

Relationship between Temperature Rises with SAR in a Head Tissue in Bandwidth Exposure

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Abstract. In this paper we suppose to discuss recent results of study influence of Electromagnetic (EM) exposure of mobile phones radiation on the user. This is the part of topic: “Developing a Thermal Exemptions Rationale for Low-Power Transmitters”. Particularly, we present results of computer simulation of the users head exposure via radiation of electrically small and resonant length antennas. Compare and contrast threshold power with temperature increase in tissue and SAR. Investigate the relationship between temperature rise with SAR and between temperature rise and bandwidth/efficiency.

Introduction.

Our aim was to investigate EM exposure and determine maximal SAR and temperature rise values in various scenarios not including blood flow and vascular structure considerations. The task consisted in following: use of the FDTD method and anatomically based human head models; compute the peak 1g and 10g mass averaged SAR [1] and the temperature increase in tissue for canonical dipole antennas at 300, 450, 900, 1450, 1900, 2450, 3700 and 6000 MHz; compute SAR and temperature increase [2] data at distances of 5, 10 and 20 mm from model; consider straight-wire dipole lengths of $\lambda/15$, $\lambda/8$, $\lambda/4$, and $\lambda/2$.

There were 8 frequency points, 4 antenna sizes, and 3 distances which makes 96 cases of simulations for the wire dipole antennas. This work was divided as follows: (1) simulations at 900, 1900, 2450, and 6000 MHz were performed in University of South Carolina (USC) and (2) simulations at 300, 450, 1450, and 3700 MHz were performed at Tbilisi State University (TSU).

Operating Frequency and Distances.

We define 300, 450, 900, 1450, 1900, 2450, 3700 and 6000 MHz as the frequencies at which the research investigation was carried out. These frequencies are chosen because they are within or near popular frequency bands of interest for existing wireless transmitters (e.g., land mobile radio, cellular, Bluetooth, WLAN, WiMax, and 4G devices).

Method of Investigation.

The proposed research was performed using the FDTD (finite difference time domain) method. Temperature increase in tissue was simulated due to RF exposure from antennas placed at different distances from the head models. An in-house FDTD code named FDTD-Lab, developed at TSU [3], was used along with XFDTD from

Remcom Inc. At the initial phases of the project various standard antenna and phantom orientations were simulated using both programs to ensure that the results obtained are the same. The USC lab used XFDTD due to their familiarity with the program during MMF/GSMA work package 1 while the Tbilisi State University Lab used FDTD-Lab. Dipole antennas of lengths $\lambda/15$, $\lambda/8$, $\lambda/4$, and $\lambda/2$ operating at 300 and 450 MHz were placed at distances of 5, 10 and 20 mm from the Duke anatomical model from IT'IS Foundation [4] Fig.1. Distances between the head and the dipole are calculated as it is shown at Fig. 2.

