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DESIGN AND MODELLING OF WCDMA MINIATURIZED MOBILE DEVICE PLANAR INVERTED-F AERIAL (PIFA) ANTENNA

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ABSTRACT*:* *In this work, we have designed, modelled and simulated a 4.9GHz to 5GHz miniature Planar inverted F-Antenna (PIFA) on COMSOL Multiphysics. The COMSOL antenna physics was based on the geometry of the device with mobile phone modelled using silicon body frame with FR4 circuit plate and plastic as well as glass for the mobile phone screen and body. The antenna was mounted within a mobile model in order to determine the performance. It was obtained that the antenna is very well acquired from -4dBi to 1dBi, 7.59dBi with 36 and 296 degrees respectively, voltage standing ratio (VSWR) less than -10dB of ratio 2:1. The downlink frequency obtained through the adaptive frequency sweep (AWE), with directivity of 5.7dB falls between the range for chip patch and the radiation pattern for 3D and 2D shows a perfect electric and magnetic radiation for the PIFA chip. The smith chart indicates the S-parameter plot for the impedance matching properties along with the surface far-field gain variation, thereby increasing confidence on viability of our device.*

KEYWORDS*:* COMSOL, Planar Inverted-F Antenna (PIFA), Permittivity, Mobile, directivity and radiation

INTRODUCTION

In recent years, a new trend in the creation of antennas has emerge for integrating antennas for mobile terminals that are generated by embedding a tiny antenna into the dielectric casing of cell radio. Compared to traditional whip or rod antennas, this form of hidden antenna is desirable for ergonomic purposes and less likely to be harmed. These antennas have increasingly found applications in portable phone systems and other purposes. The dual-band and tri-band cell phones for example, have become more common because of the various frequency bands used by wireless applications. The low profile of a PIFA thus renders it tempting to use as a hidden antenna (Pozar, 1998; Hossa *et al.*, 2004).

Many recent designs based on the Planar Inverted-F Antenna (PIFA) have become common for handheld wireless devices due to their many attributes such as basic construction, lightweight, low cost, low profile, comfortable character and reliable efficiency (Lu and Wong, 1998; Chair et *al*., 2000, Chiou and Wong, 2001; Raghavan and Jayanthi, 2009; Chattha *et al*., 2012; Kuo and Wong, 2001; Chang *et al*., 2010; Jeon, 2008).

Electrical elements in mobile communications system use a structure that is small, light for portability and with high productivity to maintain perfect performance and efficiency, so that miniaturization of equipment and instruments become necessary and of utmost importance

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due to mobility and easy accessibility. Described as a low-profile radio device, antenna can be mounted on a flat surface recognizing that the metallic substratum or that the conductive component is engraved on the surface above a ground plane. Patch antenna has easy-to-manufacture, alter, and adapt shapes and configurations (Eugene, 2020 and Mustapha *et al*., 2014). The original type patch antenna is the microstrip antenna. Paired metal plates used to create a resonance in patch transmission lines with duration of about one-half radio wavelength and discontinuity radiation happens at these microstrip transmission lines (Eugene, 2020). Microstrip interference from the antenna allows the antenna a greater region of electrical field than the actual measurements suggesting that the antenna is resonant. The duration of the microstrip patch is marginally shorter than one-half (1/2λ) of the involved frequency wavelength since the antenna is mounted on a dielectric substratum / plate (Arit *et al*., 2019 and Ankit and Shobhit, 2014).

Multiband internal antenna incorporates frequency bands for Global Mobile Communications Service (GSM), Digital Cellular Service (DCS), Personal Communication System (PCS), Multiple Access (WCDMA) Wideband Code Distribution, Long Term Evolution (LTE) networking infrastructure and 5 G mobile networks (Eugene,2020). Thanks to the simplicity of the framework, the PIFA antenna appears to be a suitable choice for the future of technology, because it can quickly be built into networking equipment (AbuTarboush *et al.,* 2009). The inverted F antenna typically consists of a planar rectangular portion above the ground layer, a short-circuiting plate or button, and a planar portion feeding mechanism (Arit *et al*., 2017 & Madhav et al., 2014). It's a proprietary type in which the top segment was folded back to be parallel to the ground plane (Arit *et al.,* 2017 & AbuTarboush *et al.,* 2009). This is done to reduce the antenna height, while maintaining a length of resonant trace.

