Computation of SAR distributions in human brain tissue for different types of antennas and frequencies

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The very rapid evolution of wireless telecommunications systems has led to public concern about the health hazards of electromagnetic energy. For many years, this question has been studied and the exposure limits have been established by such international organizations as ICNIRP and IEEE to protect the body from the hazards of exposure to RF electromagnetic fields. Before the use of portable personal wireless communication equipments was widespread, it was rare for a RF source to be located close to human head. Damages caused by electromagnetic field on biological tissues are thought to play role in temperature increase in cerebrospinal fluid, formation of cancers like brain tumors and ear tumors. It is aimed in this study to determine specific absorption rate (SAR) values created in human brain tissue by 900 MHz and 1800 MHz different antenna types. In the simulations helix and PIFA antenna structures are modeled using CST Microwave Studio. As a result of these simulations, SAR values were determined for different frequencies and antennas.

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1. Introduction

There has been increasing public concern about the possible health effects of human exposure to electromagnetic (EM) waves [1,2]. Due to the cell phones entered into our lives especially after 1990s, a significant increase in the field exposure is suffered by individuals from all ages and genders. Moreover, this field is used in a place close to brain which is a sensitive and important organ. Therefore, the potential health effects caused by cell phone usage are studied extensively in scientific field [3,4].

Based on the international standards [5,6] specific absorption rate (SAR) is used as a metric of basic restriction for RF whole-body exposure. The limit is 0.4 W/kg for occupational exposure or 0.08 W/kg for public exposure. An incident electric/magnetic field or power density, which does not produce EM absorption exceeding the above basic limit, is referred to as the reference level or maximum permissible exposure [7].

2. Specific Absorption Rate (SAR) calculation

SAR is a dosimetric parameter used widely in the interactions of RF and microwave fields in biological systems. While SAR is defined as the amount of energy passing through the unit mass of a body per unit time, average SAR is the total energy passing through the entire mass of the body per unit time [8,9].

$$SAR = \frac{d(\Delta W)}{dt(\Delta m)} \quad \Delta m = \rho \Delta V \tag{1}$$

$$SAR = \frac{d\,(\Delta W)}{dt\,(\rho \Delta V)} \tag{2}$$

Here, ΔW is the energy transferred to a Δm mass, ρ is the density of the body in kg/m^3 units, ΔV is the volume covering Δm [10]. For sinusoidal varying fields, SAR is calculated by the following equation from the electric field in tissue.

$$SAR = \int_{sample} \frac{\sigma\,(r)\left|E\,(r)\right|^2}{\rho\,(r)}\,dr \tag{3}$$

Here σ is sample electrical conductivity, E_{RMS} is the electric field and ρ is the sample density. SAR is expresses as W/kg or mW/gr [11,12].

As it can be seen in SAR formulas, electric field intensity in tissue needs to be measured in order to find SAR value. It is applied only to medical subjects for living organisms. For this reason, SAR analysis can only be performed on robots having electrical parameters same with humans and made with salty water and various gels or it is simulated with powerful computers [13-15].

The purpose of this study is to SAR values created in human brain tissue by various antenna types in 900 MHz and 1800 MHz. In the simulation, helix and PIFA antenna structures are modeled by using CST Microwave Studio.

3. The antennas used in simulation

Antennas have deep effect in the development of wireless communication that includes cell phones for GPS systems, laptops adapted with third generation mobile system [16].

In this study two types of antennas typically used in cellular telephones: helix and PIFA antenna has been selected for this study. Because, the volume is the most concerning problem for an antenna types [17]. Therefore, chancing the type of the antenna plays a key role in the design [18,19].

a) Helix antenna

Helix antenna used in the simulation is called as helical antenna or axial-mode helix antennas. The advantages of this helical antenna are wide bandwidth, easy implementation, real input impedance and ability to produce circularly polarized fields.

