

Considerations for the evaluation of human exposure to electromagnetic fields (EMFs) from mobile telecommunication equipment (MTE) in the frequency range 30 MHz – 6 GHz

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National foreword

This Published Document, which has been prepared under the direction of the Electrotechnical Sector Policy and Strategy Committee, is identical with CENELEC European Specification ES 59005:1998.

The UK participation in its preparation was entrusted to Technical Committee GEL/211, Human exposure to electromagnetic fields, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

The SAR values considered are those given in DD ENV 50166-2:1995 *Human exposure to electromagnetic fields — High frequency (10 kHz to 300 GHz)* and ICNIRP:1998 (see clause 9).

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

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled “International Standards Correspondence Index”, or by using the “Find” facility of the BSI Standards Electronic Catalogue.

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European Committee for Electrotechnical Standardization
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Foreword

This European Standard has been prepared by SC 211B, High-frequency EM radiation, of Technical Committee CENELEC TC 211, Electromagnetic fields in the human environment.

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1 Introduction

This work was carried out in response to mandate M/032 derived from Directives 91/263/EEC and 73/23/EEC which requests guidance on procedures to evaluate human exposure to mobile telecommunication equipment. This document presents procedure for the evaluation of specific absorption rate (SAR) resulting of such exposure. The SAR values considered in this document are those of the ENV 50166-2 [ENV, 1995] and ICNIRP [ICNIRP, 1998].

2 Scope

The purpose of this European Specification (ES) is to specify the measurement and numerical modelling requirements for testing compliance of mobile telecommunication equipment (MTE) in the frequency range of 30 MHz to 6 GHz with the basic restrictions in terms of SAR.

It does not consider the effects of electromagnetic fields on implants, such as cardiac pacemakers. Additional considerations may also be necessary for persons with metallic implants in the area of the brain or ear (i.e. metal plates or clamps).

MTE are all types of telecommunications equipment classified as “mobile” in the Radio Regulations of the ITU, Chapter 1 “terminology”, Article 1 “terms and definitions”, Section IV “radio stations and systems”. The list of the equipment falling under this category is comprised of the following categories: survival craft station (4.5), mobile station (4.8), mobile earth station (4.9), land mobile station (4.12), land mobile earth station (4.12A), ship station (4.15), ship earth station (4.16), on-board communication station (4.17), aircraft station (4.21), aircraft earth station (4.22), radionavigation mobile station (4.25), radiolocation mobile station (4.287).

Although this report assumes a fairly wide interpretation of the word “mobile” (also see annex A), the material herein concentrates solely on hand-held and other portable wireless MTE.

3 Physical quantities, units and constants

3.1 Quantities

The internationally accepted SI-units are used throughout this specification.

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	Kilo per cubic metre	kg/m^3
Permeability	μ	Henry per metre	H/m
Permittivity	ϵ	Farad per metre	F/m
Power density	S	Watt per square metre	W/m^2
Specific absorption rate	SAR	Watt per kilogram	W/kg
Wavelength	λ	Metre	m
Temperature	T	Kelvin	K

3.2 Constants

Physical constant		Magnitude
Velocity of light	c	$2,997 \times 10^8$ 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 377Ω

4 Terms and definitions

4.1

average (temporal) absorbed power ($\bar{P}_{avg}$)

the time-averaged rate of energy transfer defined by:

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

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.

4.2

averaging time (t_{avg})

the appropriate time over which exposure is averaged for purposes of determining compliance with the limits

4.3

basic restriction

the basic restriction is the limits that should not be exceeded under any conditions. The basic restriction includes the necessary safety margins

4.4

conductivity (σ)

the ratio of the conduction-current density in a medium to the electric field strength. Conductivity is expressed in units of Siemens per metre (S/m)

4.5

continuous exposure

exposure for a duration exceeding the corresponding averaging time. Exposure for less than the averaging time is called short-term exposure

4.6

dielectric constant (ϵ), see permittivity

4.7

duty factor (duty cycle)

the ratio of pulse duration to the pulse period of a periodic pulse train. A duty factor of unity corresponds to continuous-wave operation

4.8

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)

