

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

ICS 13.280; 97.030

National foreword

This British Standard is the UK implementation of EN 62311:2008. It was derived by CENELEC from IEC 62311:2007. It supersedes BS EN 50392:2004 which is withdrawn.

The CENELEC common modifications have been implemented at the appropriate places in the text and are indicated by tags (e.g. [C] <C>).

The UK participation in its preparation was entrusted to Technical Committee GEL/106, Human exposure to low frequency and high frequency electromagnetic radiation.

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

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 May 2008

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ISBN 978 0 580 53575 8

Amendments/corrigenda issued since publication

Date	Comments

English version

**Assessment of electronic and electrical equipment
related to human exposure restrictions
for electromagnetic fields (0 Hz - 300 GHz)
(IEC 62311:2007, modified)**

Evaluation des équipements
électroniques et électriques
en relation avec les restrictions
d'exposition humaine
aux champs électromagnétiques
(0 Hz - 300 GHz)
(CEI 62311:2007, modifiée)

Bewertung von elektrischen
und elektronischen Einrichtungen
in Bezug auf Begrenzungen
der Exposition von Personen
in elektromagnetischen Feldern
(0 Hz - 300 GHz)
(IEC 62311:2007, modifiziert)

This European Standard was approved by CENELEC on 2007-12-04. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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

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CENELEC

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

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

Foreword

The text of document 106/129/FDIS, future edition 1 of IEC 62311, prepared by IEC TC 106, Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure, was submitted to the IEC-CENELEC parallel vote.

A draft amendment, prepared by the Technical Committee CENELEC TC 106X, Electromagnetic fields in the human environment, was submitted to the Unique Acceptance Procedure.

The combined texts of IEC 62311:2007 and the draft amendment prAA were approved by CENELEC as EN 62311 on 2007-12-04.

This European Standard supersedes EN 50392:2004.

The following dates were fixed:

- | | | |
|--|-------|------------|
| – latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement | (dop) | 2009-01-01 |
| – latest date by which the national standards conflicting with the EN have to be withdrawn | (dow) | 2011-01-01 |

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 62311:2007 was approved by CENELEC as a European Standard with agreed common modifications.

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ASSESSMENT OF ELECTRONIC AND ELECTRICAL EQUIPMENT RELATED TO HUMAN EXPOSURE RESTRICTIONS FOR ELECTROMAGNETIC FIELDS (0 Hz – 300 GHz)

1 Scope and object

This International Standard applies to electronic and electrical equipment for which no dedicated product- or product family standard regarding human exposure to electromagnetic fields applies.

The frequency range covered is 0 Hz to 300 GHz.

The object of this generic standard is to provide assessment methods and criteria to evaluate such equipment against basic restrictions or reference levels on exposure of the general public related to electric, magnetic and electromagnetic fields and induced and contact current.

NOTE This standard is intended to cover both intentional and non-intentional radiators. If the equipment complies with the requirements in another relevant standard, e.g. EN 50371 covering low power equipment, then the requirements of this standard (IEC 62311) are considered to be met and the application of this standard to that equipment is not necessary. See also Clause 7.2.

2 Normative references

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

IEC 60050-161, *International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility*

☐ Council Recommendation 1999/519/EC of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz), Official Journal L 199 of 30 July 1999 ☐

3 Terms and definitions

For the purposes of this document, the terms and definitions contained in IEC 60050-161 as well as the following terms and definitions apply.

3.1 averaging time

t_{avg}
appropriate time over which exposure is averaged for purposes of determining compliance

3.2 basic restriction

maximum exposure level that should not be exceeded under any conditions

NOTE Examples of basic restrictions can be found in Annex II of the Council Recommendation 1999/519/EC [6]¹⁾, ICNIRP Guidelines [1] IEEE Std C95.6™ [2] and IEEE Std C95.1™ [3].

¹⁾ Figures in square brackets refer to the Bibliography.

3.3**contact current**

current flowing into the body resulting from contact with a conductive object in an electromagnetic field. This is the localised current flow into the body (usually the hand, for a light brushing contact)

3.4**induced current density J** J

current per unit cross-sectional area flowing inside the human body as a result of exposure to electromagnetic fields

3.5**duty factor**

duty cycle

ratio of pulse duration to the pulse period of a periodic pulse train. Also, a measure of the temporal transmission characteristic of an intermittently transmitting RF source such as a paging antenna by dividing average transmission duration by the average period for transmissions. A duty factor of 1,0 corresponds to continuous operation

3.6**electric field strength** E

magnitude of a field vector at a point that represents the force (F) on an infinitely small charge (q) divided by the charge

$$E = \frac{F}{q}$$

3.7**equipment under test****EUT**

an electrical or electronic apparatus that is tested for compliance with exposure limits

3.8**exposure**

exposure occurs whenever and wherever a person is subjected to electric, magnetic or electromagnetic fields or to contact current other than those originating from physiological processes in the body and other natural phenomena

3.9**exposure level**

value of the quantity used to assess exposure

NOTE This may be an induced current density, SAR , power density, electric or magnetic field strength, a limb current or a contact current.