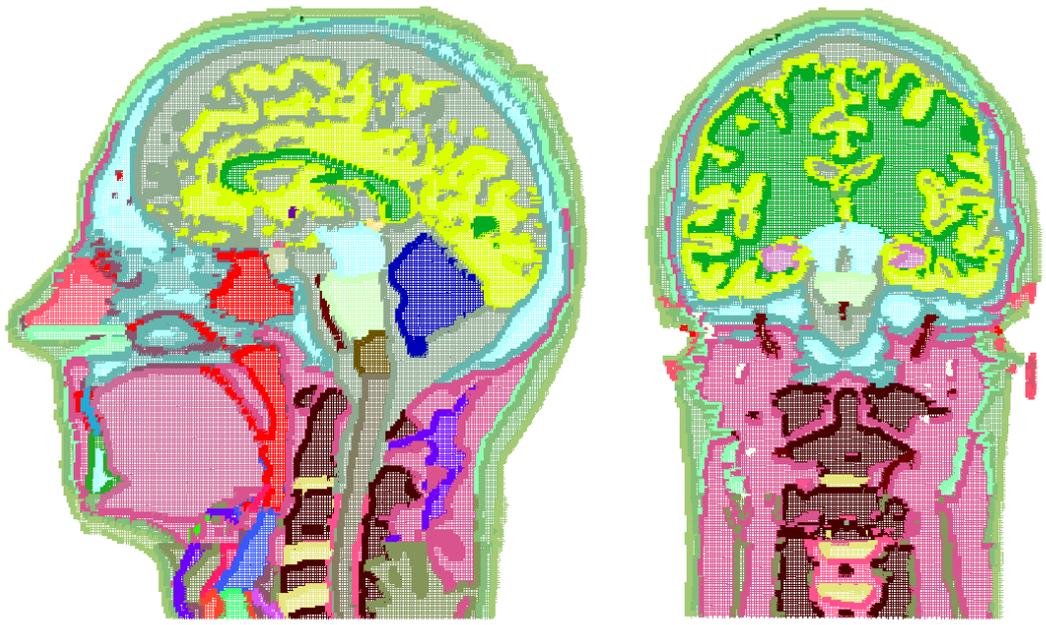


Fig. 1. A 1mm grid of the Duke's head model, with L/4 450 MHz antenna

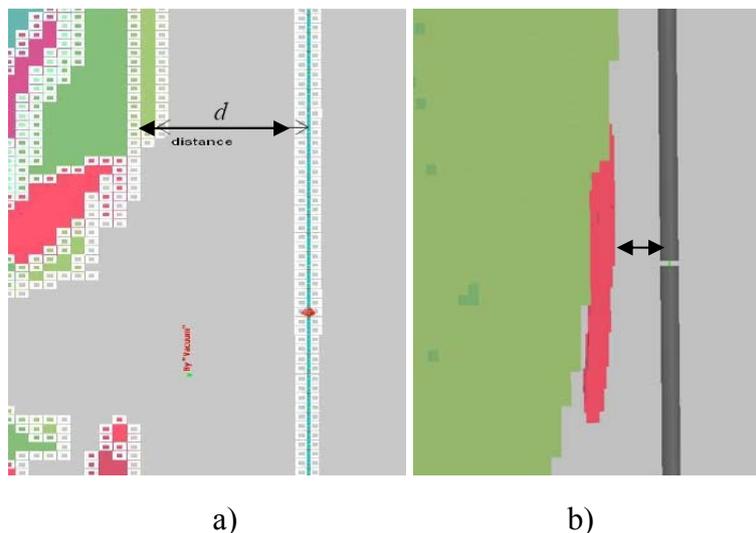


Fig. 2) Calculating distance between antenna and the head model.
a) In FDTD Lab, b) in XFDTD

Duke is a 34 year male whose human body model was developed from MRI data with a resolution of 1mm in each direction [4]. The resolution of the head model was 1 mmx1 mm x1 mm The head and torso model is 700 mm long and contains 70 types of

different tissues/organs whereas the head only model is 250 mm long and contains 47 different tissues/organs. Most of the permittivity and conductivity values of different tissues/organs were obtained from the Italian National Research Council (<http://niremf.ifac.cnr.it/tissprop>) database. The permittivity and conductivity values of the average brain tissue and the connective tissue were obtained from the FCC (www.fcc.gov/fcc-bin/dielec.sh) database. The values of thermal parameters, such as heat capacity, thermal conductivity, metabolic heat and blood perfusion were gleaned from [1]-[2].

The thickness of the ear of the Duke Head model was reduced from 18 mm to 5 mm by compressing the tissues of the ear. This compression was performed to simulate the morphology of the ear during a phone call. Each dipole placed next to the model was excited using a 1 mm gap excitation and with a continuous wave sinusoidal source with appropriate frequency. All SAR and temperature rise data were normalized to 1W of power and reflection losses due to impedance mismatch were completely ignored. Hence the SAR and temperature rise data will reflect the maximum absorption of power by the specific antenna under consideration.

Results of Calculations.

The relationships between temperature rise and SAR and between temperature rise and bandwidth/efficiency were investigated. We can clearly see these relationships from Fig. 3 and Fig.4.

