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Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project, Technical Specification Group Terminals (TSG-T)

The contents of this TR may be subject to continuing work within the 3GPP and may change following formal TSG-T approval. Should the TSG modify the contents of this TR, it will be re-released with an identifying change of release date and an increase in version number as follows:

Version m.t.e

where:

- m indicates [major version number]
- x the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.
- y the third digit is incremented when editorial only changes have been incorporated into the specification.

1 Scope

The present document provides information on radiofrequency (RF) exposure limits and assessment methods for IMT-2000 terminals. It summarises international, regional and national recommendations, standards and regulations relevant to current and future mobile communication devices.

The present document cover only terminal devices that are normally operated close to the user, approximately within 20 cm of any part of the body. For other IMT-2000 RF transmitting equipment, for example base stations, other RF exposure standards, limits and assessment methods than those described in the present document may be applied.

The present document does not define any new RF exposure limits or assessment methods. It refers to recommendations, standards and regulations that already exist or are under development. Like other existing mobile communication terminals, IMT-2000 terminals will be recommended or requested to comply with these guidelines.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

[1] ICNIRP, "Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)", International Commission on Non-Ionizing Radiation Protection (ICNIRP), Health Physics, vol. 74, pp 494-522, April 1998.

[2] CENELEC ENV 50166-2, "Human exposure to electromagnetic fields: High-frequency (10 kHz – 300 GHz)", European Prestandard, European Committee for Electrotechnical Standardization (CENELEC), January 1995.

[3] CENELEC ES 59005, "Considerations for evaluation of human exposure to Electromagnetic Fields (EMFs) from Mobile Telecommunication Equipment (MTE) in the frequency range 30 MHz – 6 GHz", European Specification, European Committee for Electrotechnical Standardization (CENELEC), October 1998.

[4] MPT, "Radio-radiation protection guidelines for human exposure to electromagnetic fields", Telecommunications Technology Council, Ministry of Posts and Telecommunications, Japan, April 1997.

[5] ARIB STD-T56, "Specific Absorption Rate (SAR) estimation for cellular phone", ARIB Standard Version 1.0, Association of Radio Industries and Businesses (ARIB), January 27, 1998.

[6] IEEE C95.1-1991, "Safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 kHz to 300 GHz", The Institute of Electrical and Electronics Engineers Inc., New York, 1991.

[7] FCC Report and Order, ET Docket 93-62, FCC 96-326, Federal Communications Commission (FCC), August 1996.

[8] FCC OET Bulletin 65, Supplement C, "Evaluating compliance with FCC guidelines for human exposure to radiofrequency electromagnetic fields", Edition 97-01, Federal Communications Commission (FCC), 1997.

[9] AS/NZS 2772.1(Int):1998, Interim Australian/New Zealand Standard, "Radiofrequency fields, Part 1: Maximum exposure levels – 3 kHz to 300 GHz", Standards Australia/Standards New Zealand, 1998.

[10] R&TTE directive 99/5/EC, DIRECTIVE 1999/5/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity, OJ L 91, 7.4.1999, pp. 10 - 26.

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following definitions apply.

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

basic restrictions: restrictions on the effects of exposure that are based on established health effects. Depending of frequency, the basic restrictions on exposure to electromagnetic fields are current density, SAR and power density. In the frequency range of interest in this document, the basic restrictions are expressed as SAR values.

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

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

electric field strength (E): the magnitude of a field vector at a point that represents the force ($\boldsymbol{F}$) on a positive small charge ($\boldsymbol{q}$) divided by the charge.

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

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

exposure: occurs whenever a person is subjected to external electric, magnetic or electromagnetic fields.

exposure level: the value of the quantity used when a person is exposed to electromagnetic fields.

exposure, partial-body (non uniform): partial-body exposure results when fields are substantially non-uniform over the body. Fields that are non-uniform over volumes comparable to the human body may occur due to for example near-field sources or highly directional sources.

far field region: the region where 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.

IMT-2000 terminals: terminals intended for use in third generation mobile system.

NOTE: The term is used in order to indicate that SAR requirements are valid independent of 3G technology chosen.

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. 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.

radio frequency (RF): the frequency range between 300 Hz and 300 GHz (ICNIRP definition).

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.

short-term exposure: an exposure duration of less than the specified averaging time.

specific absorption rate (SAR): the time derivative of the incremental energy *(dW)* absorbed by an incremental mass *(dm)* contained in a volume element *(dV)* of given mass density (r)

$$SAR = \frac{d}{dt}\left(\frac{dW}{dm}\right) = \frac{d}{dt}\left(\frac{dW}{r\,dV}\right)$$