3.10**exposure limit**

value of an electric, magnetic or electromagnetic field derived from the basic restrictions using worst-case assumption about exposure. If the exposure limit is not exceeded, then the basic restrictions will never be exceeded

3.11**exposure, direct effect of**

result of a direct interaction in the exposed human body from exposure to electromagnetic fields

3.12

exposure, indirect effect of

result of a secondary interaction between the exposed human body and an electromagnetic field, often used to describe a contact current, shock or burn arising from contact with a conductive object

3.13

exposure, partial-body

localised exposure of part of the body, producing a corresponding localised *SAR* or induced current density, as distinct from a whole-body exposure

3.14

exposure, whole-body

exposure of the whole body (or the torso when induced current density is considered)

3.15

induced current

current induced inside the body as a result of exposure to electromagnetic fields

3.16

limb current

current flowing in an arm or a leg, either as a result of a contact current or else induced by an external field

3.17

magnetic field strength

H

magnitude of a field vector in a point that results in a force (*F*) on a charge (*q*) moving with velocity (*v*)

$$F = q(v \times \mu H)$$

(or magnetic flux density divided by permeability of the medium, see 3.18 “magnetic flux density”)

3.18

magnetic flux density

B

magnitude of a field vector that is equal to the magnetic field *H* multiplied by the permeability (*μ*) of the medium

$$B = \mu H$$

3.19

multiple frequency fields

superposition of two or more electromagnetic fields of differing frequency.

NOTE These may be from different sources within a device, e.g., the magnetron and the transformer of a microwave oven, or they may be harmonics in the field of a nominally single frequency source such as a transformer

3.20

power density

S

power per unit area normal to the direction of electromagnetic wave propagation. For plane waves the power density (*S*), electric field strength (*E*) and magnetic field strength (*H*) are related by the impedance of free space, i.e., 377 Ω

$$S = \frac{E^2}{377} = 377 H^2 = EH$$

NOTE 1 Although many survey instruments indicate power density units, the actual quantities measured are E or H or the square of those quantities.

E and H are expressed in units of V/m and A/m, respectively, and S in the unit of W/m².

NOTE 2 It should be noted that the value of 377 Ω is only valid for free space, far field measurement conditions.

3.21

power density, average (temporal)

instantaneous power density integrated over a source repetition period. This averaging is not to be confused with the measurement averaging time

3.22

power density, plane-wave equivalent

commonly used term associated with any electromagnetic wave, equal in magnitude to the power density of a plane wave having the same electric (E) or magnetic (H) field strength as the measured field

3.23

reference levels

levels of field strength or power density derived from the basic restrictions using worst-case assumptions about exposure. If the reference levels are met, then the basic restrictions will be complied with, but if the reference levels are exceeded, that does not necessarily mean that the basic restrictions will not be met

3.24

root-mean-square

r.m.s.

the effective value or the value associated with joule heating, of a periodic electromagnetic wave. The r.m.s. value is obtained by taking the square root of the mean of the squared value of a function

$$F = \sqrt{\frac{1}{T} \int_{-\frac{T}{2}}^{\frac{T}{2}} (F(t) \cdot F(t)^* dt)} \quad (\text{expression in time domain})$$

$$X = \sqrt{\sum_{n=1}^n (X_n)^2} \quad (\text{expression in frequency domain})$$

NOTE Although many survey instruments in the high frequency range indicate r.m.s., the actual quantity measured is root-sum-square (rss) (equivalent field strength).

3.25

root-sum-square

rss

the value rss is obtained from three individual r.m.s. field strength values, measured in three orthogonal directions, combined disregarding the phases.

$$X = \sqrt{X_x^2 + X_y^2 + X_z^2}$$

3.26

specific absorption

SA

energy absorbed per unit mass of biological tissue, expressed in joule per kilogram (J/kg); specific energy absorption is the time integral of specific energy absorption rate

3.27

specific absorption rate

SAR

power absorbed by (dissipated in) an incremental mass contained in a volume element of biological tissue when exposure to an electromagnetic field occurs. *SAR* is expressed in the unit watt per kilogram (W/kg). *SAR* is used as a measure of whole-body exposure as well as localised exposure

3.28 exposure assessment

for purposes of this standard the term exposure assessment means conformity assessment with respect to applicable exposure limit(s).

4 Compliance criteria

The electronic and electrotechnical apparatus shall comply with the basic restriction as specified in Annex II of Council Recommendation 1999/519/EC.

NOTE 1 The time averaging in the EU-Recommendation applies.

The reference levels in the Council Recommendation 1999/519/EC on public exposure to electromagnetic fields are derived from the basic restrictions using worst-case assumptions about exposure. If the reference levels are met, then the basic restrictions will be complied with, but if the reference levels are exceeded, that does not necessarily mean that the basic restrictions will not be met. In some situations, it will be necessary to show compliance with the basic restrictions directly, but it may also be possible to derive compliance criteria that allow a simple measurement or calculation to demonstrate compliance with the basic restriction. Often these compliance criteria can be derived using realistic assumptions about conditions under which exposures from a device may occur, rather than the conservative assumptions that underly the reference levels.

NOTE 2 The limit is the basic restriction.

If the technology in the apparatus is not capable of producing an E-field, H-field or contact current, at the normal user position, at levels higher than 1/2 the limit values then the apparatus is deemed to comply with the requirements in this standard in respect of that E-field, H-field or contact current without further assessment. 

5 Assessment methods

One or more of the examples of assessment methods in 7.2 may be used.

