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An Efficient Microstrip Patch Antenna for Specific Absorption Rate Reduction in Human Tissues

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ABSTRACT
SAR is a value describing how much power absorbed in biological tissue when the Body is exposed to electromagnetic radiation. The use of microstrip patch antenna for measuring SAR in human tissues leads to various effects such as thermal effect, cancer, cognitive effects, MRI biological effects, etc. Because of these biological effects, there is a need of SAR reduction. There are various SAR reduction techniques of microstrip patch antenna. Here we construct the antenna using two methods together such as slotting technique on patch and ground plane with defects. This paper demonstrates the technique for microstrip patch antenna to reduce SAR in human body on an 800MHz. SAR was studied as well to illustrate how on-body communication or mobile phones antennas of GSM band might affect human body.

KEYWORDS-*Biological Effects, Human Tissues, Microstrip Patch, Power Absorbed, SAR.*

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I. INTRODUCTION

Specific absorption rate (SAR) measures how much radiation is absorbed by the human body under the worst possible circumstances. Technically speaking, SAR is a measure of the rate at which radiofrequency (RF) energy is absorbed by our body from a cell phone. SAR provides a straightforward method for evaluating the radiation exposure to our bodies from cell phones in order to ensure that they are within the safety guidelines set by regulatory bodies, such as the FCC in the US. In mobile telephony, the SAR value indicates the energy absorbed by a particular mass of human tissue in a certain amount of time. SAR is measured in units of power per mass (W/kg).

The use of microstrip patch antenna for measuring SAR in human tissues leads to various effects such as thermal effect, cancer, cognitive effects, MRI biological effects, etc. [1].

In Thermal effect the living tissue is heated with electromagnetic field. Heating affects the surface of the head which causing its temperature to increase by some fraction of degree. Excess heat increases the blood flow in blood circulation in brain. In Cancer effect, excess use of mobile phones increases the risk of brain tumor and brain cancer. Mobile phone use increases the risk of cognitive effect which in turn affects the working memory of humans. When there is pulse of radiation frequency increases then it effect on sleep.So to avoid all these biological effects, there is a need of design of microstrip patch antenna for reducing SAR in human tissues.

There are techniques which are used for SAR reduction. One of them is using “metamaterial” with two important parameters: electric permittivity and magnetic permeability that determines the response of the materials to the electromagnetic propagation [2]. “Electromagnetic Band Gap” is one of the techniques where surface waves can be suppressed due to EBG structure so as to have E field outside the EBG structure weaker [3]. In “slotting technique”, antenna can operate at multiband frequencies. It gives multiple slots and better return loss [4]. “Large ground plane and high ε_r substrate” provide an extended current path which results in decrease in current concentration which in turn decreases SAR [5]. SAR can also be reduced by “current slop discontinuity reduction”. By “increase in deformation length”, uniformity of current increases which in turns decreases SAR [6]. The last technique is use of “meander lines” in antenna. Adjacent arms of meanderlines have opposite phase results in cancellation of E-field and hence reduce SAR [7].

In this paper, we implement microstrip patch antenna using slotting and ground plane with defects for SAR measurement. The effect of human thigh muscle on an 800 MHz antenna characteristics is analyzed. Using CST

Microwave studio, SAR inside the thigh muscle tissue is also calculated by varying the distance of antenna and thigh muscle.

II. METHODOLOGY

Here we used FR4 (lossy) substrate for antenna having relative dielectric constant (ε_r) 4.35. The operating frequency of the antenna (f_r) was 800 MHz.The height (h) of dielectric substrate was 3.15 mm. By using the known values of f_r and ε_r we calculate patch width (W), patch length (L), patch length extension (ΔL), effective patch length (L_{eff}), effective dielectric constant (ε_{reff}), substrate width (W_s), substrate length (L_s), ground plane width (W_g) and ground plane length (L_g) using following formulas [8]-[9].

