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Analysis of SAR in Human Blood, Bones and Muscles due to Mobile Waves at 900MHz,1800MHz and 2400MHz

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Abstract

Drastic increase in the usage of cell phones ,increased the adverse effects of electromagnetic radiation on human body. The EM radiations emitted from the cell phone penetrate deep inside the body. The measured rate at which energy is absorbed by the human body when exposed to a radio frequency (RF) electromagnetic (EM) field is specific absorption rate (SAR). It is also defined as the power absorbed by the tissue per unit mass and is measure in watts per kilogram (W/kg). The present paper investigations have been made to estimate specific absorption rate of electromagnetic radiations inside human blood ,muscle and bone as a function of frequency for different cellular frequency bands (800MHz - 900MHz),(1800MHz – 1900 MHz) and (2300MHz -2450Mhz), respectively. Results are obtained for different conductivities , resistivity values ,permeability at the above frequency bands for blood, muscle and bone , and are presented in this paper. To develop the model , MATLAB tools were used and the results obtained are presented in this paper. These results are analyzed and are useful to compare the SAR values with recognized FCC standards.

Keyword: EM radiations, Specific Absorption Rate, SAR , Mobile Radiation, Human Blood, Bone, Muscle

INTRODUCTION

In recent years, mobile telecommunication systems have grown significantly, to the point where more than a sixth of the world's population use mobile phones. With the increase in the use of cell phones, the health of human is getting effected by electromagnetic radiations. These effects are associated with specific absorption rate SAR, the rate which determines the amount of energy absorbed by the human body when exposed to radio frequency(RF) radiations. These radiations penetrate into human body through the skin and effects blood, bone and muscle tissues. So, it is important to investigate the possible health hazard of these tissues when exposed to mobile phone radiations at various mobile frequency bands as (800MHz-900MHz),(1800MHz – 1900 MHz) and (2300MHz -2450MHz).

Cell phones and Cell towers (BTS) emit radio frequency energy which is a form of non-ionizing radiation from their antennas. The frequency of these electromagnetic radiation ranges from 30KHz to 300 GHz..The number of cell phone users has increased rapidly. The number of cell phone calls per day , the length of each call has increased. The human body absorbs energy from devices that emit radio frequency electromagnetic radiation. The amount of absorbed energy is estimated using a measure called Specific Absorption Rate(SAR), which is expressed in watts per kilogram of body weight. The RF radiations emitted from cell phones penetrate through the exposed tissues and produces heat. Two type of effects are produced in human tissues due to radiation i.e., thermal and non-thermal effects. Non-thermal effects includes changes in molecular and cellular level. Thermal effect causes harm by increasing body temperature and damaging the biological tissues particularly head and brain as they are near to the phone.

The specific absorption rate (SAR) is a measure of the rate of energy that is either absorbed or dissipated by any part of the human body due to the use of electronic equipment such as cell phone where "Specific" refers to normalization to mass of the object. In EM field interactions, the E field transfers energy to electric charges where B field does not transmit energy to charges. B field can change only direction of charges because B filed is always perpendicular to the velocities of charges. The average SAR can be determined by measurement of the total absorbed power, the time rate of energy transferred to charges when exposed to biological tissues.

A particular safe limit for SAR should be chosen such that maximum EM radiation can be sustained by the human health without introducing any biological changes. The SAR standards are regulated by world regulatory bodies like International Commission on Non-Ionizing Radiation Protection (ICNIRP) and Federal Communications Commission (FCC). According to ICNIRP standard, the safe SAR limit is 2W/kg for 10g of body tissue.

SAR of cell phone absorbed by humans depends on mobile network carrier, characteristics of mobile phone antenna positioning and radiated power from the cell phone. The other which causes EM absorption is the positioning of the cell phone .The dielectric values of human also effects SAR values. The permittivity and conductivity of the tissues remain constant as they are exposed to constant frequency. Exposure to different operational frequencies alters the conductivity and permittivity accordingly.

