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Report

Dosimetric Assessment of a Nokia 5110 mobile telephone with and without the *Wave Buster*

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1 Subject of Investigation

The *Wave Buster* for mobile phones is intended to reduce the electromagnetic field inside the human head. The objective of the measurements done by IMST was the dosimetric assessment of a Nokia *5110* mobile phone with and without *Wave Buster*. The *Wave Buster* consists of two pads which were attached to the mobile phone: the large oval pad is positioned over the earpiece of the phone and the small circular pad is positioned above the display of the phone. The configuration under investigation is shown in Fig. 1.

The mobile phone operates in the 900 MHz frequency range. The system concept used is the GSM 900 standard.

The objective of the measurements done by IMST was the dosimetric assessment of one device. The mobile was investigated with respect to guidelines referring to limits for electromagnetic field exposure in order to avoid adverse health effects to human beings.

The examinations have been carried out by the use of the dosimetric assessment system „DASY“ described below.

Fig. 1: The measurement setup with a phantom containing tissue simulating liquid and a MTE under test.

2 Radiofrequency Field Exposure Standards

In nearly any country the protection of human beings against harmful influences is a task of government. Many different organizations are trying to get a work-out of national and international rules and standards to get technical conditions to put this political aim into practice.

2.1 Standards Associations

The approved institution by the German government for preparing standards is the „Deutsches Institut für Normung (DIN)“, which promotes the harmonization of the standards for Europe. In the field of high frequency electromagnetic fields the reference levels of the current CENELEC (Comité Européen de Normalisation Electrotechnique) prestandard [ENV 50166] are very close to the most recent draft of the DIN/VDE standard 0848 [DIN 0848 91]. The corresponding guideline ANSI C95.1 published by the American National Standards Institute [ANSI 1992] is not only used in the USA, but also by many other countries.

The US Federal Communications Commission (FCC) issued a report on August 1997 [FCC 1997], which requires routine dosimetric assessment of mobile telecommunications devices, either by laboratory measurement techniques or by computational modeling, prior to equipment authorization or use.

One of the most important organizations treating with the international development of standards is the ICNIRP (ICNIRP: International Commission on Non-Ionizing Radiation Protection). ICNIRP is a successor of the IRPA/INIRC (INIRC: International Non-Ionizing Radiation Committee; IRPA: International Radiation Protection Association). Its publications [IRPA 1988], [IRPA 1991] take a special place as they represent a summary of the „Environmental Health Criteria“ published in the WHO (World Health Organization) [WHO 1993]. If they have not established national standards themselves, some countries, for example Norway, directly use the IRPA values (CENELEC survey [CENELEC 1995]). The current guidelines of ICNIRP are from 1998 and include the frequency range up to 300 GHz.

2.2 Legal Classification of Standards

To classify standards, rules and regulations it is important to distinguish between the following terms:

- National and international standards
- Laws (for example national laws of protection against immission like the German „Bundes-Immissionsschutzgesetz“ [BImSchV 1996])
- Recommendations (for example presented by the German national radiation protection commission „Strahlenschutzkommission“ [SSK 1993])
- Voluntary consumer protection standards (for example standard for „low radiation“ computer screens, the MPR II standard)

From the legislator’s point of view a careful distinction between the terms must be made. In Germany the standard DIN 0848 part 2 (similar to ANSI C95.1 [ANSI 1992]) dealing with the protection of human beings from electromagnetic fields, has not been put into asserted German right so far. A German law, called „Bundes-Immissionsschutzgesetz“, is just valid for wireless non mobile installations (indeed there is currently an attempt to extend this law in respect to the DIN 0848). The recommendation of the national German radiation protection association has no legally binding function as well as the voluntary consumer protection standards.

In nearly every country there exist normative regulations for the protection of the population against electromagnetic fields. Often these conditions are not worked out due to own research, but are based on standards and recommendations of other countries or organizations.

2.3 Distinction Between Areas, Time of Exposure and Frequencies

In nearly all standards a distinction between exposure areas and exposure times is made. There is a general distinction between two different areas (with different names, but very close meaning), which are called exposure area number 1 and 2 in the DIN standard and controlled and uncontrolled environment in the ANSI document.

