SAR Evaluation In Human Heads

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ABSTRACT

Existing scientific data on absorption of electromagnetic fields in the human body during the use of mobile telephones are mainly based on measurements on phantoms and on simulations. Up to now it has been unclear if measurements in human tissue would lead to the same conclusions as evaluations in phantoms and simulations did.

During this project, the specific absorption rate (SAR) was evaluated in the heads of five fresh cadavers. The evaluation was performed at the frequencies 433 MHz, 900 MHz, 1,300 MHz, 1,800 MHz and 2,450 MHz. We used dipole antennas at varying radiated powers. The emitted fields were unmodulated. Measurements were performed in the brain, the inner ears and the eyes of the heads. Evaluations were performed at two antenna positions: next to the ear (at 20 mm distance to the skull) and at 40 mm in front of the eye.

The specific absorption rate was evaluated by performing measurements of the electric field strength in human tissue and also by measuring the temperature versus time during irradiation of the heads.

The evaluation of the absorption rate requires the knowledge of the permittivity of the human tissue. Therefore permittivity and conductivity were examined in isolated samples of human brain, muscle and eyes before performing the SAR evaluation.

At a radiated power below 1 W the limit of the specific absorption rate of the Austrian prestandard ÖNORM S1120 of 4 W/kg averaged over 1 gram tissue was not exceeded. A radiated power of 2 W led to SARs above the mentioned limits in some cases.

For comparison reasons measurements of the SAR were also performed in phantom heads. We found good correspondence between the SAR values evaluated in the human heads and the phantom heads.

INTRODUCTION

The purpose of this work was to determine the SAR inside the heads of five fresh human cadavers exposed to RF fields. Heterogeneous head phantoms were built up for the frequency range from 430 MHz to 2,450 MHz to determine the specific absorption rate next to RF sources commonly used in industry and for mobile communication.

Most of the scientific investigations made so far to determine the SAR in tissue are based on simulations and/or measurements in phantoms. To compare measurements in real human tissue with phantom measurements we assessed the SAR in the mentioned heads.

METHODS

SAR evaluation

The quantity of absorbed power in tissue per mass unit is defined as the specific absorption rate (SAR [W/kg]). The SAR is used as basic restriction in different standards and recommendations as the Austrian prestandard ÖNORM S1120 or the ICNIRP recommendations. Limits of the SAR have to be met when people are exposed next to radiating sources.

One method to determine the SAR is to measure the temperature rise in tissue versus time. The specific heat of the tissue under investigation must be known for this purpose. A second method is to determine the specific absorption by measuring the electric field strength in tissue. This method requires the knowledge of conductivity and density values of the tissue.

A fiberoptic system was used to measure temperature rise versus time at several positions in the heads. These data were used to determine the temperature rise caused by the RF exposure as shown in figure 1. It has to be taken into account that only the temperature rise immediately after the onset of the radiation is used for evaluating the SAR because heat compensation falsifies the measurements with increasing time. Therefore the tangent of the temperature curves was used to determine the SAR as can be seen in figure 1.

The SAR was also determined using the second method. The field strength was measured in tissue with especially developed isotropic field probes. These probes were made using thick film technique; details of these probes are given elsewhere (9). The dimension of the field probes excluded a use in the inner and the eye so that only a placement in the brains was performed.

