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Human head influence on the performance of a planar inverted-F antenna for different positions

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ABSTRACT

Wireless communication has been experiencing an exceptional growth at the end of the last century. This growth is likely to continue or even accelerate in the new millennium. One of the challenging areas in wireless communication has been research into interaction between wireless device antenna (e.g., telephone, laptop computer, and pager) and user's body [1]. This interaction significantly changes the antenna characteristics from those in free spaces or even on the device (handset, laptop). In order to study this problem, we are interested in this paper firstly to design and simulate a planar inverted-F antenna (PIFA) for operating over the frequency 2,45 GHz. Secondly, to study the influence of the human head on the return loss and on the radiation efficiency of the antenna. Furthermore, the relative amount of the electromagnetic power absorbed in the head has been obtained for different positions of the PIFA antenna.

Key words : Planar inverted-F antenna, PIFA, Human head-Antenna Interaction, SAR.

1. INTRODUCTION

It is well known that big efforts have been undertaken by researchers all over the world to address the problem of optimizing performance of mobile communication devices and increase radiation efficiency of antennas [2-4]. At the same time, it is clear that radiation properties of the antenna in free space are different from those in practical situations when it is located in locality of the user hand [5], body [6] or head due to electromagnetic coupling. These activities are motivated by two factors [7], the first factor is the need to evaluate deterioration of the antenna performance and to develop better antennas, and the second is a need to evaluate the rates of RF energy deposition, called specific absorption rates (SAR), in order to evaluate potential health effects and compliance with standards [8-10].
Our motivation in this paper to study the influence of the head on the return loss and radiation proprieties of a planar inverted-F antenna and find the better position which give as the less Specific Absorption Rate.

The methodology adopted in our paper is as follows. A mono-band PIFA antenna was studied; designed and simulated to operate over frequency band 2.45 GHz; the major elements of the proposed antenna are detailed. After that, we simulated the same antenna, but now, in the presence of a human head model to analyze the head's influence. First the influence of the human head on the return loss and radiation pattern for the antenna next to the left ear of the head in an arbitrary position. Second the relative amount of the electromagnetic power absorbed in the head has been obtained for different position of the antenna. The motivation of this study is to improve that the location of the antenna on a handset is very important to minimise the interaction between the human head and the antenna.

2. ANTENNA CONFIGURATION

2.1 Planar inverted-F antenna (PIFA)

PIFA is the abbreviation of Planar-Inverted-F-Antenna. The PIFA antenna has advantages of having small and multiband resonant properties, simple design, lightweight, low cost, conformal nature, attractive radiation pattern, and reliable performance [11]. These characteristics make the PIFA a suitable antenna candidate to mobile phones.

The inverted-F antenna is evolved from a quarter-wavelength monopole antenna. It is basically a modification of the inverted F antenna IFA which is consisting of a short vertical monopole wire.

To increase the bandwidth of the IFA a modification is made by replacing the wires with a horizontal plate and a vertical short circuit plate to obtain a PIFA antenna.

The conventional PIFA is constituted by a top patch, a shorting plate and a feeding plate. The top patch is mounted above the ground plane, which is connected also to the shorting pin and feeding pin at proper positions. They have the same length as the distance between the top patch and the ground plane. The standard design formula for a PIFA is [13]:

$$f=C/4(L+W) \qquad (1)$$

Where f is the resonant frequency of the main mode, C is the speed of light in the free space; W and L are width and length of the radiation patch, respectively.

2.2 Antenna Configuration

The configuration of the studied PIFA antenna consists of a radiating top plate with the dimensions W x L, and the ground plane dimensions are W_g x L_g . The dielectric material used above the rectangular ground plane is FR-4 having a thickness t and a relative permittivity ε_r, this is meant for the application when the antenna is integrated with the printed circuit board (PCB). The antenna height is h, and the space between the top plate and the substrate is filled with air (free space). The shorting plate has dimensions of Ws x (h+t), and the feed plate has dimensions of W_f x h. The distance between the shorting plate and the feeding plate is Fs.

The Figure 1 shows the illustration of our developed PIFA antenna.

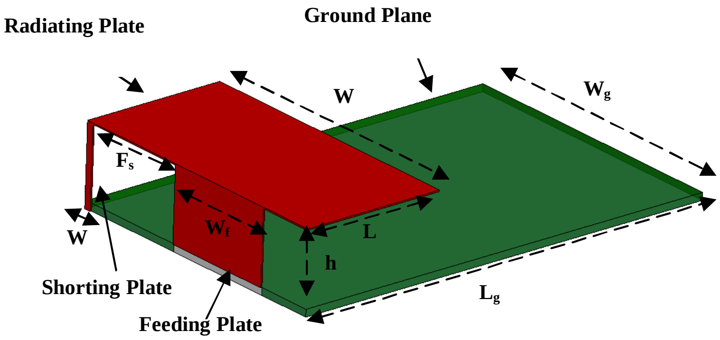


Figure 1: The Geometry of the studied PIFA antenna

In this section we made a parametric study of all the physical parameters of the PIFA. Were several simulations necessary to properly fit the antenna and find the desired resonance frequency 2,45 GHz. Different sets of parameters are simulated to cover a wide range of values. The optimized values of all the parameters of the PIFA antenna are as follows (Table .1):

