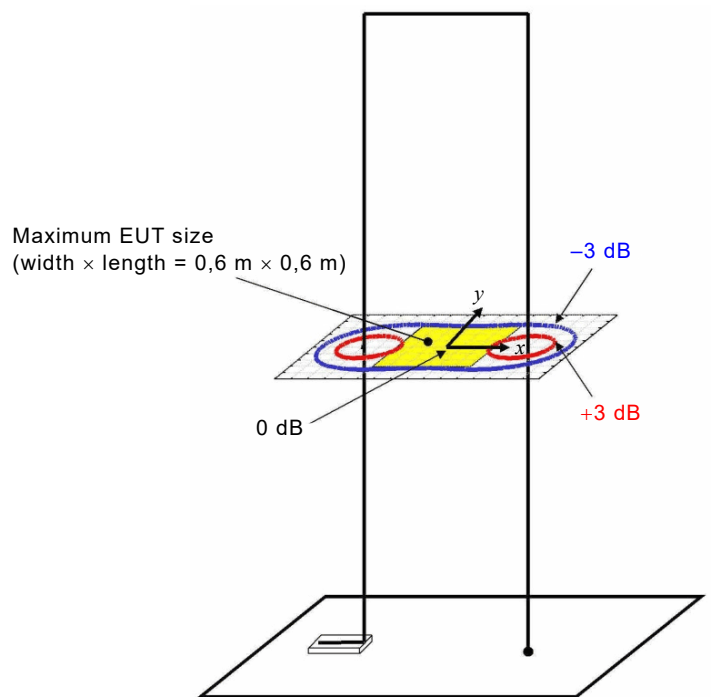
For the calculation of the ± 3 dB isolines the size of the reference ground plane is considered as infinite.



IEC

NOTE The -3 dB isoline is not shown because it is outside the loop.

Figure B.3 – +3 dB isoline for the magnetic field strength (magnitude) in the x - z plane for the 1 m $\times$ 2,6 m induction coil with reference ground plane

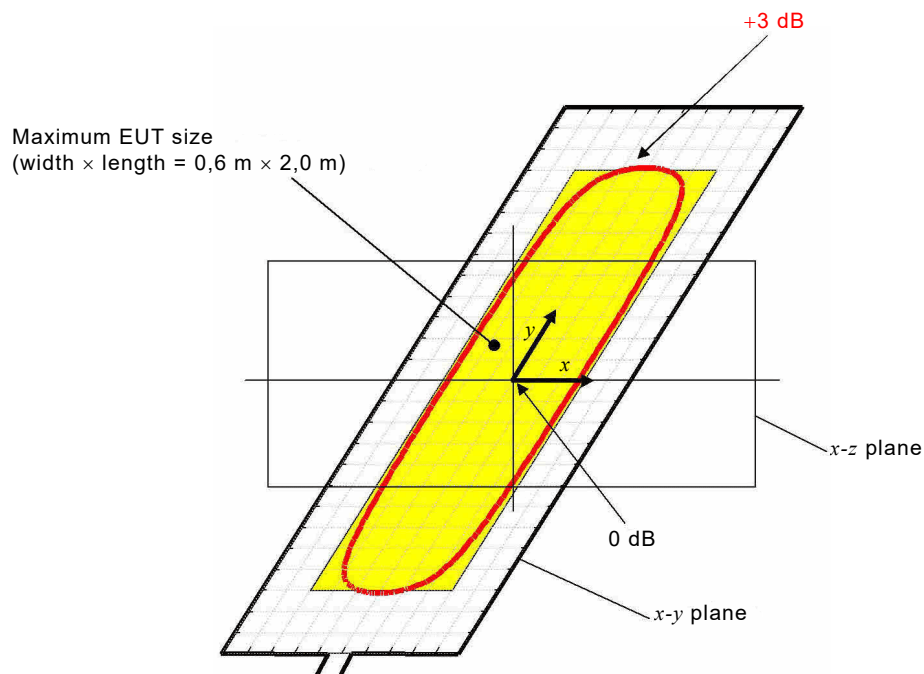


IEC

Figure B.4 – +3 dB and -3 dB isolines for the magnetic field strength (magnitude) in the x - y plane for the 1 m $\times$ 2,6 m induction coil with reference ground plane

B.4 1 m × 2,6 m induction coil without reference ground plane

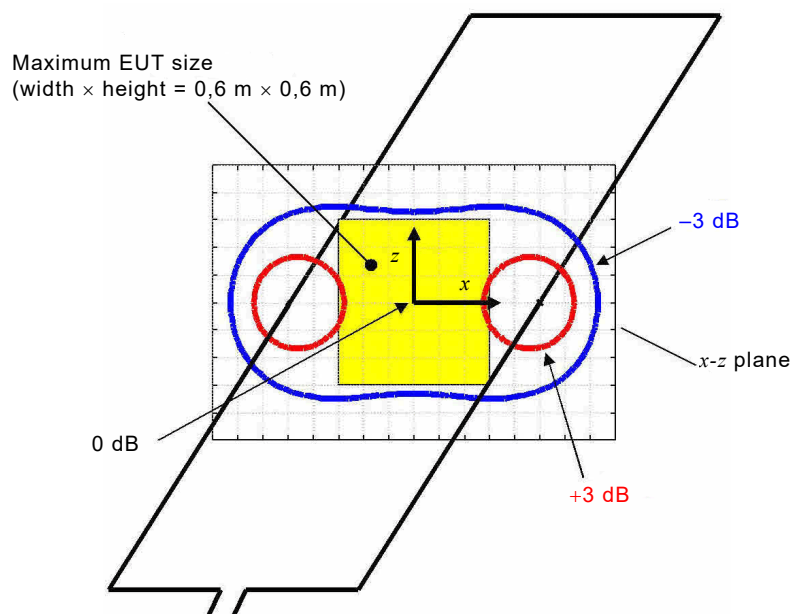
The +3 dB and –3 dB isolines for the magnetic field strength (magnitude) are shown in Figure B.5 for the x - y plane and in Figure B.6 for the x - z plane. The maximum EUT size is width × length × height = 0,6 m × 0,6 m × 2 m.