The assessments should be made according to an existing basic standard. If the assessment method in the basic standard is not fully applicable then deviations are allowed as long as

- a description of the assessment method used is given in the assessment report;
- an evaluation of the total uncertainty is given in the assessment report.

For transmitters intended for use with external antennas at least one typical combination of transmitter and antenna shall be assessed. The technical specification (under far field conditions) of this antenna shall be documented in detail such that the boundary where the basic restrictions are met can be identified, e.g., by documented radiation patterns.

For non-radio transmitting apparatus, the compliance assessment to emissions of E or H field has to be made according to the highest internal frequency used within the apparatus under analysis or at which the apparatus operates with the following criteria:

- if the highest internal frequency of the apparatus is less than 100 MHz, the assessments shall only be made up to 1 GHz;
- if the highest internal frequency of the apparatus is between 100 MHz and 400 MHz, the assessment shall only be made up to 2 GHz;
- if the highest internal frequency of the apparatus is between 400 MHz and 1 GHz, the assessment shall only be made up to 5 GHz.

If the highest internal frequency of the apparatus is above 1 GHz, the measurement shall be made up to 5 times the highest frequency.

6 Evaluation of compliance to limits

The apparatus is deemed to fulfill the requirements of this standard if the measured values are less than or equal to the limit and if the actual assessment uncertainty is less than the maximum measurement uncertainty specified for the applied assessment method(s). The assessment uncertainty of assessment method shall be determined by calculating the expanded uncertainty using a confidence interval of 95 %.

Generally, a relative uncertainty of 30 % is used for a number of EMF assessment methods. Therefore this level of relative uncertainty is used as a default maximum in this generic standard.

If the relative uncertainty is less than 30 %, then the measured value L_m shall be compared directly with the applicable limit L_{lim} for evaluation of compliance.

If the relative uncertainty is larger than 30 %, then the actual uncertainty shall be included in the evaluation of compliance with the limit as follows.

If the actual assessment uncertainty is larger than the specified maximum allowed uncertainty value and if it is also larger than the maximum default uncertainty value of 30 %, then a penalty value shall be added to the assessment result before comparison with the limit. Conversely, one can also reduce the applicable limit L_{lim} with the same penalty value, and compare the actual measured L_m value with the reduced limit. The right-hand side of Equation 1 shows how the limit L_{lim} is reduced in case the actual relative uncertainty is larger than 30 %.

NOTE The uncertainty of EMF assessment methods is generally given in %. If the uncertainty is stated in non-linear units e.g. in dBs, then this value shall be converted into percentage (%) first.

Equation 1 shall be used to determine whether the measured value L_m complies with reduced limit if the actual measurement uncertainty of the applicable assessment method is 30 % or more.

$$L_m \leq \left(\frac{1}{0,7 + \frac{U(L_m)}{L_m}} \right) L_{lim} \quad (1)$$

where

- L_m is the measured value;
- L_{lim} is the exposure limit;
- $U(L_m)$ is the absolute expanded uncertainty.

EXAMPLE:

Suppose the relative uncertainty of a certain EMF assessment method is 55 %. Then

$$\frac{U(L_m)}{L_m} = 0,55$$

Using Equation (1), the acceptance criterion for the measured value is then:

$$L_m \leq \left(\frac{1}{0,7 + \frac{U(L_m)}{L_m}} \right) L_{lim} = \left(\frac{1}{0,7 + 0,55} \right) L_{lim} = \frac{1}{1,25} L_{lim} = 0,8 L_{lim}$$

The uncertainty penalty (the amount of reduction of the limit) is then:

$$U_{pen} = L_{lim} - 0,8 L_{lim} = 0,2 L_{lim}$$

The uncertainty values specified for each EMF assessment method are the maximum allowed uncertainties. If the uncertainty value is not specified, then a default value of 30 % shall be used.

NOTE Guidance on the uncertainty can be found in ANSI NCSL Z540-2 [8]: US guide to the expression of uncertainty in measurement and in the ISO/IEC Guide on Measurement Uncertainty [9].

7 Applicability of compliance assessment methods

7.1 General

An analysis can be made to investigate which parts emit EMF. A description of the several parts of an equipment is recommended in order to determine what parts are emitting EMF. Table 1 gives the characteristics and parameters of the equipment to be considered. Table 2 gives a list of possible assessment methods.

