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A Multiband Pifa with Slotted Ground Plane For Personal Communication Handheld Devices

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Abstract:- In mobile phones and several other wireless communication devices, antenna is an important element which decides the quality & performance of the device over various communication standards. In this paper, a compact internal Planar Inverted-F Antenna (PIFA) with a ground plane having two open ended slots is proposed which is very thin compared to conventional PIFA structure. By using the ground plane as a radiator element along with top plate of PIFA structure, the height of PIFA can be reduced to a great extent, which further results in reducing thickness of mobile phones. In this paper the proposed antenna has volume as 25 x 15 x 3.8 mm^3 and it is simulated & analyzed using HFSS software. The antenna is designed to operate at GPS, GLONASS, DCS (1800 MHz), PCS (1900 MHz), UMTS (2100 MHz), Bluetooth (2400 MHz), 4G LTE (2300 MHz & 2600 MHz), WLAN (5.2 GHz) standards. The simulation results show that the performance parameters of the antenna are satisfying the requirements of advance wireless communication devices.

Keywords:- Compact, Planar Inverted-F Antenna (PIFA), GLONASS, HFSS, radiator, GPS, LTE.

I. INTRODUCTION

The recent growth and rapid development of mobile communication and devices operating at multiple frequency bands has lead to the requirement of antennas which supports multiband or wideband operation. Planar Inverted-F Antennas (PIFAs) are widely used for mobile phone applications and other communication devices due to its merits of small size, light weight, low SAR values, good gain & multiband operation [1]-[2]. In last few years mobile phones has evolved rapidly and they are required to give various services like data, voice, Internet & multimedia content without compromising on their weight, volume and performance. Latest communication standards such as GPS, Wi-Fi, 3G, WiMAX, 4G LTE, GLONASS etc are needed to be supported by handsets [2]. For such mobile phones, several PIFA designs having different configurations have been reported in open literature and are implemented to achieve single and multiband operation. The main objective while designing a PIFA structure is to cover the required operating bandwidth; due to this the height of PIFA is generally taken in the range of 7-12 mm above ground plane [3]. Implementing the antenna with such heights results in thicker phones which affects aesthetic and appearance of the handsets. So, the height of PIFA can be taken as small as 4mm which reduces phone thickness, but this results in narrow bandwidth coverage [4]. PIFA structure consists of a ground plane, a rectangular radiating element i.e. a patch, a feed wire or strip & one or more shorting pins or plates to connect the top patch and the ground plane. Simple PIFA structure is fed at the base by a feed wire. There are several design variables which can be varied and the performance of the desired antenna is achieved [2]. Some of the design variables are width, length and height of the top radiating patch, width and position of shorting pin or plate, location of the feed point, dimensions of the ground plane. For the past few years, many works have been reported on modifying the ground plane by introducing slots on it & using it as a radiator along with the main patch [5]. By working on ground plane length and modifying it results in reduced size of antenna and enhancement of operational bandwidth [6]. In several designs, position of the antenna on the dielectric substrate is important as enhancement in the operating bandwidth can be achieved to few more percentage.

Next section discusses the geometry of the proposed PIFA and its detailed dimensions are presented. Section III discusses simulated results of the proposed antenna such as Return Loss (S_{11}), Gain, VSWR & Radiation patterns. Section IV provides conclusion of the proposed work and its applications.

II. PROPOSED ANTENNA

The geometry and 3-D view of the proposed PIFA antenna with two open ended slots on the ground plane is shown in Fig. 1(a) and (b). The proposed antenna consists of planar radiating element, two rectangular slots on the ground plane, a shorting plate, coaxial feed and a ground plane. The dielectric material used in antenna design is FR-4 substrate which has loss tangent, δ=0.02, dielectric constant, ε_r = 4.4 and substrate height, h = 1.6 mm. Feeding mechanism simultaneously excites both the upper patch and ground plane of the antenna. The dimensions of the rectangular patch of the antenna are 25 x 15 x 3.8 mm^3 and that of ground plane are 70 x 40 x 4 mm^3. In order to shape the geometry of the antenna, the slots introduced in ground plane are placed underneath the antenna area resulting in improvement of bandwidth and simplified PCB design & leaving more space available for other electronic components like battery, RF components, displays, speakers etc [7]-[9].