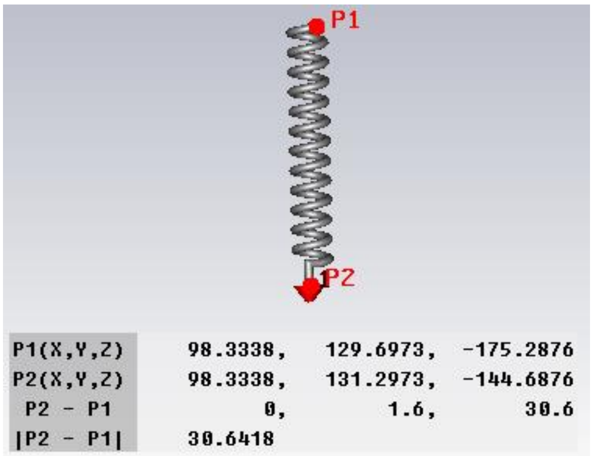


Fig. 1. Helix antenna used in the simulation.

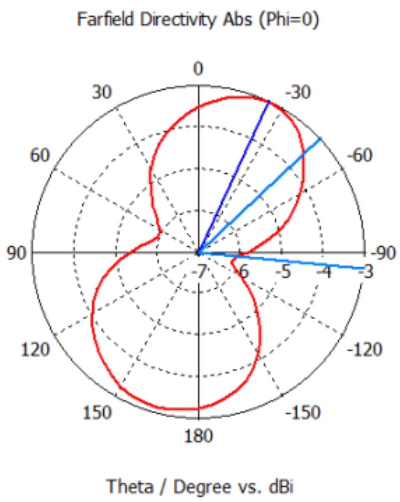


Fig. 2. Helix antenna radiation pattern.

b) PIFA antenna

PIFA (Planar Inverted F Antenna), the antenna type used widely in cell phone industry, is known as an antenna type which has a good SAR and resonance in quarter wavelength. This antenna earns its name by its inverse F looking shape. There are two reasons for PIFA to be used widely. Those are versatility and low profile. A sample PIFA design can be seen in Fig. 2.

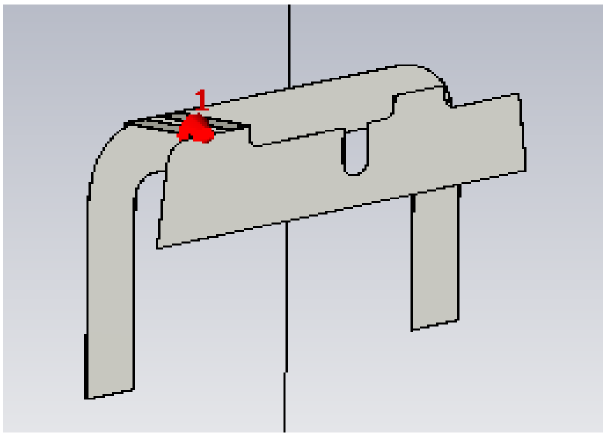


Fig. 3. PIFA antenna used in the simulation.

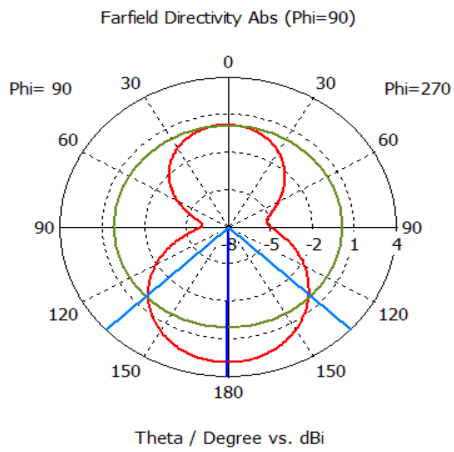


Fig. 4. PIFA antenna radiation pattern.

Antennas under investigation have different radiation patterns and so result in different SAR levels in the head tissues. We compare the power deposition with respect to the SAR levels to determine the antenna that best complies with the safety standards. The following antennas are used in the simulation: helix (Fig. 1) and PIFA (Fig. 3). The simulation outputs used as measures for this comparative study include the SAR.

4. Computational models

In order to create head models and determine SAR values, various software and computers which can run these software in a good performance are needed. Since the head model created in computer program consists of

1500000 meshes, memory and CPU components need to be high-capacity. A laptop computer with CPU Core 2 Duo T6600 2.2 GHz, RAM 4GB DDR3 and 512 MB AMD Mobility HD4570 GDDR3 memory card is used. To investigate in which area the complex and SAR variations occur the most or the least, the image is transferred to a 40” screen and SAR distributions formed in head modeling were investigated. Simulation software are Antenna Magus Classroom Edition 4.0.0 and 2012 Beta test version which is the candidate of the newest edition of Microwave Studio (CST MWS).