Controlled environments are locations where there is exposure that may be incurred by persons who are aware of the potential for exposure as a concomitant of employment, by other cognizant persons. Concerning these areas, the maximum permissible exposure is defined in respect to human safety. These areas contain:

- Controlled areas, for example manufacturing plants
- General accessible areas where it is secured that the exposure is only at short times due to the operation of equipment or due to the time of stay. Short time means due to DIN regulation up to 6 hours a day.

The reference levels in uncontrolled environment have been fixed under consideration of additional safety precautions. These areas include long-term exposure and locations with exposure of individuals who have no knowledge or control of their exposure:

- Areas with residential and social buildings

- Facilities for sports, leisure and relaxation
- Working places where an electromagnetic field is unexpected.

The limits for uncontrolled environment are 5 times lower than those of controlled environment.

In addition to the introduction of different exposure areas a distinction between exposure times is made. An international limit is made at 6 minutes exposure time. For short-term exposure below 6 minutes duration, higher field strengths are admissible, because it takes a certain time until the warm up of the human body starts.

Due to the influence of frequency on important parameters, as the penetration depth of the electromagnetic fields into the human body and the absorption capability of different tissues, the limits in general are frequency dependent.

2.4 Basic Restrictions and Derived Reference Levels

There is a distinction between basic restrictions and derived reference levels concerning all normative regulations. Basic restrictions are defined for

- the specific absorption (SA, dimension: energy/mass),
- the specific absorption rate (SAR, dimension: power/mass)
- the electrical current density in the body and
- the current through the body

because they can be referred directly to thermal based biological effects and stimulation of nerves and muscles respectively. It has been pointed out that in the high frequency range especially the specific absorption rate (SAR) is a useful and a biologically relevant quantity to describe the effect of the electromagnetic field. It is a measure of the power absorbed per unit mass. The unit of specific absorption rate is watt per kilogram [W/kg]. The SAR may be spatially averaged over the total mass of an exposed body or its parts, and may be time-averaged over a given time of exposure or even a single pulse or modulation period of the radiation. The SAR is calculated from the electric field strength E_{eff}, the conductivity σ and the mass density ρ of the material ρ (e.g. biological tissue):

$$SAR = \sigma \frac{E_{\text{eff}}^2}{\rho} = c \left. \frac{\partial T}{\partial t} \right|_{t \to 0} \quad . \tag{1}$$

The specific absorption rate describes the temperature rise $\partial T / \partial t$ as a function of the specific heat capacity c of the tissue. A limitation of the specific absorption rate prevents an excessive heating of the human body by electromagnetic energy. Therefore it is used for the dosimetric assessment of mobile telephones.

As it is difficult to determine these basic quantities directly by measurement, the standards specify a set of more-readily-measurable reference levels in terms of external electric and magnetic field strength and power density, derived from the basic restrictions. One of the derived reference levels is the electric field strength E_{eff}, which is calculated by:

$$E_{\mathrm{eff}} = \sqrt{\frac{\Delta t}{t_{\mathrm{r}}}\left(E_{\mathrm{x,eff}}^{2} + E_{\mathrm{y,eff}}^{2} + E_{\mathrm{z,eff}}^{2}\right)} \ . \qquad (2)$$

For pulsed fields like for GSM mobile telephones the duration Δt and the time t_{r} between two pulses have to be considered in (2). The magnetic field strength H_{eff} is calculated similarly. It has to be considered, that for short pluses special reference levels are applied.

The limits for E_{eff} , H_{eff} and the power density $S = E_{\mathrm{eff}} \times H_{\mathrm{eff}}$ have been fixed so that even under worst case conditions, the basic limits are not exceeded. It must be noted that already precaution factors have been introduced into the basic restrictions, which are different from each other due to deviations in the rating of the potential of danger of electromagnetic fields. Thus there exist different values in the limits although all standards consider the latest scientific knowledge.

The most general claim in every standard is: **Compliance is established when the basic limits are not exceeded.**

At frequencies between 100 kHz and 6 GHz the limits for the electromagnetic field strengths may be exceeded if the exposure condition can be shown by appropriate techniques to produce SARs below the corresponding limits [ANSI 1992].

2.5 SAR Limits for Mobile Phones

In this report the comparison between existing standards and measured data is made using the basic restrictions for the specific absorption rate SAR.