Table 1 – Characteristics and parameters of the equipment to be considered

Information needed	Further detailed description of the information needed
Frequency	Frequency of emissions
Waveform	Waveform and other information such as duty factor for establishment of peak-and/or average emission
Multiple frequency sources	Does the equipment produce fields at more than one frequency or fields with a high harmonic content? Are the emissions simultaneous?
Emission of electric fields	Voltage differences and any coupling parts e.g., metallic surfaces charged at a voltage potential
Emission of magnetic fields	Current flow and any coupling parts e.g., coils, transducers or loops
Emission of electromagnetic fields	Generation or transmission of high frequency signals and any radiating parts e.g., antennas, loops, transducers and external cables
Contact currents	Possibility of touching conducting surfaces when either the surface or the person is exposed to electromagnetic fields?
Whole body exposure	Fields produced by equipment extend over region occupied by the whole body
Partial body exposure	Fields produced by equipment extend over only part of region occupied by the body, or over region occupied by limbs
Duration/time variation	Duty cycle of emissions, on/off time of power used or emitted by equipment. Variation of power use or emissions during production process
Homogeneity	Extent to which the strength of the fields varies over the body or region of the body that is exposed. Shall be measured without the presence of a body
Far/near field	Are exposures in near field? (see Annex A) Propagating near field? Far field?
Pulsed/transient fields	Are the emissions pulse-modulated or true pulses? Are there occasional or periodic transients in the field?
Information needed	Further detailed description of the information needed
Physical size	Is the equipment so small that any significant exposure will be to part of the body? In relation to the wavelength (operating frequency) Is it so big that different parts will contribute to exposures “independently”?
Power	What is the emitted power? What is the power consumption? If there is an antenna system, what is the effective radiated power?
Distance (source to user)	What is the spatial relationship between the equipment and the operator or user when it is used normally? The distance used for the assessment shall be specified by the manufacturer and be consistent with the intended usage of the equipment
Intended usage	How is the equipment commonly used? Conditions of intended usage producing the highest emission or absorption? Operating conditions? How does the intended usage affect the spatial relationship between the equipment and the user? Can the usage affect the emission characteristics of the equipment? Can the equipment be part of a system?
Interaction sources/user	Do the emitted fields change if the equipment is close to the body? Does the equipment couple to the body during use?

Table 2 – List of possible assessment methods

Assessment methods	Applicability area and limitations	Reference
Far field calculation	Electromagnetic fields far from source. Very small microwave equipment not used close to body, or large lower-frequency transmitters at greater distances. That region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna. In this region (also called the free space region), the field has a predominantly plane-wave character, i.e., locally uniform distribution of electric field strength and magnetic field strength in planes transverse to the direction of propagation	See Annex A
Near field calculation	Electromagnetic fields very close to the source. There can be an interaction between the radiated fields from the source and the user	See Annex A
Simulation with/without a phantom	Evaluation of measurement results inside the phantom representing a body	See Annex B
Numerical modelling	Calculation only	See Annex C
Body/limb current	Measurement or calculation	See Annex C or D
<i>SAR</i>	Calculation and measurements; 100 kHz – 10 GHz. For modelling	See Annex E See Annex C
<i>E</i> and <i>H</i> measurement	Near or far field. Direct measurement for comparison with reference levels or as input for more detailed assessment	See Annex F
Source modelling	Prediction of exposures from calculation of emissions at a specific distance	See Annex G
Direct measurement of physical properties: Contact current		See Annex D, E or F
The physical characteristics and intended use of the equipment may have an impact on the choice of assessment method. E.g., radiators of EMF intended for use in close proximity to the body shall be assessed differently from transmitters intended for fixed installations in buildings.		

7.2 Generic procedure for assessment of equipment

The following generic procedure for assessment of equipment involves a decision tree drawing on information from Tables 1 and 2.

- (1) The equipment should be characterised to determine the nature of EMF emissions (see 8.1) and also the intended usage conditions.

An assessment shall be performed: Fields and body currents should be determined at the typical user position under normal operating conditions giving the highest emission – see note – e.g., based on limited pre-tests, but consistent with the normal operating conditions as specified by the manufacturer.

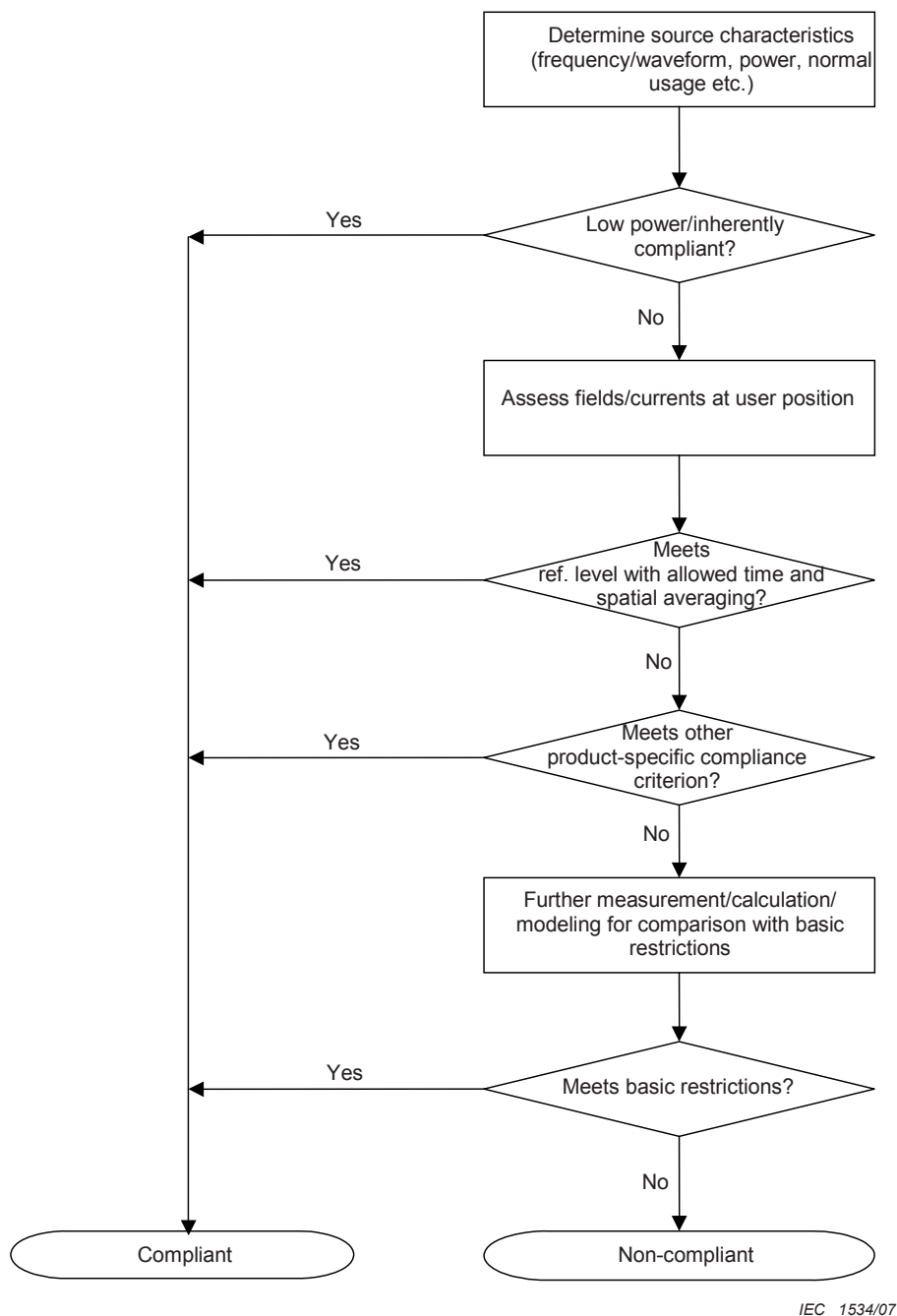
NOTE For practical reasons it is acceptable to perform the assessment with the equipment being operated with the maximum settings (e.g., maximum rated load, maximum rated power consumption, maximum speed or other), consistent with the intended use as specified by the manufacturer. The equipment is operated for a sufficient period to ensure that the conditions of operation are typical of those during normal use.

