# SLOVENSKI STANDARD
# SIST EN 50413:2009

**01-marec-2009**

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**Osnovni standard za merjenje in izraļ unavanje izpostavljenosti ljudi elektriļ nim, magnetnim poljem in elektromagnetnim sevanjem (0 Hz - 300 GHz)**

Basic standard on measurement and calculation procedures for human exposure to electric, magnetic and electromagnetic fields (0 Hz - 300 GHz)

Grundnorm zu Mess- und Berechnungsverfahren der Exposition von Personen in elektrischen, magnetischen und elektromagnetischen Feldern (0 Hz bis 300 GHz)



Norme de base pour les procédures de mesures et de calculs pour l'exposition des personnes aux champs électriques, magnétiques et électromagnétiques (0 Hz - 300 GHz)



**Ta slovenski standard je istoveten z: EN 50413:2008**

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| 17.220.20 | Merjenje elektriļ nih in magnetnih veliļ in | Measurement of electrical and magnetic quantities |
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EUROPEAN STANDARD

NORME EUROPÉENNE

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# EN 50413

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ICS 17.220.20; 33.100.01

English version

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This European Standard was approved by CENELEC on 2008-09-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.



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

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

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CENELEC

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

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



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## Foreword

This European Standard was prepared by the Technical Committee CENELEC TC 106X, Electromagnetic fields in the human environment. The text of the draft was submitted to the formal vote and was approved by CENELEC as EN 50413 on 2008-09-01.

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) | 2009-09-01 |
| – latest date by which the national standards conflicting with the EN have to be withdrawn | (dow) | 2011-09-01 |

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**Tables**

# 1 Scope

This European Standard gives elements to establish methods for measurement and calculation of quantities associated with the assessment of human exposure to electric, magnetic and electromagnetic fields (EMF) in the frequency range from 0 Hz to 300 GHz. The major intention of this Basic Standard is to give the common background and information to relevant EMF standards. This Basic Standard cannot go into details extensively due to the broad frequency range and the huge amount of possible applications. Therefore it is not possible to specify detailed calculation or measurement procedures in this Basic Standard. This standard provides general procedures only for those product and workplace categories for which there do not exist any relevant assessment procedures in any existing European EMF basic standard.

If there exists an applicable European EMF standard focused on specific product or workplace categories then the assessment shall follow that standard. If an applicable European EMF standard does not exist, but an applicable assessment procedure in another European EMF standard does exist, then that assessment procedure shall be used.

This standard deals with quantities that can be measured or calculated in free space, notably electric and magnetic field strength or power density, and includes the measurement and calculation of quantities inside the body that forms the basis for protection guidelines.

In particular the standard provides information on

- definitions and terminology,
- characteristics of electric, magnetic and electromagnetic fields,
- measurement of exposure quantities,
- instrumentation requirements,
- methods of calibration,
- measurement techniques and procedures for evaluating exposure,
- calculation methods for exposure assessment.



# 2 Normative references

Void.



# 3 Definitions

For the purpose of this document, the following terms and definitions apply.

**3.1**
**action values**
magnitude of directly measurable parameters, provided in terms of electric field strength (*E*), magnetic field strength (*H*), magnetic flux density (*B*) and power density (*S*), at which one or more of the specified measures in Directive 2004/40/EC must be undertaken. Compliance with these values will ensure compliance with the relevant exposure limit values (from 2004/40/EC)

**3.2**
**antenna**
device that serves as a transducer between a guided wave for example in a coaxial cable and a free space wave, or vice versa

**3.3**
**basic restriction**
restrictions on exposure to time-varying electric, magnetic, and electromagnetic fields that are based directly on established health effects (from ICNIRP guidelines)

**3.4**
**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)

**3.5**
**current density (*J*)**
current per unit cross-sectional area flowing inside the human body as a result of direct exposure to electromagnetic fields, expressed in the unit ampere per square m ($A/m^2$)

**3.6**
**electric flux density (*D*)**
vector quantity obtained at a given point by adding the electric polarization ***P*** to the product of the electric field strength ***E*** and the permittivity of free space $\varepsilon_0$:

$$\boldsymbol{D} = \varepsilon_0 \boldsymbol{E} + \boldsymbol{P}$$

Electric flux density is expressed in units of coulombs per square m (C/m²).

NOTE In vacuum, the electric flux density is at all points equal to the product of the electric field strength and the permittivity of free space: $D = \varepsilon_0 E$

**3.7**
**electric field strength (*E*)**
vector quantity obtained at a given point that represents the force (***F***) on an infinitely small charge (*q*) divided by the charge:

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

Electric field strength is expressed in the unit volt per m (V/m)

**3.8**
**exposure**
exposure occurs when there is an electric, magnetic or electromagnetic field at the same location as the person from an external source



**3.9**
**exposure limit values**
limits on exposure to electromagnetic fields which are based directly on established health effects and biological considerations. Compliance with these limits will ensure that workers exposed to electromagnetic fields are protected against all known adverse health effects (from 2004/40/EC)



**3.10**
**far-field region**
region of the field of an antenna where the radial field distribution is essentially dependent inversely on the distance from the antenna. In this region the field has a predominantly plane-wave character, i.e. locally uniform distribution of electric field and magnetic field in planes transverse to the direction of propagation

NOTE In the far-field region the vectors of the electric field *E* and the magnetic field *H* are perpendicular to each other and the quotient between the value of the electric field strength *E* and the magnetic field strength *H* is constant and equals the impedance of free space $Z_0$.

**3.11**
**impedance of free space**
the impedance of free space $Z_0$ is defined as the square root of the free space permeability $\mu_0$ divided by the permittivity of free space $\varepsilon_0$

$$Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} \approx 120\pi\ \Omega \approx 377\ \Omega$$

**3.12**
**isotropic**
qualifies a physical medium or technical device where the relevant properties are independent of the direction

**3.13**
**induced current (*I*)**
current induced inside the body as a result of direct exposure to electromagnetic fields, expressed in the unit ampere (A)

**3.14**
**linearity of measurement instrument**
maximum deviation over the measurement range of the measured quantity from the closest linear reference curve defined over a given interval

**3.15**
**magnetic flux density (*B*)**
the field vector in a point that results in a force (***F***) on a charge ($q$) moving with the velocity (***v***)

$$\boldsymbol{F} = q\,(\boldsymbol{v} \times \boldsymbol{B})$$

The magnitude of the magnetic flux density is expressed in the unit tesla (T)

**3.16**
**magnetic field strength (*H*)**
vector quantity obtained at a given point by subtracting the magnetization ***M*** from the magnetic flux density ***B*** divided by the permeability of free space $\mu_0$:

$$\boldsymbol{H} = \frac{\boldsymbol{B}}{\mu_0} - \boldsymbol{M}$$

Magnetic field strength is expressed in the unit ampere per metre (A/m)

NOTE In vacuum, the magnetic field strength is at all points equal to the magnetic flux density divided by the permeability of free space: $\boldsymbol{H} = \boldsymbol{B} / \mu_0$



**3.17**
**modulation**
is the process of modifying the amplitude, phase and/or frequency of a periodic waveform in order to convey information



**3.18**
**near-field region**
region generally in proximity to an antenna or other radiating structure, in which the electric and magnetic fields do not have a substantially plane-wave character, but vary considerably from point to point. The near-field region is further subdivided into the reactive near-field region, which is closest to the radiating structure and that contains most or nearly all of the stored energy, and the radiating near-field region where the radiation field predominates over the reactive field, but lacks substantial plane-wave character and is complex in structure

**3.19**
**peak value**
the peak value of the electric or magnetic field strength or magnetic flux density represents the maximum magnitude of the field vector. It is built up out of three individual components of the electric or magnetic field strength or magnetic flux density, which are instantaneous values in three mutually orthogonal directions

$$V_\mathrm{P} = \max\left[\sqrt{V_x^2(t) + V_y^2(t) + V_z^2(t)}\right]$$

**3.20**
**permeability ($\mu$)**
property of a material which defines the relationship between magnetic flux density *B* and magnetic field strength *H*. It is commonly used as the combination of the permeability of free space ($\mu_0$) and the relative permeability for specific materials ($\mu_r$)

$$\mu = \mu_r \mu_0 = \frac{B}{H}$$

where

$\mu_r$ is the relative permeability of the material
$\mu_0$ is the permeability of free space.

The permeability is expressed in units of henry per metre (H/m)

**3.21**
**permittivity ($\varepsilon$)**
property of a dielectric material, e.g., biological tissue, defined by the electric flux density *D* divided by the electric field strength *E*

$$\varepsilon = \varepsilon_r \varepsilon_0 = \frac{D}{E}$$

where

$\varepsilon_r$ is the relative permittivity of the material
$\varepsilon_0$ is the permittivity of free space.

The permittivity is expressed in units of farads per metre (F/m)

**3.22**
**phantom**

simplified model of the human body or body part composed of materials with dielectric properties close to the organic tissue

**3.23**
**power density (*S*)**

power per unit area normal to the direction of electromagnetic wave propagation.

The power density is expressed in units of watts per square m (W/m²)

NOTE 1 For plane waves the power density (*S*), electric field strength (*E*) and magnetic field strength (*H*) are related by the impedance of free space $Z_0$

$$S = E \cdot H = \frac{E^2}{Z_0} = Z_0 \cdot H^2$$

NOTE 2 Although many survey instruments indicate power density units, the actual quantities measured are *E* or *H*, or the square of those quantities

**3.24**
**probe**
input device of a measuring instrument, generally made as a separate unit, which transforms the measured input value to a suitable output value

**3.25**
**reference level**
these levels are provided for practical exposure assessment purposes to determine whether the basic restrictions are likely to be exceeded. Some reference levels are derived from relevant basic restrictions using measurement and/or computational techniques, and some address perception and adverse indirect effects of exposure to EMF (from ICNIRP guidelines)

NOTE In any particular exposure situation, measured or calculated values can be compared with the appropriate reference level. Compliance with the reference level will ensure compliance with the relevant basic restriction. If the measured or calculated value exceeds the reference level, it does not necessarily follow that the basic restriction will be exceeded. However, whenever a reference level is exceeded it is necessary to test compliance with the relevant basic restriction and to determine whether additional protective measures are necessary

**3.26**
**root-mean-square (r.m.s.)**
the r.m.s. value is obtained by taking the square root of the average of the square of the value of the time-varying function taken throughout a suitable period of time

NOTE For periodic functions a suitable time interval is any multiple of the period of the function. For non-periodic functions the time interval used must be recorded

**3.27**
**root-sum-square (rss)**
the value rss is the square root of the sum of three field quantities squared, measured in mutually orthogonal directions

NOTE Any phase information is disregarded

**3.28**
**specific absorption rate (SAR)**
time derivative of the incremental electromagnetic energy *(*d*W)* absorbed by (dissipated in) an incremental mass *(*d*m)* contained in a volume element *(*d*V)* of given mass density ($\rho$)

$$\mathrm{SAR} = \frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{\mathrm{d}W}{\mathrm{d}m}\right) = \frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{\mathrm{d}W}{\rho\,\mathrm{d}V}\right)$$

SAR is expressed in units of watts per kilogram (W/kg)

NOTE SAR can be calculated by:

$$\mathrm{SAR} = \frac{\sigma E_\mathrm{i}^2}{\rho}, \qquad SAR = c_\mathrm{i}\left.\frac{\mathrm{d}T}{\mathrm{d}t}\right|_{\mathrm{at}\ t_0}$$



where

| | |
|---|---|
| $E_\mathrm{i}$ | r.m.s. value of the electric field strength in the tissue in V/m; |
| $\sigma$ | conductivity of body tissue in *S*/m; |
| $\rho$ | density of body tissue in kg/m[3]; |
| $c_\mathrm{i}$ | heat capacity of body tissue in J/kg K; |
| d*T* / d*t* | time derivative of temperature in body tissue in K/s. |



**3.29**
**unperturbed field**
field that exists in a space in the absence of a person or an object that could influence the field

NOTE The field measured or calculated with a person or object present may differ considerably

# 4 Introduction

## 4.1 General remarks

Electric, magnetic and electromagnetic fields can have direct and indirect effects on the human body. Depending on the frequency of the fields these effects can be stimulation of central nervous system in the low frequency range and thermal effects in the high frequency range. Besides these direct effects there exist several indirect effects such as the occurrence of contact currents or the possible influence on the intended operation of active medical implants.

Also the type (continuous wave, pulsed, single/multi-frequency, low/high frequency range), the distribution (single/multiple sources) and the localisation (whole body, head and trunk, limbs) of the electric, magnetic and electromagnetic fields greatly influence the basic concepts or principles that can be used and the field quantities which have to be assessed.

Special attention should be paid to the rationale and to the special requirements of the protection guidelines which are used for exposure assessment.

This standard is intended to be used for the assessment of emissions from products and comparison of these with the exposure levels for the general public given in Council Recommendation 1999/519/EC [9], and with exposure assessments in the workplace to determine compliance with the requirements of Council Directive 2004/40/EC [10].

The Council Recommendation 1999/519/EC [9] provides basic restrictions and derived reference levels for exposure of the general public in the areas where they spend significant time.

The Council Directive 2004/40/EC [10] provides exposure limit values and action values for exposures in the workplace. This document may be used for demonstration of compliance with National implementation of the Directive.

The basic restrictions given in the Recommendation, and the exposure limit values given in the Directive, are in both cases the actual limits which are expressed in terms of quantities that are mostly not measurable: including induced currents for low frequency, specific absorption rate (SAR) for higher frequency and power density for the highest frequencies. The values are the same as the basic restrictions for general public and occupational exposures respectively given in the ICNIRP guidelines (1998) [7], [8].

The reference levels given in the Recommendation, and the action values given in the Directive, are in both cases derived from the actual limits and are expressed in terms of quantities that are measurable: including electric field strength, magnetic field strength and contact current. The values are the same as the reference levels for general public and occupational exposures respectively given in the ICNIRP guidelines (1998) [7], [8]. The ICNIRP Guidelines [7], [8] provide basic restrictions and derived reference levels for both occupational and general public exposure.

Exposure assessments may be based either on the reference levels (action values), or on the basic restriction (exposure limit value) taking account of specific characteristics of the particular field source or device being assessed.

In general, either calculation or measurement procedures can be used for the assessment of field quantities. In specific circumstances there may be advantages of using one or the other of these. If both are suitable, then one may be used to validate the results of the other. Which ever is used, it must be applied for realistic exposure scenarios.



For any assessment procedure a maximum allowable uncertainty should be chosen. The level of this maximum allowable uncertainty will depend on which assessment procedure is used. For any procedure it shall be as low as is reasonable. The actual uncertainty for each procedure shall be below the maximum.



The following paragraphs give some special guidance for several of the topics mentioned above.

## 4.2 Static fields

Static electric and magnetic fields are independent from each other and shall – if necessary – both be assessed.

## 4.3 Low frequency range

In the low frequency range (up to 100 kHz) the electric and magnetic fields are mainly independent from each other and shall – if necessary – both be assessed. For a given exposure scenario the electric field strength depends only on the voltage used; the magnetic field strength or magnetic flux density depends only on the electric currents.

## 4.4 High frequency range

There exist several field types which should be assessed differently depending on the distance $r$ from and the dimension $D$ of the radiating source. Table 1 indicates whether to measure $E$ or $H$ or both at different distances from the field source.

For unintentional radiators, if it is not known whether the conditions for far field or radiating near field apply, then it is necessary to measure both $E$ and $H$.

**Table 1 – Evaluation parameters**

| | Reactive near field | Radiating near field | Far field |
|---|---|---|---|
| **Distance [a] *r*** | $r < \lambda$ | $\lambda < r < 2D^2 / \lambda$ | $2D^2 / \lambda < r$ |
| ***E,H* ~ 1/*r*** | No | No | Yes |
| ***Z* = *E*/*H*** | $\neq Z_0$ | $\approx Z_0$ | $= Z_0$ |
| **To measure** | *E* and *H* | *E* or *H* | *E* or *H* |

[a] Strongly depending on type of radiating structure (*D*: biggest dimension of the radiating structure; i.e. diameter of a parabolic antenna). If the EM field is modulated, Annex D gives some guidance on how to determine the required values for the exposure assessment.

### 4.5 Multiple frequency fields and multiple sources

In performing exposure evaluation all relevant frequency components and field sources have to be taken into account. Proper summation procedures given in ICNIRP Guidelines [7], ICNIRP Statement [8], EU Council Recommendation [9] and EU Workers Directive [10] have to be used. In order to get a more precise exposure evaluation in addition it may be necessary to take into account not only the amplitudes of electric and magnetic fields but also the phases of individual field components.

In the low frequency range (stimulation effects) current densities, electric and magnetic field strengths shall be superposed in a linear manner (weighted). In the high frequency range (thermal effects) power densities shall be superposed also in a linear manner, whereas electric and magnetic field strengths have to be superposed in a squared manner (weighted).

### 4.6 Exposure scenario



Depending on the field geometry, exposure evaluation has to be performed accordingly. That may require whole body or partial body exposure evaluation.

In the low-frequency range basic restrictions and exposure limit values are given for central nervous system (CNS) tissue only. For the assessment of inhomogeneous or highly- localized exposure situations (i.e. small sources used close to the body) this has to be taken into account.



## 5 Assessment of human exposure by measurement

Subclause 5.1 gives an overview of which measurements are necessary to assess human exposure to electric, magnetic and electromagnetic fields.

### 5.1 General remarks

Measurements of human exposure to electric, magnetic and electromagnetic fields can be classified as follows:

- measurement of electric, magnetic or electromagnetic field quantities (i.e. *B*, *E*, *H*, *S*);
- measurement of the limb induced current;
- measurement of the contact current;
- measurement of the Specific Absorption Rate (SAR);
- measurement of the temperature.

To make meaningful measurements, the behaviour and characteristics (for example frequency, time-variability of emission, input power) of the source of exposure (field or current) shall be determined and the operation of the measurement equipment understood. Irrespective of the type of signal, time domain measurement may be used. This can be especially helpful for non-sinusoidal, very fast, and pulsed signals. Also, the exposure quantities measured should include all those needed to assess the extent of human exposure arising from the operation of the source. What shall be measured is the maximum level to which someone is exposed under the operating conditions of the source that are used when a person is permitted access.

The expected emission characteristics of the source should be understood, and it should be confirmed that these match the results of measurements. Sometimes the source will be well documented, in which case the predicted emissions may be comparatively simple to establish. Sometimes the source will be undocumented and its characteristics must be determined mostly by measurement. There will also be influences on the behaviour of the source, such as ground conductivity, presence of reflecting objects etc. and these shall be considered.

Measurement equipment should be calibrated and suitable for the measurements to be made. The uncertainties associated with its use for the measurement undertaken shall be established.

Sometimes the exposure position is well defined, but often it may be necessary to determine the location at which maximum exposure will occur. This may be achieved by either a preliminary survey of the areas around a source or by the setting up a spatial 2D/3D-measurement matrix. Measurements should be made at all positions on the matrix. When the position of maximum exposure has been identified then detailed measurements should be made. The distances between different measurement points will depend e.g. on the kind of chosen measurement method and on frequency.

The assessment of internal electromagnetic field quantities in general can be difficult or impossible since internal quantities in real organisms cannot be measured directly. Consequently, studies to assess them are carried out using physical or numerical models of the human body referred to as phantoms. The physical and electric characteristics (dielectric properties) of experimental phantoms are manufactured to represent as closely as possible the response of a person to an incident electromagnetic field.

## 5.2 EM field measurement

### 5.2.1 General remarks

The field to be measured shall be the unperturbed field (without presence of a person).

EM field measurements have to differentiate between low- and high-frequency field measurements.

