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Specific Absorption Rate and Temperature Change Evaluation of Human Body Due to Electromagnetic Waves

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Abstract: In this work effect of electromagnetic waves interaction with human body for GSM-900 system is presented. Source of electromagnetic waves is patch antenna. Patch antenna is designed to provide a power of 2 W on human head. Human head six layer model is designed using High frequency structure simulator. Electric field obtained on various layers of head using HFSS is used to calculate the SAR and temperature change of various parts of head. Phanton head model is used to study the effect of electromagnetic radiations on human body which is very expensive method. In this work a simple and inexpensive simulation procedure to study the effect of electromagnetic radiations on human body is presented.

Keywords: Electromagnetic waves, Specific absorption rate, Temperature change of tissue.

I. INTRODUCTION

Radiation is basically energy on move. Radiations can originate from natural sources or from artificial source. Natural sources of radiations include Earth, living organism, plants, Sun, Stars and other terrestrial bodies. Earth itself produces radiations due to presence of radioactive materials. Artificial sources of radiations include radiations from cellular towers, from medical diagnosis and treatment like X rays, MRI, CT Scan and from the nuclear waste in nuclear power generation. One of the common properties of all types of radiation is that they are all electromagnetic waves. Electromagnetic wave consists of electric field and magnetic field. The direction of electric field, magnetic field and direction of propagation of electromagnetic waves are perpendicular to each other. Electromagnetic waves contain energy which is proportional to electric field and magnetic field constituting the wave. If the strength of electric field in wave is E and strength of magnetic field in wave is H then power density in wave i.e. power per unit area (P) is given by the cross product of electric field and magnetic

$$P = E \qquad \text{--------------1}$$

The total power contained in electromagnetic signal is evaluated by integrating the power density over area A. If spherical coordinates are used then expression of total power linked with the wave is given by equation 2.

$$E = \int_{\theta_1}^{\theta_2}\int_{\theta_1}^{\theta_2} P\, r^2 \sin\theta \; d\ell \qquad \text{----------------2}$$

As all waves contain some energy so they have the capability to initiate some physical changes or chemical changes when they strike the material [1-4]. Level of change depends upon the energy contained in the wave. Physical change is concerned with thermal effects of material and chemical changes are concerned with ionization of the material. All types of radiations produce thermal effects when they strike the material. When electromagnetic wave strike the material due to transfer of energy they produce heating effects in the material. The heating effect depends on the energy contained in the wave. Another important property of radiations is the penetrating capability. The penetrating capability of radiations depends on its frequency, conductivity and permeability of the material in which wave is penetrating. It is observed that wave reduces exponentially when it penetrates in to material. The equation of field when it penetrates a material is given by

$$F = F_o e^{-} \qquad \text{-----------------3}$$

Value of α is given by

$$\alpha = \sqrt{1} \qquad \text{------------------4}$$

Here F_o is initial field strength and F is final field strength at distance z from the surface. Here α is propagation constant of the wave. Depth of penetration signifies under these conditions. This is the distance at which wave is attenuated by a factor of 1/e of its initial value. The penetration distance of the wave is given by

$$\delta = \sqrt{\frac{}{1}} \qquad \text{-------------------5}$$

In order to reduce the effects of radiations international regulations had been drafted and a limit on specific absorption rate is defined [5]. Specific absorption rate is used to measure the electromagnetic energy absorbed by living tissue when exposed to electromagnetic field. It is defined as the ratio of power measured per unit mass of tissue.

So $\quad SAR = \frac{\text{Power absorbed by tissue}}{\text{Mass of tissue}}$ ----------- 6

$$\text{Power absorbed by tissue} = \text{Voltage}(V) * \text{current}(I)$$

$$\text{current density}(J) = \frac{\text{Current}(I)}{\text{Area}(A)}$$

$$\text{Power absorbed by tissue} = (V) * (J) * (A)$$

$$\text{Electric field}(E) = \frac{\text{Voltage}(V)}{\text{Length}(L)}$$

$$\text{current density}(J) = \text{Conductivity}(\sigma) * \text{Electric field}(E)$$

From above mentioned expressions it is concluded that

$SAR = \frac{E\sigma ELA}{M} = \frac{E}{}$--------------(7)

Further

$\text{Power per unit area }(S) = \text{Electric field }(E) * \text{Magnetic intensity}(H)$

And

$\text{Intrinsic impedance }(\eta) = \text{Electric field }(E)/\text{Magnetic intensity}(H)$

So we obtain that

$(S) = (E) * (/\eta$ -----------------(8)

So SAR can also be found from

$SAR = \frac{S}{}$--------------------(9)

When electromagnetic power is absorbed by human body, it generates the heating effects. The rise in temperature of living cell due to absorbed radiations is given by:

$\text{Temperature change}(\Delta T) = \frac{SAR}{(}$-----------(10)

Here ΔT is change in temperature of tissue. Δt is duration of exposure of radiations and C is specific heat of tissue. In literature various techniques are proposed to measure the SAR [6-8]. In this work human head is designed using HFSS. SAR and change in temperature of various tissues of head is calculated using electric and physical properties of head tissues and by calculating Electric field on various part of tissues.

