# AN AUTOMATED E-FIELD SCANNER FOR THE EVALUATION OF SPECIFIC ABSORPTION RATE (SAR) OF MOBILE TELECOMMUNICATION EQUIPMENT (MTE) IN HOMOGENEOUS PHANTOMS.

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## 1. Abstract

An automated E-field scanner for the evaluation of spatial peak average SAR has been developed for research purposes. The system comprises: a generic twin phantom, an isotropic E-field probe, a data acquisition unit, a probe positioning system, an MTE positioning system and software for the evaluation of spatial peak average SAR. The performance of the system has been validated by comparing measured results with those from other commercial systems.

*Key words*: *SAR, mobile phones, homogeneous phantoms.*

## 2. Introduction

Recently, there has been speculation that the use of mobile phones may stimulate health effects. Mobile phones are widely used in private and business communications as well as for public safety and emergency communications. When the mobile phone is in normal operating mode, the antenna is often very close to various parts of the human body. In order to investigate this topic, it is necessary to assess the electromagnetic field induced in the human body and to compare this field with a proper safety level related to the electromagnetic absorption. The Specific Absorption Rate (SAR) defined as the power absorbed by the unit of mass of tissue, is the basic dosimetric parameter for the evaluation of the exposure in the radio frequency and microwave ranges. [1],[2]. In particular, due to the high nonuniformity of the SAR distribution induced by a mobile phone within the body, the "peak SAR" is the relevant parameter to assess the absorption caused by these devices. Due to the high degree of inhomogenuity of the human head and equipment limitations, compliance testing is performed in realistic shaped phantoms filled with liquids that simulate the dielectric parameters of human head tissues. The overall uncertainty in the evaluation of spatial peak average SAR of such systems is in the order of 20-30%. Therefore, particular attention has been given to comparison tests in order to verify the accurate operation of our system.

## 3. The automated E-field scanner

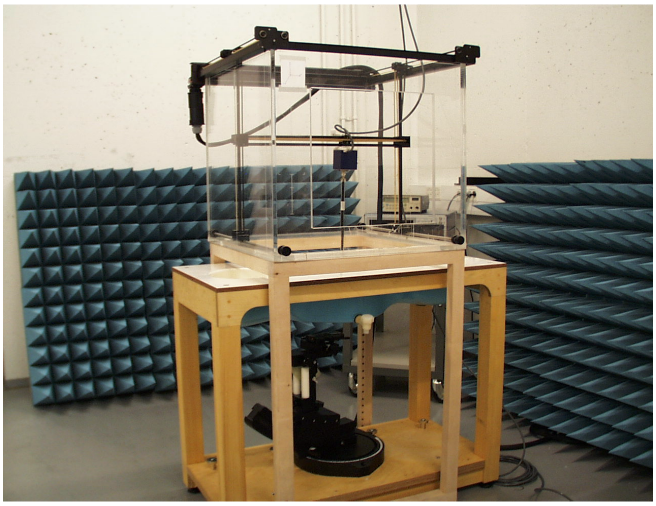

**Figure 1**: the automated E-field scanner

*3.1 The probe positioning system*

The system is fully automated by a three-dimensional (3-D) stepper motor system controlled by a computer. The system was built [3] by DOSETEK to measure isodoses and various dose distributions. It is supported by a rectangular fiberglass box where the probe can be moved a distance of 400 mm in three orthogonal directions. Movement is achieved through the use of homoheteropolar stepper motors and miniature timing belts. One step produces a linear motion of 0.1 mm.

*3.2 The E-field probe and its data acquisition system*

The E-field probe [4] is commercially available by Schmid & Partner Engineering AG. The ET3DV5 model used here is an isotropic probe for dosimetric assessments with a frequency range of 10 MHz to 6 GHz, a linearity of $\pm$ 0.2 dB and a dynamic range of 5 μW/g up to 100 mW/g.