METHODOLOGY

PIFA Antenna

PIFA can be assessed as a kind of linear Inverted F antenna with wire radiator element interchanged by a bandwidth expansion plate. The main advantages of the planar inverted antenna is that it can be hidden in the mobile housing when comparable to the whip, rod or helix antenna (Rahul & Virani, 2013), it has reduced backward radiation towards the user head, minimizing the absorption of electromagnetic wave power (SAR) and improving antenna performance thirdly PIFA exhibits moderate high gain in both vertical and horizontal state of polarization (Mohan *et a*l., 2019). Such properties are very helpful in wireless communications where the position of the antenna is not set and the reflections are received from the specific direction of the world. The total area, which is the vector number of horizontal and vertical polarization states that render it better fit for cell phones, is one the essential features to be considered (Mohan *et al*., 2019). A limitation of the PIFA is limitations are the limited feature of the bandwidth that restricts mobile wireless communication.

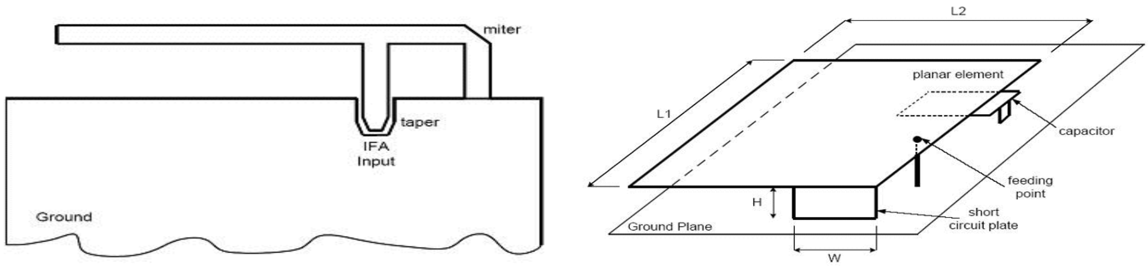

Figure 1: Planar Inverted-F Antenna (Iulian, 2019)

PIFA Antenna Design and Configuration

Antennas are basic devices fed by 50 lines of ohms as shown in Figure 1, indicating the measurements of the planned aerial used in simulation and laboratory studies. FR4 is known to be the dielectric substrate for modelling relative permittivity of 2,2 and height (h) of 5 mm, with a straightforward structure and fast integration with active instruments. To cell phones and iPad, the antenna's resonant frequency is 5GHz. Definition of parameters such as antenna duration and width were achieved using Equation 1 and 6 (Madhav, 2014).

The resonant frequency of PIFA is obtained approximately by:

$$f_r = \frac{c}{4(L_p+W_p)\sqrt{\varepsilon_r}} \qquad 1$$

Where f_r- resonance frequency, c-speed of light, L_p- length of radiator, W_p- width of the radiator, ε_r- substrate dielectric constant.

While the length and width obtained by:

$$L_1 + L_2 = \frac{\lambda}{4} \qquad 2$$

When, $\frac{W}{L_1}$=1, Then $L_1 + H = \frac{\lambda}{4}$, when W = 0 then $L_1 + L_2 + H = \frac{\lambda}{4}$

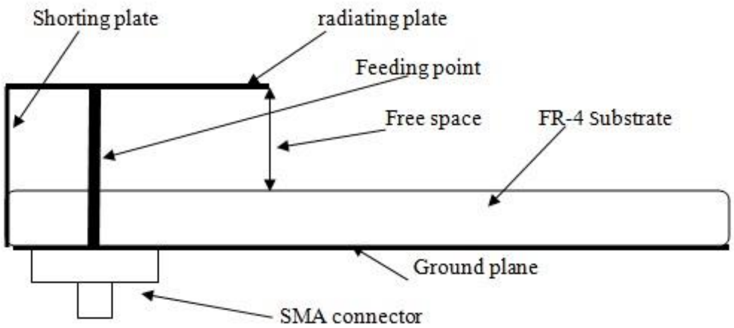

Figure 2 Geometry of the PIFA antenna (Iulian, 2019)

Simulation Procedures

The PIFA simulation was done using COMSOL Multiphysics 5.5, an electromagnetic simulator that works perfectly with the electromagnetic wave principle and theory. Following the parameters obtained, the antenna structure was mounted in the system, and the antenna shape was configured and inserted into a mobile phone designed with a silicon body and glass face and the radiating element FR4 material. Following the simulation procedure, the antenna was simulated and a perfectly matched layer was provided with Perfect Electric conduction and lumped port to assist the simulation and finally meshed for computation. The simulation uses the following study equations (COMSOL, 5.5).