II. HUMAN HEAD MODEL AND SPECIFICATIONS OF GSM 900 SYSTEM.

Human head is made of basically six human tissues. Structure of human head is as shown in Fig (1). [9]

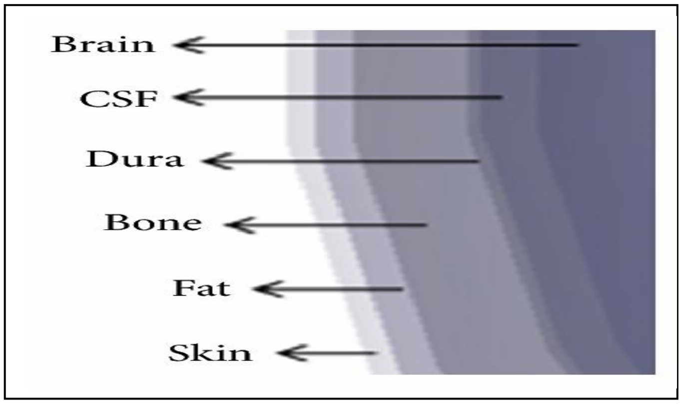


Fig 1. Human head structure

Electric parameters of various tissues for GSM 900 and GSM1800 are given as [10]

Sr. No	Name of Tissue	Thicknes (mm)	Conductivity (S/m)	Permittivity
1	Skin	1	.65	40.7
2	Fat	.14	.17	10
3	Bone	.41	.33	20.9
4	Dura	.5	.65	40.7
5	CSF	.2	2.14	79.1
6	Brain	81	.86	41.1

Density and Specific heat of various tissues are given as [11]

Sr. No	Name of Tissue	Density	Specific heat
1	Skin	1109	3391
2	Fat	911	2348
3	Bone	1908	2666
4	Dura	1174	3364
5	CSF	1007	4096
6	Brain	1046	3630

The specifications of GSM 900 and GSM 1800 are as

Specifications	GSM900	Gsm1800
Downlink Frequency	935-960 MHz	1710-1785 MHz
Uplink Frequency	890-915 MHz	1805-1880 MHz

Typical Mobile Transmitted power	2 W	1 W

III. MICROSTRIP PATCH ANTENNA

Due to its planar, conformal and compact structure microstrip patch antenna is widely used in various applications. The structure of microstrip patch antenna is as shown in Fig 2.

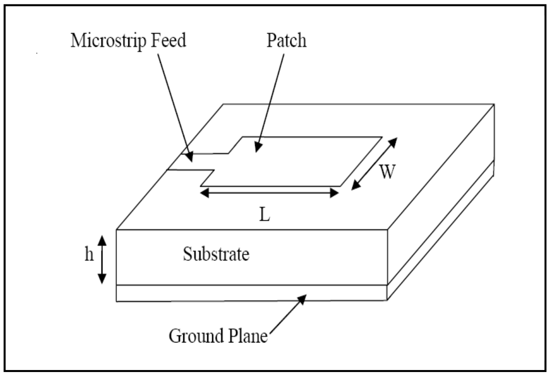


Fig 2. Microstrip patch antenna.

Substrate is of height h with effective dielectric constant ε_r and is mounted on ground plane. Patch of conducting material having length L and width W is mounted on the substrate. A microstrip line is used to feed the patch antenna.. The operative frequency of patch antenna depends on the effective length and width of patch antenna which in turn depends on the effective permittivity and height of substrate [11-13]. For operative frequency of 890 MHz and for substrate having properties with dielectric constant equal to 2.2, dielectric height of .8 mm the required dimensions and of Patch antenna are given as

Sr No	Parameter of Patch	Value
1	Length of Patch	113.31 mm
2	Width of patch	133.24 mm

IV. RESULTS

The structure of patch antenna obtained using HFSS is as shown in Fig (3).

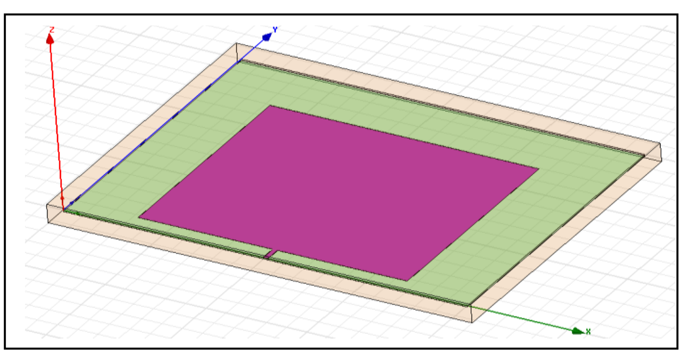


Fig 3. Microstrip patch antenna using HFSS

By modifying the source properties of this antenna the power received at a distance of 2cm is 2W as shown in Fig(6).