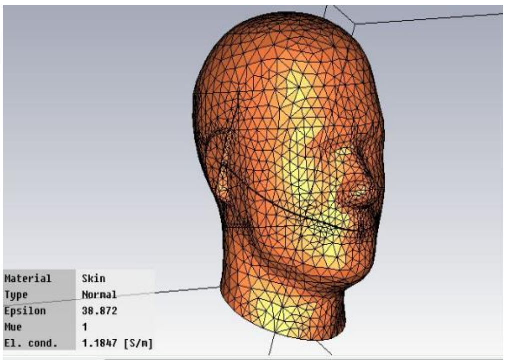


Fig. 5. CST modeling of the human head (1500000 mesh).

SAM phantom was used in the simulation. Phantom model can model the head and neck of a mobile phone user in the form proper to the reality. Model was created by using dielectric constants of the head. In order to receive results close to the reality, equivalents of skin on the head, bone and brain fluids inside the head were entered (Table 1). Results can be observed from all directions by using three-dimensional interface of the simulation program.

Table 1. Complex dielectric specifications of the head model that is used simulations [20].

Layer	Radius (mm)	900 MHz ε_r	900 MHz σ	1800 MHz ε_r	1800 MHz σ	Mass Density (kg/m^3)
Skin	100	39,5	700	38,2	900	1080
Bone (cortical)	95	12,5	170	12,0	290	1180
Brain (Grey matter)	90	56,8	1100	51,8	1500	1050

The frequencies used in the simulation are two different mobile phone frequency bands of 900 MHz and 1800 MHz used today. Cell phones used in the study are old type monopole antennas (helix) and new type PIFAs. The antenna is mounted at the left edge of the enclosure. For the mobile phone positioning; there are two locations used widely and stated in national standards like TS EN 50361 and international standards like IEC 62209-1, IEEE 1528. These are called as cheek and tilted positions. Mobile phones are examined in tilted position. Battery, LCD and keyboard could not be included into two cell phones used. In the model, no accessories such as earrings, glasses are used.

5. Results

In order to determine the effect of various antennas on SAR values caused by exposure of cell phones with 900 MHz and 1800 MHz frequencies, SAR values in 10 gr tissue were calculated and simulation results are given individually.

SAR Simulation for Helix Antenna in 900 MHz Frequency Band

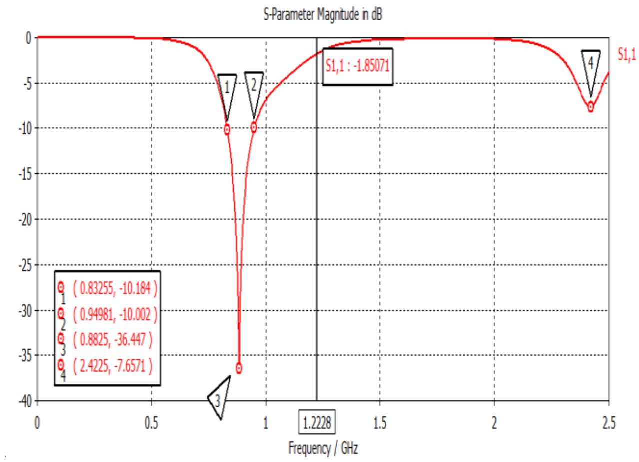


Fig. 6. S_{11} parameter.

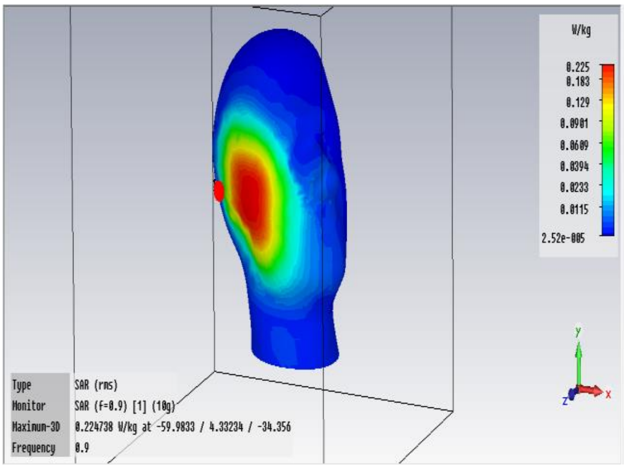


Fig. 7. SAR distribution (abs method).