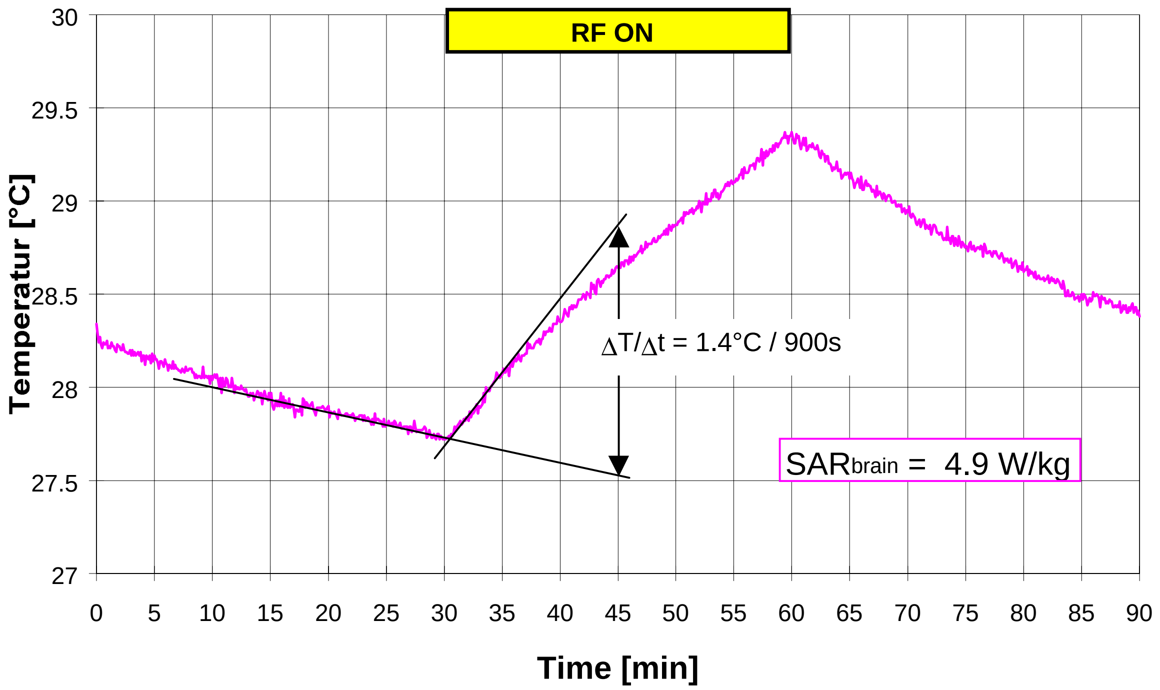

Figure 1. Temperature rise versus time at one position in brain tissue radiated by a 900 MHz dipole and 2 W input power (CW)

Investigated exposure situations

Measurements were performed in the heads of fresh not fixed human cadavers. Two typical exposure situations while handling hand-held transmitters were examined. On the one hand the feedpoints of the dipoles were fixed laterally to the right ear similar to a typical position of a mobile phone, on the other hand they were placed in front of the right eye simulating the use of radio transmitters. The distance between the feedpoint of the dipole and the surface of the ear was 2 cm, the distance between eye and feedpoint was 4 cm. Experiments were performed at input power levels in the range from 1 to 6 W and at the frequencies 433, 900, 1,300, 1,800 and 2,450 MHz. The fields were unmodulated in all cases. The SAR was evaluated in different positions in the brain, the eyes and the inner ears of the heads examined.

The exact position of the tip of the field probes (or rather the canulas to lead the field probes into tissue) were specified by CT scans after implantation. Figure 2 shows an example of a CT scan of a head. The position of four fiber optic temperature probes in brain tissue can be seen.

SAR values evaluated in the human heads were compared with those measured in heterogenous phantoms. The construction of the phantom and the development of the materials used are described in (9).

RESULTS

The SAR exceeded the limit of the Austrian prestandard ÖNORM S1120 for partial body exposure of 4 W/kg averaged over 1 g tissue in some cases, depending on the radiated power and the frequency. For averaged radiated powers below 1 W the limits were never exceeded in the experiments.

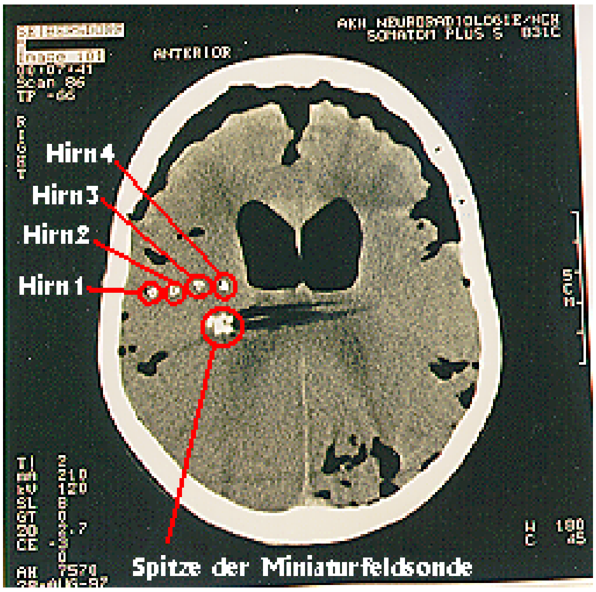

Figure 2. CT scan of the measurement positions in the brain of the 3rd head

Table 1 gives an overview of the maximum SARs in the mentioned heads at an input power of 2 W. SARs were evaluated in brain tissue, the eyes and the inner ears.

Position	Radiation conditions		max. SAR
Brain Area of right ear, approx.. 1 cm distance to the inner side of the skul	Input power 2W, lateral irradiation next to the right ear, feedpoint of antenna 2 cm away from surface of head	433 MHz 900 MHz 1300 MHz 1800 MHz 2450 MHz	2,00 W/kg 3,05 W/kg 3,50 W/kg 5,50 W/kg 6,60 W/kg
Eye In vitreous body directly behind the lense	Input power 2W, frontal irradiation of the right eye, feedpoint of antenna 4 cm away from the eye.	900 MHz 1300 MHz 1800 MHz 2450 MHz	5,57 W/kg 7,51 W/kg 5,04 W/kg 5,36 W/kg
Inner ear Area of Promontorium (basis of cochlea)	Input power 2W, lateral irradiation next to right ear, feedpoint of antenna 2 away from head surface.	433 MHz 900 MHz 1300 MHz 1800 MHz 2450 MHz	0,97 W/kg 1,80 W/kg 1,04 W/kg 0,67 W/kg 0,27 W/kg

Table 1. Maximum specific absorption rate in the heads of 3 cadavers radiated by dipoles (Radiated power 2W, Dipol antennas).

