DOI: http://dx.doi.org/10.30684/etj.36.5A.5

Specific Absorption Rate (SAR) Simulated for Square Patch Antenna of Head Tissues

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Received on: 13/04/2017
Accepted on: 23/11/2017

Abstract- *Square patch antennas (SPA) are widely used today is in wireless communication systems, mainly with a popular frequency of 2.4 GHz. Wireless devices is the main source of electromagnetic (EM) radiation, which penetrates the tissues of human and causes health danger. In this paper, SPA antenna is designed, simulated and evaluated at* $2.4\ GHz$ *for internet application by using CST Microwave studio 2014. Specific absorption rate (SAR) is the term, which measures the exposure of human to EM radiation of communication antenna. SAR values are calculated over* $1\ gm$ *and* $10\ gm$ *mass of tissues, according to the IEEE and International Commission on Non-Ionizing Radiation Protection (ICNIRP) standards for head safety. The SPA antenna produces the smallest SAR levels in adult head tissues. The SAR levels in same tissues are highest in standard (ICNIRP) compare in (IEEE).*

Keywords- *Square patch antenna (SPA), Specific Absorption Rate (SAR), head tissues.*

How to cite this article: A. M. Ahmed, "Specific Absorption Rate (SAR) Simulated for Square Patch Antenna of Head Tissues," *Engineering and Technology Journal,* Vol. 36,Part A, No. 5, pp. 509-513, 2018.

1. Introduction

The great and rapidly evolution in communication technologies make the using of cell phone, especially smart phone, widely in human communities. The main source for the electromagnetic (EM) radiation is the mobile phones, which represent, EM, the serious health hazard due to its capability to penetrate the human body tissues [1]. According to the World Health Organization (WHO), the significant pollution comes from the radio frequency (RF), which can be representing menace to the human health. If the human body is exposure to high level of radiation of EM waves, for a long period of time, this can be lead to sister chromatid exchange (SCE), brain cancer and several diseases. Besides, the biological organism body converts the energy of EM field into heat, which leads to increase the temperature of the body and thermal effects. SAR parameter explains the relation between the electromagnetic energy radiation and the human body, which is related to the strength of electric and magnetic field in the human tissues [2]. SAR is the power absorbed by body tissues, typically averaged either over the whole body or over a small part volume (typically $1\ gm\ or\ 10\ gm$of tissue). International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Institute of Electrical and Electronics Engineers (IEEE) has been developed recommendations for confining the electromagnetic field exposure to keep the protection for the users from the dangerous of electromagnetic field (EMF) exposure. The limit was set as $2\ W/kg$ regarding any $10\ gm$ of human tissues according to *IEEE C95.1:2005* by both mentioned organizations. On the other hand, SAR limit has been specified to $1.6\ W/kg$ regarding $1\ gm$ human tissues by the Federal Communication Commission (FCC) of United States [1,2]. SAR is defined as the derivative of increasing in the energy absorbed with respect to time by an increasing in mass contained in a volume part of a particular density, this definition according to IEEE [1,3], the mathematical equation of SAR is indicated in eq. (1).

$$SAR = \frac{d}{dt}\left(\frac{dw}{dm}\right) = \frac{d}{dt}\left(\frac{dw}{\rho dm}\right) \qquad (1)$$

Generally, the units of SAR is watts per kilogram (W/kg)
or milliwatts per gram (mW/gm). SAR can be defined in terms of induced electrical field as shown in equation (2) [1,3].

$$SAR = {\sigma E^2}/{\rho} \qquad (2)$$

Where: - E is the RMS value (root mean square) of electric field strength (V/m).
σ Represent the conductivity of biological tissue (S/m)
ρ Denote the density of biological tissue Kg/m^3
S Is the unit of electric (conductance, susceptance and admittance).

