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# Human head effects on the planar inverted-F antenna performances

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**Abstract.** With the current expansion and the anticipated further increase in the use of cellular telephones and other wireless communication devices, considerable research effort is devoted to investigations of interactions between antennas on handsets and the human body. This interaction significantly changes the antenna characteristics from that in free space or even on the device (handset, laptop). In this paper and in order to study this problem, firstly a planar inverted-F antenna (PIFA) was designed and simulated to operate over the frequency 2,45 GHz , then the influence of the human head on the return loss and on the radiation efficiency of the antenna has been studied.

**Keywords:** 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 [1-3]. 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 body or head due to electromagnetic coupling.

These activities are motivated by two factors [4], 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 [5-7].

In this paper we are interested on the first factor; we study the influence of the head on the return loss and radiation proprieties of a planar inverted-F antenna. Its important evaluates deterioration of the antenna performance and develop better antennas, which improve the radiation.

## 2 PIFA 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 [8]. 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 [9]:

$$f = \frac{C}{4(L+W)} \quad (1)$$

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

### 2.2 Antenna Configuration

The configuration of the studied PIFA antenna consists of a radiating top plate with the dimensions WxL, and the ground plane dimensions are WgxLg . The dielectric material used above the rectangular ground plane is FR-4 having a thickness t and a relative permittivity εr, 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 Wf x h. The distance between the shorting plate and the feeding plate is Fs(Figure 1).

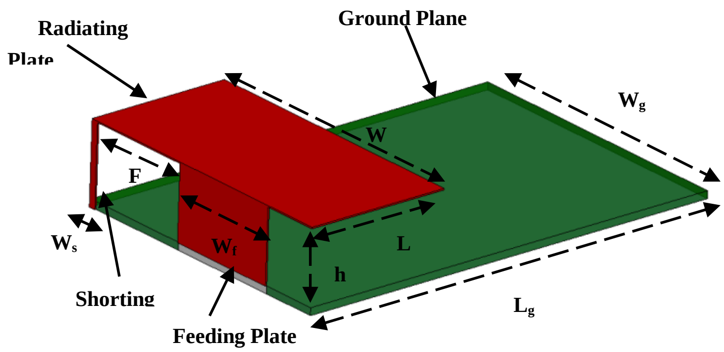



**Fig. 1.** The Geometry of the studied PIFA antenna

**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 |

## 3 Simulation Results and Discussion

### 3.1 The 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.

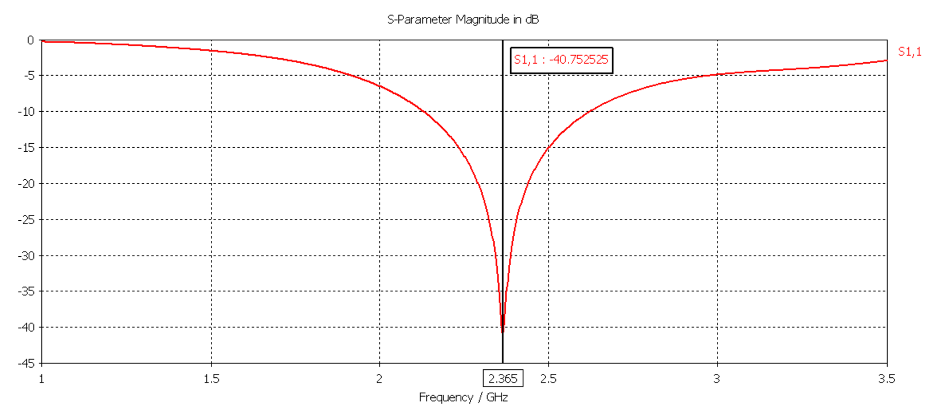



**Fig. 2.** The simulated return loss for the proposed antenna without human head

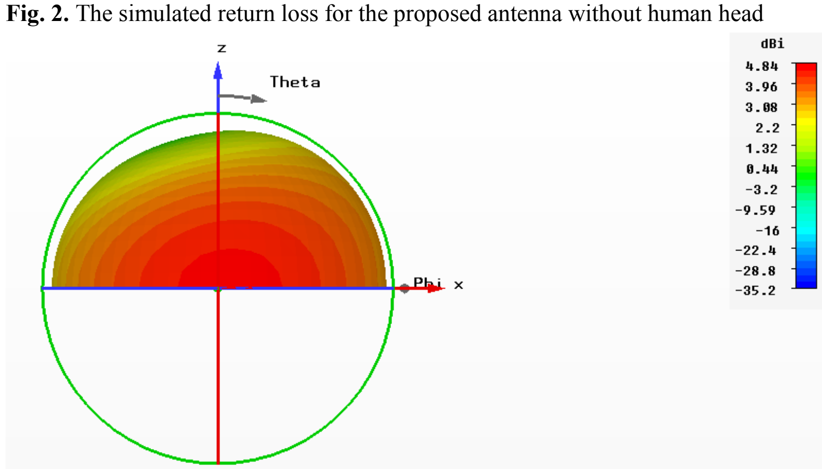
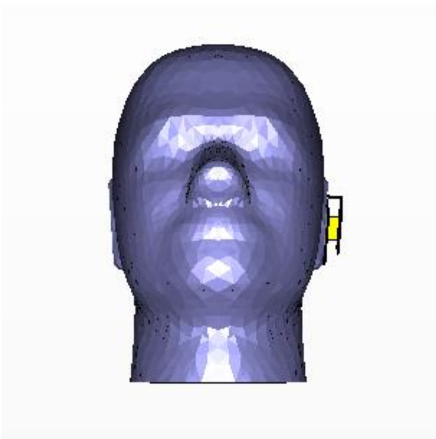