As reported in the open literature [1-10] , it has been observed that exposure to RF radiation can be harmful as the RF energy

produces heat in the complex biological human body .When exposed to very high RF power levels of the order of 100mW/cm^2 results in heating biological tissues and increase in body temperature[11]. This is because, human body is unable to cope up with excessive heat that has been generated during the exposure to high RF power densities. In this work, results of estimated SAR for blood, muscle and bones are reported as a function of RF signal frequency used at mobile frequencies.

FORMULATION

Various methods have been reported in the literature for numerical calculation of Specific Absorption Rate[12]. Most common technique used is Moment Method or MOM. The other general method is Finite Difference Time Domain (FDTD) method. The first one is frequency domain method and second one is time domain method. In this paper, SAR calculations follow YEE notation [13] assuming the grid points of the human body defined as (p,q,r) coordinates.

The SAR value depends on the incident fields intensity (or equivalent power density), tissue properties, geometry, size, orientation of the exposed object, frequency of the incident fields, and exposure time.SAR is related to the physical and electrical properties of the absorbing object by the following equations.[14]

$$\text{Specific Absorption Rate} = \text{SAR} = \frac{dP_a}{dm} = \frac{\sigma E^2}{\rho} \text{ (w/kg)} \quad (1)$$

$$\text{SAR} = \frac{3\sigma\delta^2}{2\rho} \text{(w/kg)} \quad (2)$$

Where dP_a = power absorbed to volume of the tissue (W), dm = the mass of a certain infinitesimal volume (kg) , σ = local effective conductivity of the tissue material(S/m) ,

ρ = local density(kg/m^3), E = magnitude of electric field at the inspection point (V/m), δ is the penetration depth (mm)

The conductivity[15] and local density[16] properties of human blood , muscle, bone tissues at 900MHz ,1800MHz & 2450 MHz are presented in table[1-4]

Table 1: Conductivity of Blood

Frequency	σ(S/m)
900MHz	1.53
1800 MHz	2.0435
2450 MHz	2.54

Table 2: Conductivity of Muscle

Frequency	σ(S/m)
900MHz	0.94294
1800 MHz	1.341
2450 MHz	1.60

Table 3: Conductivity of Bone

Frequency	σ(S/m)
900MHz	2.54
1800 MHz	1.60
2450 MHz	0.38459

Table 4: Density values of Blood, Muscle, Bone

Frequency	Density(kg/m^3)
Blood	1850
Muscle	3490
Bone	1042

RESULTS AND DISCUSSIONS

In the mobile communication system 800MHz-900MHz band, 1800MHz-1900MHz band and 2300MHz – 2450MHz band are very widely used. Usually, 1800MHz band is used for capacity and 900MHz band is used for coverage. 2400MHz band is used for Wi-Fi applications.

The SAR values for human blood, muscle and bone are evaluated using eqn(1) and eqn(2) and numerical values of tables [1-4] at 900MHz ,1800MHz and 2400MHz. The results are presented in figure [1-5].

The local density for blood, muscle and bone are taken as 1850kg/m^3,3490 kg/m^{3}and 1042 kg/m^3 respectively for all frequencies under consideration.

Fig.1 shows that variation of specific absorption rate for blood and muscle as a function of frequency from 860MHz – 960MHz. The same parameters for bone is presented in Fig.2

Fig.3 and Fig.4 are the variations of SAR for blood, muscle and bone as a function of frequency from1800MHz-1900MHz.

The same variation of SAR in the frequency range 2300MHz-2450MHz are shown in Fig.5

From the results, it is observed that the SAR value is varying from 1.1 to 1.4w/kg for blood in the frequency range 860MHz-960MHz, 0.1 to 0.2 w/kg for muscle in the frequency range 860MHz-960MHz and 0.13 to 0.15 w/kg for bone in the frequency range of 860MHz-960MHz.

From the results, it is observed that SAR value varies from 4.3 to4.5w/kg for blood in the frequency range 1800MHz-1900MHz, 0.55 to 0.58 w/kg for muscle in the frequency range 1800MHz-1900MHz and 0.044-0.046w/kg for bone in the frequency range 1800MHz-1900MHz

From the results it is observed that SAR value varies from 8.5 to 9.1 w/kg for blood in the frequency range 2300MHz-2450MHz, 1.01 to 1.07 w/kg for muscle in the frequency range 2300MHz-2450MHz and 0.11 to 0.117 w/kg for bone in the frequency range 2300MHz-2450MHz.