- (2) By measurement or calculation (see 8.1). If these quantities are below the relevant reference levels, taking into account waveform/frequency content (8.1), and any allowed time and spatial averaging then the equipment is deemed to meet the requirements in this standard. If not, then go to paragraph (3).
- (3) Measured emission values should be compared with any product-specific compliance criteria (e.g., kind of emission, operating frequency (range), limits) that can be derived for the equipment (Clause 5). If the emission values are below the product-specific compliance criteria then the equipment is deemed to meet the requirements in this standard. If no product-specific compliance criteria (by e.g., the manufacturer) have been specified for an *E*-field, *H*-field or contact current which is to be assessed, or if compliance criteria have been specified but not met, then go to paragraph (4).
- NOTE The technology of some products may allow assumptions about human exposure from the equipment to be made e.g., always magnetic field, always partial body exposure etc. From these assumptions it may be possible to derive compliance criteria for that product or product type, e.g., "if the magnetic field strength is below", or "if the power is below".
- (4) Further assessment involving more detailed measurement, calculation and source/ exposure modelling should be undertaken (see 8.2) to allow comparison of exposure levels with all relevant basic restrictions on exposure. If the exposures are below the basic restrictions then the equipment is deemed to meet the requirements in this standard. If not, then the equipment is deemed not to comply with the requirements in this standard.

This process is summarized in the flowchart in Figure 1.

The decision "low power / inherently compliant" shall be based on an assessment where the emissions are specified in a performance standard e.g. a transmitter performance standard and where the output power is limited to a level that can not exceed the basic restriction. It can also be any other product standard giving the same limitation on the emission level as e.g. EN 50371. Some products use a technology or input powers that have the consequence that the emissions cannot exceed the basic restrictions, e.g. non-radiotransmitter products like wrist-watches, ADSL modems, computers, telecommunications equipment and hi-fi systems. This shall also be taken into account when the assessment is made.

The choice of assessment method in stages (3) and (4) above is optional, but it must be suitable for the exposure quantity to be assessed and for the frequency of emission. Where more than one equally valid assessment method exists for a particular exposure quantity, then it is acceptable to use only one assessment method for that particular quantity. Where only one assessment method is chosen, this should be clearly stated and the reasons given for the choice.



IEC 1534/07

Figure 1 – Assessment flowchart

8 Sources with multiple frequencies

8.1 Introduction

Based on the technical characteristics of the products, the examples below gives guidance on which procedure is the most appropriate. Not all the procedures would normally be applicable to a product. If the sources are independent (phase non-coherent source) the possibility that these exposures will be additive in their effects must be considered. To take effects from unstable signals in the low frequency range into account, the measurement time shall be sufficiently long. Calculations based on such additivity should be performed separately for each effect; thus separate evaluations should be made for thermal and electrical stimulation effects on the body.

In situations where sources are not independent (phase coherent sources) or the frequencies are harmonics of only one source the phase information is relevant. As examples there are two separate summation regimes for simultaneous exposure to fields for ICNIRP and IEEE. For other limits the same principles may be used.

For ICNIRP there are two separate summation regimes of different frequencies: 1 Hz – 10 MHz for stimulation effects and 100 kHz – 300 GHz for thermal effects. Additivity should be examined separately for the effects of thermal and electrical stimulation, and the basic restriction should be met.