4.9

electric flux density (D)

the magnitude of a field vector that is equal to the electric field strength (E) multiplied by the permittivity (ϵ)

$$D = \epsilon E \quad (4.3)$$

electric flux density is expressed in units of coulomb per square metre (C/m²)

4.10

exposure

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

4.11

exposure level

the value of the quantity used when a person is exposed to electromagnetic fields or contact currents

4.12

exposure, direct effect of

the result of a direct interaction of the exposed human body with electromagnetic fields

4.13

exposure, partial-body

partial-body exposure results from concentrated deposition of the energy

4.14

exposure, non-uniform

non uniform exposure levels result when fields are non uniform over volumes comparable to the whole human body. This may occur due to standing-waves, scattered radiation or in the near field of active or passive radiators. See RF "hot spot" and "exposure, partial body"

4.15

far field region

in this region, the field has a predominantly plane-wave character, i.e. locally uniform distributions of electric and magnetic field strengths in planes transverse to the direction of propagation

4.16

general public

all persons except the persons defined as workers

4.17

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 approximately 377 Ω

4.18

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

$$B = \mu H \quad (4.4)$$

magnetic flux density is expressed in units of Tesla (T)

4.19

magnetic field strength (H)

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

$$F = q (v \times \mu H) \quad (4.5)$$

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

4.20

near-field region

a region generally in the proximity of 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 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 complicated in structure

NOTE For many antennas, the outer boundary of the reactive near field region is commonly taken to exist at a distance of one-half wavelength from the antenna surface (see 4.15).

4.21

permeability (μ)

the magnetic permeability of a material is defined by the magnetic flux density B divided by the magnetic field strength H :

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

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

4.22

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

$$\epsilon = \frac{D}{E} \quad (4.7)$$

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

4.23

power flux density (S)

power per unit area normal to the direction of electromagnetic wave propagation, usually expressed in units of watts per square metre (W/m²)

NOTE For plane-waves electric field strength (E) and magnetic field strength (H) are related by the intrinsic impedance of the medium. For free space:

$$S = \frac{E^2}{377} = 377 H^2 = EH \quad (4.8)$$

where

E and H are expressed in units of V/m and A/m, respectively; and

S is expressed in units of W/m².

although many survey instruments indicate power density units, the actual quantities measured are E or H

4.24

power flux density, plane-wave equivalent

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

4.25

reference level

the rms and peak electric and magnetic field strengths or the plane-wave equivalent power densities associated with these fields and the induced and contact currents, all derived from the basic restrictions, to which a person may be exposed without adverse effect and with an acceptable safety factor. The reference values may be exceeded, provided that the basic restrictions are met

4.26

radio frequency (RF)

for purposes of these safety considerations, the frequency range of interest is 30 MHz to 6 GHz

4.27

RF hot spot

a highly localized area or volume of irradiation or absorption due to scattered radiation, focusing effects or other non-homogenities

4.28

root-mean-square (rms)

the effective value or rms value is obtained by taking the square root of the average of the square of the value of the periodic function taken throughout one period

4.29

root-sum-square (rss)

the rss value or the Hermitian magnitude of a vector v is obtained by the square root of the sum of the squared rms values of all three orthogonal components of vector v . The rss value is proportional to the joule heating and can be quite different from the rms amplitude of vector v

4.30

short-term exposure

an exposure duration of less than the specified averaging time

4.31

specific absorption rate (SAR)

the time derivative of the incremental energy (dW) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dV) of given mass density (ρ)

$$\text{SAR} = \frac{d}{dt} \left(\frac{dW}{dm} \right) = \frac{d}{dt} \left(\frac{dW}{\rho dV} \right) \quad (4.9)$$

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

NOTE SAR can be calculated by:

$$\text{SAR} = \frac{\sigma E_i^2}{\rho}$$
(4.10)

$$\text{SAR} = c_i \frac{dT}{dt}$$
(4.11)

$$\text{SAR} = \frac{J^2}{\rho \sigma}$$
(4.12)

where

- E_i is the rms value of the electric field strength in the tissue in V/m;
- σ is the conductivity of body tissue in S/m;
- ρ is the density of body tissue in kg/m³;
- c_i is the heat capacity of body tissue in J/kg K;
- $\frac{dT}{dt}$ is the time derivative of temperature in body tissue in K/s;
- J is the magnitude of the induced current density in the body tissue in A/m².