**Fig. 3.** The radiation pattern for the proposed antenna without head

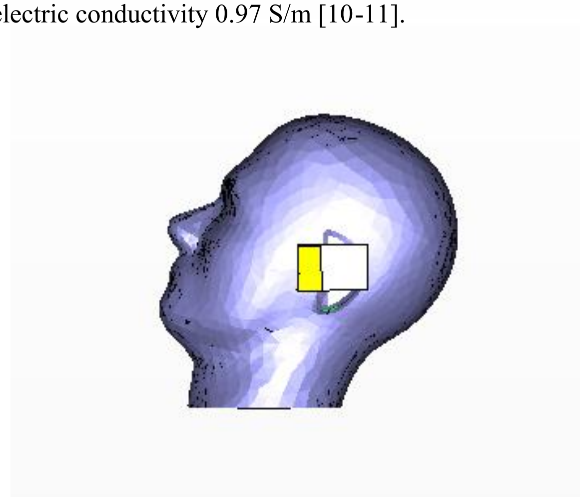
We have also simulated the far field radiation patterns of the studied PIFA antenna before adding the human head model (Figure 3).

### 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 $\varepsilon r = 41.5$ and electric conductivity 0.97 S/m [10-11].



(a)



(b)

**Fig. 4**. The PIFA antenna next to the model of the human head
(a) Front view
(b) Left view

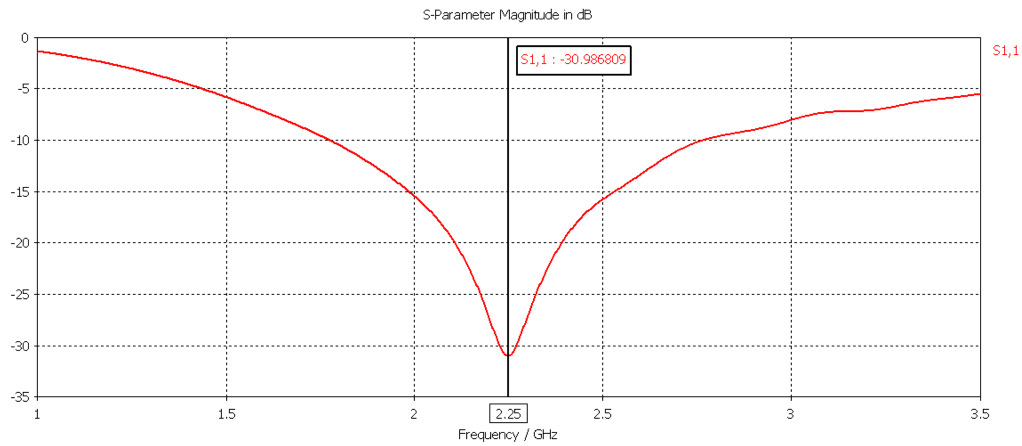



**Fig. 5**. The simulated return loss for the proposed antenna with  the human head model

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.

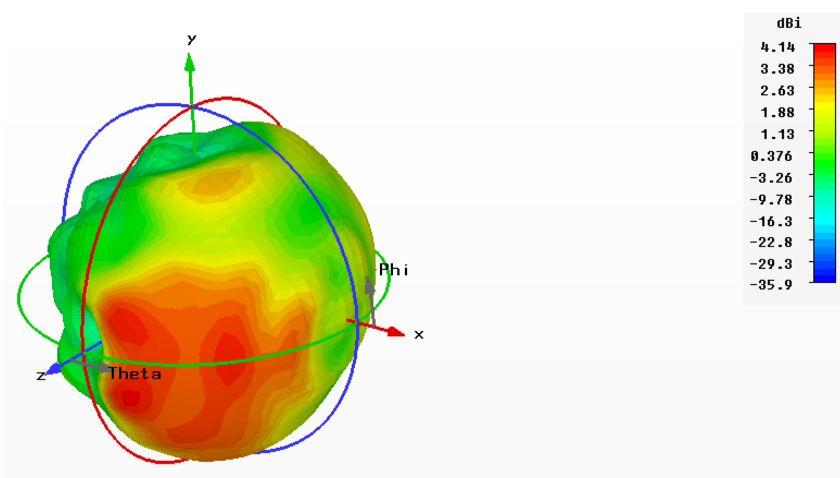



**Fig. 6**.. The radiation pattern for the proposed antenna with the human head model

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.

Table II provides a comparison between a PIFA antenna with and without a human head model in terms of resonance frequency, directivity and the specific absorption rate (SAR).

**Table 2.** Effect of human head on the PIFA antenna performances.

| | PIFA without human head model | PIFA with human head model |
|---|---|---|
| Frequency | 2.36 GHz | 2.25 GHz |
| Directivity | 4.84 dBi | 4.13 dBi |
| SAR10g | -- | 2.78 W/Kg |
| SAR1g | -- | 4.32 W/Kg |
| Frequency | 2.36 GHz | 2.25 GHz |

## 4 Conclusion

In this paper a planar inverted-F antenna has been designed and its performance and interaction with the human head evaluated in terms of the resonance frequency, radiation pattern and SAR in the head. It's possible to conclude that the radiation patterns have a strong change with the human head. Moreover, the return loss is affected to.

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