Having in mind a worst case consideration, all following listed limits count for the uncontrolled environment, for exposure times longer than 6 minutes [ENV 50166], [DIN 0848 91] and 30 minutes [ANSI 1992] respectively and for SAR values which may appear in the head. At the same time local SAR values have to be averaged over a mass specified in Table 1 with a shape of a cube. Corresponding to the different masses for the averaging procedure there will be distinguished between SAR values for 10 g mass (SAR_{10g}) and for 1 g mass (SAR_{1g}).

2.6 Instructions for the Measurement Procedure to Determine SAR Values

Instructions about the measurement of emissions produced by devices like mixers, heatable blankets etc., are defined for a long time [EN 55014]. Recently there has been a measurement instruction for SAR values for mobile communication systems: "Considerations for evaluation of human exposure to Electromagnetic Fields (EMFs) from Mobile Telecommunication Equipment (MTE) in the frequency range 30 MHz - 6 GHz" approved by the CENELEC SC111B Task Group [ES 59005]. For the practical application it is important, that the measurement positions of the MTE in respect to a head phantom are defined by the CENELEC specification and that the MTE has to operate at maximum power level during the measurement.

Standard	**Status**	**Averaging**	***SAR* limit [W/kg]**	**Reference**
DIN VDE 0848 Teil 2, 1991	draft	10 g mass	2.0	[DIN 0848 91]
CENELEC ENV 50166-2, 1995	draft	10 g mass	2.0	[ENV 50166]
ANSI C95.1-1991	in force	1 g mass	1.6	[ANSI 1992]
ICNIRP	in force	10 g mass	2.0	[ICNIRP 1998]

Table 1: Relevant basic limits for the specific absorption rate (SAR), valid for mobile phones in the frequency range from 30 MHz to 6 GHz.

The derived reference levels are shown in Table 2 for two frequencies of interest.

Standard	**Status**	E_{eff} **[V/m]**	H_{eff} **[A/m]**	S **[W/m²]**	**Reference**
CENELEC ENV 50166-2, 1995	draft	41.1 59.7	0.109 0.159	4.5 9.5	[ENV 50166]
DIN VDE 0848 Teil 2, 1991	draft	41.1 59.7	0.109 0.159	4.5 9.5	[DIN 0848 91]
ANSI C95.1-1991	in force	47.6 69.1	0.126 0.183	6 12.7	[ANSI 1992]
ICNIRP	in force	41.3 59.9	0.111 0.161	4.5 9.5	[ICNIRP 1998]

Table 2: Derived reference levels for the frequencies 900 MHz and 1.9 GHz (the higher values are valid for 1.9 GHz).

3 The Dosimetric Assessment System

DASY is an abbreviation of „Dosimetric Assessment System“ and describes a system which is able to determine the SAR distribution inside a phantom of a human being according to the CENELEC specification [ES 59005]. It consists of a robot, several field probes calibrated for use in liquids, a shell phantom, tissue simulating liquid and software. The software controls the robot and processes the measured data to compare them with the limits of several guidelines [ANSI 1992], [ENV 50166] or [DIN 0848 91]. Fig. 2 and Fig. 3 show the equipment, similar to the installations in other laboratories [DASY 95]. It was delivered by the Swiss company Schmid & Partner Engineering AG.

Fig. 2: The measurement setup with a phantom containing tissue simulating liquid and a MTE under test.

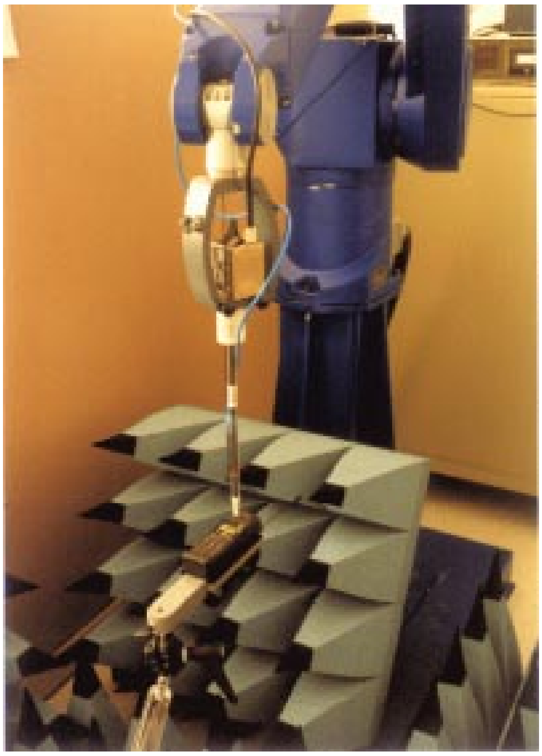

Fig. 3: The robot controlled probe during a near field measurement in air.