In a previous study, Metamaterials are used instead of materials between the human body and antenna. To reduce the SAR effects, studying are carried out on antenna operated at $900\ MHz$ (GSM), and the parameters of metamaterials are set to negative at $900\ MHz$. FDTD (finite-difference time-domain) technique is used to analyze SAR reduction effectiveness for several positions, sizes, and negative medium parameters of metamaterials, in convergence with human head models. In consequence of largest SAR reducing effect, ferrite sheet is recommended for choosing and designing. Ferrite materials, which consider a natural electromagnetic absorbing material and metamaterials which represent artificial constructed material, are two procedures used to reduce the SAR [3]. CST Microwave studio is used to modeling numerically several antennas, monopole, a helical, a patch and a PIFA antenna, generally used with portable telephones, the models are investigated and compared. Evaluation is carried out for the behavior for each antenna with variable distances $(0 - 20\ mm)$ from head geometry.SAR levels measurements for each antenna is convenience with safety health standards [4]. SAR measurements with high resolution Magnetic Resonance Imaging (MRI), is performed with FM broadcasting(100 MHz), based on full body models. Exposure source was modeled with FDTD modeling as a half-wave dipole. The relationship between the distance and the input power of an antenna is developed and described with experimental formula to limiting the values of SAR [2]. The effects, dominance, of mobile phone used on the exposure of the brain to radio-frequencies (RF) and electromagnetic fields (EMF) from several mobile phone models are investigated and analyzed using the finite difference time-domain (FDTD) technique [5]. The influences of EM radiation emitted from the mobile phone on the human head, with several holding situations, were analyzed with. Besides, the absorption was analyzed over simulation by applying finite-difference time domain (FDTD) method using CST microwave studio. SAR is calculated for two popular holding positions of mobile phone; Cheek and Tilt. Tilt position shows lower values of SARs with respect to the cheek position [6]. At particular SAR, the influence of the distances between the internal antenna of cellular device and the human head is studied and investigated. Additionally, the effect of incline angles between the mobile antenna and human head on the SAR values is analyzed. The previous analyses were carried out using FDTD method on CST microwave studio. The obtained results show that SAR values decreased with the increasing distance between the human head and mobile antenna. On the other hand, the changing in the incline angle does not change the SAR values at all cases [1]. Dual-band PIFA antenna design is presented with [7], for $GSM900$ and $GSM1800$ bands. Different criteria taken into account with designing PIFA antenna, limited structure, preserve dimensions. CST MWS software is employed to simulate and evaluate the radiation influence of the model on the human head and hand. In this paper, the design of square patch antenna (SPA) is presented and evaluated using CST Microwave studio 2014. SPA is designed and simulated at $2.4\ GHz$ for internet application.Specific absorption rate (SAR) values are calculated over $1\ gm\ and\ 10\ gm$ mass of tissues, according to the IEEE and International Commission on Non-Ionizing Radiation Protection (ICNIRP) standards for head safety. The evaluation of the presented antenna is carried out when the distance is $5\ mm$ between human head and wireless device at frequency of $2.4\ GHz$. The evolution of SAR values are carried out for three different ages (4 years, 11 years, and adult human), and for each selected age the head tissues is consist of three layer (skin, skull and brain).

2. Square Patch Antenna Design

The rapidly evolution in communication electronics devices in terms of size, greater integration of electronics, make the antenna is the larger element of the whole collection of communication electronics circuits, this developed leads to reduce the size of antenna of communication devices. Several patch antennas are analyzed and predict the performance of them, like square, rectangular, circular, triangular, and elliptical [8]. Square patch antenna is common used antenna with new application among the others microstrip antennas which are presented. The performance of microstrip antenna is determined by substrate material, feeding techniques, antenna's dimension. Inset fed technique is selected among different techniques of feeding for the square patch antenna on frequency of $2.4\ GHz$ [9]. Figure 1 shows the structure of microstrip patch antenna, which has a radiating patch side and the other side aground plane of dielectric substrate, square patch used as the essential radiator. Copper and gold, which is conducting material, are used to manufactures the microstrip patch with many different designed shapes. The best performance of patch antenna is obtained with low dielectric constant with thick dielectric substrate because it provides best efficiency, radiation, and larger bandwidth. Typically, the range of dielectric constant of