For IEEE there are two separate summation regimes of different frequencies: 0 Hz – 5 MHz for stimulation effects and 3 kHz – 300 GHz for thermal effects.

8.2 Frequency range from 1 Hz – 10 MHz (ICNIRP-based)

8.2.1 Frequency domain assessment

For investigation in the frequency domain, it is most realistic to include relative phase. This can be achieved by using a waveform capture approach with *post hoc* Fourier analysis. This procedure is applicable if there is only line spectra in the signal, for example for magnetic fields having a fundamental frequency and some harmonics.

In this frequency range the underlying basic restriction is induced current density or in situ electric field. The basic-restriction-based summations may or may not include consideration of phase. The most conservative is to neglect phase information.

Therefore, as a worst case assumption, multiple current densities/in situ electric fields at different frequencies or measured field values should be evaluated according to the following formulas:

$$\sum_{i=1\text{Hz}}^{10\text{ MHz}} \frac{J_i}{J_{L,i}} \leq 1$$

where

J_i is the current density at frequency i ;

$J_{L,i}$ is the current density basic restriction at frequency i .

When electric and magnetic field strengths are measured, the exposures should be summed according to these formulas:

$$\sum_{i=1\text{Hz}}^{1\text{ MHz}} \frac{E_i}{E_{L,i}} + \sum_{i>1\text{ MHz}}^{10\text{ MHz}} \frac{E_i}{a} \leq 1$$

and

$$\sum_{j=1\text{Hz}}^{65\text{ kHz}} \frac{H_j}{H_{L,j}} + \sum_{j>65\text{ kHz}}^{10\text{ MHz}} \frac{H_j}{b} \leq 1$$

where

E_i is the electric field strength at frequency i ;

$E_{L,i}$ is the electric field strength reference level at frequency i ;

H_j is the magnetic field strength at frequency j ;

$H_{L,j}$ is the magnetic field strength reference level at frequency j ;

a is 87 V/m;

b is 5 A/m (6,25 μ T).

For contact current, the following requirements should be applied:

$$\sum_{k=10\text{ MHz}}^{110\text{ MHz}} \left(\frac{I_k}{I_{L,k}} \right)^2 \leq 1, \sum_{n=1\text{ Hz}}^{10\text{ MHz}} \frac{I_n}{I_{C,n}} \leq 1, \sum_{n=100\text{ kHz}}^{100\text{ MHz}} \left(\frac{I_n}{I_{C,n}} \right)^2 \leq 1$$

where

I_k is the limb current at frequency k ;

$I_{L,k}$ is the reference level for limb current at frequency k ;

I_n is the contact current component at frequency n ;

$I_{C,n}$ is the reference level for contact current at frequency n .

Most values and formulas presented above are based on ICNIRP Guidelines [1].

NOTE 1 The values a and b are only examples.

The pure summation always results in an overestimation of the exposure and for broadband fields consisting of higher frequency harmonic components or noise, the limitation based on summation formula is very conservative because the components do not have the same phase.

NOTE 2 Further guidance on the summation of relative phases can be found in the ICNIRP statement "Guidance on determining compliance of exposure to pulsed and complex non-sinusoidal waveforms below 100 kHz with ICNIRP guidelines" [7].

Nevertheless, using most measurement equipment, the relative phases are not measured (for example if a spectrum analyser is used), but an r.m.s. summation of frequency components can be undertaken. This will usually give a more realistic outcome than neglecting phase information completely. Examples for the r.m.s. evaluation are:

$$H = \sqrt{\sum_{n=1}^{n=K} \left(\frac{H_n}{H_{L,n}} \right)^2} \quad \text{and} \quad E = \sqrt{\sum_{n=1}^{n=K} \left(\frac{E_n}{E_{L,n}} \right)^2}$$

where

H_n, E_n is the magnitude of the n^{th} Fourier component of the exposure waveform in the same quantity as $H_{L,n}, E_{L,n}$;

$H_{L,n}, E_{L,n}$ is the maximum permissible exposure value of the E -field or H -field with a single sinusoidal waveform at frequency f_n ;

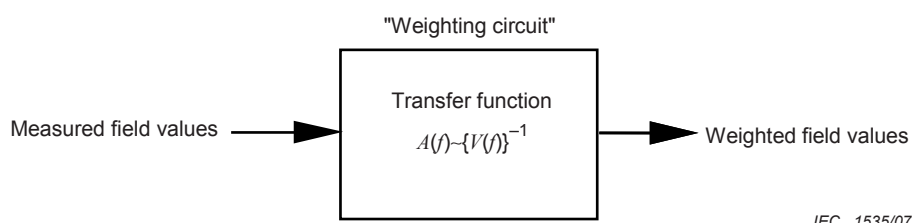
K is the maximum frequency to be considered.

8.2.2 Time domain assessment

In general for all kinds of signals (e.g., broadband, non-sinusoidal) a physical measurement system (time domain assessment), which incorporates a "weighting circuit", is applicable. The measurement will be done in the time domain, but the measured signal will be frequency depended evaluated. Typical examples for broadband sources are electric motors and power staplers.

For comparison with the given exposure levels, the weighting circuit should have a frequency response (transfer function A), which matches the frequency response of the exposure standard (function V) so that the weighting and summation of spectral components happens in the time-domain.