3.1 SAR Measurement Procedure

A MTE acting on maximum power level is placed in a well-defined position at a shell phantom of a human being as described in the CENELEC instruction and depicted below. The phantom is filled with a tissue simulating liquid. The electrical parameters of the liquid correspond to brain tissue for the frequency under investigation. The distribution of the electric field strength E_{eff} is measured within the head model in the tissue simulating liquid. For this miniaturized field probes with high sensitivity and low field disturbance are used. Afterwards the corresponding SAR values are calculated using (1) with the known electrical conductivity σ of the tissue and ρ is the mass density. The software controlling the robot is able to determine the averaged SAR values (averaging region 1 g applying the ANSI guidelines or 10 g using the European prestandard) for the compliance test.

Because the electric parameters of human tissue (and the synthetic liquid also) are frequency dependent, it becomes necessary to report these parameters in order to support comparison with other measurements. The tissue parameters to be used are still under discussion in the scientific community and may (slightly) change in the future.

3.2 Handheld Mobile Phone Positions

As it cannot be expected that the user will hold the phone exactly in only one well defined position, different reasonable operational conditions shall be tested. The CENELEC specification recommends four positions. For an exact definition helpful geometric constructions are introduced and shown in Fig. 4. A reference line describing the phone is defined as a line (on the surface of the phone facing the phantom) which connects the center of the ear piece with the center of the bottom of the case (typically near the microphone). The human head position is given by means of a reference plane defined by the following three points: auditory canal opening of both ears and the center of the closed mouth.

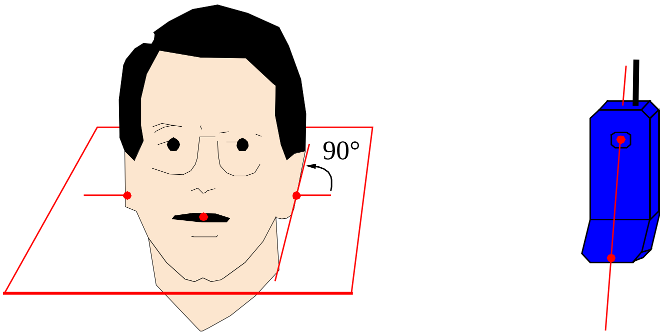

Fig. 4: Geometric constructions supporting the definition of different positions for a mobile phone at a human head. The phone is described by a line and the head by means of a plane.

The positions itself are given by:

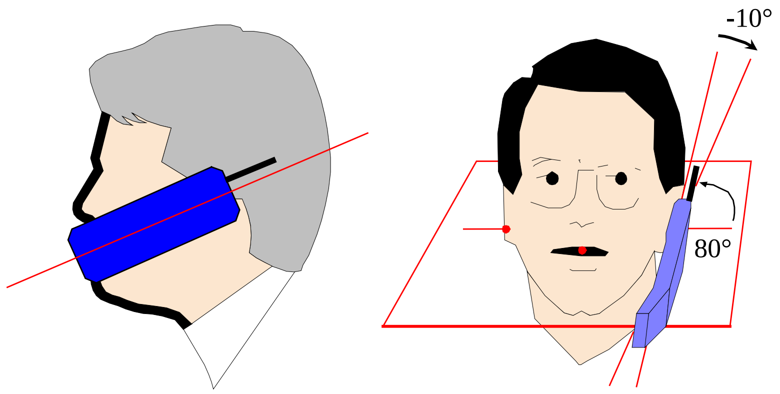

Fig. 5: The „intended use“ position.

The center of the ear piece shall be placed directly at the entrance of the auditory canal. The telephone line shall lie in the head plane and the angle between the telephone line and the line connecting both auditory canal openings shall be 80°.

