SARs FOR BODY- AND POCKET-MOUNTED MOBILE

TELEPHONES AT 835 AND 1900 MHz

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ABSTRACT

As recommended by U.S. FCC, we have used a planar phantom to assess peak 1- and 10-g SAR of two typical cellular telephones operating at 835 or 1900 MHz if it were mounted at the waist or left in the shirt pocket with a connection to the ear via an earphone. An agreement within ±10% is obtained for calculated and experimental 1-g SARs for both of the commercial telephones at 835 MHz for various separations (2-8 mm) used to represent different thicknesses of the clothing both for the antenna away from or turned back toward the body. Also, as expected, the peak 1- and 10-g SARs are considerably higher (by up to a factor of 3) for pocket-mounted telephones as compared to the SARs obtained using a plastic ear head model -- a procedure presently accepted both in the U.S. and Europe.

INTRODUCTION

Increasingly, the mobile telephones are becoming pocket-sized and are being mounted at the waist or left in the shirt pocket with a connection to the ear via an earphone. In the absence of specific instructions to the contrary, the telephones may be placed with antennas away from or close to the body. Some of the antennas may thus be in contact with the chest with a separation of no more than a few millimeters depending on the thickness of the clothing between the pocket and the torso. The SAR distributions for such telephones are radically different than these telephones held against the ear. The telephones are presently tested held against a homogeneous model of the head for compliance with peak 1- or 10-g SAR prescribed in IEEE or ICNIRP Safety Guidelines, respectively [1, 2]. The purpose of this paper is to compare peak 1- and 10-g SARs for a couple of typical telephones shown in Fig. 1 when they are held against the ear or put in the shirt pocket. The latter configuration is being increasingly used while driving. For the body-worn operating configurations (including the pocket-mounted situations), the United States Federal Communications Commission recommends use of a flat planar phantom such as the one shown in Fig. 2 [3]. Furthermore, this same FCC Supplement C (Edition 01-01) recommends a base thickness of 2.0 ± 0.2 mm for this phantom and dielectric properties that must be used to simulate body tissues at various frequencies. The dielectric properties recommended in [3] are: ε_r = 55.2, σ = 0.97 S/m at 835 MHz, and ε_r = 53.3, σ = 1.52 S/m for frequencies between 1800-2000 MHz. Even though a base thickness of 2.0 ± 0.2 mm has been recommended in FCC Supplement C [3], we have also taken additional separations of 4, 6, and 8 mm to simulate the situations when different layers of clothing are used by individuals and would alter the separation between the telephone and the planar phantom as a simulant of the torso.

NUMERICAL CALCULATIONS

The finite-different time-domain (FDTD) method has been extensively used for calculations of SAR distributions for cellular telephones by many authors (e.g. see Ref. 4) and has also been used here. The two telephones, Telephones A (left) and B (right), shown in Fig. 1 are of approximate dimensions 2.2 x 4.2 x 10.6 and 2.6 x 5.6 x 16.8 cm and use antennas of lengths 8.8 and 9.0 cm, respectively. Both of the telephones operate in the frequency band 824-849 MHz. Since these telephones are fairly similar to the telephones on the market today, both for the 835 MHz and 1900 MHz PCS bands, we decided to use the same dimensions for assumed 1900 MHz telephones as well. For the higher-frequency telephones, we used nominal quarter-wavelength antennas of length 4.0 cm that are more typical at 1900 MHz. The resolution of both the planar phantom and the telephones modeled as a metal box covered with a plastic of effective dielectric constant ε_r = 1.43 (reduced as in [4] because of thinner plastic and thicker 2 mm cell size for the FDTD cell grid) was 2 x 2 x 2 mm for all of the calculations. Assumed for the calculations is a dielectric constant ε_r = 2.56 for the Acrylic base used for the planar phantom that is filled with corresponding fluids to simulate the aforementioned dielectric properties of the body tissues.
The peak 1- and 10-g SARs calculated for various separations of 0, 2, 4, 6, and 8 mm for Telephones A and B (of Fig. 1) are given in Figs. 3 and 4, respectively. In these figures, given are the SARs when the antenna is pointed away from the planar phantom (marked "front") as well as when the cellular telephone is turned "back" and the antenna is closer to

the phantom. As expected, the peak 1- and 10-g SARs reduce monotonically with increasing separations from the body. Also shown in Figs. 3 and 4 are the calculated peak 1- and 10-g SARs for the respective Telephones A and B placed against the Utah Model of the human head with a 6 mm thick plastic ear, as recommended in [3]. It is interesting to note that both the peak 1- and 10-g SARs for the planar model are considerably higher than those calculated for the telephone placed against the plastic-ear head model as recommended for SAR compliance testing both in the U.S. [3] and in Europe [5].
Fairly similar monotonically reducing peak 1- and 10-g SARs are also obtained at 1900 MHz for Telephones A and B with assumed antenna lengths of 4.0 cm. As for 835 MHz in Figs. 3 and 4, here too the SARs for antennas closer to the body ("back") are a factor of 2-3 times higher than antennas away from the body ("front").