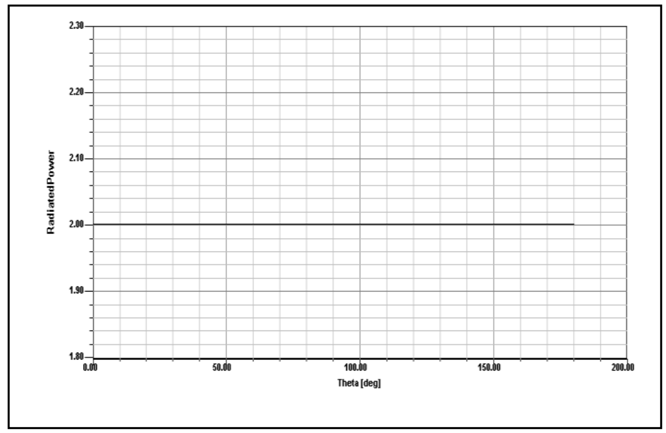


Fig 4. Radiated power of patch antenna

The scattering parameters of this antenna at 890 MHz are as shown in Fig (5). At .89 GHz reflective scattering parametric is 21.77 dB i.e input impedance of patch antenna is perfectly matching with source.

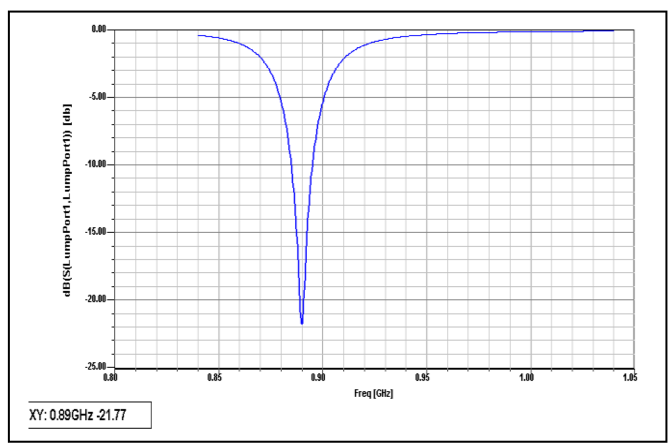


Fig 5. S_{11} parameters of patch antenna

The six layer structure of human head designed using HFSS having length and width of 60*60 mm. The thickness and electric properties of various layers is as per the table given above. The structure of Human head model along with patch antenna designed in HFSS is as shown in Fig 6. The magnitude of electric field distribution on various tissues obtained using HFSS is shown from Fig (7) to Fig (9).