SAR Simulation for Helix Antenna in 1800 MHz Frequency Band

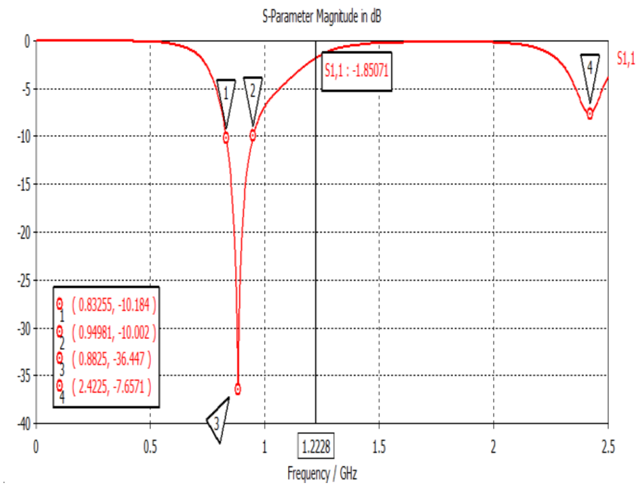


Fig. 8. S_{11} parameter.

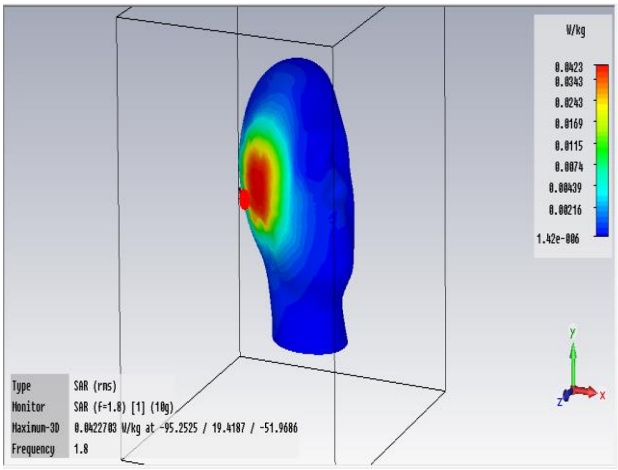


Fig. 9. SAR distribution (abs method).

SAR Simulation for PIFA Antenna in 900 MHz Frequency Band

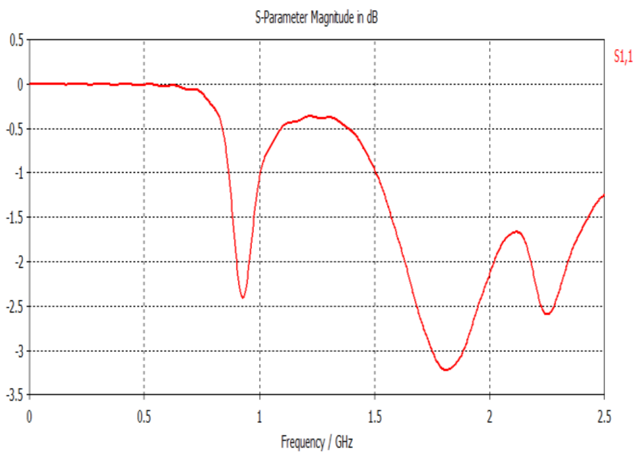


Fig. 10. S_{11} parameter.

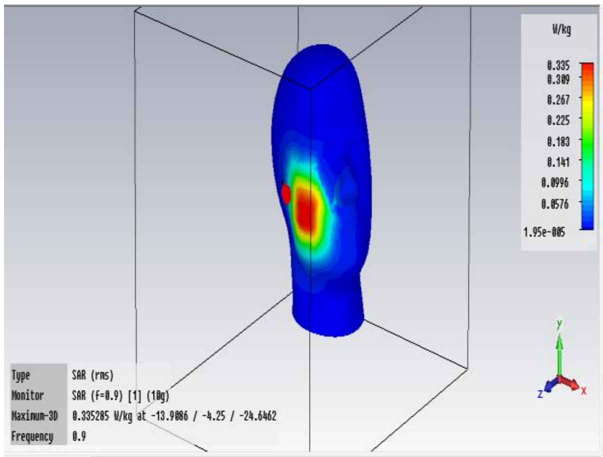


Fig. 11. SAR distribution (abs method).

