DESIGN AND SIMULATION OF MULTIBAND PLANAR INVERTED-F ANTENNA FOR MOBILE PHONE APPLICATIONS

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***Abstract*— The proposed multiband planar inverted-F antenna has a very simple structure. The antenna has only one layer so it is easy to fabricate. The size of radiating patch of proposed antenna is 20mm× 25mm, while the size of ground plane is 39mm×39mm and height of antenna is 3mm. Mathematical tools are used to determine the initial dimensions of the patch and RT Duroid has been used as a dielectric material. Slots in radiating patch have been used to introduce multiband operations into the proposed antenna. Slits in the ground plane of the proposed antenna have been employed to enhance the bandwidth and the number of frequency bands. The proposed antenna can cover UMTS, LTE2300, m-WiMAX and WLAN. The gain of the antenna at 2.1987, 3.7208, and 5.1798 GHz are obtained as 2.18, 4.73 and 5.87 dBi, respectively and the radiation efficiencies are 89.88, 88.34, and 81.69% respectively. So, the proposed antenna is suitable for modern mobile phone applications.**

Keywords - pifa; multiband; WLAN, 3G.

I. INTRODUCTION

Wireless communication has become an important and integral part of human beings. It is being used for voice calls, video calls, internet, video conferencing etc. A better and faster wireless communication system is in demand and therefore, lots of improvements are taking place in this field. Many mobile devices have been invented which have made this world a global village. Conventional devices have been very large in size and bulky. However, the miniaturized devices in wireless communication are required. The most important and essential component/device needed for wireless communication system is an antenna which transmits/receives an electromagnetic wave. A wireless communication cannot be imagined without the antenna. Conventional mobile devices uses monopole antenna. Whip antenna is the most common quarter wavelength monopole antenna which is used with conventional mobile phones. These monopole antennas are large in size and operate at only one frequency. However, modern wireless mobile devices are becoming small and slim day by day and thus, these devices are not suitably matched with big monopole antenna. Also, these mobile devices are performing different wireless applications and so different antennas for different applications cannot be afforded. Therefore, these wireless mobile devices used at wide range of frequency require the antenna having smaller size and lighter weight. Inverted-F shaped wire-form Antenna (IFA), microstrip antenna and Planar Inverted-F Antenna (PIFA) are widely used as built-in antennas. Despite of having small size and light weight, half wavelength microstrip antennas have been too large at lower bands for mobile phone applications. Therefore, it has become quite obvious that PIFA is quarter wavelength antenna suitable for mobile phone applications because of its small size and light weight. The PIFA consists of a ground plane, radiating patch, shorting pin or wall and feed. It exhibits high gain and omnidirectional radiation pattern. Also, it provides a wider bandwidth which is enough for mobile phone operations. A multiband PIFA can be achieved by using different methods such as slot in the radiating patch, parasitic element etc. Therefore, it has become quite necessary to use multiband PIFA with smaller size in mobile phone applications.

In cellular phone system, improvements are taking place from one generation to another and therefore, a mobile phone should cover more than one frequency band. Cellular phone system operates at various frequency bands such as Global System for Mobile communication (GSM, 890-960 MHz), Universal Mobile Telecommunication System (UMTS, 1900-2200 MHz), Personal Communication Service (PCS, 1880-1990 MHz), Digital Cellular Service (DCS, 1710-1880 MHz), Long Term Evolution (LTE, 2300-2400 MHz), Wireless Local Area Network (WLAN), Global Positioning System (GPS, 1575 MHz), BLUETOOTH (2400 MHz) and Mobile Worldwide Interoperability for Microwave Access (m-WiMAX, 3.5, 3.7, 5.5 GHz). **AbuTarboush *et al.* (2011)** have proposed a small ultra-thin planar inverted-F antenna with independent control on the resonant frequency. The antenna consists of slotted radiator, shorting walls and a small ground plane. It operates at 2.09, 3.74 and 5GHz with bandwidths of 11%, 8.84%, and 10%, respectively. Thus, it covers UMTS, m-WiMAX, and