EXPERIMENTAL MEASUREMENTS

The 3-D stepper-motor-based University of Utah SAR measurement system [6] is used to measure peak 1-g SARs for Telephones A and B placed against the flat planar phantom of internal dimensions 30 x 30 cm with separations of 2, 4, 6, and 8 mm from the bottom of the lossy tissue-simulant fluid (see Fig. 2). The experimentally-determined peak 1-g SARs are also plotted in Figs. 3 and 4, respectively. Agreement with numerically-calculated SARs is very good and generally within ±10%.

CONCLUSIONS

As recommended by U.S. FCC [3], a planar phantom is used to assess peak 1- and 10-g SAR of two typical cellular telephones operating at 835 and assumed for 1900 MHz as though it was mounted at the waist or placed in the shirt pocket to compare the SARs thus obtained with those used for the head-shaped model with a 6 mm thick plastic ear [3]. Recognizing that the thickness of clothing may vary, separations of 0-8 mm are used for numerical calculations and 2-8 mm are used for experimental measurements. An agreement within ±10% is obtained for calculated and experimental peak 1-g SARs at 835 MHz. Also, as expected, the peak 1- and 10-g SARs are considerably higher (by up to a factor of 3) for "pocket-mounted" telephones as compared to the SARs obtained using a plastic-ear head model. The peak 1- or 10-g SARs for the head model are very close to those obtained for a flat phantom with a 6 mm base rather than the 2 mm base presently recommended by the FCC [3].

REFERENCES

[1] IEEE STD. C95.1 "IEEE standard for safety levels with respect to human exposure to radiofrequency electromagnetic fields 3 kHz to 300 GHz," published by Institute of Electrical and Electronics Engineers, New York, NY, 1999.

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

[3] U.S. FCC (Federal Communications Commission), "Evaluating compliance with FCC guidelines for human exposure to radiofrequency electromagnetic fields," Supplement C (Edition 01-01) to OET Bulletin 65 (Edition 97-01), Washington DC 20554.

[4] O.P. Gandhi, G. Lazzi, and C.M. Furse, "Electromagnetic absorption in the human head and neck for mobile telephones at 835 and 1900 MHz," *IEEE Trans. Microwave Theory and Techniques*, vol. 44, pp. 1884-1897, 1996.

[5] European Standard EN50361, "Basic standard for the measurement of specific absorption rate related to human exposure to electromagnetic fields from mobile phones (300 MHz-3 GHz)," CENELEC European Committee for Electrotechnical Standardization.

[6] Q. Yu. O.P. Gandhi, M. Aronsson, and D. Wu, "An automated SAR measurement system for compliance testing of personal wireless devices," *IEEE Trans. Electromag. Compatibility*, vol. 41, pp. 234-245, 1999.

Fig. 1. Two commercial telephones A (left side) and B (right side) selected for SAR testing at 835 MHz.

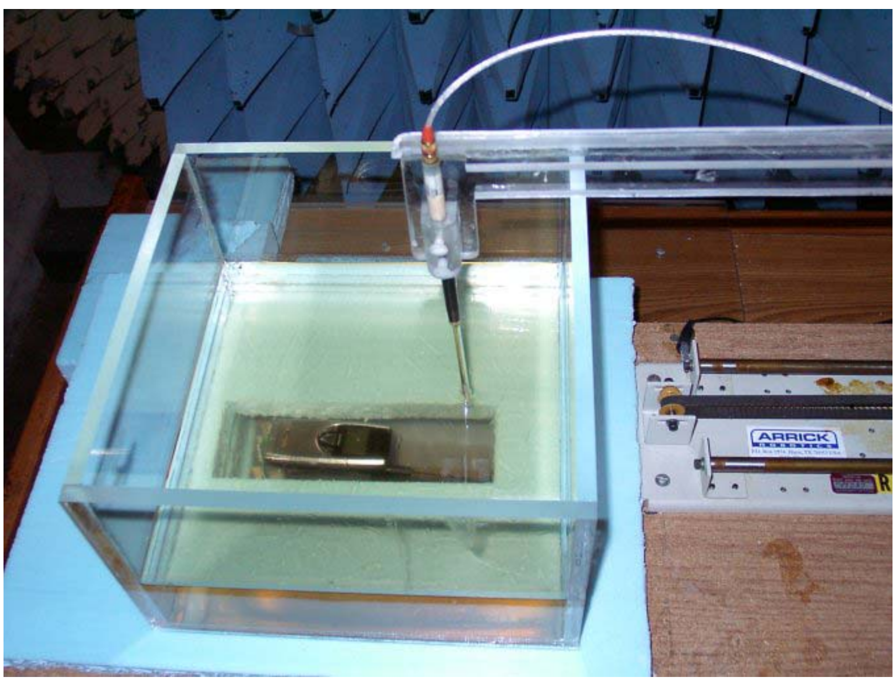

Fig. 2. A flat 2.0 mm (0.079") base-thickness phantom used for SAR testing. A Styrofoam block is used under the base to prevent buckling.