substrate is $(2.2 < \epsilon_r < 12)$ [8-10]. The parameters which describe the structure of square microstrip antenna are specified as follows: -
W is the antenna width which selected along y axis direction, L represents the length which is along with x axis and the last parameter is the h which determines the high of antenna and its along with z axis direction, the square patch antenna is depicted with Figure 1. The length of square patch is selected less than $\lambda/_2$, in order to operates at the fundamental mode, when λ is the wave length and found as: [9]

$$\lambda = \lambda_0/\sqrt{\epsilon_{reff}} \quad (3)$$

And ϵ_{reff} represents Effective dielectric constant
In this work, the square patch antenna has been designed at the center frequency, which is equal to $2.4\ GHz$. Hybrid structure and FR-4, as substrate, are used with designed antenna.
The dimensions of the antenna $W\ and\ L$ are calculated from classical equations, [9,10] the width W is given as:

$$W = \frac{c}{2f_r\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (4)$$

Where f_r is center frequency
The high of dielectric substrate is determined by [9, 10]:

$$h = \frac{0.3c}{2\pi f_r\sqrt{\varepsilon_r}} \qquad h \leq 0.06\ \frac{\lambda}{\sqrt{\varepsilon_r}} \quad (5)$$

The actual length can obtain using:

$$L = L_{eff} - 2\Delta L \quad (6)$$

Where L_{eff} is the effective length of the patch, and it's given by

$$L_{eff} = \frac{c}{2f_r\ \sqrt{\varepsilon_{reff}}} \quad (7)$$

And ΔL is the extension in length and given by [10]:

$$\Delta\ L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left[\frac{w}{h}+0.264\right]}{(\varepsilon_{reff}-0.258)\left[\frac{w}{h}+0.8\right]} \quad (8)$$

From [7], the effective dielectric constant can be obtained as:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\ \frac{h}{w}\right]^{-\frac{1}{2}} \quad (9)$$

To determine the values of ground plane dimensions, width and length ($W_g\ and\ L_g$) respectively, following [10]:

$$W_g = 6h + W \quad (10)$$

$$L_g = 6h + L \quad (11)$$

Finally, the notch width for patch line feed is calculated as:

$$g = \frac{c}{\sqrt{2x\varepsilon_{reff}}}\frac{4.65x10^{-12}}{f_r} \quad (12)$$