As seen from the results the SAR for blood is always higher than muscle and bone at 900MHz, 1800MHz and 2450MHz bands. From these findings, presented in the figures [1-5] we observe that SAR is more at higher frequencies than lower frequencies. For theoretical calculations of SAR in the human blood, muscle and bone we considered signal frequencies from 800MHz-2500MHz.

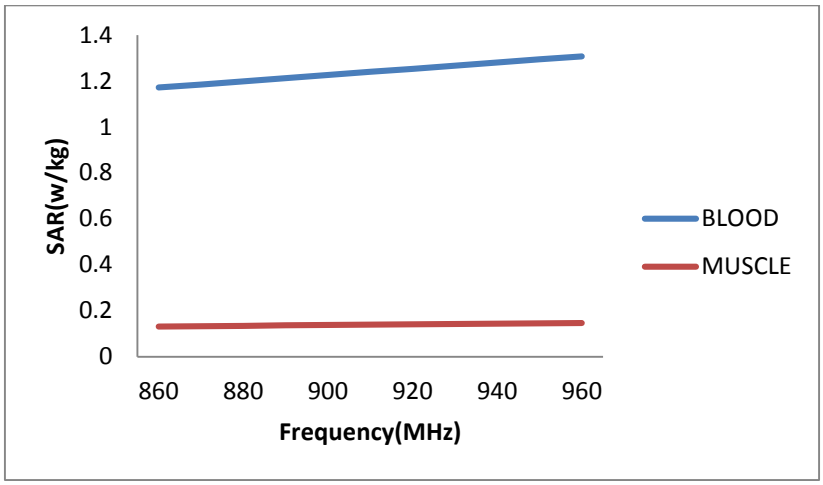

Figure 1: Variation of SAR for Blood and Muscle at 860MHz -960MHz