- Calculation of patch width (W):

$$W = \frac{c}{2f_{r_0}\sqrt{\frac{\varepsilon_r+1}{2}}}$$

Where, c = velocity of light in free space

- Calculation of effective dielectric constant (ε_{reff}):

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\frac{1}{\sqrt{1+12(\frac{h}{W})}}\right]$$

- Calculation of patch length extension (ΔL):

$$\Delta L = 0.412h\left(\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)}\right)$$

- Calculation of effective patch length (L_{eff}):

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}}$$

- Calculation of patch length (L):

$$L = L_{eff} - 2\Delta L$$

- Calculation of substrate width (W_s), substrate length (L_s), ground plane width (W_g) and ground plane length (L_g):

$$W_s = W_g = 6h + W$$
$$L_s = L_g = 6h + L$$

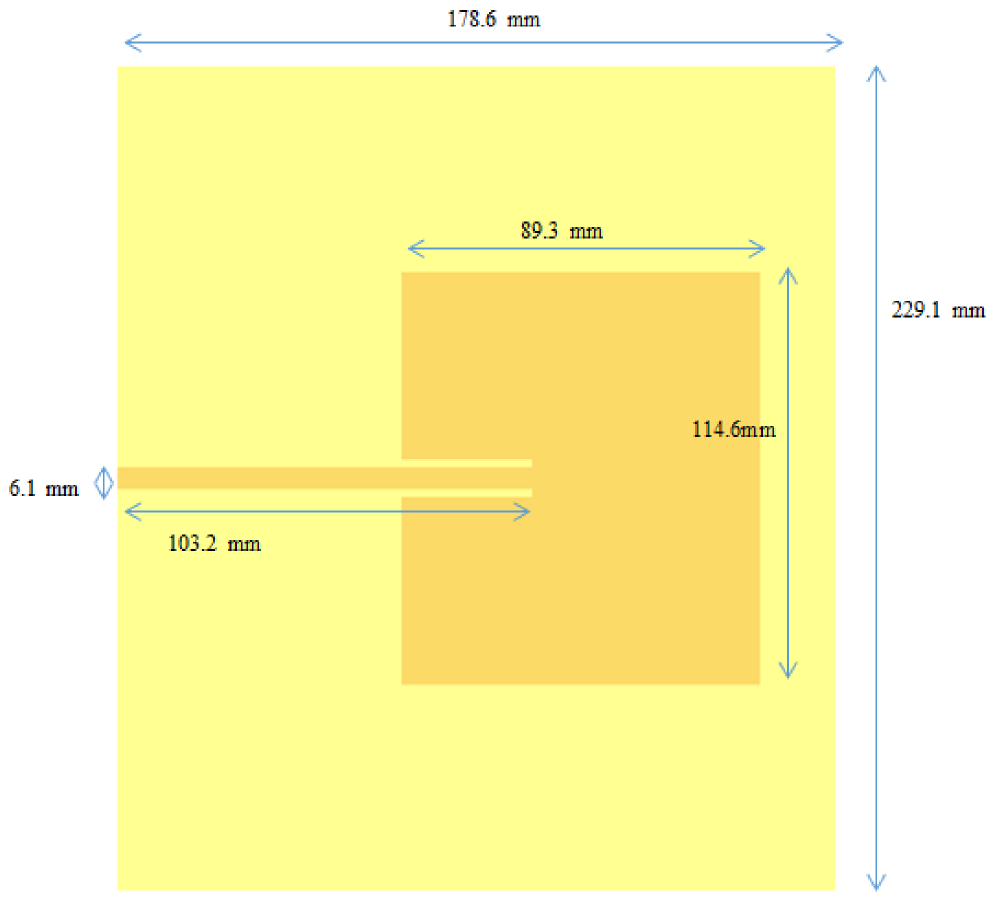
The calculated parameters of ground plane, substrate, patch and feeding line are summarized in table 1:

TABLE 1.GENERAL SPECIFICATIONS OF ANTENNA

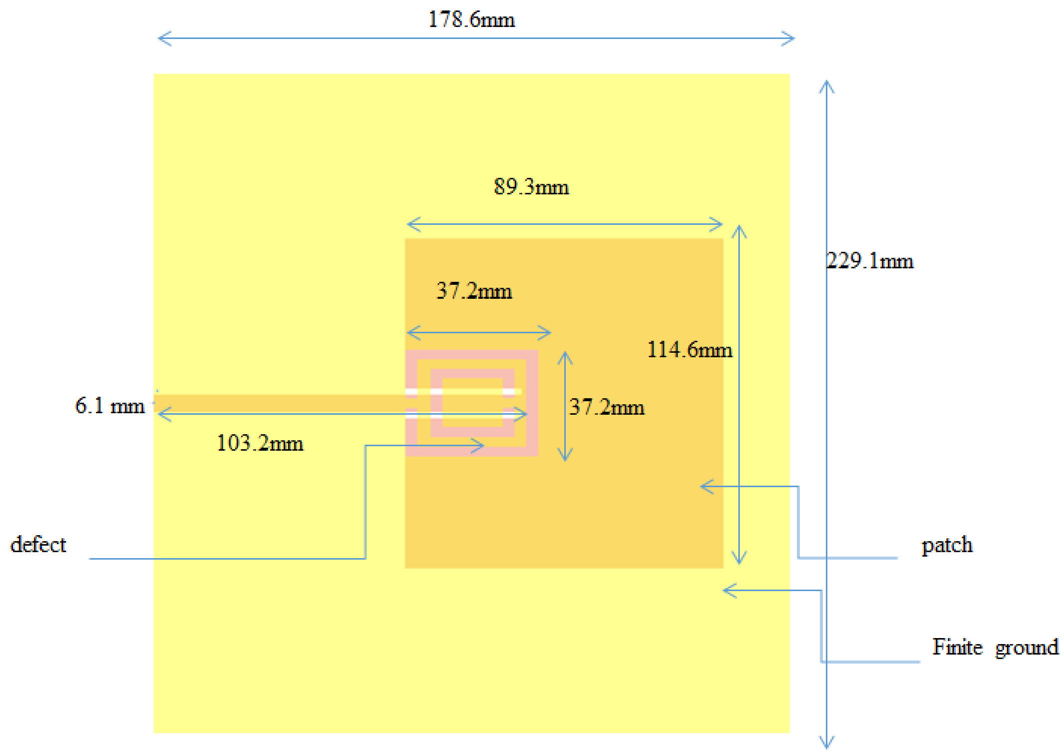
Antenna part	Parameters (symbol)	Value (mm)
Substrate	Width (W_s)	229.1
	Length (L_s)	178.6
	Height (h)	3.15
Patch	Width (W)	114.6
	Length (L)	89.3
	Thickness (t)	0.3
Ground plane	Width (W_g)	229.1
	Length (L_g)	178.6
	Thickness (t)	0.3
Feed line	Width (W_f)	6.1
	Length (L_f)	103.2
	Feed inset from edge of patch (S_i)	32.6
	Spacing between feed line and patch (S_g)	2.2

III. ANTENNA DESIGN

The 800 MHz antenna was designed using CST Microwave Studio using design parameters of table 1. The patch with defected ground plane structure are presented in Fig .1.



(a) Antenna Patch



(b) Patch Antenna with Ground Plane Defect

Fig 1. Dimensions of antenna: (a) Antenna Patch; (b) Patch Antenna with Ground Plane Defect.

The ground plane has defect in the form of Complementary Split Ring Resonator (CSRR). It is the negative image of metaresonator split-ring resonator (SRR). It is made up of two concentric copper rings with a slit in each ring. The CSRR is made by removing the copper in the shape of the SRR from ground plane of microstrip antenna [10].