4.32
wavelength (λ)

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

4.33
workers

employed and self-employed persons are termed workers, whilst following their employment

5 References

The basic restrictions given in Table 1 are defined in the European Pre-standard ENV 50166-2 [ENV, 1995] and ICNIRP 1998 guidelines [ICNIRP, 1998] to protect the general public and workers from the adverse health effects of exposure to electromagnetic fields. The basic restrictions for workers should only apply when the MTE is used for work purposes only. If the MTE is neither technically nor administratively limited to workers use, the MTE should comply with the basic restrictions for the general public.

6 Measurements/simulations and modelling

6.1 Preliminary considerations

This section describes the measurement/simulation and modelling requirements for the procedures involved in testing compliance of MTE with the basic restrictions. Measurement and computational simulation procedures should be considered as suitable approaches under the conditions of 6.4. In case of numerical compliance testing, at least one position of mobile phone should be verified by measurements. The testing of compliance with the basic restrictions requires special considerations, particularly in extremely close near fields. In annex C several measurement and simulation techniques are described with respect to their suitability for testing compliance.

Compliance with the basic restrictions of Table 1 can be tested by directly determining the spatial distribution of the specific absorption rate (SAR) induced in experimental or theoretical phantoms representing the human body, from which the maximum SAR averaged over any 10 g of tissue shall be determined.

Procedures described in this section shall be used to demonstrate compliance with the basic restrictions.

6.2 Basic requirements

The method should ensure that the assessed SAR values do not underestimate the exposure of a reasonable cross-section of mobile telecommunications users, including children¹⁾, under the tested operational conditions. It should also take into account the manufacturing tolerances.

The MTE should be tested under operational conditions at the highest power at the central transmitting band frequency. Tests shall be performed for each configuration (e.g. with all antennas provided) and for each system with which the MTE can operate (multi-system devices).

Test procedures should give reproducible results for all devices and various operating conditions.

Table 1 — Basic restrictions

	SAR averaged over any 6 min time interval and over the whole body	SAR averaged over any 6 min time interval and any 10 g ^a tissue other than hands, wrists, feet, ankles	SAR averaged over any 6 min time interval and any 10 g ^a tissue in the hands, wrists, feet, ankles
General population	0.08 W/kg	2 W/kg	4 W/kg
Workers	0.4 W/kg	10 W/kg	20 W/kg

^a For practical reasons the averaging mass has been chosen as a cube, as specified in the ENV 50166-2.

¹⁾ The group of users shall also include children of three years and older. The group of users can be covered based on worst-case considerations without knowing the actual maximum local SAR value induced in the group of users.

6.3 Operational conditions for certain classes of devices

The technical realization and handling differ significantly for types of MTEs. Hence, the operational conditions for each class of MTE must be well defined for testing.

6.3.1 Hand-held mobile phones

In this context hand-held mobile phones are those cellular telephones consisting of one unit with integrated microphone, ear piece, transceiver and antenna. When testing the compliance of these devices with basic SAR values, measurements must be taken under the exposure conditions specified below.

6.3.1.1 Intended use

The intended or normal operating condition of the MTE is generally established by fully extending the antenna of the MTE, i.e. when the case plus the antenna are extended to the maximum possible overall length.

The intended use or normal position is a position which is convenient and provides good acoustic coupling. If the manufacturer does not specify the intended use position, then it is defined as follows and illustrated in Figure 1.

- a) The centre of the ear piece shall be placed directly at the entrance of the auditory canal.

- b) The reference line of the phone is defined to be the "tangential" line (on the surface of the phone's case facing the phantom) which connects the centre of the ear piece with the centre of the bottom of the case (typically near the microphone). Exceptions would be foldable phones or phones with flip covers, for which the reference is defined to be the line (on the surface of the phone's case facing the phantom) which connects the centre of the ear piece with the centre of the hinge. For strongly curved phones ("banana" shaped phone), the reference line must be specified by the manufacturer.

- c) The reference line defined above shall lie in the reference plane defined by the following three points: auditory canal openings of both ears and the centre of the closed mouth. The plane of the earpiece of the device is normal to the reference plane.