In one head the SAR in brain tissue was measured versus distance in brain tissue. The four fiber optic temperature probes were arranged in a line as shown in figure 3. The distance between the inner side of the skull and the probe 1 was 1 cm, between the probe 1 and 2 0.7 cm, between 2 and 3 0.8 cm and between 3 and 4 0.8 cm. The distance between the outer side of the skull and the feedpoint of the dipole was 2 cm. The decrease of the SAR with augmenting distance can be seen in figure 3. It has to be noticed that the decrease is more pronounced at higher frequencies (see 2,450 MHz and 433 MHz).

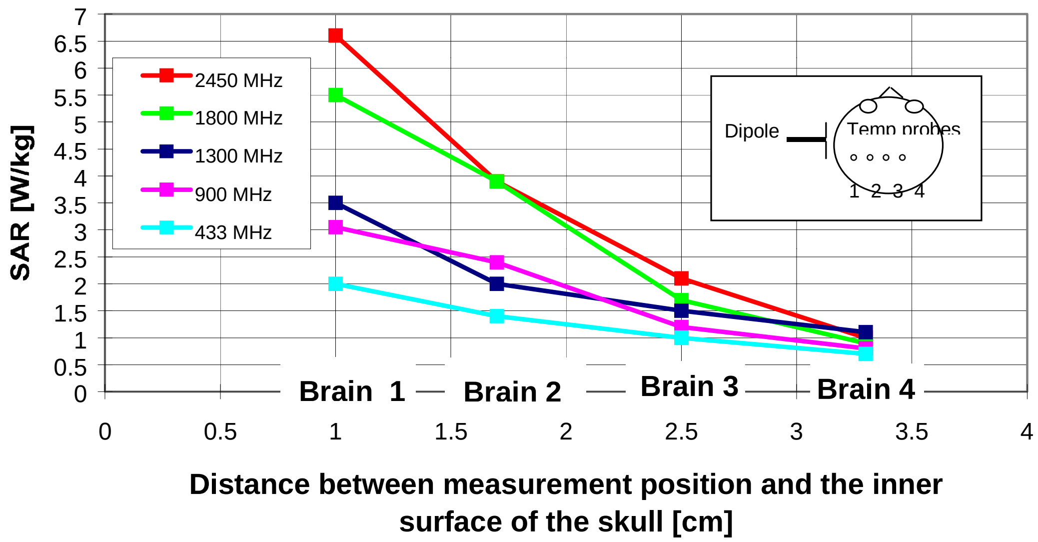

Figure 3. SAR versus distance in the 3rd head

DISCUSSION

The SAR values obtained in the heads of the five human cadavers were compared with the SAR measured in the phantom at 900 MHz. Comparison of the results showed correspondence between the phantom and the third head both exposed next to the right ear (see figure 4). The errorbars define the range of uncertainty of the SAR measured. The uncertainty is mainly caused by the relatively high variation of tissue parameters (physiological variations and uncertainties of assessment of the dielectric properties) and also by anatomical variations (different shape of the skull, differences in the thickness of the fat layers, thickness of bones,....). The values measured in the phantom are always inside this uncertainty area.

In conclusion we found good agreement while comparing the SAR values from phantoms and cadavers. We feel that it is not adequate to draw direct conclusions in respect of exposure next to mobile phones upon the SAR values obtained during these investigations. This is mainly caused by differences of the emitted power, antenna types and modulations.

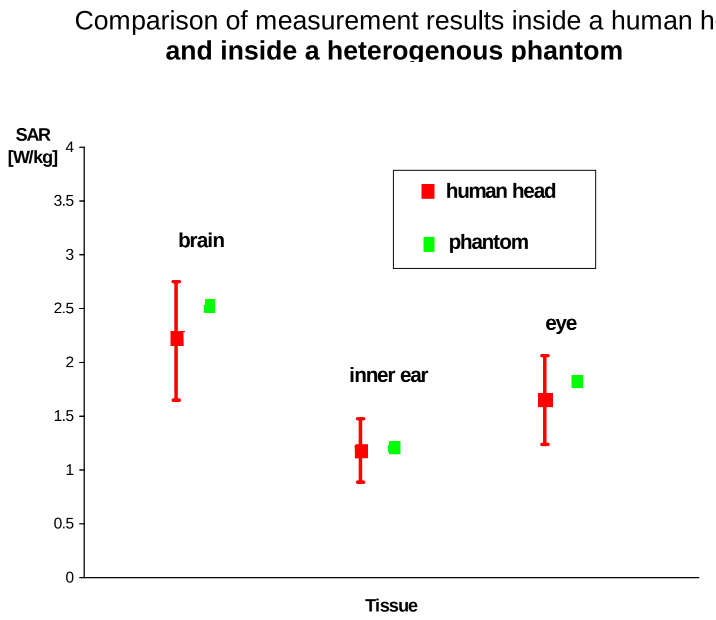

Figure 4 Comparison of SAR inside a human head and in a phantom using $\lambda/2$ – dipols at 900 MHz with radiated power of 2 Watts.

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