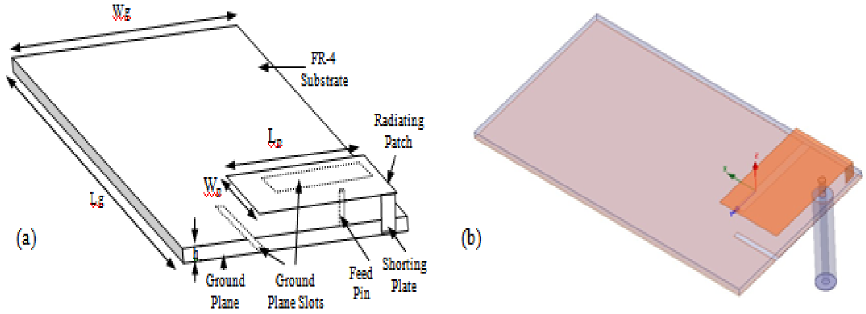


Fig. 1: (a) Geometry of Antenna (b) 3-D view of Multiband PIFA in HFSS

Fig. 2 shows the detailed dimensions of the proposed antenna having two open ended rectangular slots on ground plane. One slot is along the length of the ground plane and the other one is along width of the ground plane. The distance of slots and shorting plate from the edges of ground plane are also shown in Fig 2 (a) & (b). The location of feed and short circuit points are selected after optimization and observations so that the antenna structure resonates at 1.86 GHz, 2.42 GHz & 5.38 GHz. The dimensions and positions of two open ended slots are optimized to achieve maximum operating bandwidth at resonating frequencies. Also the dimensions of shorting strip are optimized for better impedance matching over the desired frequencies. Values of all the dimensions are given in Table 1.

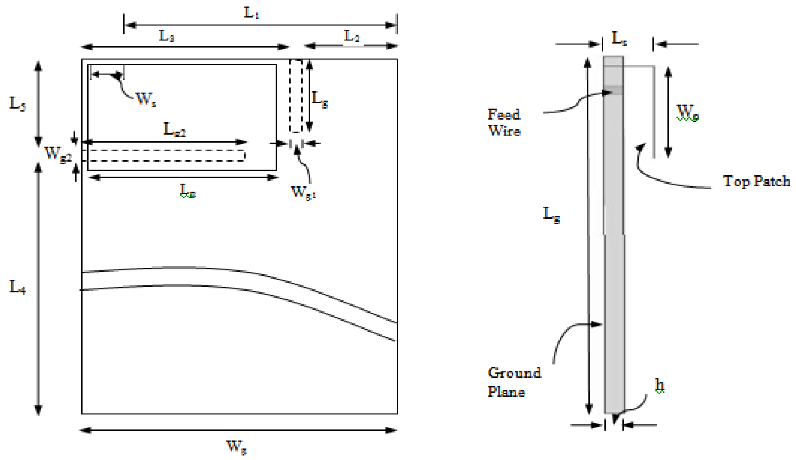


Fig. 2: Detailed Dimensions of Proposed Antenna (a) Top view, (b) Side View

TABLE 1: Detailed Dimensions of Proposed Antenna

Parameter	Value (mm)	Parameter	Value (mm)
L_g	70	W_{g1}	1.2
W_g	40	L_{g2}	22
L_p	25	W_{g2}	2
W_p	15	L_1	36.7
L_s	3.8	L_2	11.5
W_s	2.4	L_3	27.3
H	1.6	L_4	55
L_{g1}	12	L_5	13

III. SIMULATED RESULTS

The simulation & optimization of the proposed antenna is done by using High Frequency Structure Simulator (HFSS). Dielectric and conductor losses are not included in the simulation set up. The simulated reflection coefficient (S_{11}) plot is as shown in Fig. 3. It can be observed from S_{11} plot that there are three frequencies at which resonance is achieved and those are 1.90 GHz, 2.40 GHz and 5.40 GHz with return loss of

-26.94 dB, -25.80 dB and -19.02 dB respectively. The cellular and non-cellular bands covered by the proposed antenna are GPS L1 band (1575.42 MHz), GLONASS-M L1 band (1602 MHz), DCS (1800 MHz), PCS (1900 MHz), UMTS (2100 MHz), Wi-Fi/Bluetooth (2.4 GHz), 4G LTE (1.7 GHz, 2.3 GHz & 2.6 GHz), WLAN (5.2 GHz). Comparing the operating bandwidth & overall size of the proposed PIFA antenna with the design proposed in [6] shows that there is 5% reduction in the volume of antenna proposed in this paper with slots on ground plane and also it supports more cellular & non-cellular bands. The main objective of this research work is to propose a compact antenna having small & thin structure, the height of PIFA selected is 2.2 mm from the FR-4 substrate and 3.8 mm from the ground plane.