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

SAR is usually calculated by:

$$SAR = \frac{s\ E^{2}}{r}$$

where

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

s : conductivity of body tissue in S/m

r :density of body tissue in kg/m^3

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ACA	Australian Communications Authority
ANSI	American National Standards Institute (USA)
ARIB	Association of Radio Industries and Businesses (Japan)
AS/NZS	Australian Standard / New Zealand Standard
CDMA	Code-Division Multiple Access
CENELEC	European Committee for Electrotechnical Standardization
CW	Continuous wave
DOC	Declaration of Conformity
E-field	Electric field
EMF	Electromagnetic Field
ES	European Specification
FCC	Federal Communications Commission (USA)
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers (USA)
IMT-2000	International Mobile Telecommunications-2000
MPT	Ministry of Posts and Telecommunications (Japan)
MTE	Mobile Telecommunication Equipment
NIR	Non-Ionizing Radiation
R&TTE	Radio equipment and telecommunications terminal equipment
RF	Radio Frequency (300 Hz – 300 GHz)
SAR	Specific Absorption Rate (W/kg)
WHO	World Health Organization
TDMA	Time-Division Multiple Access

4 Summary of international RF exposure guidelines and standards

4.1 ICNIRP exposure limits

The independent scientific organisation ICNIRP, which is sponsored by WHO, investigates potential health effects of NIR and develops international guidelines on exposure limits [1]. These guidelines form the basis of many national standards and regulations. The ICNIRP guidelines are based on consensus of all the existing scientific results and provide protection against all established health effects of NIR exposure.

In the frequency range from 10 MHz to 10 GHz, the fundamental exposure limits, which are called basic restrictions, are expressed as SAR limits. SAR is a measure of the rate of absorption of electromagnetic energy in tissue during exposure. There are two sets of limits, one for general public exposure and another for occupational exposure. Furthermore, there are three different SAR limits; whole-body averaged SAR, localised SAR in the head and trunk, and localised SAR in the limbs. The averaging mass for the latter two limits is 10 g of tissue and these are primarily applied for partial-body and near-field exposure situations.

Table 1 below shows the ICNIRP general public SAR restrictions. The localized SAR limits are those applicable to low-power mobile communication terminals that are used close to the body by the general public, including IMT-2000 terminals. Most important is the limit for the head and trunk, 2 W/kg in a 10 g of tissue, since most devices are held close to these parts of the body. The whole-body averaged SAR limit can never be exceeded by this type of devices.

The averaging time is 6 minutes, which means that higher exposure levels are accepted for shorter exposure times than six minutes. Since mobile terminals can be used for periods longer than the averaging time (continuous exposure), the limits in Table 1 shall always be used.

The ICNIRP guidelines do also specify reference levels expressed as power density or field strength levels. These should however not be applied for IMT-2000 and other mobile communication terminals that are used close to the body.

Table 1: ICNIRP SAR limits for IMT-2000 terminals (General public exposure, 10 MHz – 10 GHz)

SAR limit (W/kg) Whole-body	SAR limit (W/kg) 10 g, head and trunk	SAR limit (W/kg) 10 g, limbs
0.08	2	4

4.2 SAR test procedures

4.2.1 Measurement methods

In order to show that a mobile communication terminal is in compliance with the ICNIRP exposure limits the maximum localized SAR has to be evaluated in a human body model. The only SAR evaluation method that provides sufficient accuracy, sensitivity and reproducibility is the *E-field probe technique*. With this method, a homogeneous human body model is exposed to the RF fields from the mobile terminal, and the internal electric field strength distribution is measured with a miniature probe. From the electric field strength data, the SAR distribution and the maximum localized SAR value are derived.

Complete and fully automatic SAR test systems are commercially available. Such systems are used by mobile terminal manufacturers, network operators, universities and test laboratories. The tests are performed using scientifically based procedures that slightly over-estimate the maximum localized SAR in a real human body.

4.2.2 Standardization activities

International standards that will specify SAR test procedures for mobile communication terminals are under development. IEC (TC85, WG15) is working on a general international standard that will define RF exposure evaluation methods in the frequency range from 9 kHz to 300 GHz. This standard, which is planned to be finalized in 2000, will also include a section about SAR testing of mobile communication terminals.

IEC will most probably also start developing an international product standard for mobile communication terminals in 1999. This standard will describe how SAR compliance testing shall be performed. The IEC activity will be harmonized with the work of CENELEC in Europe (see section 5). The standard will be applicable for IMT-2000 terminals.

In USA, IEEE is also developing a SAR test standard (see section 5) which is scheduled to be published in 2000-2001. This will be written as an international standard, and large parts of the information will probably be reused by IEC.

Based on the status of the activities in IEC and IEEE, it is clear that the final international SAR test standard will define a test method for handheld mobile telephones that is well in line with the measurement procedure that is used today. The most important characteristics of this procedure are:

- Automatic E-field probe measurements using isotropic miniature probe.
- Adult-sized and anatomically shaped plastic shell head model filled with a liquid that simulates human head tissue. Hand excluded.
- Test in a normal use position. Measurements at both left and right ear.
- Test with antenna both fully extended and fully retracted (if applicable).
- Measurements at maximum output power and at three frequencies (low, center, high) of all used bands and with all different antennas.
- Internal RF transmitter and power supply (no external connections).
- No time averaging unless the radio signal has a deterministic power variation (for example TDMA signals which have well defined duty factors). For CDMA a CW signal may be used.
- The total measurement uncertainty should be less than about 30%.
- The device is in compliance with the exposure guidelines if the measured maximum SAR value is less than localized SAR limit.