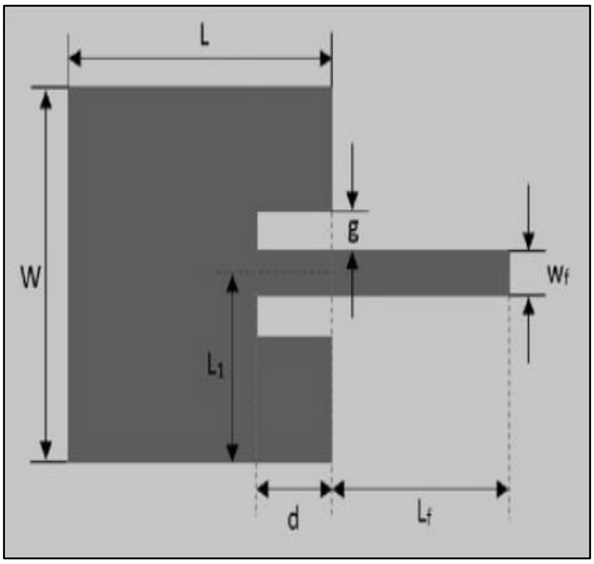


Figure 1: structure of square patch antenna

3. Simulation and results

The design of square patch antenna (SPA) is simulated and carried out by using computer simulation technology studio 2014 (CST software 2014). The structure of the square patch antenna is crossbred and using FR-4 as substrate with dielectric constant $\varepsilon_r = 4.3$, loss tangent is 0.019 and thickness of $h = 1.6\ mm$. The thickness of the ground material which is made of copper is $0.1\ mm$, the size of feeding line is calculated to rendering the impedance of the designed antenna equal to $50\ \Omega$.The overall parameters and dimensions of the SPA antenna which are mentioned in previous equations are shown in Table 1. In Figures 2-6, the S-parameters and radiation pattern are presented. The SPA covers 2.4 GHz for all dimensions of the head tissues and the directivity calculated at azimuth angle, and the values of directivity are (7.18, 7.13, and 6.89) dBi. The efficiency has slightly differences for proposed antenna in all cases.

Table 1: dimensions of the SPA

Parameters	$f_r = 2.4\ GHz$
L	29
ΔL	0.28
W	38
h	1.6
g	1
L_g	55
W_g	70
w_f : width of strip line	0.8
d: length of strip line	20

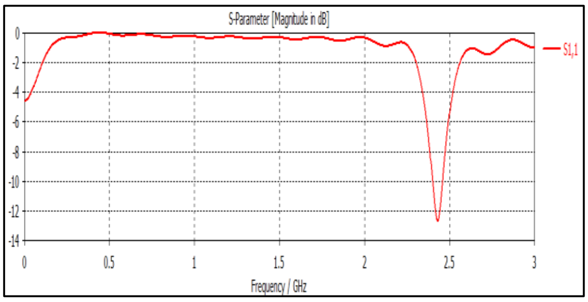


Figure 2: Return Loss (dB) for SPA at (2.4 GHz) for child's head (4 years old)

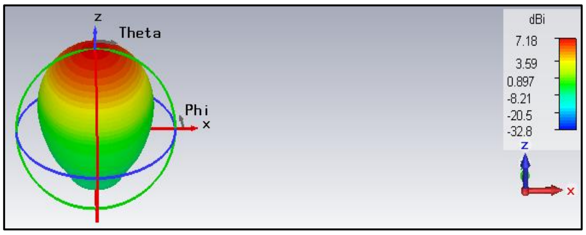


Figure 3: Directivity (dBi) for SPA at (2.4 GHz) for child's head (4 years old)

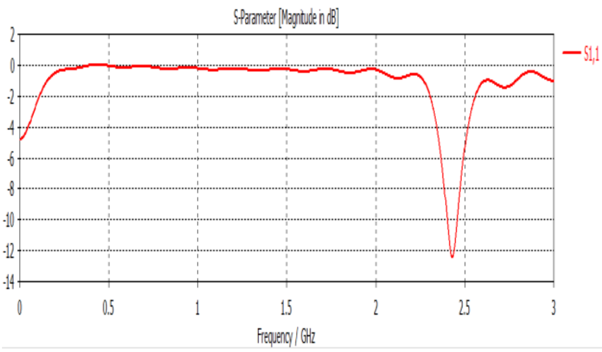


Figure 4: Return Loss (dB) for SPA at (2.4 GHz) for child's head (11 years old)

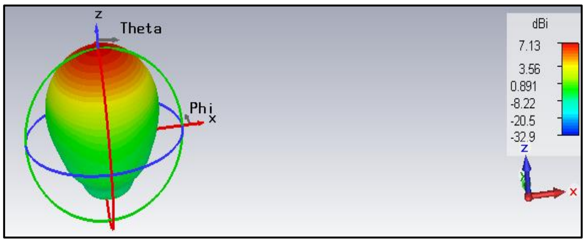


Figure 5: Directivity (dBi) for SPA at (2.4 GHz) for child's head (11 years old)