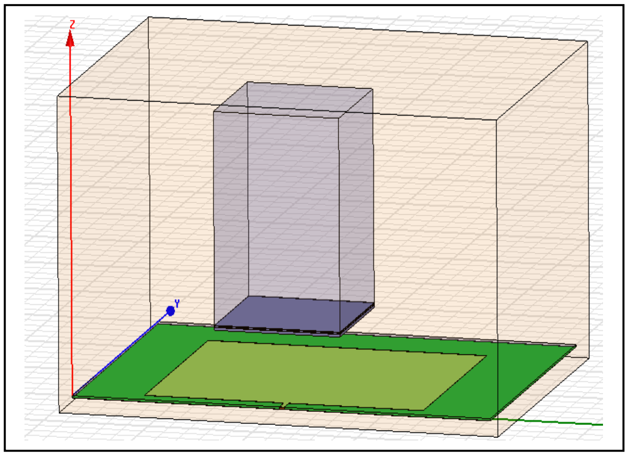
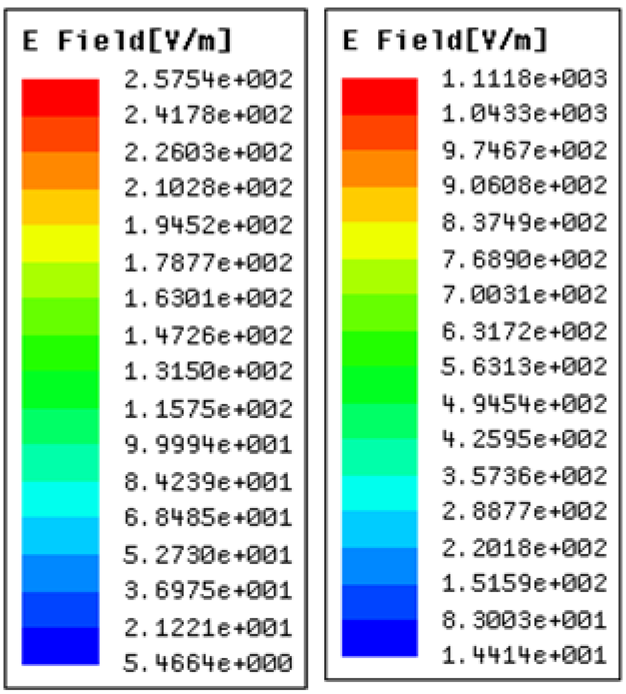
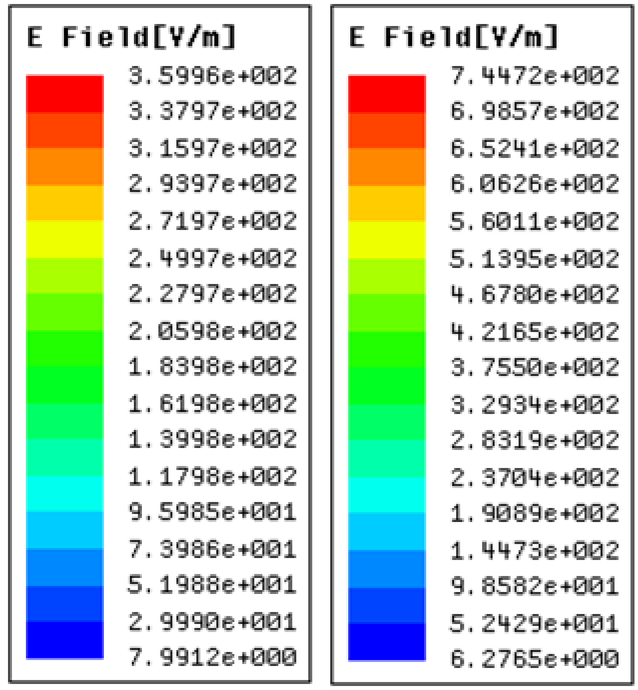


Fig 6. Human head model along with microstrip patch antenna using HFSS



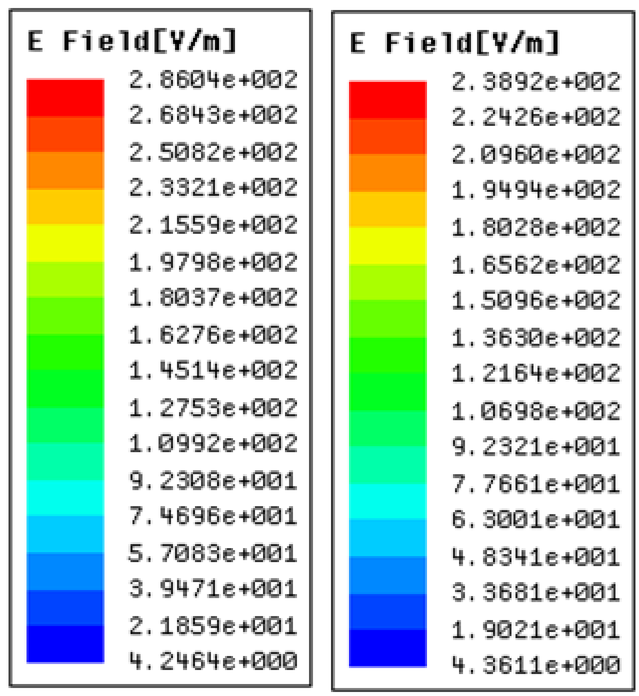
Electric field on skin   Electric field on Fat

Fig 7



Electric field on bone   Electric field on dura

Fig 8



Electric field on csf   Electric field on brain

Fig 9

By using simulated results

Electric field on skin = 15.4524 V

Electric field on Fat = 66.66 V

Electric field on bone = 21.54 V

Electric field on Dura = 44.64 V

Electric field on CSF = 17.16 V

Electric field on Brain = 14.28 V

SAR of various tissues by using equation 7 is

SAR of skin = .1399 W/kg

SAR of Fat = .82 W/kg

SAR of bone = .08 W/Kg

SAR of Dura = 1.1 W/Kg

SAR of CSF = .625 W/Kg

SAR of Brain = .16 W/Kg

For radiation exposure of 2 minute Temperature rise of various tissues as given by equation 10 is

Tem rise of skin = .0049 K

Tem rise of Fat = .0419 K

Tem rise of bone = .0036 K

Tem rise of Dura = .039 K

Tem rise of CSF = .0183 K

Tem rise of Brain = .0052 K

IV. CONCLUSION

The mathematical model is used to calculate the change in temperature of various tissues of head due to electromagnetic radiations. From the results it is concluded that the change in temperature is very minute due to radiations. It appears that electromagnetic radiations have negligible thermal effects on human body.

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