The probe is mounted on a data acquisition system which transmits data from the probe to the PC-card through an optical downlink for data and status information and which receives commands from the PC-card by an optical uplink.

*3.3 The phantom*

Currently the generic twin phantom commercially available by Schmid & Partner Engineering AG is used [5], [6]. Various standardization committees are now drafting standards for the experimental assesment of SAR. IEEE SCC-34 SC-2 and CENELEC have proposed a new generic phantom based on the data from [7]. The new proposed phantom will be utilized in our system as soon as it will be commercially available.

*3.4 Data acquisition and positioning system control*

Dasy3 mini, a simplified version of the Dasy3 software developed by Schmid & Partner Engineering AG, acquires the data coming from the data acquisition card mounted on the computer and allows the user to define the type of the probe, the used medium and the type of the device under test. Then, TestPoint [8], a tool for creating custom tests, measurement and data acquisition, controls the probe movements and triggers measurements. Finally, to link these two softwares, Microsoft Excell is used.

4. Algorithms for the evaluation of spatial peak average SAR.

The SAR distribution in the phantom's head is evaluated in two steps. First, the entire head is scanned using a grid which covers the largest surface of the head. This coarse grid is performed at a distance of few millimeters from the inner surface of the phantom and the step separating two consecutive points is 15 mm. From this stage, the location with the maximum peak SAR is found and the probe is moved to this specific point. Then, a cubic grid of 175 points ($5 \times 5 \times 7$) centered on this local peak is performed.

Various algorithms written in Matlab are then used for the evaluation of spatial peak average SAR in 1 or 10g from the measured points. The first stage of data processing is to extrapolate the measured values to the inner surface of the phantom. Then, the data is interpolated with a one-dimensional interpolation algorithm (spline) along the three orthogonal axis with a 1 mm interpolation step. Finally, the spatial peak average SAR in 1 or 10g can be computed with two methods: A) as a cube centered on the local peak interpolated value with 1 or 10g of mass or B) as the cube with the maximum SAR and the corresponding mass of 1 or 10g which is contained in the entire cubic grid. The second method is obviously time-demanding since the entire cubic grid must be scanned for all the cubes of a corresponding mass of 1 or 10g.

5. Comparison tests.

6 commercial GSM900 phones were measured in 7 laboratories [9]. The measurements were then repeated with our system and compared to 3 laboratories where a similar lossless ear spacer and DASY system were used. In Table1 and 2, the mean value (mean of 6 consecutive measurements in each laboratory) for 1 and 10g respectively is presented for each laboratory. Besides, in the last column, the raw measured data from Laboratory1 (Lab1) has been evaluated with our spatial peak

average SAR algorithm. Out of the 6 raw data files which were obtained in Lab1 for each phone, only one was evaluated once again in Nokia Research Center. Therefore, in this last column, one will find the SAR results (X/Y) coming from this specific measurement in Lab1 (X) which was re-evaluated with our spatial peak average algorithms (Y). In Table3 and 4, the variation in percentage between the mean value of the 6 phones in Lab1 (assumed as reference values) and the mean value of the phones in all the rest of the laboratories is presented. As well as in the two previous tables, the last column gives the deviation in percentage between the measured value coming from Lab1 and the result we got when evaluating the same raw data file.

**Table 1**: Mean value of 1g average SAR in the 4 laboratories.

| | NRC | Lab1 | Lab2 | Lab3 | Lab1 raw data– NRC algorithm |
|---|---|---|---|---|---|
| Phone1 | 0.53 | 0.50 | 0.62 | 0.58 | 0.50/0.50 |
| Phone2 | 0.69 | 0.67 | 0.76 | 0.73 | 0.65/0.65 |
| Phone3 | 0.70 | 0.66 | 0.75 | 0.74 | 0.65/0.65 |
| Phone4 | 0.94 | 0.98 | 1.08 | 1.10 | 0.97/0.96 |
| Phone5 | 1.13 | 1.22 | 1.32 | 1.37 | 1.22/1.21 |
| Phone6 | 1.29 | 1.30 | 1.38 | 1.39 | 1.25/1.25 |