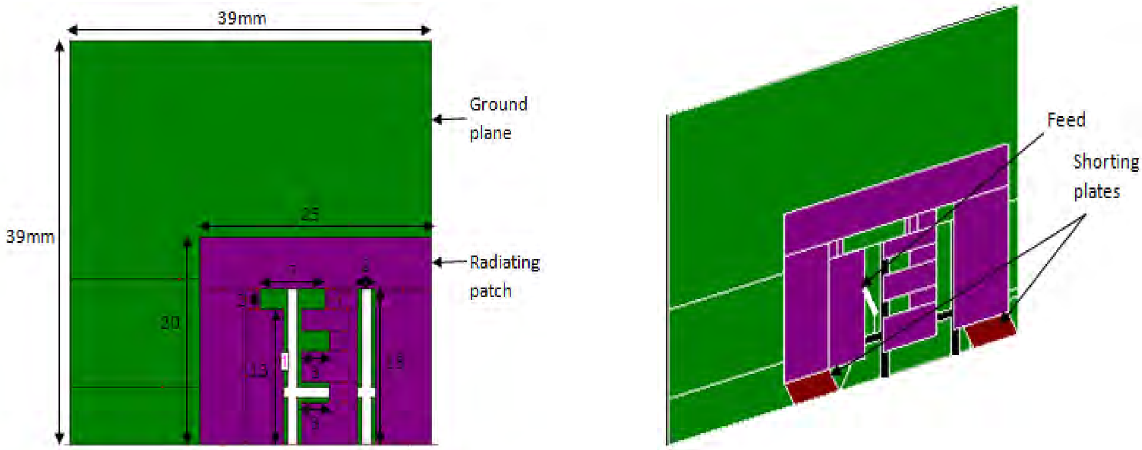


Figure 1: 2D and 3D view of the final design of the proposed antenna (All Dimensions are in mm)

WLAN bands. The antenna is thin in structure and occupies a less volume. The measured peak gains of the antenna at resonant frequencies 2.09, 3.74, and 5 GHz are 2.05, 2.32 and 3.47 dBi, respectively and the radiation efficiencies are 70.12, 60.29, and 66.24%, respectively. Keeping the above in view, an attempt has been made to design and simulate a multiband Planar Inverted-F Antenna. (PIFA) for mobile phone applications by using Spatial Network Method (SNM) and Zeland IE3D software. Initial Dimensions of PIFA are calculated by using Spatial Network Method (SNM). IE3D full wave EM solution based on Method of Moment (MOM) is carried out for design and simulation of the proposed multiband PIFA for mobile phone applications.

II. DESIGN OF MULTIBAND PIFA

A. Antenna configuration and its return loss

For the design of proposed multiband PIFA, size of ground plane has been taken as 39mm×39mm. Duroid has been used as a dielectric material having substrate height of 0.8 mm to have a compact antenna. The dimensions of the initial patch have been calculated by using following equation for resonant frequency of 2.2GHz.

$$f = \frac{G}{4(L_1 + L_2 + H - W)}$$

where L_1 and L_2 are dimensions of the patch and H and W are the height and width of the shorting plate respectively. RT Duroid has been used as a dielectric material having height of 0.8mm. Slots in radiating patch have been used to introduce multiband operations into the proposed antenna. The effects of these slots have been observed by analyzing the simulations in Zeland IE3D software. Slits in the ground plane of the proposed antenna have been employed to enhance the bandwidth and the number of frequency bands. Figure 1 shows the 2D and 3D view of the proposed antenna having different slots in radiating patch and slits in ground plane.

The simulated reflection coefficients are shown in Figure 2. The result shows the resonant frequencies are obtained at 2.1987GHz, 3.7208GHz and 5.1798GHz with return loss of -21.42dB, -16.31dB and -36.74dB. The -6dB bandwidth at the resonant frequencies 2.1987GHz, 3.7208GHz and 5.1798GHz are obtained as 319.7MHz (2.0868-2.4065GHz), 132.9MHz(3.6 684-3.8013GHz) and 642.7GHz (4.7334-5.3761GHz) respectively.

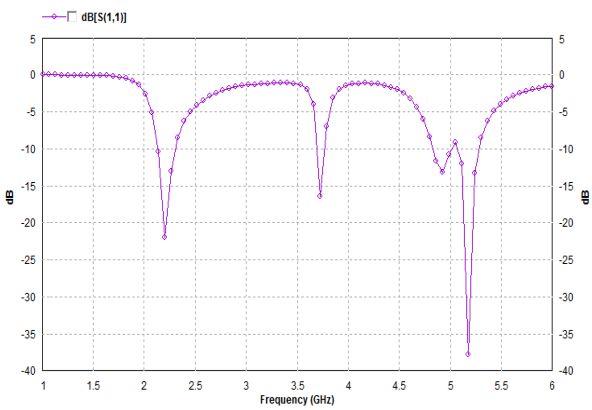
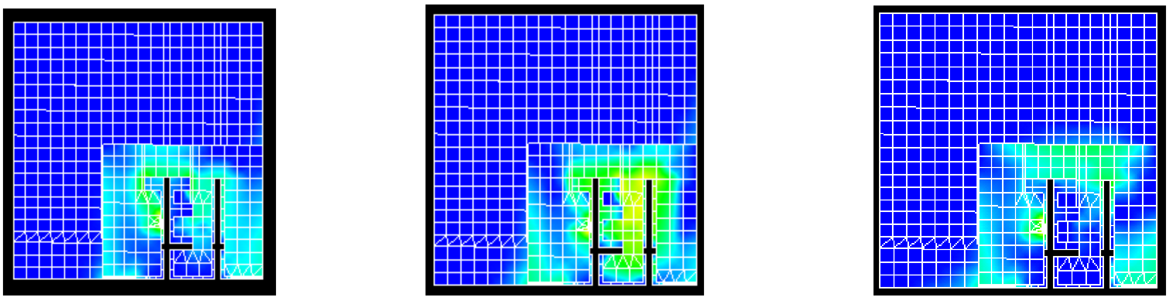
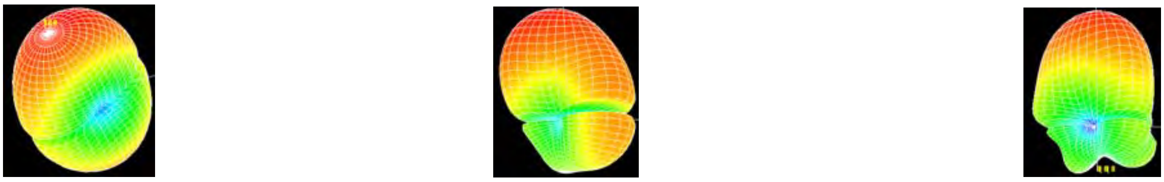