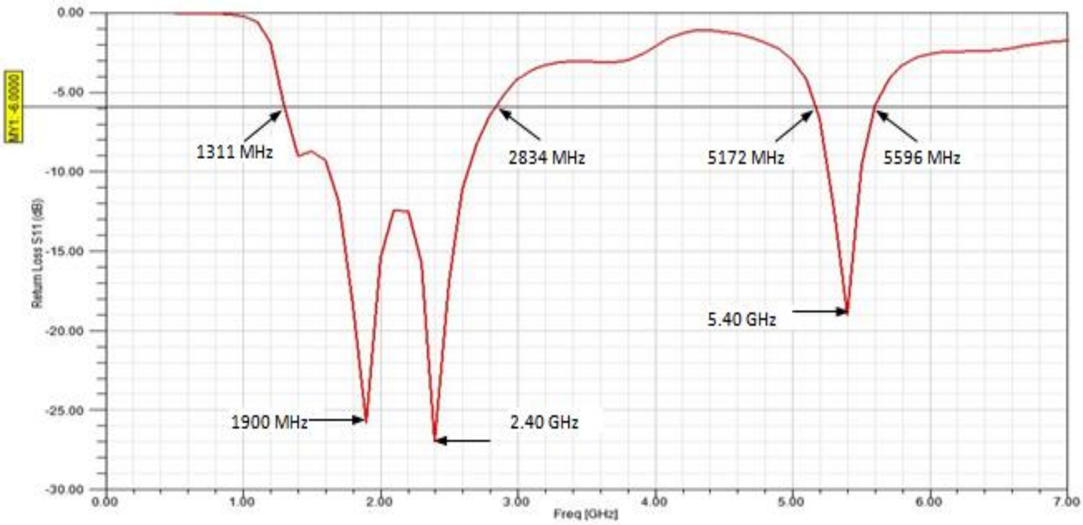


Fig. 3: The Simulated S_{11} (dB) of proposed PIFA

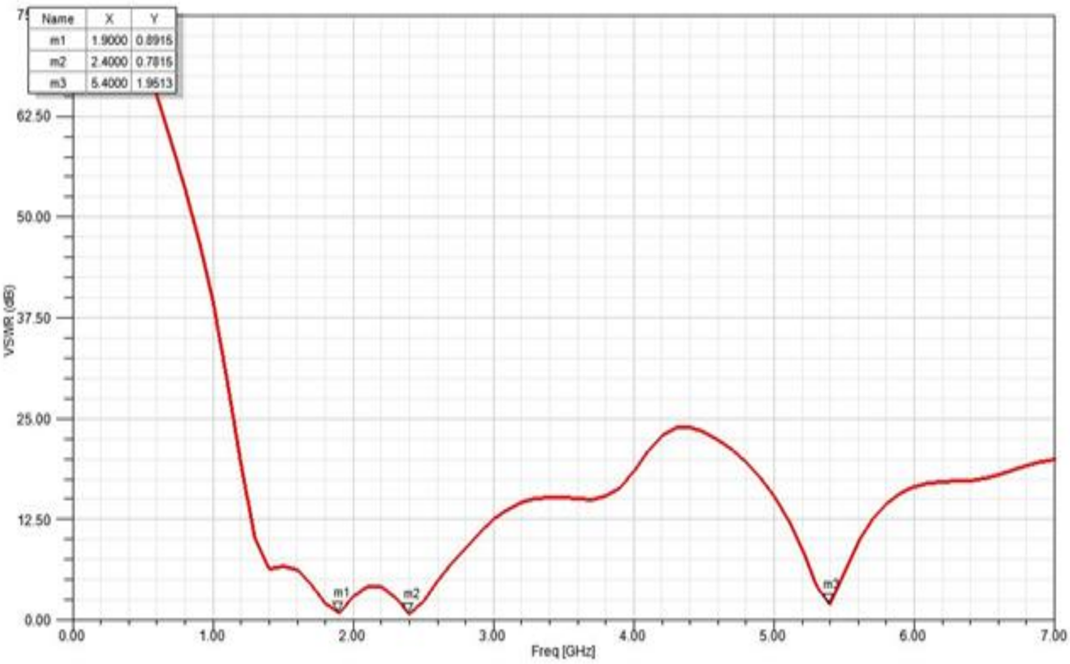


Fig. 4 : The Simulated VSWR (dB)