SAR Simulation for PIFA Antenna in 1800 MHz Frequency Band

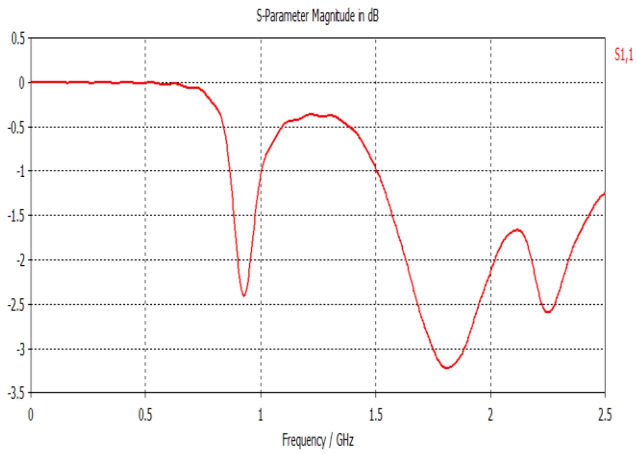


Fig. 12. S_{11} parameter.

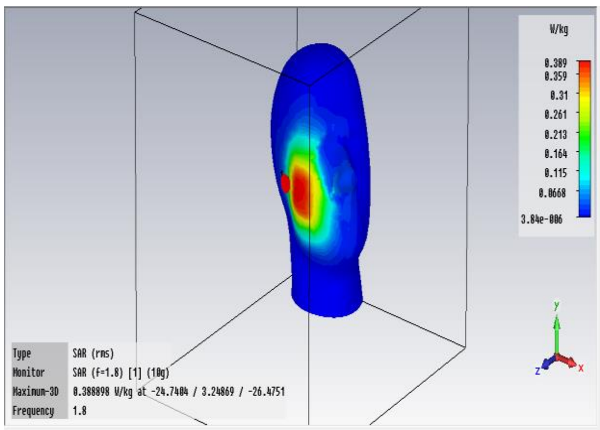
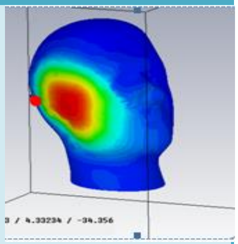
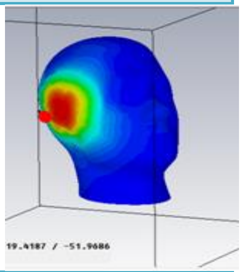
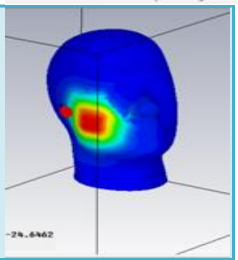
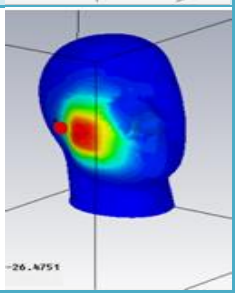


Fig. 13. SAR distribution (abs method).

Table 2. Comparison of the simulation results for helix and PIFA antennas.

Antenna Types	SAR (W/kg)	Frequency (MHz)	Tissue	3D Propagation
Helix Antenna	0.225	900	10 g	
	0.0423	1800	10 g	
PIFA Antenna	0.335	900	10 g	
	0.389	1800	10 g	

6. Conclusions

Together with the advancing technology, RF field sources using wireless communication technologies and the users of these devises have increased. As a result of this rapid increase, possible health effects of this technology have come to the attention in scientific area and among the people. Therefore, knowing SAR values that people are exposed due to cell phone exposure are extremely important.

In this study SAR created by electromagnetic field on the brain, for various frequencies and antenna types was simulated. It has been understood that helix antenna used has much lower effect on the brain at 1800 MHz frequency band than the one in 900 MHz. However, PIFA antenna type used in today's phones has lower effect on 900 MHz frequency band than in 1800 MHz (Table 2).

When SAR values in the same frequency bands are compared, helix antennas found to be more innocent than the new technology PIFA antennas. Accordingly, parallel studies should be continued with groups who conduct measurement researches.

As a result, long term measurements and statistical evaluations should be done before making any declarations related to public health and safety.

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