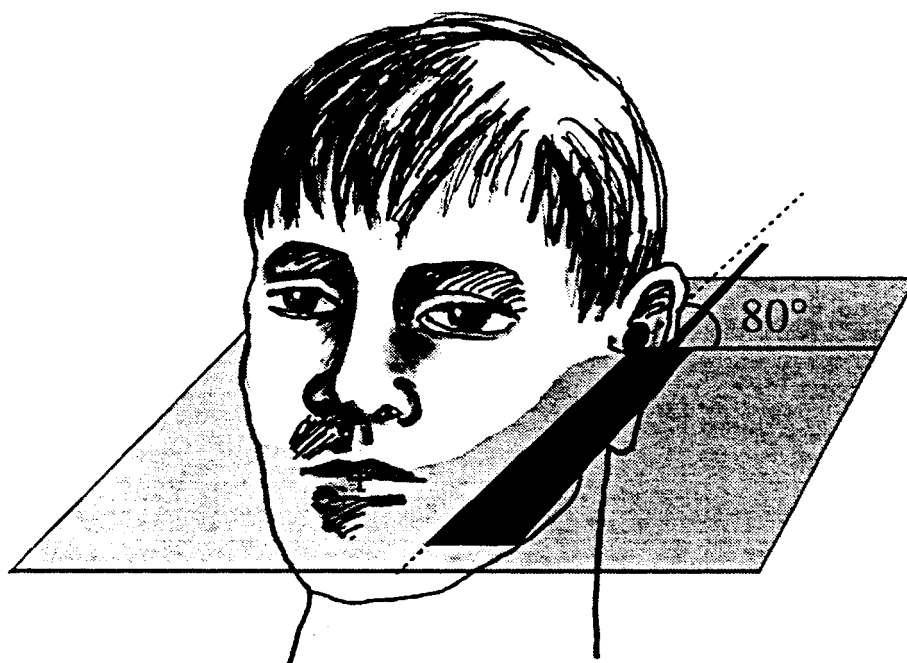


Figure 1 — Intended use position

6.3.1.2 Test operational conditions and positions

Since it is often difficult for the user of a hand-held mobile phone to precisely control the position of the device with respect to the head, considerable variations of this intended use cannot be avoided. Parallel shifts as well as different orientations must be expected. Since the range of parallel shifts can be covered by the requirements for the modelling of the head (see 6.4.1), the following additional operational conditions shall cover the variation range of the intended use orientation.

- 1) The intended use position is defined by an angle of 80° between the reference line of the phone and the line connecting both auditory canal openings. If this position is not applicable, then it may be deduced by referring to the user's manual.
- 2) The angle between the reference line of the phone and the line connecting both auditory canal openings shall be reduced until the device touches the face of the phantom.
- 3) The angle between the reference line of the phone and the line connecting both auditory canal openings shall be increased to 100° , provided that the antenna does not touch the head. If the antenna does touch the head before an angle of 100° has been reached, this smaller angle shall be applied.
- 4) The reference plane shall be tilted by 30° in the direction of the body's axis, whereby the angle between the reference line of the phone and the line connecting both auditory canal openings shall be 90° .

6.3.1.3 Conditions to be tested

Tests shall be done in the intended use and additional positions. If the antenna can be extended, tests shall be performed for the antenna fully extended and fully retracted, in all the positions defined 6.3.1.2 as well as the intended use position defined in 6.3.1.1²⁾.

The phones shall be tested for both right-hand and left-hand use, i.e. phone on the right or left side of the head.

6.3.2 MTE held in front of the face

This section applies to MTE held in front of the face. The appropriate minimum operational distance between the centre of the mouth and the microphone should be clearly indicated in the user manual, or preferably on the device. If the minimum operational distance is larger than 5 cm, the tests shall be conducted at a distance of 5 cm between the centre of the mouth and the microphone, otherwise at the specified distance.

The vertical axis of the radio shall be parallel to the axis of the phantom, whereby the line perpendicular to the axis through the centre of the closed mouth shall meet the centre of the microphone which faces the phantom.