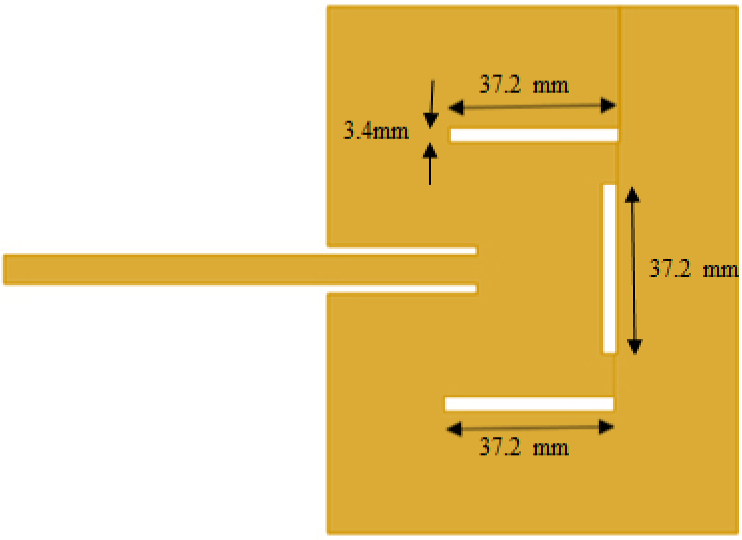


Fig 2. Patch with peripheral slotting

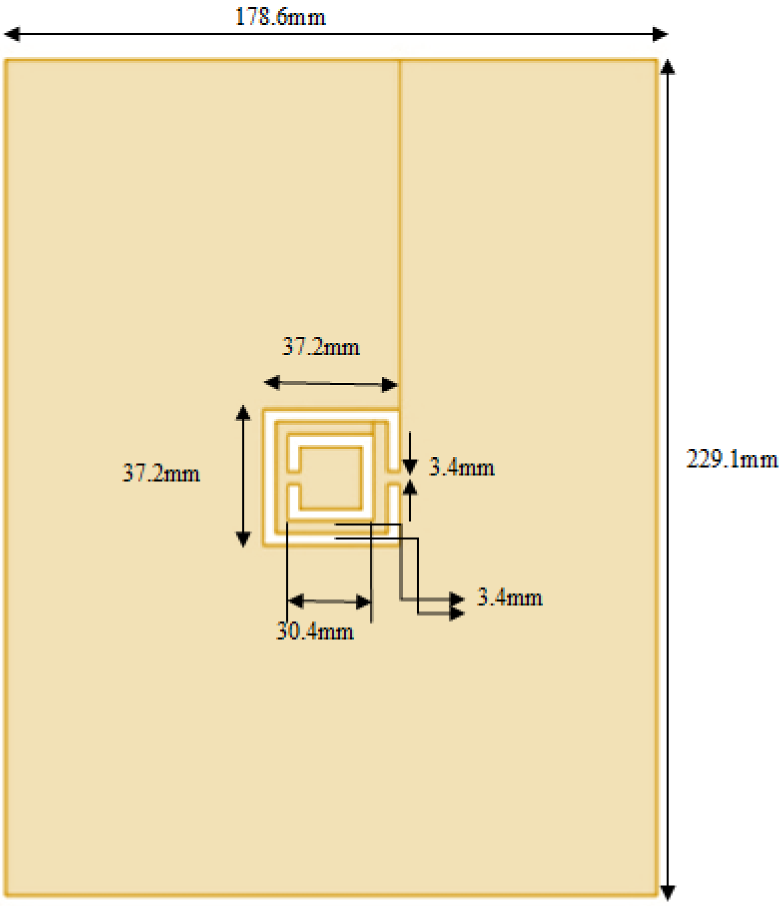


Fig 3. Antenna ground plane with defect

On the patch of the antenna slots was etched on peripheral sides which is shown in Fig. 2. At the center of ground plane, the square CSRR structure was etched which is demonstrated in Fig. 3.

IV. HUMAN TISSUE PROPERTIES

Tissue properties such as permittivity, electrical conductivity, density, thermal conductivity, heat capacity and dimensions of all 3 layers of the tissue were documented from the Tissue Properties Database of Foundation for Research on Information Technologies in Society (IT'IS Foundation) [11] and Italian National Research Council [12]. The tissue properties of all 3 layers are measured at 800 MHz which are summarized in table II.

TABLE II. HUMAN TISSUE PROPERTIES AT 800 MHz

Tissue Name	Skin	Fat	Thigh Muscle
Permittivity	42	5.48	55.316
Electrical Conductivity (S/m)	0.83	0.0485	0.90636
Density (kg/m^3)	1109	911	1060
Thermal Conductivity (W/K/m)	0.37	0.21	0.56
Heat Capacity (kJ/K/kg)	3.391	2.348	3.686
Dimensions (mm)	200 × 250 × 2	200 × 250 × 4	200 × 250 × 15

V. SIMULATION RESULT

In each simulation, we consider 3 different antennas such as patch antenna with finite ground, patch antenna ground plane with defect and patch antenna ground plane with defect and peripheral slotting on patch. The distance between the antenna and human tissue is varied by 2 mm in each simulation. The IEEE and ICNIRP standards of SAR are 2.0 W/Kg averaged over 10g of tissue [13]. The simulation results are summarized in table III.

TABLE III. SIMULATED SAR VALUE OBTAINED FROM SIMULATION OF 800 MHz ANTENNA OVER THE HUAMAN TISSUE AT VARYING DISTANCES.

Antenna Name	Distance				
	2 mm	4 mm	6 mm	8 mm	10 mm
Antenna Patch	2.1990	1.8458	1.5068	1.2135	0.8864
Patch antenna ground plane with defect	1.8748	1.6548	1.2994	1.0691	0.6310
Patch antenna ground plane with defect and peripheral slotting on patch	1.7064	1.5201	1.1068	0.9251	0.4821

VI. SUMMERY AND CONCLUSION

This paper demonstrate the noteworthy impact of human body on an 800 MHz antenna characteristics. The impact of antenna on human body was also analyzed. The SAR value decreases with increment of distance between the antenna and human body. Due to slotting along with SAR reduction minimum return loss was also obtained. It was also observed that more the number of slots on radiation element lesser the SAR value will be obtained. The SAR value for 2 mm distance of patch antenna do not satisfy IEEE and ICNIRP standards. Further research could be done to analyze the impact of SAR on antenna directivity and surface current characteristics.

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