Table 1: The overall dimensions of the studied PIFA antenna

Parameter	Designation	Value
W	Width of the radiating plate	40 mm
L	Length of the radiating plate	21.5 mm
Wg	Width of the ground plane	40 mm
Lg	Length of the ground plane	55 mm
T	Thickness of the ground plane	1 mm
H	Antenna height	10.2 mm
Wf	Width of the feeding plate	18 mm
Ws	Width of the shorting plate	1 mm
Fs	Distance between the shorting plate and the feeding plate	15 mm
εr	Relative permittivity	4.4

3. SIMULATION RESULTS AND DISCUSSION

3.1The simulated results without human head model

The simulated return losses of the proposed PIFA antenna without the human head is presented in Figure 2, we note that the maximum return loss is -39.43 dB at 2.35 GHz. The upper and lower band frequencies are 2.12 GHz and 2.62 GHz respectively.

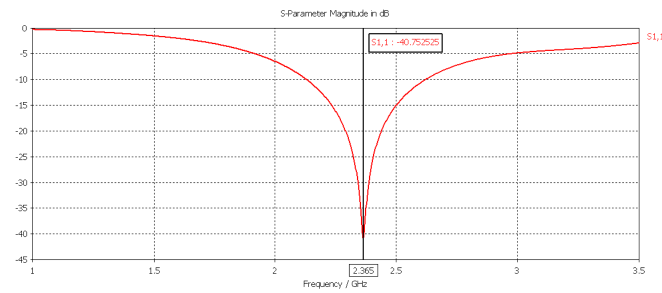


Figure 2: The simulated return loss for the proposed antenna without human head

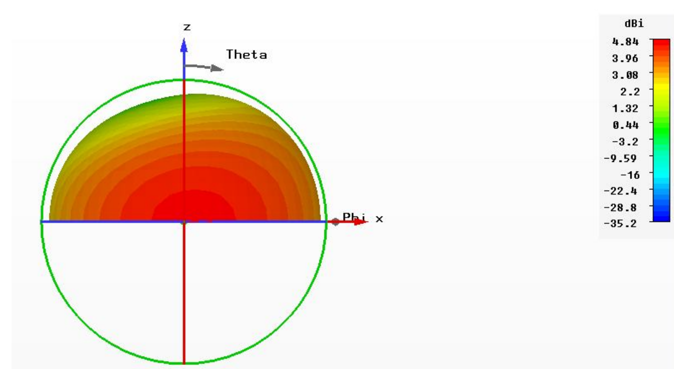
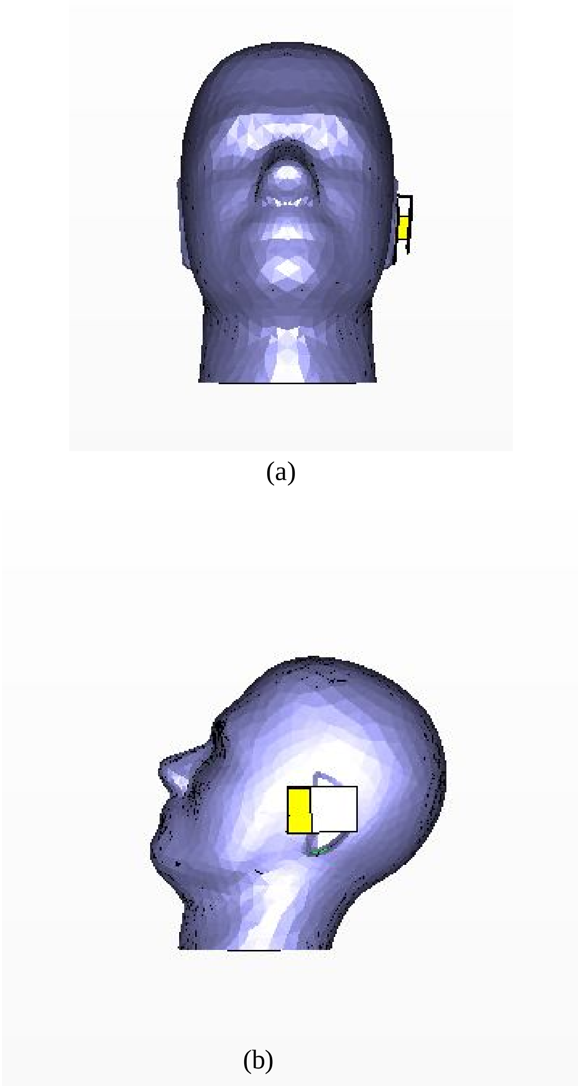


Figure 3: The radiation pattern for the proposed antenna without head

We have also simulated the far field radiation patterns of the studied PIFA antenna before adding the human head model (Fig.3).

3.2 The simulated results with human head model

In this section, a model is built as shown in Figure 4, of the antenna next to the left ear on SAM model; the shape of the head model is similar with real human head shape. The head model consists of homogenous dielectric representing the human tissue with relative permittivity εr = 41.5 and electric conductivity 0.97 S/m [13-14].