The international standard will also specify test procedures for other exposure situations.

5 Comparison of regional and national standards and regulations

5.1 Introduction

In some countries and regions RF exposure standards or regulations including SAR limits applicable for mobile telecommunication equipment have been published. A number of SAR test specifications have also been published. In a few countries SAR testing is required for type approval of mobile telephones. This section summarizes these regional and national standards and regulations.

5.2 Europe (EU)

SAR limits

In 1995 CENELEC published the European pre-standard ENV 50166-2 [2], which has been adopted as national standards in some countries. The localized SAR limits are the same as those in the ICNIRP guidelines, see table 1.

The ENV may be withdrawn in 1999, and it is planned to be replaced with a new document with reference to the ICNIRP guidelines. This document will presumably become an EN.

In 1999, an EU council recommendation will be issued, which is expected to recommend that the member states adopt the ICNIRP guidelines as national regulations. A new EU directive, R&TTE, 99/5/EC [10], has been published April 7, 1999. In this directive, it is required that radio terminal equipment complies with RF exposure standards.

SAR test procedures

In 1993, CENELEC received a mandate from the European Commission (DGXIII) to develop a European Standard with procedures for testing of mobile communication equipment compliance with RF exposure limits. In 1998, a general document was published as a European Specification, ES59005 [3]. In 1999, CENELEC (TC211) has started developing the ES into a standard with a well-defined test procedure. The work will be coordinated with the activities in IEC and IEEE.

Level of SAR test regulation

SAR testing is not yet mandatory in Europe, or in any of the member states. Manufacturers and network operators perform SAR testing on a voluntary basis.

5.3 Japan

SAR limits

MPT published national RF exposure guidelines in 1997 [4]. The SAR limits are the same as those in the ICNIRP guidelines, see table 1. The localized SAR limit for the head and trunk is **2.0 W/kg (10 g**).

SAR test procedures

In 1998, ARIB published the standard STD-T56 [5], which describes methods and procedures for SAR testing of mobile telephones. This will be revised in 1999. When the international IEC SAR test standard is finalized, this will probably be adopted as a Japanese standard.

Level of SAR test regulation

SAR testing is not yet mandatory in Japan. Manufacturers and network operators perform SAR testing on a voluntary basis. Testing will become mandatory when the international SAR test standard is published.

5.4 USA

SAR limits

The FCC has adopted the SAR limits from the U.S. standard ANSI/IEEE C95.1-1992 [6] in its RF exposure rules [7]. The SAR limits are the same as the ICNIRP levels except for the limit for the head and trunk, which is slightly lower, **1.6 W/kg**. The averaging mass and time are also different, 1 g and 30 minutes, respectively. The current FCC rules were published in 1996 and SAR testing is required for mobile telephones.

A new version of C95.1 will be published in 1999. However, no changes of the SAR values are expected.

SAR test procedures

In 1997, IEEE (SCC34, SC-2) started to develop a standard that will define procedures for testing compliance with the localized SAR limits for mobile terminals. This standard will be completed in 2000, and adopted by the FCC.

As an interim standard, in 1997 the FCC published a document that provides information for evaluating compliance with the FCC SAR limits (OET Bulletin 65 Supplement C) [8]. This document will be updated in 1999 with the latest information from the IEEE activity.

Level of SAR test regulation

SAR testing is mandatory for mobile telephones (PCS and cellular) in USA. A SAR test report has to be submitted to the FCC before type approval.

5.5 Australia

SAR limits

The ACA adopted a new RF regulation framework in February 1999. Mobile terminals have to comply with the SAR limits from the interim Australian standard AS/NZS 2772.1-1998 [9]. The SAR limits are the same as the IEEE limits adopted by the FCC in USA; i.e. the localized SAR limit for the head and trunk is **1.6 W/kg (1g)**. SAR testing is required for mobile telephones.

Australia is considering adopting the international ICNIRP RF exposure limits. However, no final decision has yet been taken.

SAR test procedures

The ACA has published an interim SAR test standard, which is partly based on an IEC SAR test draft and on the FCC interim SAR test standard mentioned above. When an international standard is available, this will replace the current interim standard.

Level of SAR test regulation

SAR testing is mandatory for mobile telephones in Australia.

5.6 Canada

SAR limits

Health Canada has adopted the same SAR limits as the IEEE in its draft standard "Safety Code 6". The localized SAR limit for the head and trunk is thus **1.6 W/kg (1g)**.

SAR test procedures

Industry Canada is developing a new Radio Standards Specification regarding RF exposure from mobile radio transmitters (RSS-102), which will be finished in 1999. This document will define SAR limits (from Health Canada), SAR test conditions, and compliance criteria for certification of mobile transmitters.

Level of SAR test regulation

Today mobile transmitters type approved by the U.S. FCC are certified in Canada. With the new regulation, SAR testing will be mandatory and a DOC has to be submitted to Industry Canada for equipment certification.

History

Document history		
V 0.0.1	April 9, 1999	First draft for discussion on the E-mail reflector
V 0.0.2	April 14, 1999	Draft to be presented at the Yokohama meeting April 20, 1999