Also it is observed from the results that at resonant frequencies the Voltage Standing Wave Ratio (VSWR) is below 2 dB which is required level for most of the antenna applications [1]. It is shown in Fig. 4 that at 1900 MHz VSWR is 089 dB, at 2.40 GHz is 0.78 dB & at 5.40 GHz is 1.95 dB. The overall gain (dB) of the antenna in the simulated results is 2.76 dB. A 3-D view of gain total in all the directions is shown in Fig. 5. The impedance matching of the PIFA is achieved by positioning the feed and shorting plate and by optimizing the distance between them.

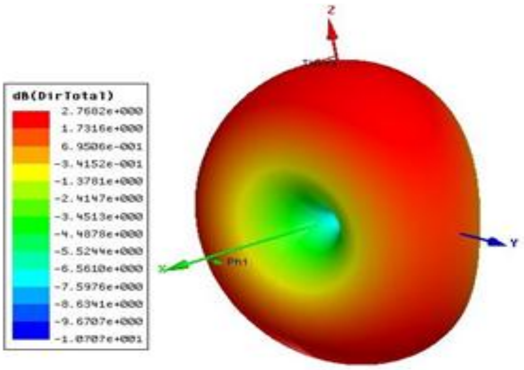
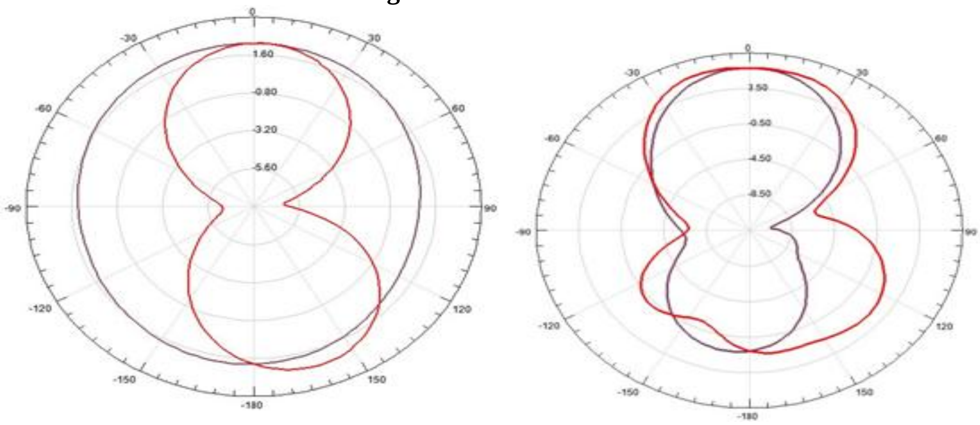


Fig. 5: 3-D Gain Total



(a)

(b)

Fig. 6 : The radiation Pattern of the antenna at (a) 1900 MHz (b) 2.4 GHz (E_{φ} Phi=0, E_{ψ} Phi=90^{o} at y-z plane)

The simulated radiation patterns at resonant frequencies are given Fig. 6. The radiation pattern is the relative distribution of power radiated as a function of direction. Usually radiation pattern is determined in the far-field region.

IV. CONCLUSION

In this paper, a multi-band planar inverted-F antenna (PIFA) with two open ended slots on the ground plane is designed and optimized in HFSS. The ground plane of the antenna is used as a radiator and helped in improving the operating bandwidth and resonance of the antenna. Use of slots in ground plane also reduces volume of the antenna making it suitable for use in compact & slim handsets. Various bands covered by propose antenna are GPS L1 band (1575.42 MHz), GLONASS-M L1 band (1602 MHz), DCS (1800 MHz), PCS (1900 MHz), UMTS (2100 MHz), Wi-Fi/Bluetooth (2.4 GHz), 4G LTE (1.7 GHz, 2.3 GHz & 2.6 GHz), WLAN (5.2 GHz).

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