IEC

NOTE The –3 dB isoline is not shown because it is outside the loop.

Figure B.5 – +3 dB isoline for the magnetic field strength (magnitude) in the x - y plane for the 1 m × 2,6 m induction coil without reference ground plane



IEC

Figure B.6 – +3 dB and –3 dB isolines for the magnetic field strength (magnitude) in the x - z plane for the 1 m × 2,6 m induction coil without reference ground plane

Annex C (informative)

Selection of the test levels

Test levels shall be selected in accordance with the electromagnetic environment in which the equipment concerned is intended to be used, taking into account most realistic installation and environmental conditions.

These Recommendations for test levels are outlined given in Clause 5.

~~The immunity tests are correlated with these levels in order to establish a performance level for the environment in which the equipment is expected to operate.~~ The actual selection of test levels ~~shall be chosen according to~~ should take into account:

- the electromagnetic environment;
- the potential proximity of impulse magnetic field disturbances sources to the equipment concerned;
- the installation conditions typically to be expected for an installation in the electromagnetic environment under consideration;
- the need and amount of compatibility margins, i.e. the margin between the maximum disturbance level and considered immunity level.

An appropriate test level for equipment depends on the electromagnetic environment in which equipment is intended to be used. Based on common installation practices which are representative for the electromagnetic environment concerned, a guide for the selection of test levels for ~~pulse~~ impulse magnetic fields testing may be the following:

Class 1: Electromagnetic environment with particular mitigation measures employed in order to allow electromagnetic phenomena to occur to a certain extent only (e.g. phenomenon does not occur, phenomenon occurs with a relatively low amplitude only, etc.)

Controlled electromagnetic environment: where sensitive devices are planned to be used (e.g. electron microscopes, cathode ray tubes, etc.)

The test is not applicable to equipment intended to be used in this class of environment ~~where sensitive devices using electron beam can be used (monitors, electron microscope, etc., are representative of these devices).~~

Class 2: ~~Well-protected~~ Electromagnetic environment representative for residential areas

The test is not applicable to equipment intended to be used in this class of environment because the ~~areas~~ locations concerned are not subjected to the influence of ~~lightning and initial transient fault current~~ switching phenomena in medium-voltage and high-voltage substations.

~~Residential, office, hospital protected areas far away from earth conductors of lightning protection systems may be representative of this environment.~~

Class 3: ~~Protected~~ Electromagnetic environment representative for office/commercial areas

Locations of this class of environment are characterized by a potential proximity ~~of earth conductors of lightning protection systems and metallic structures~~ to medium-voltage and high-voltage switchgear or to conductors carrying corresponding transients. A computer room in the vicinity of a sub-station might be a representative for such location.

~~Commercial areas, control building, field of not heavy industrial plants provided with lightning protection system or metallic structures in the proximity, computer room of H.V. sub-stations may be representative of this environment.~~

Class 4: ~~Typical industrial~~ Electromagnetic environment representative for industrial areas
Locations of this class of environment are characterized by ~~the ground conductors of the lightning protection system or structures~~ the presence of medium-voltage or high-voltage substations and of conductors carrying transient fault currents. Control rooms of sub-stations and fields with high-current equipment/installations might be representatives for such locations.

~~Fields of heavy industrial and power plants and the control room of H.V. sub-stations may be representative of this environment.~~

Class 5: ~~Severe industrial environment~~

Harsh electromagnetic environment ~~is~~ which can be characterized by the following attributes: conductors, bus-bars or M.V. or H.V. lines carrying tens of kA; ~~ground conductors of the lightning protection system or high structures like the line towers carrying the whole lightning current.~~

Switchyard areas of heavy industrial plants, M.V./H.V. sub-stations and power stations ~~may~~ might be representatives ~~of this~~ for locations with such an electromagnetic environment.

Class X: Special electromagnetic environment

The minor or major electromagnetic separation of interference sources from equipment circuits, cables, lines, etc., and the quality of the installations may require the use of a higher or lower ~~environmental~~ test levels than those described above. This may need a case-by-case assessment.

It should be noted that the lines of equipment (e.g. cabling, bus bars, overhead lines) associated to electromagnetic environments with ~~a~~ higher test levels can penetrate ~~a lower severity environment~~ into locations being assigned to an environment with lower test levels. In such cases a re-assessment of the latter location with respect to the suitable test levels should be carried out.

The above selection of test levels in terms of electromagnetic environments should be used as a guide only. There might be cases where a location might be assigned to one of the above types of electromagnetic environments but due to the features of the equipment concerned or other circumstances a different test level than that associated to that type of electromagnetic environment might be more appropriate. Corresponding assessment should be done by the parties involved (e.g. product committees).

Annex D
(informative)

Information on magnetic field strength

The magnetic field strength ranges from a few hundreds A/m (peak) up to the order of 1 kA/m (peak) in the proximity of earth conductors, intended for protection from lightning and metal structures involved in the conduction of such transient currents; lower field strength values are representative of environments for equipment and systems installed inside buildings.