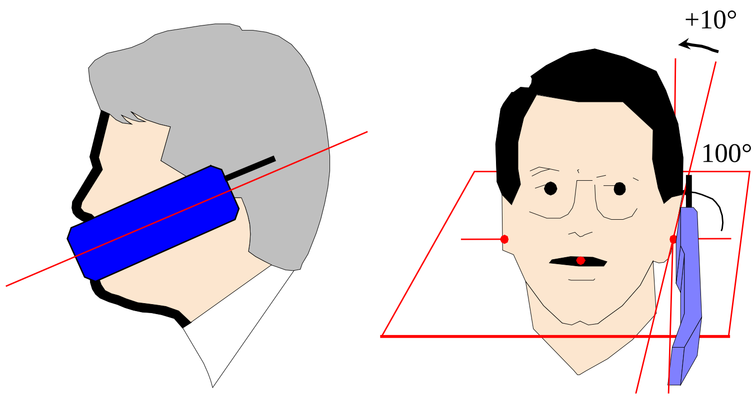

Fig. 6: The „100°“ position.

The center of the ear piece shall be placed directly at the entrance of the auditory canal. The telephone line shall lie in the head plane and the angle between the telephone line and the line connecting both auditory canal openings shall be 100°.

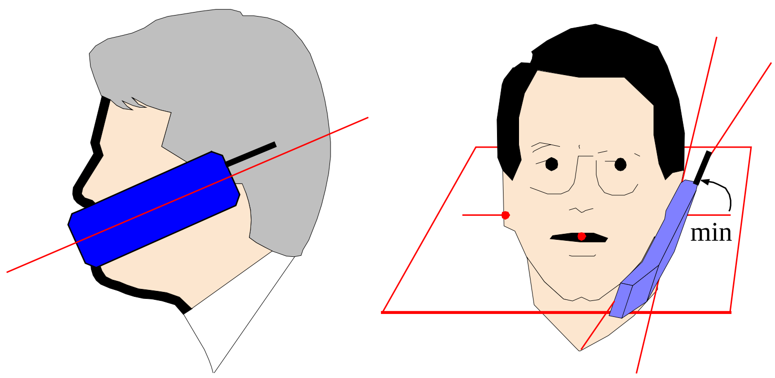

Fig. 7: The „touch“ position.

The telephone line shall lie in the head plane. The angle between the phone line and the line connecting both auditory canal openings shall be reduced until the device touches the surface of the phantom.

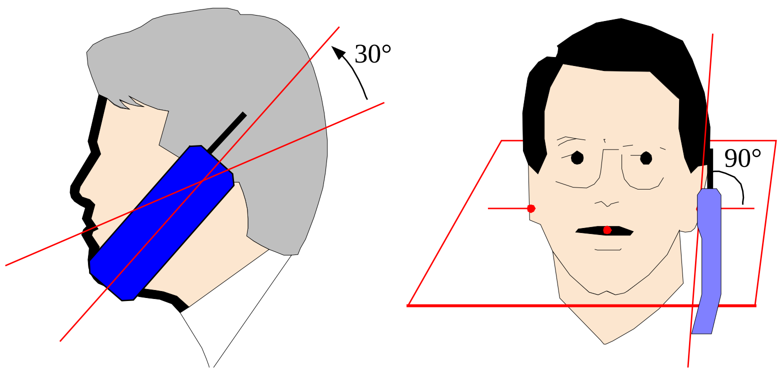

Fig. 8: The „30°“ position.

The telephone line 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 canals shall be 90°.

3.3 Technical Parameters of the Measurement System

Parameter	DASY	CENELEC Requirements
spatial resolution	5 mm	5 mm
repeatability of probe position	± 0.1 mm	± 0.5 mm
dynamic range	5 mW/kg - 100 W/kg	100 mW/kg - 100 W/kg

Table 3: System specification in comparison to requirements stated by CENELEC.

Parameter	Accuracy
frequency linearity	± 0.2 dB
deviation from isotropy (in air)	± 0.8 dB
surface detection	± 0.2 mm

Table 4: Probe specification.

Parameter	Noise Floor
SAR values	< 0.005 W/kg
field strength E_{eff} electric field	< 1 V/m
field strength H_{eff} magnetic field	< 0.003 A/m

Table 5: Sensitivity of DASY.