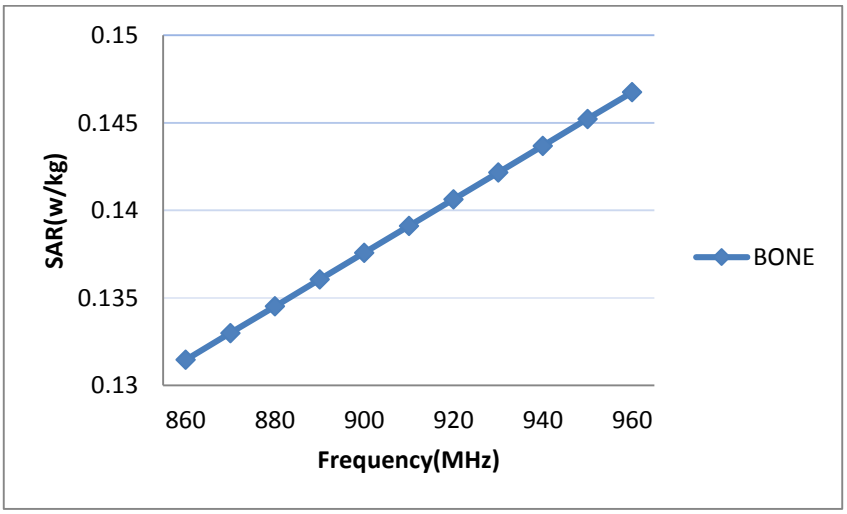

Figure 2: Variation of SAR for Bone at 860MHz -960MHz

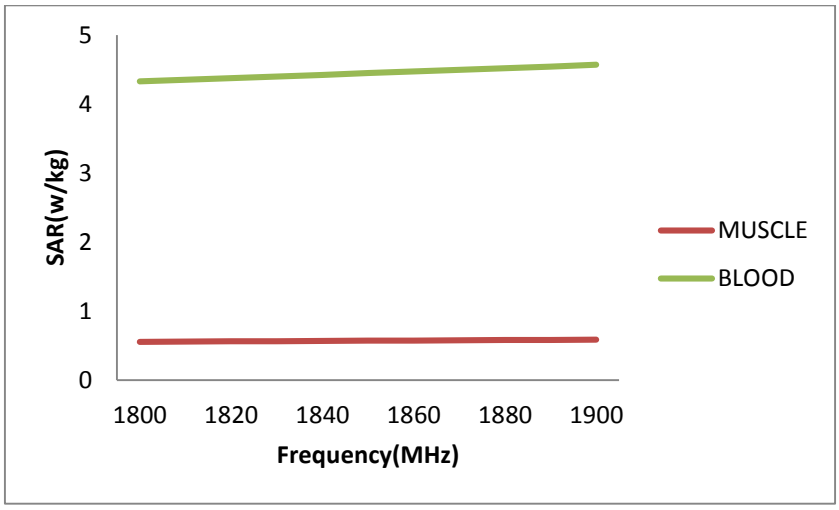

Figure 3: Variation of SAR for Blood and Muscle at 1800MHz -1900MHz

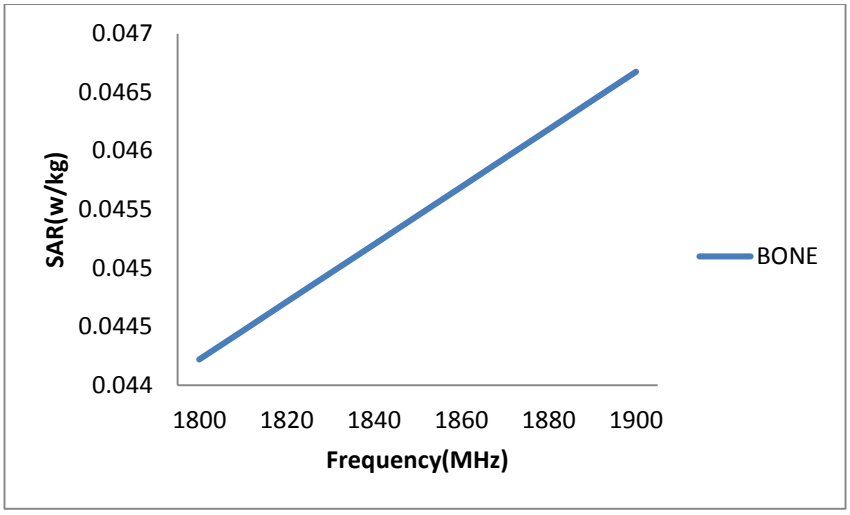

Figure 4: Variation of SAR for Bone at 1800MHz -1900MHz

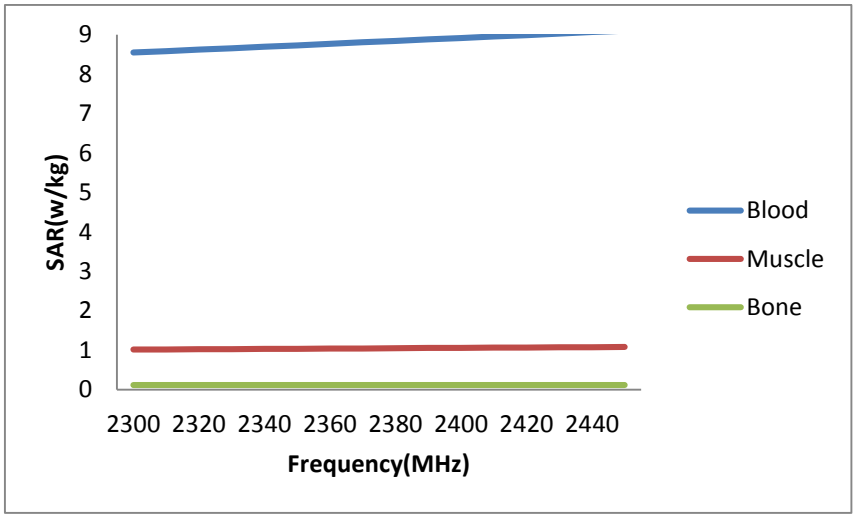

Figure 5: Variation of SAR for Blood, Muscle and Bone at 2300MHz -2450MHz

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