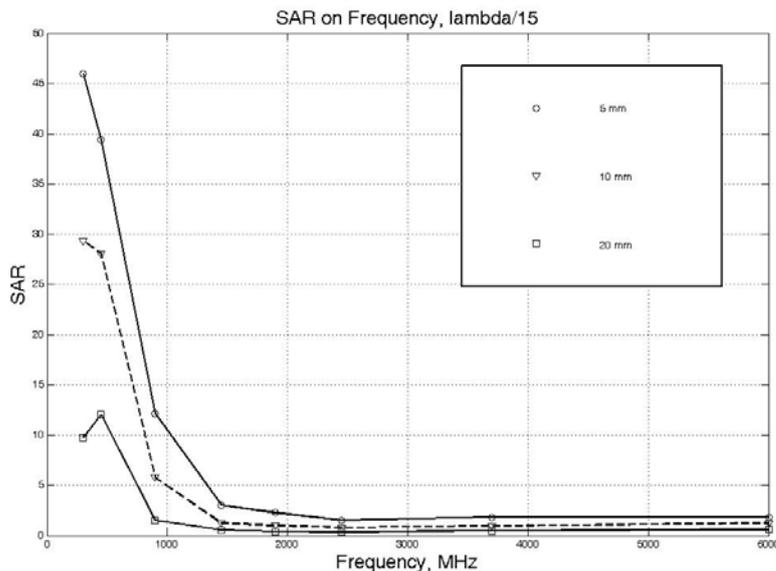


Fig.3. Dependence of SAR on frequency. At lower frequencies SAR is maximal in all scenarios, while after 1450 MHz it is not changing significantly.

On Fig. 3. we can see, that with the increase of distance the SAR decreases, which must be obvious. Also, we can see that at the frequencies less than 1000 MHz it occurs that SAR values are several times higher. It must be because of higher penetration of the fields on those frequencies or because of some resonant properties of the object of investigation – size of the Duke Head model.

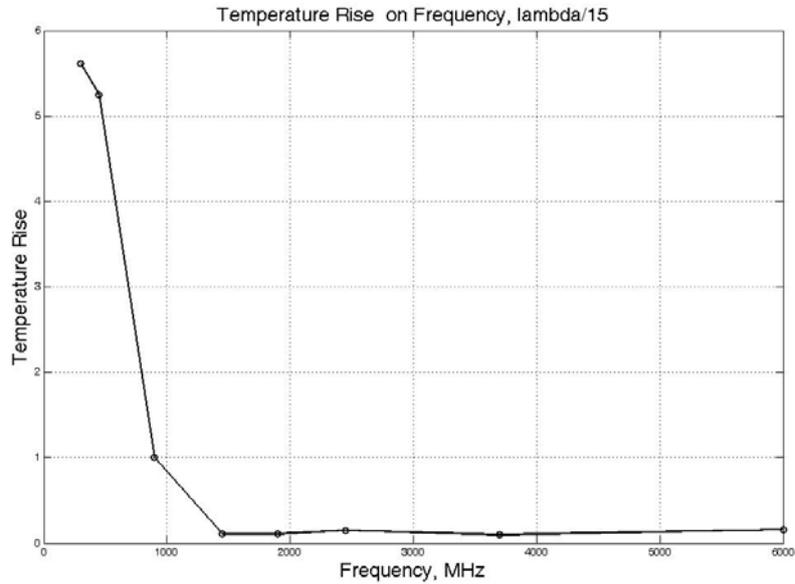


Fig.4 Temperature rise dependence on frequency. The temperature rise dependence correlates with the dependence of SAR

The SAR distribution and temperature rise for one on the studied cases is presented on Fig. 5. It can be seen that volumetric distribution for both cases is basically the same.