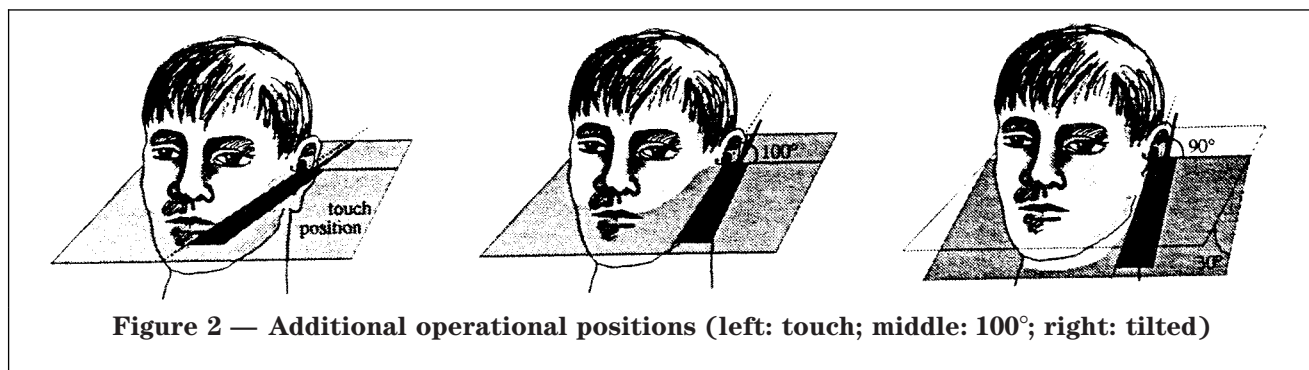
For duplex radios held like hand-held mobile phones, the test conditions of 6.3.1 shall apply.

6.3.3 Portable MTE

Portable MTEs are often used in close vicinity to the body. Most user manuals contain instructions on a minimum distance to be kept between the antenna and the human body. The measurement shall be made at this distance. If no distance is specified, the distance shall be 5 cm.

6.3.4 Other MTE

Additional guidelines for installation and test conditions for permanently-installed MTE are currently under consideration.



²⁾ Although operation with the antenna retracted does not correspond to the intended use condition, tests with the antenna retracted shall also be performed in the intended use position.

6.4 Basic technical requirements

6.4.1 Phantom requirements

The basic requirements for the phantom are as follows.

- The assessed SAR values with the phantom used shall either well represent the upper local SAR values occurring among a reasonable cross-section of users in the defined operational conditions³⁾ or shall allow to derive these values by using appropriate correction factors.
- The electromagnetic field externally scattered by the phantom shall be a good representation of the actual situation.
- The simulation of the hand is not required for frequencies above 380 MHz⁴⁾.
- The simulation of the upper body is required for frequencies larger than 380 MHz⁵⁾. For lower frequencies, a whole body phantom shall be used.
- The phantom shall enable to simulate both right and left hand operation (see 6.3.1.3) or as an alternative two laterally symmetrical phantoms can be used.
- The geometry and electric properties of the phantom should be specified.
- The compressed ear shall not be modelled thicker than 6 mm including the shell in experimental setups.
- The thickness of the shell of the phantom should be not greater than 4 mm.

6.4.2 Basic requirements for the dosimetric simulation software

The basic requirements for the dosimetric simulation software are as follows:

- ability to model a phantom satisfying the requirements of 6.4.1;
- appropriate electromagnetic modelling of the MTE in all the operational positions and conditions described in 6.3⁶⁾;
- appropriate simulation of the near-field coupling between head and device;
- capability of assessing the solution and modelling uncertainties as defined in 6.5⁷⁾.

6.4.3 Basic requirements for the dosimetric measurement system

The general requirements for the dosimetric measurement system are as follows.

- The three-dimensional SAR distribution must be determined in the exposed body part⁸⁾. Only part of the exposed body must be scanned if it can be demonstrated that the maximum local SAR occurs within that volume.
- If the local SAR at and close to the surfaces between different materials cannot be directly determined, then a procedure shall be established to assess the SAR at the surface (by appropriate extrapolation procedure).
- Appropriate measures must be taken to avoid significant errors due to reflections from objects or nearby walls. Special consideration with respect to the test environment is required for operational frequencies, i.e. below 380 MHz.
- The system must ensure accurate time-averaged SAR values for different modulated emission.
- Care should be taken to avoid significant influence on SAR measurements by environmental sources.
- Interpolation and extrapolation procedures should be reported.