Table 1.1: Simulation Parameters

Frequency (GHz)	5GHz
Circuit Board	FR4
Materials	Silicon / Glass

Frequency domain equation for the simulation is as follows:

$$\nabla \text{ X } \mu_r^{-1}(\nabla \text{XE}) - k_0^2\left(\varepsilon_r - \frac{j\sigma}{w\varepsilon_0}\right) \in = 0 \quad 3$$

Constitutive relation as:

$$B = \mu_0\mu_r H \quad 4$$

and Perfect Electric:

$$n \text{ X } E = 0 \quad 5$$

Lumped port:

$$Z = \frac{V_1}{j_1} \quad 6$$

The impedance was taken to be 50 Ω was used to excite the antenna and evaluate the input impedance where the lumped port is put between two metallic boundaries.

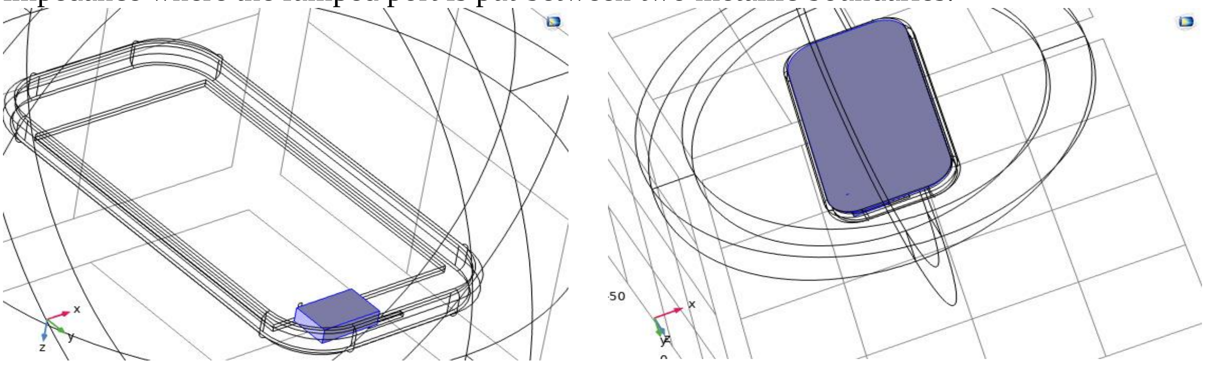

Figure 3: Finished geometry of PIFA with mobile Phone (b) Perfectly Conducting system

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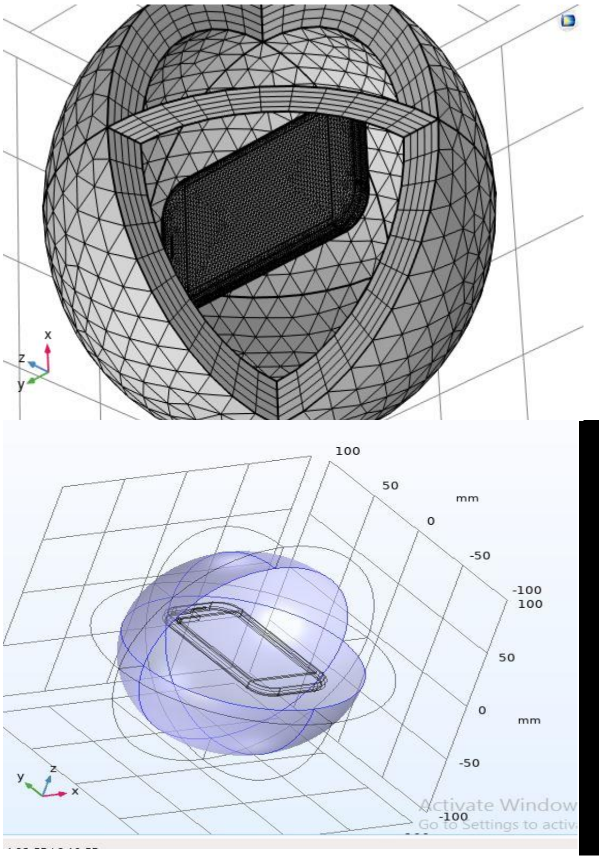
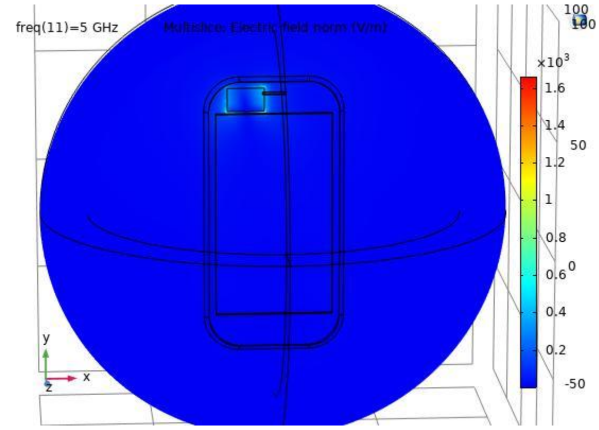