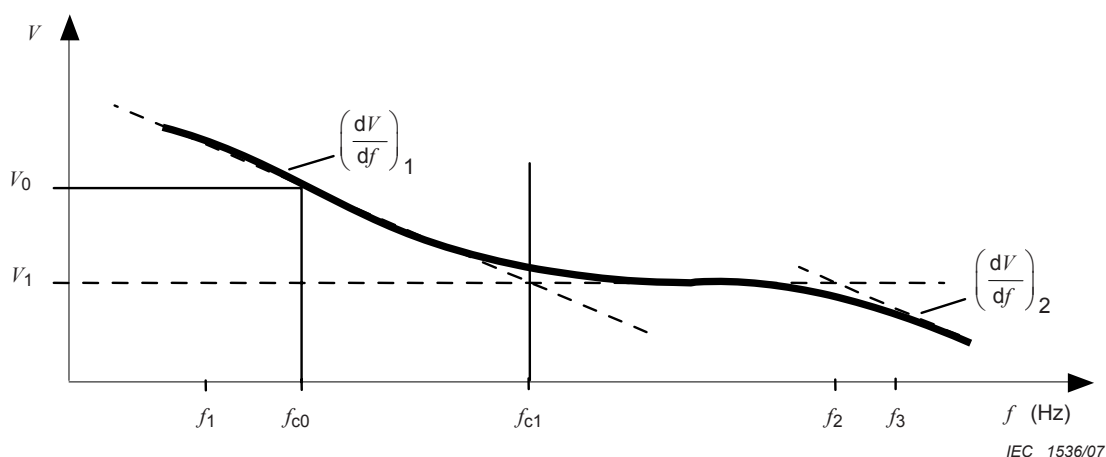
NOTE 1 Further guidance on the restriction of weighted field values can be found in the ICNIRP statement "Guidance on determining compliance of exposure to pulsed and complex non-sinusoidal waveforms below 100 kHz with ICNIRP guidelines" [7]. This approach is based on the restriction of the weighted peak value of a broadband field. The weighting function has been derived from the reference levels as a function of frequency. The weighted peak restriction can be applied for periodic non-sinusoidal waveforms where the mutual phases of harmonic components do not vary significantly.



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Figure 2 – Schematic of "weighting circuit"

EXAMPLE: Deduction of the transfer function A from the dependency on frequency f of the limits



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Figure 3 – Dependency on frequency of the reference levels V plotted with smoothing edges

with $V(f_{c0}) = V_0$, $V(f_{c1}) = V_1$ and the gradients $\left(\frac{dV}{df}\right)_n$

The transfer function A in Figure 3 is the on V_0 normalized inverse of the reference level V . The normalization shall be done at the frequency f_{C0} which is the scaling frequency of the equipment (e.g. 50 Hz or 60 Hz).

The transfer function A shown in Figure 4 shall have the following characteristics (shown in double logarithmic scale) and shall be realized with a first order filter:

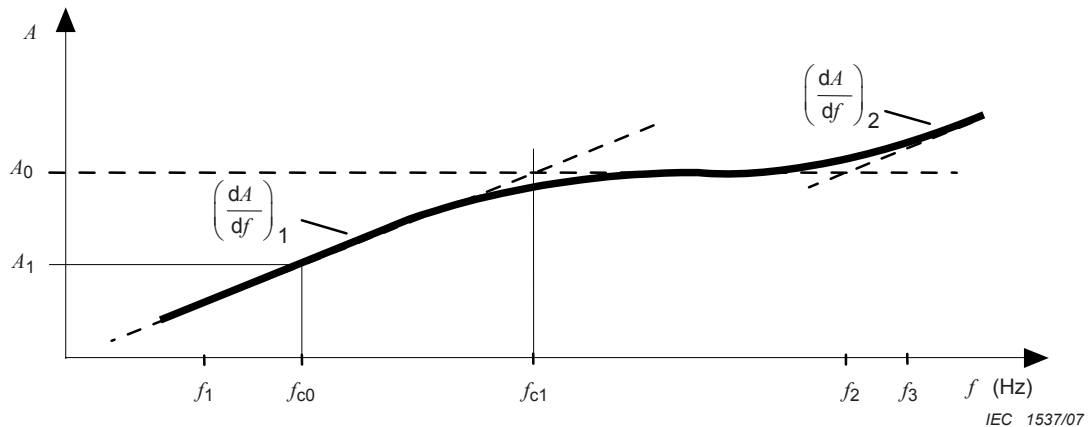


Figure 4 – Transfer function A

$$A(f) = \frac{V(f_{C0})}{V(f)}$$

For the transfer function the following shall be suitable:

$$A(f_{C0}) = A_0 = \frac{V(f_{C0})}{V_0} = 1, \quad A(f_{C1}) = A_1 = \frac{V(f_{C0})}{V_1},$$

and for the gradients

$$\left(\frac{dA}{df} \right)_n = \left[\left(\frac{dV}{df} \right)_n \right]^{-1}$$

Examples for measurement of the magnetic flux density (for other quantities similar procedures are applicable):