6.5 Assessment of uncertainties

The measured or calculated SAR values plus the uncertainty should be less than the basic restriction. The uncertainty shall be determined following the definitions of [NIS81, 1994]. The uncertainty analysis shall consider at least the following error sources.

6.5.1 Assessment of measurement errors

- Uncertainty of the electrical parameters of the phantom.
- Error due to deviation from isotropy.
- Error due to deviation from linearity.
- Error induced by unwanted interactions of the measurement equipment with the ambient low and high frequency fields.
- Error due to the assessment of the SAR near the surface of the phantom (boundary effects of the probe) and introduced by the extrapolation procedure.

³⁾ A way to derive such a generic worst-case phantom is given in annex B.

⁴⁾ The human hand is an anatomically and geometrically complex structure which can cover an MTE in almost an infinite number of configurations. Certain ways of holding the device with the hand significantly lower the induced SAR values and others not at all. Significant increases have never been observed. Thus, non-modeling of the hand represents a worst case method of holding the device. Below 380 MHz, the conductive coupling between device and body through the arm might enhance the radiation.

⁵⁾ Since the attenuation for body induced currents is substantial at frequencies above 380 MHz, enhancement effects due to body resonances can be neglected for handheld transmitters.

⁶⁾ In most cases, the modeling of the device as a metallic box is not appropriate, since constructional details, even internal details, may significantly alter the absorption.

⁷⁾ Code validation is not sufficient, since significant errors may be introduced by modeling uncertainties and non-physical solutions.

⁸⁾ It is generally difficult to predict *a priori* exactly where the maximum local SAR will occur in the segment of the body that is close to the radio. In complex phantoms the peak SAR may occur in any tissue, i.e. assessments of the induced SAR in all tissue types must be possible.

- Errors due to the interaction between the measurement device and the induced field.
- Uncertainty of the probe calibration (required for each frequency and tissue simulating material for which the system is used).
- Error at or close to a material discontinuity.
- Uncertainty due to the limited spatial resolution.
- Uncertainty due to the implemented averaging procedure (volume, time).
- Uncertainty of the phantom with respect to the maximal induced SAR values occurring among a reasonable cross-section of users (see 6.4.1).
- Uncertainty due to MTE positioning.

6.5.2 Assessment of errors in computational simulation procedures

- Uncertainties of each solution by appropriate numerical or experimental validation tools⁹⁾.
- Uncertainties due to inadequate modelling of the device and the antenna. A procedure to assess these uncertainties must be provided.
- Uncertainty due to effects on the output circuit of the transmitter from the proximity of the scatterer to the MTE.
- Uncertainty of the phantom with respect to the maximal induced SAR values occurring among a reasonable cross-section of users (see 6.4.1).

6.6 Testing procedure

Tests must be performed according to the following procedure.

- The tests must be performed by simulation software or a measurement system satisfying the requirements specified in 6.4.2 or 6.4.3 respectively, using a phantom satisfying the requirements specified in 6.4.1.
- All tests must be performed with the highest power under operational conditions (e.g. fully charged batteries, highest power level defined by the system).
- The maximum local SAR value shall be assessed in all positions as specified for the particular MTE in 6.3.

6.7 Verification procedures and documentation

- The values to be compared with the basic restrictions shall be achieved by adding the uncertainty assessed according to 6.5 to the measured or numerically obtained values.
- The documentation shall provide the maximum local SAR for all conditions and positions (6.3) to be tested. In addition, the method used for determining the uncertainty shall be documented.

6.8 Compliance criteria

Compliance is established when the maximum value found among the test operational conditions and positions defined in 6.3.1.2 is within the basic restrictions, defined in clause 5.

7 Exclusionary clause from SAR measurements/simulations

7.1 General

This clause allows exclusion of mobile telecommunication equipment from SAR measurements and/or modelling as defined in clause 6, when it can be ensured by other measures that the basic restrictions are satisfied. One more simple alternative mean is described in the following.

Such devices which emit low RF power and are used close to the body can be regarded as sources producing SAR values sufficiently below the basic restrictions when the RF radiating source and hardware fulfil the following conditions.

7.2 Exclusion condition

MTE generating a RF averaged output power below 20 mW, measured at the source impedance of the transmitter or as the equivalent isotropic radiated power (EIRP).