Figure 4: Meshed geometry of PIFA with mobile Phone

RESULTS AND DISCUSSION

Following simulation with COMSOL 5.5 the results obtained were used for the antenna performance analysis. In Figure 2, the entire system that is installed in a mobile telephone simulated by means of COMSOL geometry is shown with the matrix materials allocated for all parts. The meshed system put into the sphere is presented in Figure 4 while Figure 5(a) and (b) show the region of the distribution of electrical field standard on the PIFA surface antenna, also referred to as the "multislice" indicating that electric field distribution is strong at one of the highest levels of the metallic surface, far away from the flow point. Figures 5 further shows the antenna's polar far-flung radiation pattern where the azimuthal radiation pattern is all-way. Though, the radiation is little affected by the mobile device's ground plane while Figure 6 displays the far field gain at the surface of the mobile phone. The radiation pattern acquired from simulation is shown by the prefect antenna. The real 3D performance of the mobile antenna, indicating a more detailed radiation pattern is shown in Figure 7 and 8. Antenna gain on the XY plane ranges from -4.5dBi to 1dBi and S parameters (S11) from -10dB to 2.53dB to 5GHz, while 5.95GHz to -2.36dB.



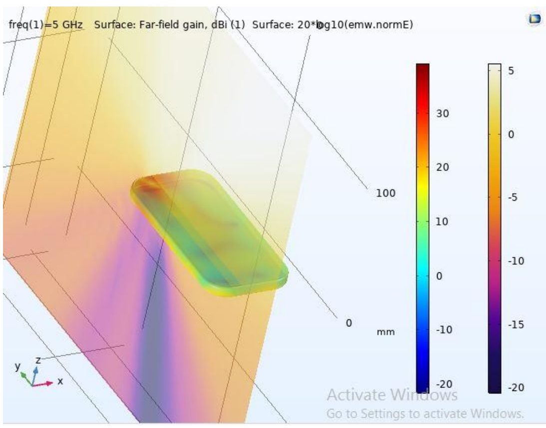
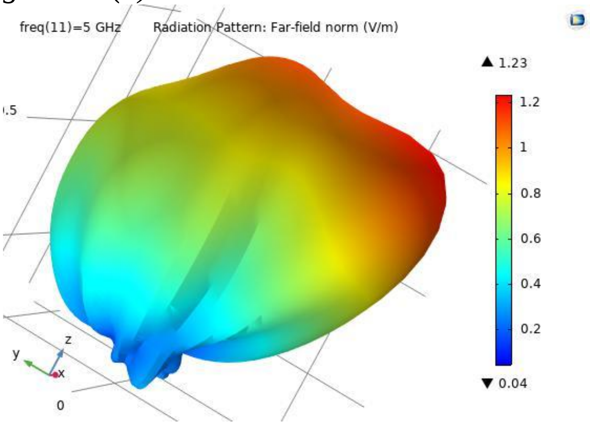


Figure 5: Electric Field distribution on the Multi-sliced system *Figure 6: Surface Far field gain dB (1)*



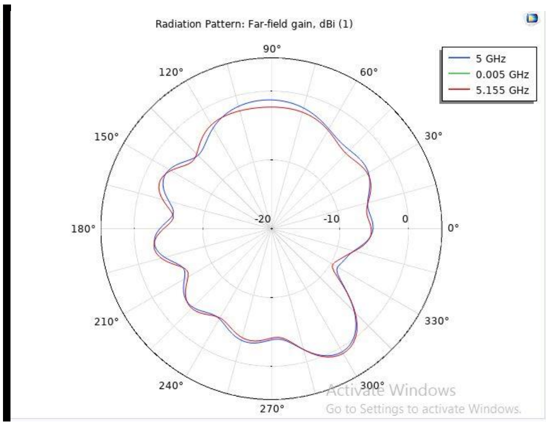


Figure 7: 3D Simulated radiation pattern of PIFA (b) 2D Simulated radiation pattern