The reference level $B_{RL}(f)$ based on ICNIRP can be used to calculate the transfer function as follows:

$$V(f) := B_{RL}(f)$$

$$(f_1 = 10 \text{ Hz}) \leq f \leq (f_{C1} = 800 \text{ Hz}): \quad A(f) = \frac{B_{RL}(f_{C0} = 50 \text{ Hz})}{B_{RL}(f)} = \frac{\frac{5000}{50} \mu\text{T}}{\frac{5000}{f} \mu\text{T s}} = \frac{f}{50 \text{ Hz}}$$

$$(f_{C1} = 800 \text{ Hz}) \leq f \leq (f_2 = 150 \text{ kHz}): \quad A(f) = \frac{B_{RL}(f_{C0} = 50 \text{ Hz})}{B_{RL}(f)} = \frac{\frac{5000}{50} \mu\text{T}}{6,25 \mu\text{T}} = 16$$

$$(f_2 = 150 \text{ kHz}) \leq f \leq (f_{n=3} = 400 \text{ kHz}): \quad A(f) = \frac{B_{RL}(f_{C0} = 50 \text{ Hz})}{B_{RL}(f)} = \frac{\frac{5\,000}{50} \mu\text{T}}{\frac{920\,000}{f} \mu\text{T}} = \frac{f}{9,2 \text{ kHz}}$$

The actual measured value of the magnetic flux density B shall be compared with the maximum permissible exposure value $B_{RL}(f)$ at frequency f_{C0} ($A_0 = 1$):

$$\frac{B}{B_{RL}} \leq 1$$

where

B is the actual measured value with proper normalisation with transfer function (see Figure 2);

B_{RL} is the maximum permissible exposure value at frequency f_{C0} in the same quantity as B . If B is a r.m.s. value, it should be r.m.s., otherwise peak.

NOTE 2 For measurement of short duration fields (< 1s) an instrument with peak-hold function is recommended. The automatic range selection if any should be switched off.

8.3 Frequency range from 100 kHz – 300 GHz (ICNIRP-based)

In this frequency range, the exposure standard is based on the avoidance of thermal effects. The basic restrictions are on SAR and power density, and summation of these quantities should follow the formula

$$\sum_{i=100 \text{ kHz}}^{10 \text{ GHz}} \frac{SAR_i}{SAR_L} + \sum_{i>10 \text{ GHz}}^{300 \text{ GHz}} \frac{S_i}{S_L} \leq 1$$

where $SARs$ can be for the whole body or part of body. Partial-body $SARs$ should be summed together; whole body $SARs$ should be summed together. Partial body should not be summed with total body.

where

SAR_i is the SAR caused by exposure at frequency i ;

SAR_L is the SAR basic restriction;

S_i is the power density at frequency i ;

S_L is the power density basic restriction.

Exposure field strengths can be compared to the reference levels on an rss basis:

$$\sum_{i=100 \text{ kHz}}^{1 \text{ MHz}} \left(\frac{E_i}{c} \right)^2 + \sum_{i>1 \text{ MHz}}^{300 \text{ GHz}} \left(\frac{E_i}{E_{L,i}} \right)^2 \leq 1$$

and

$$\sum_{i=100 \text{ kHz}}^{1 \text{ MHz}} \left(\frac{H_i}{d} \right)^2 + \sum_{i>1 \text{ MHz}}^{300 \text{ GHz}} \left(\frac{H_i}{H_{L,i}} \right)^2 \leq 1$$

where

E_i is the electric field strength at frequency i ;

$E_{L,i}$ is the electric field reference level;

H_i is the magnetic field strength at frequency i ;

$H_{L,i}$ is the magnetic field reference level ;

c is $87/f^{1/2}$ V/m (f in MHz);

d is $0,73/f$ A/m (f in MHz).

The summation formula for limb current is:

$$\sum_{k=10 \text{ MHz}}^{110 \text{ MHz}} \left(\frac{I_k}{I_{L,k}} \right) \leq 1$$

where

I_k is the limb current component at frequency k ;

$I_{L,k}$ is the reference level for limb current, 45 mA.

All values and formulas above are based on the ICNIRP Guidelines [1].

NOTE The values c and d are only examples.

Under this thermal summation regime, the relative phases of the spectral components can be neglected.

8.4 Frequency range from 0 kHz – 5 MHz (IEEE-based)

8.4.1 Frequency domain assessment

The summation is carried out from the lowest frequency of the exposure waveform, to a maximum frequency of 5 MHz. Note that N_i and ME_i must measure the same quantity, as well as be in the same units.

For instance, if N_i is the magnitude of a flux density waveform, then ME_i must also be a measure of flux density. Alternatively, both N_i and ME_i could be measures of the time derivative of the field, the induced *in situ* electric field, or induced current density.

$$\sum_{i=0 \text{ Hz}}^{5 \text{ MHz}} \frac{N_i}{ME_i} \leq 1$$

where

N_i is the magnitude of the i^{th} Fourier component of the exposure waveform in the same quantity as ME ;

ME_i is the maximum permissible exposure or the basic *in situ* field restriction with a single sinusoidal waveform at a frequency f_i .

NOTE The Formula is based on the IEEE Std C95.6™-2002. For further explanation refer to the mentioned document.

8.4.2 Time domain assessment

The time domain valuation in 8.2.2 can also be applied for IEEE. In this case, the transfer function for the IEEE reference level $B_{RL}(f)$ has to be calculated as follows: