SLOVENSKI STANDARD
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Basic standard for the measurement of Specific Absorption Rate related to human exposure to electromagnetic fields from mobile phones (300 MHz - 3 GHz)

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Grundnorm zur Messung der Spezifischen Absorptionsrate (SAR) in Bezug auf die Sicherheit von Personen in elektromagnetischen Feldern von Mobiltelefonen (300 MHz bis 3 GHz)

Norme de base relative à la mesure du Débit d'Absorption Spécifique relatif à l'exposition des personnes aux champs électromagnétiques émis par les téléphones mobiles (300 MHz - 3 GHz)

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English version

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CENELEC

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

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Foreword

This European Standard was prepared by the Technical Committee CENELEC TC 211, Electromagnetic fields in the human environment.

The text of the draft was submitted to the Unique Acceptance Procedure and was approved by CENELEC as EN 50361 on 2001-07-03.

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)	2002-03-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2003-03-01

Annexes designated "normative" are part of the body of the standard.
Annexes designated "informative" are given for information only.
In this standard, annex D is normative and annexes A, B and C are informative.

Contents

1 Scope

This basic standard applies to any electromagnetic field (EM) transmitting devices intended to be used with the radiating part of the equipment in close proximity to the human ear including mobile phones, cordless phones, etc. The frequency range is 300 MHz to 3 GHz.

The objective of the standard is to specify the method for demonstration of compliance with the specific absorption rate (SAR) limits for such equipment.

2 Normative references

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 197 of 30 July 1999)

International Commission on Non-Ionising Radiation Protection (1998), *Guidelines for limiting exposure in time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)*. Health Physics 74, 494-522

ISO/IEC 17025:1999, *General requirements for the competence of testing and calibration laboratories*

IEC “*Guide to the expression of uncertainty in measurement*”, Ed. 1, 1995.

Phantom CAD files, *SAM_in*, *SAM_out* in 3D-IGES and DXF formats, and reference SAR distributions publicly available on CD-ROM.

3 Physical quantities, units and constants

3.1 Physical quantities

The internationally accepted SI-units are used throughout the standard.

Quantity	Symbol	Unit	Dimensions
Current density	J	ampere per square metre	A/m^2
Electric field strength	E	volt per metre	V/m
Electric flux density	D	coulomb per square metre	C/m^2
Electric conductivity	σ	siemens per metre	S/m
Frequency	f	hertz	Hz
Magnetic field strength	H	ampere per metre	A/m
Magnetic flux density	B	tesla (Vs/m^2)	T
Mass density	ρ	kilogram per cubic metre	kg/m^3
Permeability	μ	henry per metre	H/m

Permittivity	ε	farad per metre	F/m
Specific absorption rate	SAR	watt per kilogram	W/kg
Wavelength	λ	metre	m
Temperature	T	kelvin	K
Heat capacity	c_i		J/kg K

NOTE In this standard, temperature is quantified in degrees Celsius, as defined by:

$$T(°C) = T(K) – 273,16$$

3.2 Constants

Physical constant		Magnitude
Speed of light in vacuum	c	$2{,}998 \times 10^{8}$ m/s
Permittivity of free space	ε_0	$8{,}854 \times 10^{-12}$ F/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ H/m
Impedance of free space	Z_0	120π or 377 Ω

4 Definitions

4.1.1
average (temporal) absorbed power (P_{avg})
the time-averaged rate of energy transfer defined by:

$$\bar{P}_{avg} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} P(t)dt \qquad (4.1)$$

where t_1 and t_2 are the start and stop time of the exposure. The period t_2 - t_1 is the exposure duration time

4.1.2
averaging time (t_{avg})
the appropriate time over which exposure is averaged for purposes of determining compliance with the limits

4.1.3
basic restriction
the basic restrictions are the restrictions on exposure to time-varying electric, magnetic, and electromagnetic fields that are based directly on established health effects. Concerning the frequency range of this standard, the physical quantity used is the Specific Absorption Rate (SAR)

4.1.4
boundary effect
in this context the boundary effect is the influence of the boundaries between two media of the phantom on the sensitivity of the probe, as well as the influence of the probe on the field distribution and the current density if the probe approaches the boundary between two media

4.1.5
CAD
acronym for Computer Aided Design. Standard formats are IGES and DXF

4.1.6
continuous exposure
exposure for a duration exceeding the averaging time

4.1.7
detection limits
the lower (respectively upper) detection limit is defined by the minimum (respectively maximum) quantifiable response of the measuring equipment

4.1.8
dielectric constant (ε)
see permittivity

4.1.9
duty factor
ratio of the pulse duration to the pulse period of a periodic pulse train. A duty factor of 1 means that the duration of the period is equal to the duration of the pulse

4.1.10
electric conductivity (σ)
the ratio of the conduction-current density in a medium to the electric field strength. Electric conductivity is expressed in units of siemens per metre (S/m)

4.1.11
electric field strength (*E*)
the magnitude of a field vector at a point that represents the force (***F***) on a positive small charge (***q***) divided by the charge

$$E = \frac{F}{q} \quad (4.2)$$

Electric field strength is expressed in units of volts per metre (V/m)

4.1.12
electric flux density (*D*)
the magnitude of a field vector that is equal to the electric field strength (*E*) multiplied by the permittivity (ε)

$$\boldsymbol{D} = \varepsilon \boldsymbol{E} \quad (4.3)$$

Electric flux density is expressed in units of coulomb per square metre (C/m^2)

4.1.13
intrinsic impedance (of free space)
the ratio of the electric field strength to the magnetic field strength of a propagating electromagnetic wave. The intrinsic impedance of a plane wave in free space is 120 π ohms (approximately 377 ohms)

4.1.14
isotropy
deviation of the measured value with regard to various angles of incidence of the measured signal. In this document it is defined for incidences covering a hemisphere centred at the tip of the probe, with an equatorial plane normal to the probe and expanding outside the probe. The axial isotropy is defined by the maximum deviation of the SAR when rotating the probe along its main axis with the probe exposed to a reference wave with normal incidence with regard to the axis of the probe. The hemispherical isotropy is defined by the maximum deviation of the SAR when rotating the probe along its main axis with the probe exposed to a reference wave with varying angles of incidences with regard to the axis of the probe in the half space in front of the probe

4.1.15
linearity
maximum deviation over the measurement range of the measured quantity from the closest linear reference curve defined over a given interval

4.1.16
loss tangent
the loss tangent *tan(δ)* is the ratio of the imaginary part of the complex dielectric constant of a material to its real part

4.1.17
magnetic flux density (*B*)
the magnitude of a field vector that is equal to the magnetic field strength H multiplied by the permeability (μ) of the medium.

$$B = \mu\ H \tag{4.4}$$

Magnetic flux density is expressed in units of tesla (T)

4.1.18
magnetic field strength (*H*)
the magnitude of a field vector in a point that results in a force ($\vec{F}$) on a charge q moving with the velocity $\vec{v}$

$$\vec{F} = q(\vec{v} \times \mu\vec{H}) \tag{4.5}$$

The magnetic field strength is expressed in units of ampere per metre (A/m)

4.1.19
measurement range
the measurement range is the interval of operation of the measurement system, which is bounded by the lower and the upper detection limits

4.1.20
mobile phone
for the purpose of this standard, the term “Mobile Phone” covers any equipment within the scope of this standard

4.1.21
multi-band
a multi-band mobile phone is operating in one single radiocommunication system (mode) in various frequency bands, e.g., GSM 900 and GSM 1 800

4.1.22
multi-mode
a multi-mode mobile phone is operating with various radiocommunication systems, e.g., GSM and DECT

4.1.23
permeability (μ)
the magnetic permeability of a material is defined by the magnetic flux density *B* divided by the magnetic field strength *H*:

$$\mu = \frac{B}{H}, \qquad (4.6)$$

where μ is the permeability of the medium expressed in henry per metre (H/m)

4.1.24
permittivity (ε)
the property of a dielectric material, e.g., biological tissue, defined by the electrical flux density *D* divided by the electrical field strength E.

$$\varepsilon = \varepsilon_r . \varepsilon_0 = \frac{D}{E}$$
$$\varepsilon_r = \varepsilon_r' - j.\varepsilon_r'' = |\varepsilon_r| . e^{-j\delta} = \varepsilon_r' + \frac{\sigma}{j\omega\varepsilon_0} \qquad (4.7)$$

where

ε_r is t the complex relative permittivity

ε' is t the real part of the relative permittivity

ε'' is t the negative imaginary part of the relative permittivity

δ is the angle using Euler´s notation of the complex relative permittivity

σ is the conductivity

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

4.1.25
phantom
in this context a phantom is a simplified representation or a model similar in appearance to the human anatomy and composed of materials with electrical properties similar to the corresponding tissues

4.1.26
reference SAR distributions
the reference SAR distributions are derived from calculations of a set of configurations representative of the use of mobile phones. They shall be used for evaluation of uncertainties due to post-processing and mismatching of probe and phantom references

4.1.27
response time
the response time is the time required by the measuring equipment to reach 90 % of its final value after a step variation of the exposure signal

4.1.28
scanning system
the scanning system is the automatic positioning system capable of placing the measurement probe at the specified positions

4.1.29
sensitivity
the sensitivity of the measurement system is the ratio of the magnitude of its response (i.e. voltage) to the magnitude of the quantity measured (i.e. electric field square)

4.1.30
skin depth
the skin depth is defined as the distance from the boundary of a medium to the point at which the field strength or induced current density have been reduced to 1/e of their boundary values. Skin depth is expressed in meters (m)

4.1.31
Specific Absorption Rate (SAR)
the time derivative of the incremental electromagnetic energy *(dW)* absorbed by (dissipated in) an incremental mass *(dm)* contained in a volume element *(dV)* of given mass density (ρ)

$$SAR = \frac{d}{dt}\left(\frac{dW}{dm}\right) = \frac{d}{dt}\left(\frac{dW}{\rho dV}\right) \quad (4.8)$$

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

NOTE SAR can be calculated by:

$$SAR = \frac{\sigma E_i^{\,2}}{\rho} \quad (4.9)$$

$$SAR = c_i \left.\frac{dT}{dt}\right|_{t=0} \quad (4.10)$$

where

E_i: rms value of the electric field strength in the tissue in V/m

σ: conductivity of body tissue in S/m

ρ: density of body tissue in kg/m^3

c_i: heat capacity of body tissue in J/kg K

$\left.\frac{dT}{dt}\right|_{t=0}$ initial time derivative of temperature in body tissue in K/s

4.1.32
wavelength (λ)
the wavelength (λ) of an electromagnetic wave is related to the frequency (*f*) and speed of light (*c*) by the expression $c = f\,\lambda$. In free space the velocity of an electromagnetic wave is equal to the speed of light

5 Measurement system specifications

The measurement system is composed of the phantom, the SAR measurement equipment, the scanning system and the mobile phone holder.

5.1 General requirements

The test shall be performed using a miniature probe that is automatically positioned to measure the internal E-field distribution in a phantom model representing the human head exposed to the EM fields produced by mobile phones. From the measured E-field values, the SAR distribution and the maximum mass averaged SAR value shall be calculated.

The test shall be performed in a laboratory conforming to the following environmental conditions:

- the ambient temperature shall be in the range of 15 °C to 30 °C and the variation shall not exceed ± 2 °C during the test;

- the mobile phone shall not interact with the local mobile networks;
- care shall be taken to avoid significant influence on SAR measurements by ambient EM sources;
- care shall be taken to avoid significant influence on SAR measurements by any reflection from the environment (such as floor, positioner, etc.).

Validation of the system shall be done at least once a year according to the protocol defined in annex D.

5.2 Phantom specifications (shell and liquid)

5.2.1 General requirements

The physical characteristics of the phantom model (size and shape) shall resemble the head and neck of a user since the shape is a dominant parameter for exposure. The phantom shall be made from material with dielectric properties similar to those of head tissues. To enable field scanning within it, the material shall be liquid contained in a head and neck shaped shell model. The shell model acts as a shaped container and shall be as unobtrusive as possible. The hand shall not be modelled (see annex A).

5.2.2 Phantom shape and size

The phantom shape is based on the size and dimensions of the 90 percentile large adult male reported in a 1989 anthropomorphic study and has been adapted to represent the flattened ear of a mobile phone user (see annex A). A physical representation of these requirements is shown in Figure 1.a and Figure 1.b.

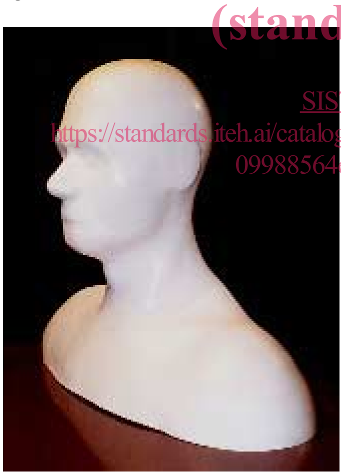

Figure 1.a

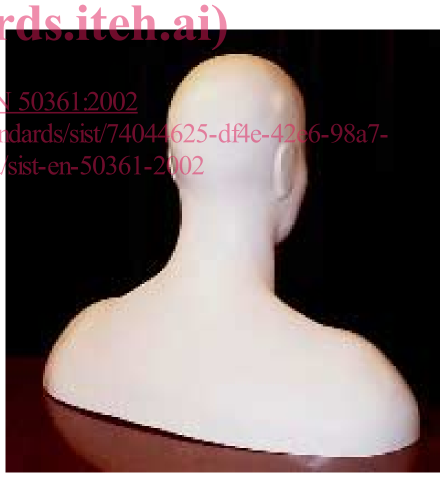

Figure 1.b

Figure 1 - Picture of the phantom

The Specific Anthropomorphic Mannequin (SAM) shall be used for SAR measurements. CAD files of the inner surface (*SAM_in*) and outer surface (*SAM_out*) of the reference phantom used in this standard are publicly available in 3D-CAD formats including 3D-IGES and DXF on CD-ROM.

5.2.3 Phantom shell

The shell of the phantom shall be made of low loss and low permittivity material: $\tan(\delta) \leq 0{,}05$ and $\varepsilon \leq 5$. The thickness of the phantom is defined in the CAD files and the tolerance shall be $\pm$ 0,2 mm in the area defined in the CAD files (where the phone touches the head).

Reference points on the phantom:

The probe positioning shall be defined in relation to three well defined points on the phantom. These points R1, R2 and R3 shall be used to calibrate the positioning system. Three other points, M for mouth, LE for left ear and/or RE for right ear (maximum acoustic coupling), shall be defined on the phantom(s) (see Figure 2). These points shall be used to allow reproducible positioning of the mobile phone in relation to the phantom.

These points are specified in the CAD files.

5.2.4 Liquid material properties

The dielectric properties of the liquid material required to fill the phantom shell shall be:

$$\varepsilon_r = 46{,}52 - 0{,}006\ f(\mathrm{MHz}) + 1{,}59\mathrm{x}10^{-6}\ f(\mathrm{MHz})^2 - 1{,}40\mathrm{x}10^{-10}\ f(\mathrm{MHz})^3 \qquad (5.1)$$

$$\sigma\ (\mathrm{S/m}) = 0{,}805\ 4 + 0{,}000\ 15\ f(\mathrm{MHz}) + 4{,}12\mathrm{x}10^{-8}\ f(\mathrm{MHz})^2 + 2{,}87\mathrm{x}10^{-11}\ f(\mathrm{MHz})^3 \qquad (5.2)$$

Table 1 - Dielectric properties of the liquid material

Frequency (MHz)	ε_r	σ (S/m)
300	45	0,85
450	44	0,88
900	42	0,99
1 450	41	1,20
1 800	40	1,38
2 450	39	1,84
3 000	39	2,40

The measured dielectric properties of the liquid shall be used in SAR calculations rather than the theoretical values defined in Equation 5.1 and Equation 5.2 and shown in Table 1. Examples of recipes for liquids defined in Table 1 used at mobile communication frequencies are proposed in annex A.

5.3 Specifications of the SAR measurement equipment

The measurement equipment shall be calibrated as a complete system. The probe shall be calibrated together with the amplifier, measurement device and data acquisition system. The measurement equipment shall be calibrated in each tissue equivalent liquid at the appropriate operating frequency and temperature according to the methodology defined in annex B.

The minimum detection limit shall be lower than 0,02 W/kg and the maximum detection limit shall be higher than 100 W/kg. The linearity shall be within ± 0,5 dB over the SAR range from 0,02 to 100 W/kg. The isotropy shall be within ± 1 dB. Sensitivity, linearity and isotropy shall be determined in the tissue equivalent liquid. The response time shall be specified.

In order to meet these requirements, it is recommended that the length of the individual sensing elements in the E-field probe shall not exceed 5 mm and that the outside dimension of the protective cover shall not exceed 8 mm.

If the measured signal is a pulsed signal, e.g., a TDMA frame, the integration and averaging time of the SAR measurement equipment (based on rms-detection) shall be able to yield results reproducible to within ± 5 %.

5.4 Scanning system specifications

5.4.1 General requirements

The scanning system holding the probe shall be able to scan the whole exposed volume of the phantom in order to evaluate the three-dimensional SAR distribution. The mechanical structure of the scanning system shall not interfere with the SAR measurements.

5.4.2 Technical requirements

Accuracy:

The accuracy of the probe tip positioning over the measurement area shall be less than ± 0,2 mm.

Sampling resolution:

The sampling resolution is the step at which the measurement system is able to perform measurements. The sampling resolution shall be 1 mm or less.

5.5 Mobile phone holder specifications

The mobile phone holder shall permit the phone to be positioned according to the definitions given in 6.1.4 with a tolerance of ± 1° in the tilt angle. It shall be made of low loss and low permittivity material(s): $\tan(\delta) \leq 0{,}05$ and $\varepsilon_r \leq 5$.

5.6 Other equipment

5.6.1 Measurement of liquid dielectric properties

The dielectric properties of the tissue equivalent liquid shall be measured at the relevant frequency and temperature. This measurement can be performed using the equipment and procedure described in annex A.

6 Protocol for SAR assessment

6.1 Measurement preparation

6.1.1 General preparation

The dielectric properties of the tissue equivalent materials shall be measured prior to the SAR measurements and at the same temperature with a tolerance of ± 2° C. The measured values shall comply with the values defined at the specific frequencies in 5.2.4. with a tolerance of ± 5 % for relative permittivity and conductivity. The measurement procedures are described in annex A.

The phantom shell shall be filled with the tissue equivalent liquid. The depth of the tissue equivalent liquid inside the phantom and at the vertical position of the ear canal shall be at least 15 cm. The liquid shall be carefully stirred before the measurement and it shall be free of air bubbles.

The coordinate system of the scanning system shall be aligned to the coordinate system of the phantom with a tolerance of ± 0,2 mm.

6.1.2 Simplified performance checking

A simplified performance check and a noise level check according to 7.2.1.7 shall be made before the measurements if any of the above parameters are changed.

The purpose of the simplified performance check is to verify that the system operates within its specifications. The simplified performance check is a simple test of repeatability to make sure that the system works correctly during the compliance test. The simplified performance check shall be performed in order to detect possible drift over short time periods and other errors in the system, such as:

- changes in the liquid parameters, e.g., due to water evaporation or temperature change,
- component failures,
- component drift,
- operator errors in the set-up or the software parameters,
- adverse conditions in the system, e.g., RF interference.

The simplified performance check shall be carried out according to annex D. It shall be a measurement of the 10 g averaged SAR using a simplified set-up with a dipole source. The components and procedures in the simplified performance check are the same as those used for the compliance tests. The simplified performance check shall be performed prior to compliance tests and the result shall be within ± 10 % of the target value. The target value shall be determined in the system itself, e.g., after the system validation check. The simplified performance check shall be performed at a central frequency of each transmitting band of the mobile phone.

6.1.3 Preparation of the mobile phone under test

The tested mobile phone shall use its internal transmitter. The antenna(s), battery and accessories shall be those specified by the manufacturer. The battery shall be fully charged before each measurement and there shall be no external connections.

The output power and frequency (channel) shall be controlled using an internal test program or by the use of appropriate test equipment (base station simulator). The mobile phone shall be set to transmit at its highest output peak power level allowed by the system. If a wireless link is used, an antenna shall be connected to the output of the base station emulator. The antenna shall be placed at least 50 cm from the phone. The signal emitted by the emulator at antenna feed point shall be lower than the output level of the phone by at least 30 dB.

6.1.4 Position of the mobile phone in relation to the phantom

The mobile phone shall be tested in the “cheek” and “tilted” positions on left and right sides of the phantom.

Definition of the “cheek” position:

a) position the device with the vertical centre line of the body of the device and the horizontal line crossing the centre of the ear piece in a plane parallel to the sagittal plane of the phantom ("initial position" see Figure 2). While maintaining the device in this plane, align the vertical centre line with the reference plane containing the three ear and mouth reference points (M, RE and LE) and align the centre of the ear piece with the line RE-LE;

b) translate the mobile phone box towards the phantom with the ear piece aligned with the line LE-RE until the phone touches the ear. While maintaining the device in the reference plane and maintaining the phone contact with the ear, move the bottom of the box until any point on the front side is in contact with the cheek of the phantom or until contact with the ear is lost.