Figure 2: Return loss of the proposed antenna.



(a) (b) (c)

Figure 3: Current distributions at resonant frequencies (a) 2.1987 GHz (b) 3.7208 GHz (c) 5.1798 GHz for the final design of the proposed antenna.



(a) (b) (c)

Figure 4: 3D radiation patterns at resonant frequencies (a) 2.1987 GHz (b) 3.7208 GHz (c) 5.1798 GHz of the proposed antenna.

B. Current Distributions and radiation patterns.

Current distributions at the three resonant frequencies 2.1987GHz, 3.7208GHz and 5.1798GHz are shown in Figure 3. For the resonant frequency at 2.1987 GHz, it can be seen from the figure that the current is mainly across the left horizontal edge of the radiating patch, current for the resonant frequency at 3.7208 GHz is maximum at the middle part of the radiating patch and for the resonant frequency at 5.1798 GHz the current is mainly observed at the top horizontal edge of the radiating patch. Figure 4 shows the 3D radiation pattern at the three resonant frequencies 2.1987GHz, 3.7208GHz and 5.1798GHz. It can be seen that the radiation pattern at the three resonant frequency is almost omnidirectional which is suitable enough for mobile phone applications.

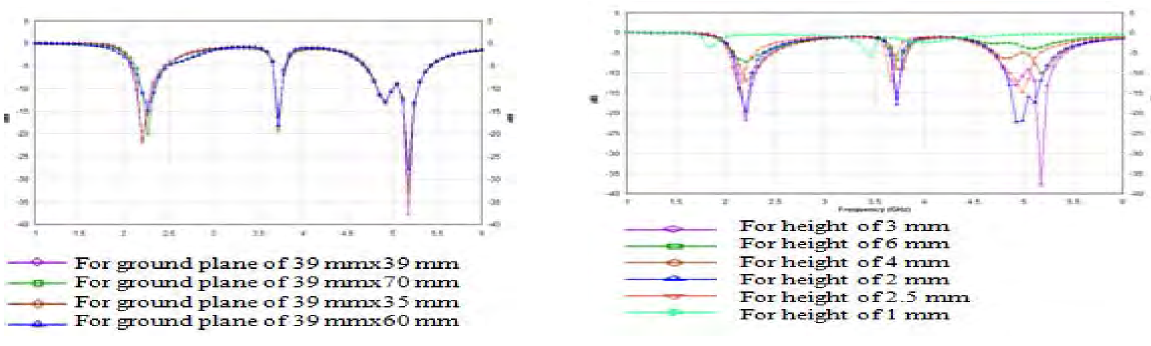
III. Effects of Some Parameters on the Proposed Antenna Performance

A. Ground Plane Effect

Figure 5(a) shows the performance of proposed antenna in terms of antenna parameters for different dimensions of the ground plane. It can be seen from the figure that with different dimensions of ground plane, resonant frequency do not change significantly but there is a variation in gain, antenna efficiency and radiation efficiency. The proposed antenna having ground plane of dimension 39mm×39mm exhibits better results.

B. Height of antenna

Figure 5(b) shows the performance of the proposed antenna for different height of the radiating patch from the ground plane. It can be seen from the figure that the proposed antenna gives desired characteristics with a height of 3mm.