Under worst case conditions, the whole RF power of 20 mW is deposited in the tissue, resulting in a SAR maximum of 2 W/kg integrated over 10 g. Therefore, MTE generating RF output power below 20 mW can be regarded as producing SAR values below the basic limits of Table 1 for all intended operating conditions.

7.3 Test methods and compliance requirements

7.3.1 Test methods

If the mobile telecommunication device has an accessible RF output connector, the output power may be measured using a calibrated power metre. For mobile telecommunication equipment without accessible RF output connections (e.g. fixed mounted or built-in antenna) the EIRP values must be measured using the test procedures given in the relevant ETSI document [ETSI, 1991].

7.3.2 Requirements

The averaged output power should be below 20 mW measured at the source impedance of the transmitter or below 20 mW EIRP. The uncertainties of the test equipment must be taken into account.

8 Information

8.1 Additional information

The user should be additionally informed in the user manual of conditions that lead to the exposure limits being exceeded.

⁹⁾ Such tools must have been shown to be highly reliable, as every simulation may have its own potential sources of error (e.g., due to the wide variety of different antenna structures operating in the closest vicinity of the lossy scatterer).

9 References

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Annex A

Characteristics of mobile telecommunication equipment

A.1 Introduction

The aim of this annex is to provide some technical information on the various types of mobile telecommunication equipment in use in Europe and throughout the world. Only systems relevant to this document, i.e. in which the mobile unit is emitting RF energy, are considered. Systems for which the mobile unit is receiving only, such as paging, broadcasting or GPS (global positioning system), are not mentioned here.

A.5 of this annex provides detailed data on a great number of existing systems, presented by means of tables listing their characteristics.

A.2 briefly describes the characteristics of the main families of systems detailed in A.5.

A.3 gives general statistics on the number of users and the penetration rates (number of users per population) in the European countries for the cellular systems. Data provided represents the situation in January and June 1996, and the expected growth rate of these systems is such that it may change quickly in the next months and years.

A.4 explains the meaning and the importance with regard to exposure of the user of some of the different parameters gathered for each system in A.5.

Finally, A.6 gives the meaning of the abbreviations used throughout this annex.

Although an attempt has been made to include as many systems as possible, this annex is not supposed to be exhaustive; some existing systems (especially for the old generation systems that were defined on a country by country basis) as well as some planned or under development systems (for which the detailed characteristics are not presently known) are not mentioned here.

NOTE Data provided here has been carefully checked and reviewed. However, it is possible that some errors still exist.

A.2 General characteristics of the different families of MTE

Mobile telecommunication equipment can be divided into main categories, depending on the type of telecommunication network they use. Each family is briefly described below, a detailed list of systems belonging to each family is provided in A.4. As mentioned before, some applications such as paging are not described here.

A.2.1 *Private/professional mobile radio (PMR)*

Sometimes also called "professional" mobile radio, PMR systems are widely used to provide an internal communication network within a fleet of vehicles or individuals using hand-held units (walkie-talkies). In some networks, the mobile units communicate via one or several base stations, in some other networks there is no base station and mobiles communicate directly with one another. Communications are only possible

within the members of the network: no interconnection with the public telephone network (generally called PSTN: public switched telephone network) is provided. Examples of applications are communication networks of taxi or ambulance companies, security teams, firemen.

Depending on the systems, voice and/or data transmission are possible. Data only services are also called WAN (wide area networks), as an opposition to the local area networks (see below).

A.2.2 *Cordless systems*

A cordless telephone (CT) is a telephone connected to an exchange line or to an extension line. It is generally made of two parts, the fixed and the mobile unit, connected via a radio link. The cordless phones are suitable for short range applications and generally show reduced performances compared with the more sophisticated cellular phones.

The first generations (CT0, CT1) consist of simple analogue cordless telephones that can only be used within a home (one base unit and one or several mobile units), and are part of the public telephone network (PSTN). The new digital generation (CT2, DECT, PHS) consists of dedicated networks (with an interconnection with the PSTN), and can be used in addition to the classical home application, within a limited service area. The principle of this new application is similar to a cellular mobile network (see below) but with reduced performances available at a lower cost. Depending on the systems, voice and/or data transmission are available with cordless systems. Cordless applications generally use low powers.