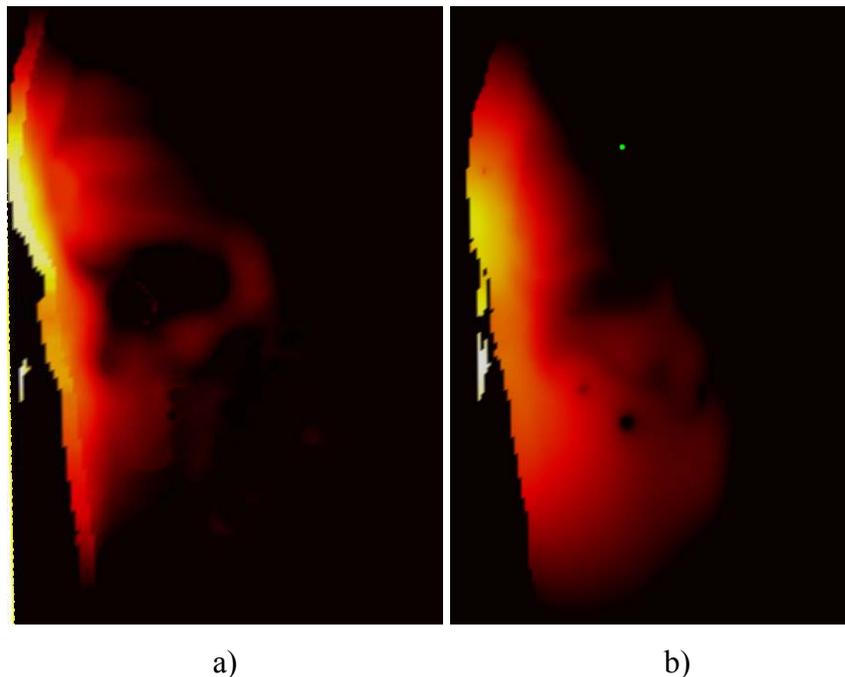


Fig 5. 300 MHz, $\lambda/15$, 5mm. a) SAR distribution b) Temperature rise. With the input power of 1W temperature rise is 6.36

At Fig.6 We can clearly see how penetration of the field differs at low and high frequencies. At 300MHz and 450MHz significant part of energy can reach the opposite side of the model. At higher frequencies 1450 MHz, 1900MHz and greater the main part of energy is being absorbed in the thin boundary layer. As a consequence

at low frequencies temperature rise in points inside of the studied model is much higher compared to same points at higher frequencies.

Despite of differences of penetration depth in most cases the peak SAR and temperature rise values were located in the ear's lobe. At low frequencies e.g. 300 400 MHz, the SAR and temperature rise values were above civil standards. This probably is due to the size of Duke's head model, which may be resonant for low frequencies. Investigation on the model of the torso with length of 700mm is planned.

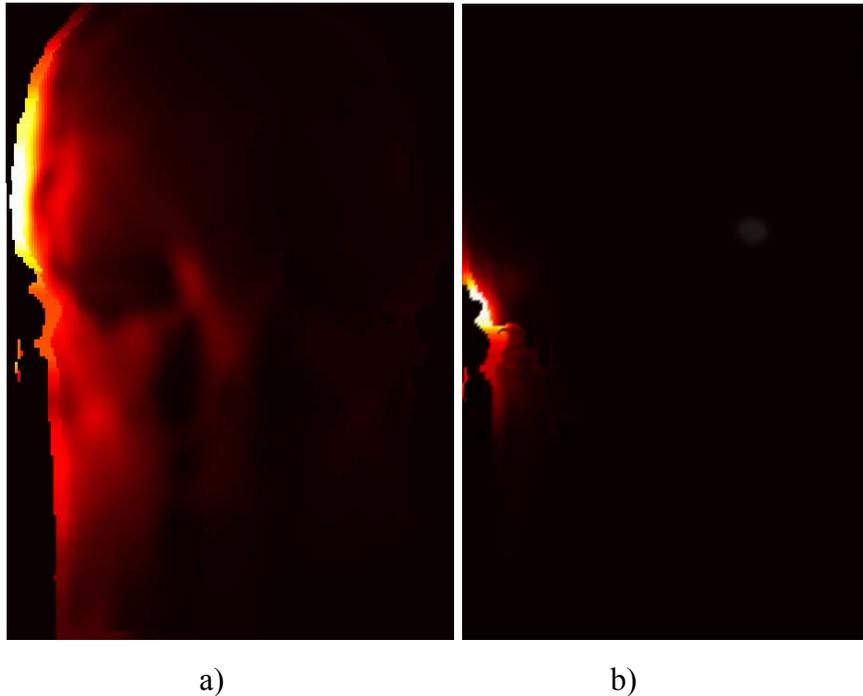


Fig.6 a) 300MHz $\lambda/4$ at 10mm, b) 3700MHz $\lambda/2$ at 10mm. Both images are in plain scale. SAR normalized to 1W input power

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