Accuracy Influencing Conditions	Accuracy of SAR Values
isotropy, calibration, noise floor	< 13 % @ 1 W/kg
extrapolation of SAR values	< 7 %
dielectric parameters	< 5 %

Table 6: Influences on accuracy of the SAR_{1g} and SAR_{10g} values determined by measurements [Kuster 1997].

4 SAR Values

The Tables below contain measured data for the SAR values averaged over a mass of 10g.

Position	Remark	SAR(10g) W/kg	File
touch		0.857 ± 0.215	5110LO_4.MEA
30 grd		0.587 ± 0.149	5110LO_3.MEA
100 grd		0.569 ± 0.144	5110LO_2.MEA
intended use		0.650 ± 0.164	5110LO_1.MEA

Table 7: Measurement results for the Nokia *5110*, left hand position (without *Wave Buster*).

Position	Remark	SAR(10g) W/kg	File
touch		0.818 ± 0.205	5110LM_4.MEA
30 grd		0.420 ± 0.108	5110LM_3.MEA
100 grd		0.454 ± 0.116	5110LM_2.MEA
intended use		0.534 ± 0.136	5110LM_1.MEA

Table 8: Measurement results for the Nokia *5110*, left hand position (with *Wave Buster*).

Position	Remark	SAR(10g) W/kg	File
touch		0.729 ± 0.184	5110RO_4.MEA
30 grd		0.554 ± 0.141	5110RO_3.MEA
100 grd		0.439 ± 0.113	5110RO_2.MEA
intended use		0.563 ± 0.143	5110RO_1.MEA

Table 9: Measurement results for the Nokia *5110*, right hand position (without *Wave Buster*).

Position	Remark	SAR(10g) W/kg	File
touch		0.720 ± 0.181	5110RM_4.MEA
30 grd		0.390 ± 0.101	5110RM_3.MEA
100 grd		0.390 ± 0.101	5110RM_2.MEA
intended use		0.487 ± 0.124	5110RM_1.MEA

Table 10: Measurement results for the Nokia *5110*, right hand position (with *Wave Buster*).

5 Evaluation

In Fig. 11 and 10 the SAR results given in Table 9 and 10 are summarized and compared to the limits.

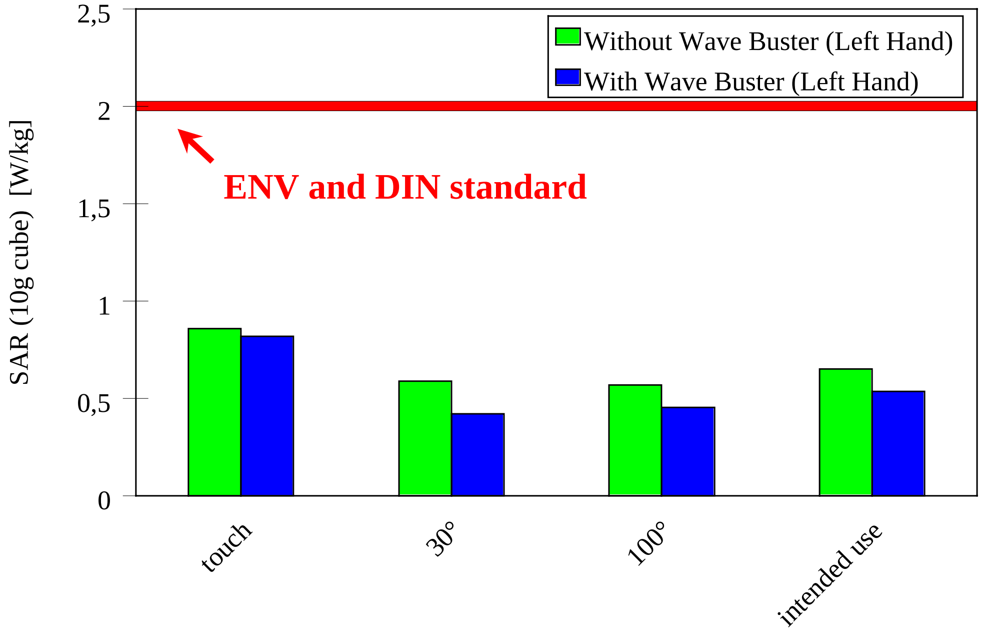

Fig. 10: The measured SAR values using the Nokia *5110* in comparison to the European prestandard with and without the *Wave Buster* (Left Hand Position).