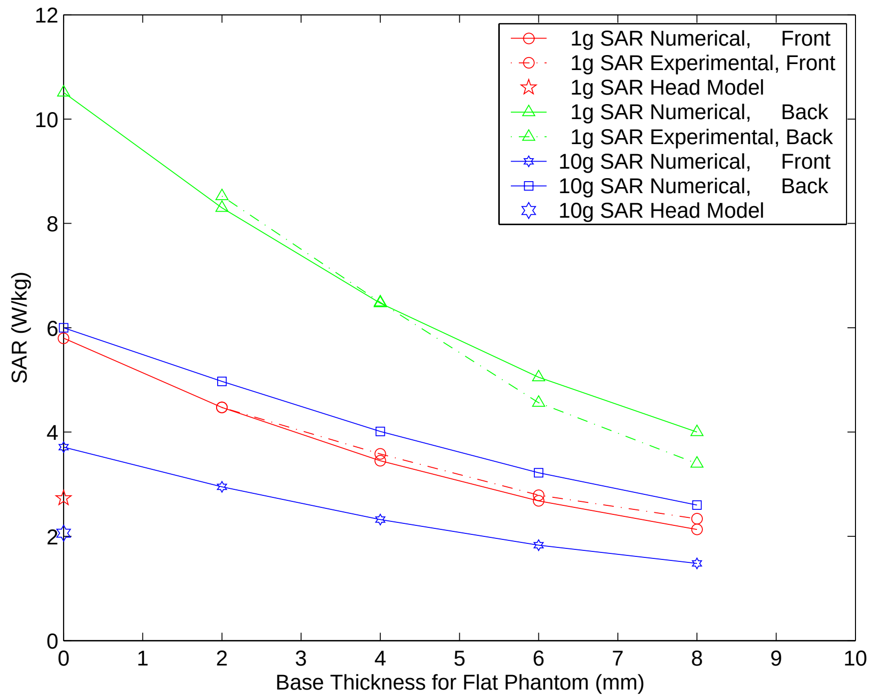

Fig. 3. Calculated and measured peak 1-g SARs as a function of separation from the tissue-simulant fluid of the flat phantom for Telephone A at 835 MHz. Also shown are the calculated 10-g values for the flat phantom and peak 1- and 10-g values for a 6 mm thick plastic ear head model.

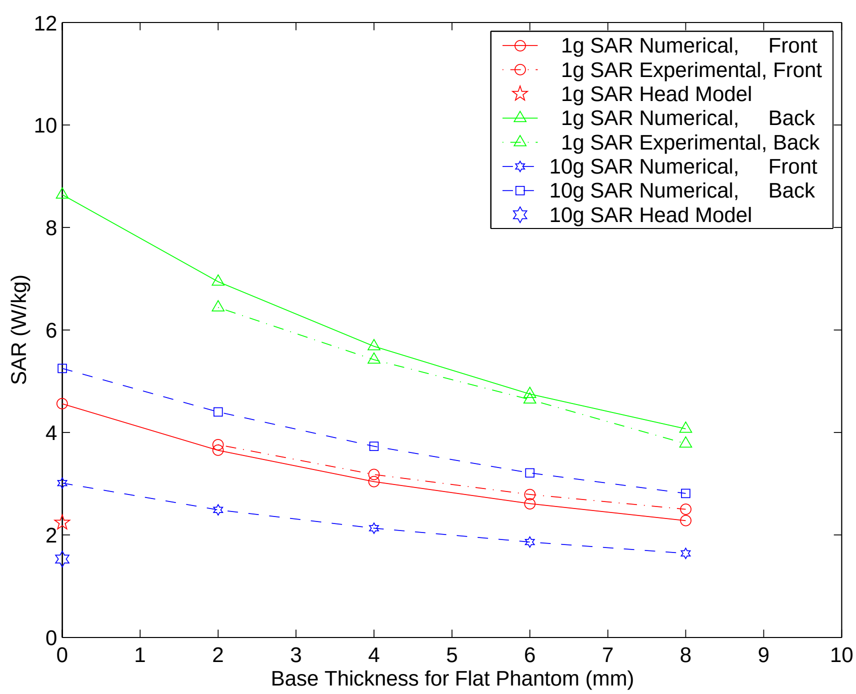

Fig. 4. Calculated and measured peak 1-g SARs as a function of separation from the tissue-simulant fluid of the flat phantom for Telephone B at 835 MHz. Also shown are the calculated 10-g values for the flat phantom and peak 1- and 10-g values for a 6 mm thick plastic ear head model.