(a) (b)

Figure 5: Return loss of the final design of the proposed antenna for (a) different size of the ground plane

(b) different height of the radiating patch from the ground plane

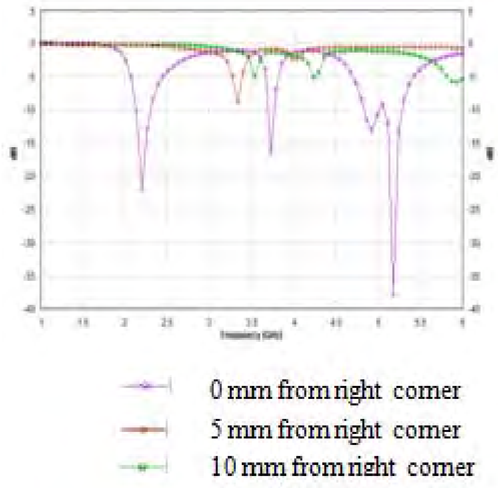


Figure 6: Return loss of the final design of the proposed antenna for different antenna location.

For height of 1mm and 6mm the return loss for the resonant frequencies are not larger than 10dB while for height of 4mm, 2mm and 2.5mm the return loss are larger than 10dB but corresponding gain and antenna efficiency are not so good. Therefore, for a height of 3mm gain, antenna efficiency and radiation efficiency of the proposed antenna are sufficient.

C. Antenna location

It can be seen from Figure 6 that the return loss for the resonant frequency are larger than 10dB only for the antenna location of 0mm from the right corner. For 0mm the return loss at the resonant frequency 2.1987GHz, 3.7208GHz and 5.1798 GHz are obtained as -21.42dB, -16.31dB and -36.74dB, respectively. For 5mm from right corner, only two resonant frequency have been obtained having return loss less than 10 dB while for antenna location of 10mm from right corner three resonant frequency have been obtained but with a return loss less than 10 dB. Therefore, it can be observed that the antenna location at the 0mm from right corner gives the best result.

D. Simulated Results.

Table 1 shows that the gain of the proposed antenna at the resonant frequencies 2.1987GHz, 3.7208GHz and 5.1798GHz are obtained as 2.18dBi, 4.73dBi and 5.87dBi, respectively. The antenna efficiencies at the resonant frequencies 2.1987GHz, 3.7208GHz and 5.1798GHz are found to be 83.44%, 86.03% and 81.52%, respectively and the radiation efficiencies at these resonant frequencies are 89.88%, 88.34% and 81.69%, respectively. The -6dB bandwidth at the resonant frequencies 2.1987GHz, 3.7208GHz and 5.1798GHz are obtained as 319.7MHz, 132.9MHz and 642.7GHz**.**

Table 1 Antenna parameters for the final design of the proposed antenna.

Resonant frequency (GHz)	**Gain (dBi)**	**Antenna Efficiency (%)**	**Radiation Efficiency (%)**	**Frequency Range (GHz)**	**Bandwidth (MHz)**
2.1987	2.18	83.44	89.88	2.0868-2.4065	319.7
3.7208	4.73	86.03	88.34	3.6684-3.8013	132.9
5.1798	5.87	81.52	81.69	4.7334-5.3761	642.7

IV CONCLUSIONS

The volume of the antenna is $20\times25\times3mm^3$. The size of the antenna is small and thin. The antenna covers different bands of mobile applications. These bands are UMTS (2.08055-2.2 GHz), LTE2300 (2.3-2.4 GHz), 3.7GHz m-WiMAX (3.6684-3.8013 GHz) and WLAN (4.7334-5.3761 GHz).

Slots in the radiating patch and the concept of find out exact feed location have been employed and its effects have been studied on the antenna parameters. It has been found that making slots in the radiating patch and slits in the ground plane provides a simple multiband PIFA with enhanced bandwidth. The simulated results obtained for the proposed multiband PIFA have been compared to that of antenna under reference (AbuTarboush *et al.,* 2011) in Table 2. It can be seen from the comparison that the proposed antenna is compact in size covering more frequency bands with increased gain and radiation efficiency.

Table 2 Comparison of proposed antenna with antenna under reference

Parameters	**Antenna under Reference (Abu Tarboush, H. F. *et al.* 2011)**	**Proposed Antenna**
Ground size	40mm×40mm	39mm×39mm
Radiating patch size	25.6mm×26mm	20mm×25mm
Height of antenna	3.57 mm	3mm
Dielectric material	FR4 ,ε_r = 4.4 ,tanδ = 0.02	Duroid, ε_r = 2.2 tanδ = 0.001
Height of dielectric substrate	1.57 mm	0.8 mm
Bands Covered	UMTS m-WiMAX WLAN	UMTS LTE2300 m-WiMAX WLAN
Peak Gain	2.14 dBi 2.4 dBi 5 dBi	2.18 dBi 4.73 dBi 5.87 dBi
Radiation Efficiency	70.12 % 60.29 % 66.24 %	89.88 % 88.34 % 81.69 %
Antenna Efficiency	-	83.44% 86.03% 81.52%

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