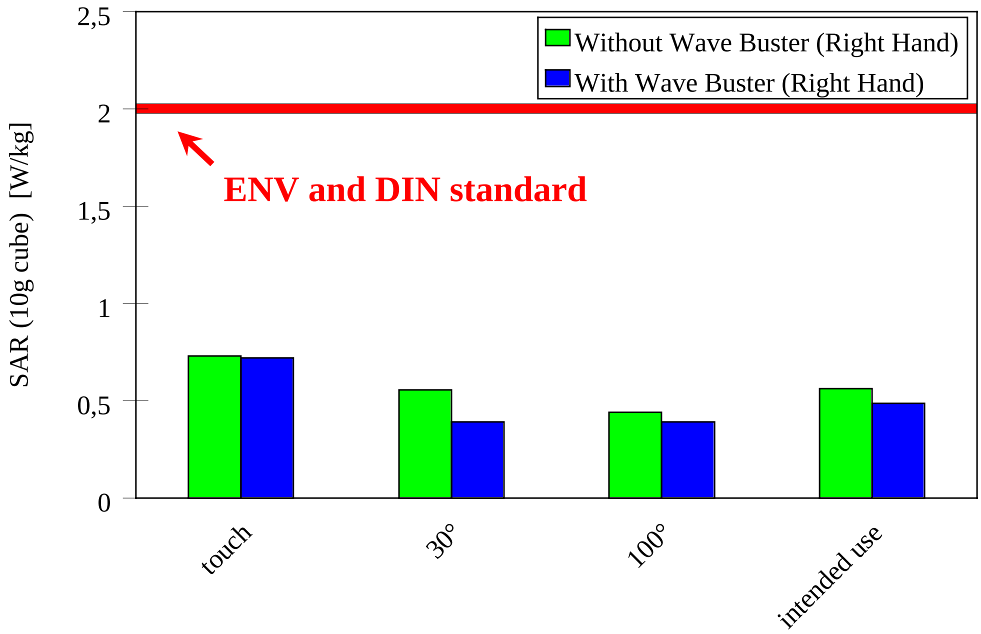

Fig.11: The measured SAR values using the Nokia *5110* in comparison to the European prestandard with and without the *Wave Buster* (Right Hand Position).

Measurements following the CENELEC [ES 59005] measurement and evaluation guideline were conducted. The maximum SAR values were compared to appropriate standards.

Taking into account the accuracy analysis compliance the European prestandard ENV 50166-2 and the German draft DIN VDE 0848 (Teil 2) can be stated for the Nokia *5110* mobile phone with and without *Wave Buster*.

Using "*Wave Buster*" a reduction of the maximum SAR value – measured in the worst case position (touch position) – of 4.5 % is found. Depending on the position of the mobile phone a maximum reduction of 29.6 % is measured.

Note: The measured SAR values depend on the material parameters. Therefore the material parameters must be enclosed in all copies and publications of these results.

6 Measurements

Administrative Data

date of measurement: 18.10.99 – 19.10.99 by: Dipl.-Ing. C.Hennes
data stored: Firstcom_6575_049

Subject and Requirements for Operation

MTE: Nokia *5110*
IMEI: 490546207536920
standard: GSM 900
base station (BS): Wavetek STABILOK 4032 GSM
frequency Tx: 900 MHz, ch. 0062
MS Pwr TCH: 33 dBm

DASY Options

software version: DASY V2.3d
probe: ET3DV5 SN:1332
calibration: 08.10.99, dipole validation kit: D900V2 SN: 006
phantom: generic twin phantom, left hand and right hand position

Material Measurement System

type: HP85070B
software version: HP85070 Rev. B.01.05 1993
VNA: HP8753D (6 GHz option)

material parameters:

	Target	Measured
permittivity ε_r	42.5	43.2 ± 6.7
conductivity σ	0.86 S/m	(0.85 ± 0.12) S/m
mass density ρ	1.04 g/cm^3	

Table 11: Parameters of the tissue simulating liquid.

7 References

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