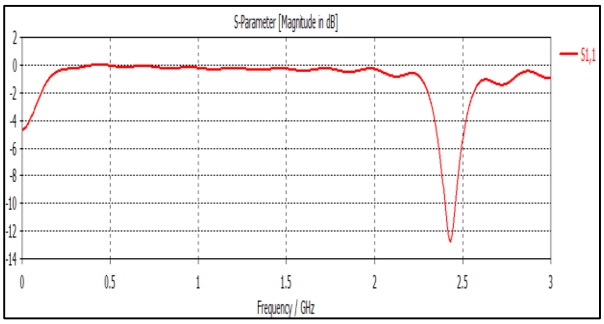
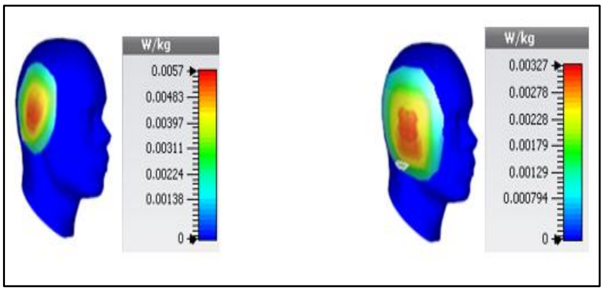


Figure 6: Return Loss (dB) for SPA at (2.4 GHz) for adult's head

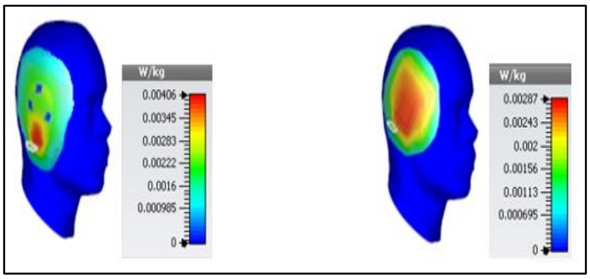
Figures 8-10, are show the results of the maximum value of SAR in (1g) and (10g) at 2.4 GHz for all dimensions of head tissues. It seems that the value of SAR in (1g) decreased with increasing the volume of head's tissues. Accordingly to the USA standard limit and IEEE standard limit, the maximum value of SAR, which is equal to 0.0057 and 0.00327 W/Kg respectively, is obtained with head of baby at 2.4 GHz. All the results of SAR values are shown in Table 2.

Figure 7: Directivity (dBi) for SPA at (2.4 GHz) for adult's head



(a) (b)

Figure 8: Specific absorbing rate (SAR) for child's head (4 years), (a) 1g, (b) 10g



(a) (b)

Figure 9: Specific absorbing rate (SAR) for child's head (11 years)(a) 1g, (b) 10g

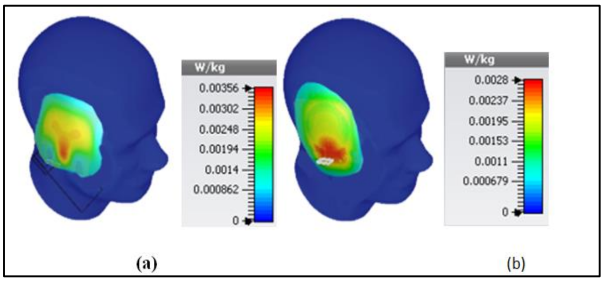


Figure 10: Specific absorbing rate (SAR) for adult's head (a) 1g, (b) 10g

Table 2: values of SAR

Age	SAR value	
	1g	10g
4 years	0.0057	0.00327
11years	0.00406	0.00287
Adult	0.00356	0.00280

4. Conclusion

The issues of health awareness become the main criterion for many countries when they looking and approve a standard. Comparative study of specific absorption rate (SAR) levels for three different ages exposed to RF frequency is carried out in this paper. Square patch antenna (SPA)is simulated at 2.4 GHz of wireless communication applications, with distance of 5mm from the wireless device the antenna away. The SPA antenna produces the smallest SAR levels in adult head tissues. The SAR levels in same tissues are highest in standard (ICNIRP) compare in (IEEE).

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