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Study of penetration depth and SAR of skin tissue exposed to cell-phone radiation

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ABSTRACT

When cell phones are used in close proximity to human body, the radiations emitted from cell phones penetrate deep inside the human skin. Penetrated radiations produce induced electric field inside the body, resulting in absorption of power, which can be analyzed using a parameter called specific absorption rate (SAR). The present study has been done to estimate penetration depth of electromagnetic radiations inside human skin and corresponding specific absorption rate for frequencies 900, 1800 and 2450 MHz, respectively. Penetration depth was found to be 0.018m, 0.012m and 0.009m and corresponding SAR was estimated to 13.8 W/Kg, 33.7 W/Kg and 58.9 W/Kg for frequencies 900, 1800 and 2450MHz, respectively. Results were also compared with the safe limit of SAR (2 W/Kg) issued by International Commission on Non-ionizing Radiation Protection (ICNIRP), which showed that estimated SAR values were much higher than recommended safe limits.

Keywords: cell phone radiations, penetration depth, specific absorption rate (SAR) and GSM frequencies.

INTRODUCTION

With the advent in cell phone communications, public concern regarding the health implications of electromagnetic radiation emitted from mobile phone has also increased. Although the mobile phone radiations are non-ionizing, yet these radiations are capable of producing thermal effects inside the human body. 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 inside the human body via skin tissue, so it is important to investigate the possible health hazard due to skin tissues being exposed to cell phone radiations of various frequencies (900, 1800 and 2450 MHz).

Studies available in literature on sensitivity of skin tissues mention that the temperature of skin tissues increases the most compared to that of fat and brain tissue under similar exposure conditions [1]. When SAR of skin tissue is added to the SAR of other tissues, then total SAR increases above safe permissible SAR limit [2]. Similarly, it has been found that Mobile phone radiation exposure can alter the protein expression in human skin [3]. However, all these studies include the interaction mechanism of radio frequency radiations with human biological tissues but not skin tissue as an independent parameter. Moreover, reported studies have not taken into consideration the permittivity parameter which contributes a lot to the radiation absorption. So the present work has been done to analyze penetration depth and specific absorption rate of human skin tissue by taking into consideration the permittivity parameter for frequencies at 900, 1800 and 2450 MHz.

EXPERIMENTAL SECTION

The Penetration depth (δ) to which non-ionizing radiations can penetrate is given by:

$$\delta = \sqrt{\frac{2}{\mu\sigma\omega}} \quad (1)$$

Where δ is the penetration depth (m), μ is the tissue magnetic permeability (H/m), σ is the tissue electric conductivity (S/m), and ω is the source angular frequency (MHz).

These penetrated radiations produced induced electric field (E) which can be calculated using following relations.

$$E^2 = P_D \text{ X } 377 \quad (2)$$

Where, P_D is called Power Density. The power density produced for the maximum penetration depth can be calculated by using the following equation

$$\text{Power Density} = \frac{Average\ power\ generated}{4\pi(r+\delta)^2} \quad (3)$$

Where r is distance between cell phone and human skin. Average power radiated can be considered as one eighth of the peak power because one frequency channel is shared by eight users at a time. For the present study, the peak power is considered to be 2 W as mobile phone generally radiates between 1W to 2 W.

The rate at which energy is being absorbed by human skin tissue per unit mass can be calculated using following equations.

$$SAR = (\sigma + \omega\, \epsilon_O\, \epsilon_r)\, E^2/\rho \quad (4)$$

Where;
σ=conductivity of biological tissue, ω= angular frequency, ϵ_0= permittivity of biological tissue, ϵ_r =relative permittivity of biological tissue, E^2= induced electric field, ρ= density of biological tissue

The electrical and thermal properties of human skin tissues at 900, 1800 and 2450 MHz are mentioned in table 1.

Table 1: Human Skin Tissue Properties [4]

Mass Density (kg/m3)	Specific Heat (J/K.kg)	Dielectric Constant ε_r			Conductivity σ (S/m)		
		900 MHz	1800MHz	2450MHz	900MHz	1800MHz	2450MHz
1100	3662	41.4	38.9	38	0.87	1.18	1.46

RESULTS AND DISCUSSION

Penetration depth, power density and specific absorption rate has been calculated using equation 1, 3 and 4 by assuming mobile phone at a distance of 2cm from human body. Results have been plotted in figures 1, 2 and 3. Penetration depth decreases with increase in frequency (Fig 1). These penetrated radiations produce induced electric fields inside the body as a result of which rate of power absorption increases. From figures 2 and 3, it is clear that with increase in power density and permittivity values, rate of absorption increases. Highest power density value 0.025 mW/m^2 and SAR value 58.9 W/Kg was estimated for 2450 MHz frequency. Serious biological effects like nervousness, weakness, fatigue, limb pain, joint pain and digestive problems have been reported at this power density value [5]. The results of SAR values were also compared with the international exposure limits set by International Commission on Non-ionizing Radiation Protection (ICNIRP) [6]. The recommend safe SAR limit for whole body set by ICNIRP is 2W/Kg. It has been found that estimated SAR values were 5.9%, 15.85% and 28.45% higher than recommended SAR limit for frequencies 900, 1800 and 2450MHz, respectively.