A.2.3 *Cellular mobile radio systems*

Cellular radio systems involve communication from hand-held radio telephones or vehicle mounted transceivers to fixed base stations that each provide coverage of a given area. The communications are full duplex (transmit/receive capability) with a separate RF channel provided for the signal travelling via the uplink to the base station and the downlink back to the mobile. The coverage of a base station is known as a cell and is ideally hexagonal in shape so a honeycomb mesh of cells can give total coverage. The base station may be at the centre of a cell or at the junction of three cells dependent on the volume of call traffic within the cells. Typical cells range from 0.5 km to 15 km with a limit of about 35 km for the digital communication systems. Interconnection with the PSTN is provided both ways and conversation between two mobile units is of course also possible.

From the early 1980s, various analogue cellular systems have been introduced in the USA and in Europe with frequency bands around 150 MHz, 200 MHz, 450 MHz and 900 MHz and have today several millions of customers. They are expected to remain in existence until early next century when digital communications will most probably supplant them.

A new digital system, based on the harmonized European Specification GSM, has been introduced since 1992. It offers enhanced performance and better spectrum efficiency than the analogue systems, and the number of users is rapidly increasing. A new system called DCS 1800 has been recently introduced in some countries, its characteristics are very similar to GSM except that it operates at 1.8 GHz and not at 900 MHz. Other digital systems are used in other parts of the world (see tables). The output power of the hand-held devices is progressively being reduced with the development of new systems, as they work on smaller cells.

A.2.4 Radio local area networks (RLANs)

Local area networks (LANs) allow data communication between computers within a confined region, e.g. a campus or a large building. Today, most of these networks use wire connections but some new wireless applications of Radio LANs (or RLANs) have been introduced and will be more and more widely used. RLANs are sometimes also called WLANs: wireless local area networks. Each node of the network is equipped with a small radio transceiver and interconnecting cables are no longer necessary, simplifying the use of the network and allowing mobility of its components (portable computers). Compared to the other radio data services (PMR), RLANs provide a lower mobility, but higher data rates.

In terms of standards, RLANs being a new technology, very few harmonized standards exist and several manufacturers have defined their own protocol (see tables).

A.2.5 Flight telephone

The aim of such systems is to provide communication (voice/data) for the passengers of commercial flights, where the cellular phones of the ground networks can not be used for safety (not to interfere with the plane navigation systems) and functional (not to disturb the base stations with fast moving signals) reasons. Equipment used in the flight telephone systems is therefore specially designed from an electromagnetic compatibility point of view, to be fully compatible with the aircraft navigation and functional equipment. In such systems, mobile stations on board planes communicate with fixed ground stations that provide interconnection with the PSTN (i.e. reverse situation than the satellite systems, see below).

A.2.6 Satellite systems

Satellite systems are in principle very similar to the cellular systems, except that the base stations are not on the ground but on board satellites. Compared to the land networks, satellite systems provide a wider coverage but a lower capacity; they are therefore aimed to be complementary with the land networks by enabling communications from remote locations (sea, deserts, mountains) or low population density areas (where a cellular land network would not be economically viable). The first systems are those of the international maritime satellite organization (Inmarsat) and involve mobile satellite dishes on board ships or ground stations that communicate through a network of four geostationary satellites (at an altitude of 36 000 km) that cover the world (except the Poles). Different standards Inmarsat A, B, C and M were developed with specific characteristics. The most recent involve small portable units (the size of a suitcase) that can operate throughout the world and are generally used in remote areas not covered by the cellular networks. New systems under development (Inmarsat P, Iridium, Globalstar) are aimed to allow use of hand-held units (similar to the existing hand-held cellular telephones). They will be based on a constellation of low earth orbit (LEO) satellites, enabling to reach the satellite from the ground with much less power.

A.3 Statistical information on the number of users and penetration rates

The mobile telecommunication market is evolving very quickly in Europe, so statistical information would need to be updated regularly to remain up to date. In this first publication of this annex, we have mentioned the statistics at two periods in time: January 1996 and June 1996, in order to illustrate the growth of this market. Statistics given here only refer to the cellular phones (both analogue and digital): these data do not include the PMR, cordless phones, satellite systems users.