The range for low frequency measurements is from 0 Hz up to 100 kHz and the range for high frequency measurements is from 100 kHz up to 300 GHz.



NOTE The underlying physiological effects of electromagnetic fields on the human body have no sharp frequency limit value to distinguish between stimulation and thermal effects; this also shows up in the selection of the measurement equipment necessary.



For meaningful EM field measurements to be carried out the following information needs to be known:

– the type of field source, e.g. supply current and voltage, radiated power;
– the characteristics of the source of field e.g. frequency, operational behaviour, modulation, duty cycle;
– the measuring instruments and their characteristics e.g. measurement principle;
– the evaluation bases such as standards, limit values etc.;
– the uncertainty of the measurements.

Once these are known the most appropriate method of field measurement can be chosen.

### 5.2.2 Measurement equipment

EM field measurement equipment consists of two parts, the probe or field sensing element, and the measuring instrument, which processes the signal from the probe and indicates the value of the EM field quantity with an analogue or digital display.

The measuring equipment should be suitable for the desired application. The characteristics of the relevant sources, the environmental conditions of the locations where persons can be present and the characteristics of the measuring system should be taken into account.

The following aspects of measuring equipment should be considered:

- the equipment should have sufficient dynamic and frequency range for the particular application. The measurement equipment should be designed for practical use in rough industrial environment and for outdoor use, e.g. broadcasting towers, where this is appropriate;
- generally, field measurement equipment can be differentiated into broadband and narrowband (frequency selective) instrumentation;

- frequency selective measurement equipment can provide information on field strength and also information about the spectral characteristics of the measured fields. Typically spectrum analysers, tuned receivers or pass-band filters are used for this purpose. Narrow band instrumentation could be used if frequency resolution and higher sensitivity is needed or where the signal to be measured is discontinuous (e.g. pulse-modulated with a low pulse repetition frequency);
- broadband measurement equipment normally indicates field strengths independent of signal frequency.

### 5.2.3 Measuring instrumentation

In most cases, measuring instruments should respond to, and indicate, r.m.s. values, but for some purposes, instruments responding to peak values should be used. This may apply, for example, if the peak value is well-defined but the r.m.s. value varies considerably with time and with the averaging time of an r.m.s. measurement.

Several factors may influence the measurement results and should be observed carefully. A non-exhaustive list of such factors is given below:

- **Power supply**

  The instrument shall not be influenced by fields from its own power supply. It shall also be unaffected by any interaction of external fields with its power supply or mains connection. It is often preferable for the equipment to be operated from batteries.

- **Measurement range**

  The measurement range of the instrumentation is required to be in accordance with the field strengths to be measured.

  The sensitivity should be sufficient to determine the lowest level to be measured within the accuracy at that level as stated by the instrument's manufacturer.

- **Frequency range**

  

  The frequency range of the measuring equipment should be sufficient to cover the frequencies of the EM field sources to be characterised.

- **Sampling rate**

  

  The sampling rate of the measuring instrument shall be higher than twice the highest signal frequency.

- **Integration time**

  The integration time for an r.m.s. measurement shall exceed the period of the lowest frequency, or modulation frequency, present in the signal. In some cases, a much longer time is required in order to obtain a stable and repeatable measured value.

- **Readability of display**

  In order for the operator to be far enough away from the meter to avoid perturbation of the EM field, the display shall be easy to read from a distance. Alternatively, the use of remote displays is recommended.

- **Uncertainty**

  The uncertainty of the measuring equipment shall be known and has to be considered in the final assessment.

- **Environmental conditions**

  The measuring equipment shall be appropriate to the environmental conditions (e.g. temperature, humidity, vibration, EMC-phenomena) existing at the time of measurement.

- **Response to ionising radiation, light and out-of-band electromagnetic fields**

  The response of the measuring equipment to ionising radiation, artificial light, sunlight or corona discharge should be considered. The response of the instrument to out-of-band fields should be specified for both magnetic and electric fields.

- **Overload and failure levels**

  Overload and failure levels of the instruments including the probes shall be specified for continuous wave (CW) and pulsed signals within the frequency range of the probe.