(a)

(b)

Figure 4: The PIFA antenna next to the model of the human head
(a) Front view
(b) Left view

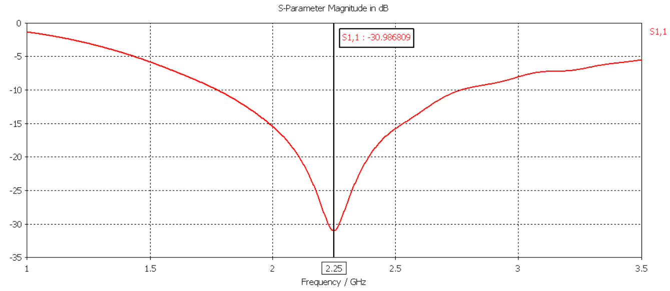


Figure 5: The simulated return loss for the proposed antenna with the human head model

The simulated return loss of the PIFA antenna with the human head model is shown in Figure 5. We note that the maximum return loss now is -30.99 dB at 2.25 GHz. The upper and lower band frequencies are 1.77 GHz and 2.75 GHz respectively. As expected, the resonant frequency of the PIFA antenna is decreased by adding the human head model.

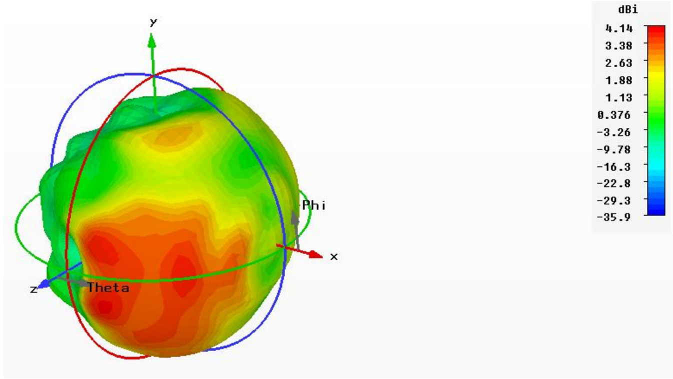


Figure 6: The radiation pattern for the proposed antenna with the human head model

The 3D radiation pattern for the PIFA antenna with the human head model is shown in Figure 6. As can be seen, the interaction with the human head results in noticeable changes to the shape, polarization, and directivity of the pattern.

3.3 Specific Absorption Rate (SAR)

Is one of the parameters to discuss related to health risk caused by the interaction between the human with the mobile antenna.

SAR is a value that measures how much power is absorbed in biological tissue when the body is exposed to electromagnetic radiation [15]. The SAR is defined as:

$$SAR = \frac{\sigma}{\rho} |E|^2 \ (W/kg) \qquad (2)$$

Where E is the electric field (V/m), σ is the conductivity (S/m) and ρ is the density (Kg). Spatial-peak SAR is defined as the maximum average SAR of a 10g or a 1g cubic volume of tissue.

The ANSI/IEE standard C95.1-1992 RF Safety Guideline suggests that the 1g averaged peak SAR should not exceed 1.6 W/Kg and the whole body average peak-SAR should be less that 0.08 W/Kg [14].

Table II provides a comparison between SAR measurements for different positions of the PIFA antenna. We conclude that that the antenna location on a handset is very important to minimise the interaction between the human head and the PIFA antenna.

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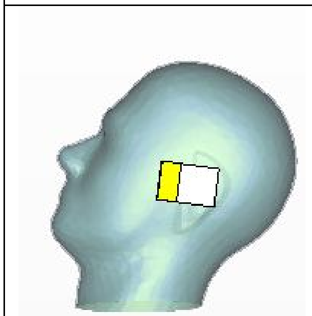
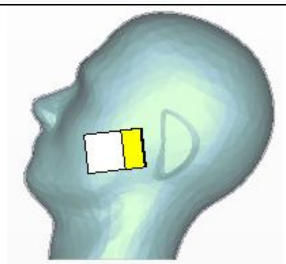
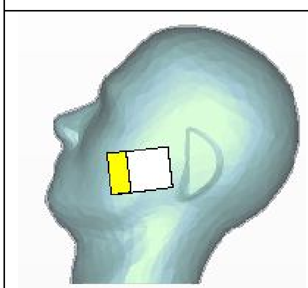
Position	**SAR_{10g}**	**SAR_{1g}**
	0.614 W/Kg	1.09 W/Kg
	0.763 W/Kg	1.330 W/Kg
	1.596W/Kg	2.359 W/Kg
	1.44 W/Kg	2.15 W/Kg

4. CONCLUSION

In this paper a planar inverted-F antenna has been designed to study its performance and interaction with the human head evaluated in terms of the resonance frequency, radiation pattern and SAR in the head. From the obtained results we note that the radiation patterns have a strong change with the human head and the return loss is affected too.

The obtained results of the relative amount of the electromagnetic power absorbed in the head for different positions of the PIFA antenna demonstrate that the position affect strongly the Specific Absorption Rate value.

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