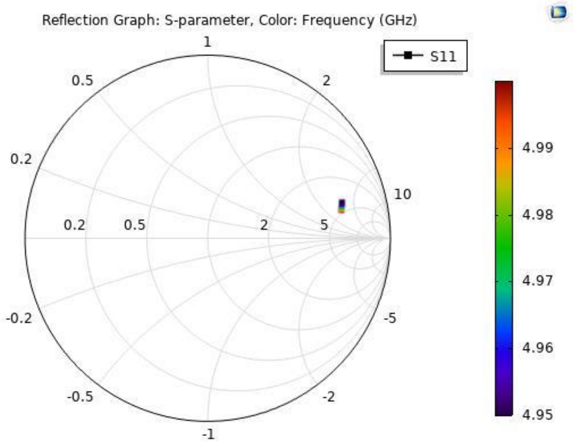


Figure 8: Smith Chart for the system

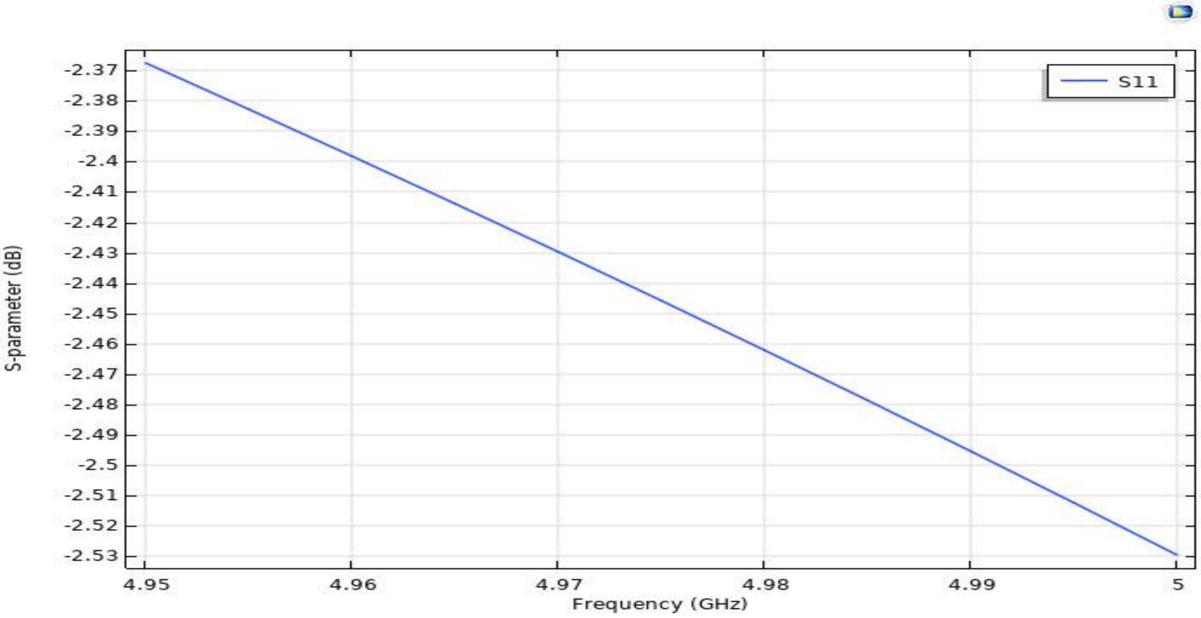


Figure 9: S- parameter

Table 1.1: Obtained Antenna Parameters

Θ(deg)	φ(deg)	Directivity	Directivity dBi
36.818	296.00	5.7438	7.5920

CONCLUSION

The modelled antenna for mobile device is suitable for mobile telecommunication applications at 5GHz range. The compact printed antenna was designed using the existing model for the design of planar inverted F antenna, modelled and simulated on COMSOL Multiphysics for mobile devices that cover the mobile WCDMA and CDMA network strips. The Electric and magnetic radiation patterns in the range 36,818degree with less than -10 and Omnidirectional shape proved the radiation ability at the considered frequency and magnetic field 296.00 degree with 5.74 and 7.59dBi directivities, frequency range of 4,95GHz and 5GHz and voltage standing ratio (VSWR) less than -10dB of ratio 2:1. This was achieved by the ability of the COMSOL Multiphysics to model a mobile phone with FR4 as the circuit plate, silicon body and glass and plastic for the mobile phone body and the screen. This was also important in selecting the perfect electric field and perfect conducting paths for the system. The downlink frequency obtained through the adaptive frequency sweep (AWE), with directivity of 5.7dB falls within the range for microstrip patch. The far field radiation pattern for 3D and 2D shows a perfect electric and magnetic radiation for the PIFA chip. The Smith chart shows a reasonable S-parameter plot for the impedance matching properties along with the surface far-field gain variation, thereby increasing confidence in the viability of the device.

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