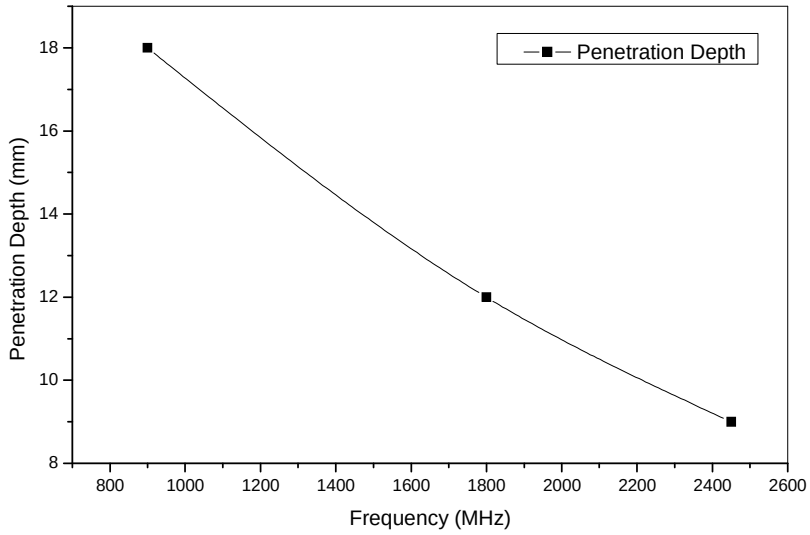

Figure 1: Variation in penetration depth with varying frequency

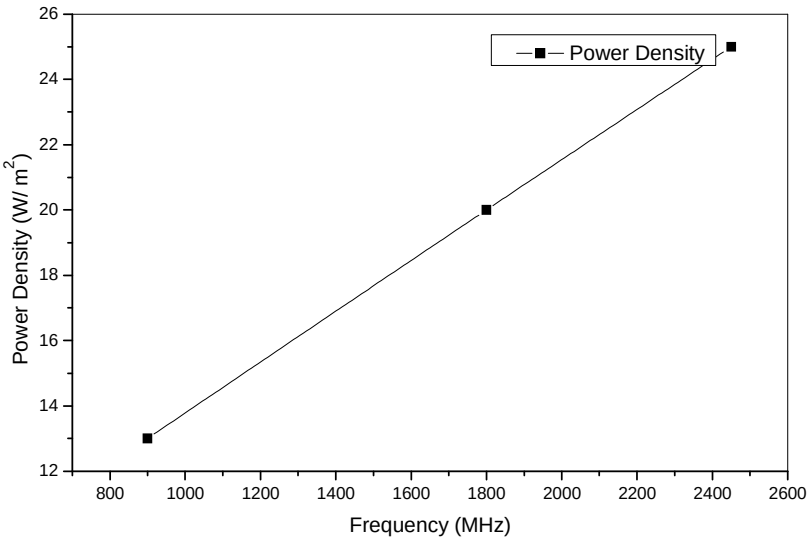

Figure 2: Variation in power density with varying frequency

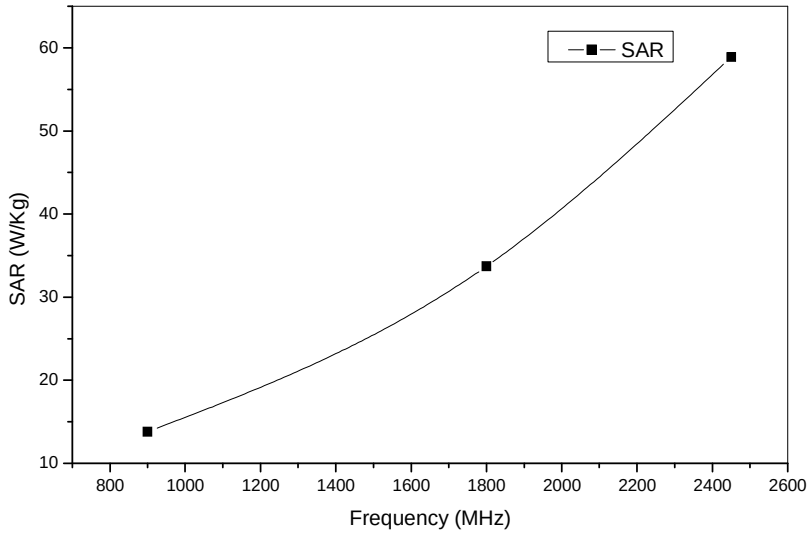

Figure 3: Variation in specific absorption rate with varying frequency

CONCLUSION

Penetration depth and specific absorption rates have been calculated in human skin tissues exposed to GSM frequencies 900, 1800 and 2450 MHz from cellular phones. Results conclude that when cell-phone device is placed very close to human body, the chances of absorption of radiations increases which can cause adverse health effects. So it is preferable that one should use mobile phone at least at a distance of 5cm from the human body. Penetration depth and specific absorption rate in human tissue depend upon the dielectric, biological and thermal properties of human tissue and most significantly on the intensity of electromagnetic waves. Detailed studies of above mentioned parameters will allow in future a better understanding of the realistic situation of the interaction between the EM fields and the human tissues.

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