**Table 2**: Mean value of 10g average SAR in the 4 laboratories.

| | NRC | Lab1 | Lab2 | Lab3 | Lab1 raw data– NRC algorithm |
|---|---|---|---|---|---|
| Phone1 | 0.32 | 0.31 | 0.38 | 0.36 | 0.31/0.31 |
| Phone2 | 0.47 | 0.48 | 0.52 | 0.51 | 0.45/0.45 |
| Phone3 | 0.46 | 0.45 | 0.50 | 0.47 | 0.44/0.44 |
| Phone4 | 0.53 | 0.60 | 0.66 | 0.66 | 0.59/0.59 |
| Phone5 | 0.63 | 0.74 | 0.78 | 0.79 | 0.74/0.74 |
| Phone6 | 0.78 | 0.82 | 0.86 | 0.85 | 0.79/0.79 |

**Table 3**: Variation(%) between the mean value of Lab1 assumed as a reference value and the mean values from the rest of the Labs – 1g averages

| | NRC | Lab2 | Lab3 | Lab1 raw data– NRC algorithm |
|---|---|---|---|---|
| Phone1 | 6 % | 24 % | 16 % | 0.64 % |
| Phone2 | 2.98 % | 13.4 % | 8.9 % | 0.09 % |
| Phone3 | 5.7 % | 13.6 % | 12.1 % | 0.08 % |
| Phone4 | 4.08 % | 10.2 % | 12.2 % | 0.63 % |
| Phone5 | 7.38 % | 8.2 % | 12.3 % | 0.58 % |
| Phone6 | 0.77 % | 6.15 % | 6.9 % | 0.02 % |
| **Overall deviation** | **4.48 %** | **12.59 %** | **11.4 %** | **0.34 %** |

**Table 4**: Variation(%) between the mean value of Lab1 assumed as a reference value and the mean values from the rest of the Labs – 10g averages

| | NRC | Lab2 | Lab3 | Lab1 raw data– NRC algorithm |
|---|---|---|---|---|
| Phone1 | 3.23 % | 22.6 % | 16.13 % | 0.19 % |
| Phone2 | 2.08 % | 8.33 % | 6.25 % | 0.18 % |
| Phone3 | 2.22 % | 11.11 % | 4.44 % | 0.9 % |
| Phone4 | 11.67 % | 10 % | 10 % | 0.42 % |
| Phone5 | 14.86 % | 5.4 % | 6.76 % | 0.01 % |
| Phone6 | 4.88 % | 4.88 % | 3.66 % | 0.12 % |
| **Overall deviation** | **6.49 %** | **10.39 %** | **7.87 %** | **0.30 %** |

6. Conclusion

The automated E-field scanner developed in Nokia Research Center laboratory and presented here is based on the commercial system Dasy3 manufactured by Schmid & Partner Engineering AG. The existing differences between the two systems come from the probe positioner and from the fact that the used probe is not yet equipped with proximity sensors which will give a feedback to the user concerning the distance probe tip – inner surface of the phantom. Nevertheless, this feature, which is closely linked with the uncertainty coming from the extrapolation of the measured SAR levels towards the inner surface of the phantom where maximum peak SAR exists, will be implemented this year.

A very good agreement (5 % in 1g and 7 % in 10g) exists between the measured average SAR values in our laboratory and the results coming from the laboratory taken as a reference. When the raw data from Lab1 is evaluated with our algorithms for 1g and 10g averages, the deviation is negligible (0.34%). The overall deviation of our system compared to the reference is even lower than the deviation between the reference and the two other commercial systems utilized during the interlaboratory comparison.

In the near future, after the proximity sensors would have been implemented on the system developed in Nokia Research Center, the idea would be to repeat the same study using other commercial SAR measuring systems and other MTE and then check whether a better accuracy could be achieved or not.

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