A Multiband PIFA with a Slot on the Ground Plane for Wireless Applications

Seyed Ehsan Hosseini, *Member*, *IACSIT*, Amir Reza Attari, and Aref Pourzadi

***Abstract*—In this paper, we present a new configuration of planar inverted-F antenna (PIFA) for mobile communication devices. Simulated results demonstrate that the new configuration covers DCS/PCS/UMTS/WiBro/Bluetooth/S-DMB/WiMax/WLAN frequency bands. Simulated return loss of the proposed antenna is acceptable over all the mentioned frequency bands. Overall size of the proposed design is 40 mm×21 mm×5 mm on a 100-mm-long chassis. In designing the PIFA, we propose a slot on the ground plane for increasing bandwidth at about 2 GHz that around of this frequency, there are many wireless communication bands. The antenna is simply printed on an inexpensive FR4 of 0.8-mm thickness and dielectric constant of 4.4. Structural dimensions of the proposed antenna are optimized by using HFSS. Details of the multiband PIFA characteristics are presented and studied.**

***Index Terms*—Handset antenna, multiband, planar inverted-F antenna (PIFA), slot.**

I. Introduction

Recently, with the increasing interest in covering various frequency bands, attention was drawn toward the study of multiband antennas. For multiband antennas, achieving maximum possible frequency bands with suitable return loss and radiation pattern are desirable.

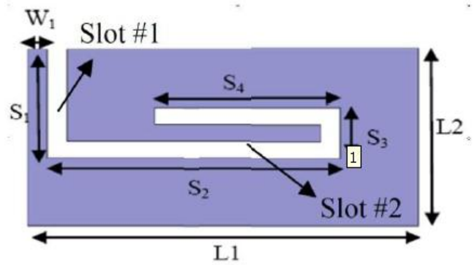
Planar inverted-F antennas (PIFAs) can cover two or more standard frequency bands and due to their thin planar structures, they have been frequently used for cellular phone handsets [1]-[5]. Also, PIFAs have features such as simple fabrication, light weight, low-profile and flexibility. In this type of antenna structure, locating the ground plane below the radiation element of PIFA leads to reducing specific absorption rate (SAR). Due to low absorption of energy in the human body, this antenna provides good efficiency. In addition, little influence of electronic components of a mobile handset on the PIFA performance is considered as a significant advantage.

Generally the basic PIFA radiator determines the frequency bands that can be covered. In addition, increasing the number of frequency bands or bandwidth of a specific frequency band can be provided by insertion of a slot (or slit) in the ground plane.

Several techniques for designing multiband PIFA antennas are reported including insertion of slots in the radiating element and cutting slots (or slits) in the ground plane [6]-[9]. In this paper, we present a new multiband PIFA antenna based on combination of a meandered slot in the antenna structure and an additional slot in the ground plane. Introducing slot in the PIFA radiating element and on its ground plane leads to creating multiple resonance frequencies and increasing the bandwidth, respectively. The proposed antenna operates at Digital Communication Systems (DCS,1710-1880 MHz), Personal Communication Services (PCS,1880-1990 MHz), Universal Mobile Telecommunications Systems (UMTS, 1.9-2.17 MHz), WiBro (2300-2390 MHz), Bluetooth (2.4-2.48 GHz), Satellite-Digital Multimedia Broadcasting (S-DMB, 2605-2690 MHz), Worldwide Interoperability for Microwave Access (WiMax, 3400-3600 MHz), Wireless Local Area Network (WLAN, 5.725-5.875GHz) and an additional frequency band (4.3-4.8 GHz). Details of the proposed antenna design and results of its performance are studied in this paper.

II. Antenna Design

Fig. 1 shows the configuration of the proposed multiband PIFA antenna for using in mobile handsets. The antenna geometry with total area of 21mm ×40mm is printed on a 0.8-mm thick FR4 substrate (ε_r=4.4, loss tangent=0.0245) of the same size. The inserted slot in the radiating element of antenna provides multiband characteristic. Dimensions of slot configuration have been optimized using High Frequency Structure Simulation (HFSS) in order to achieve the maximum covering wireless communication bands with desired return loss.



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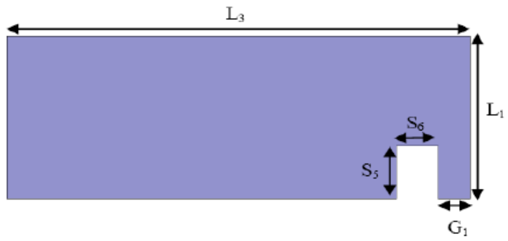

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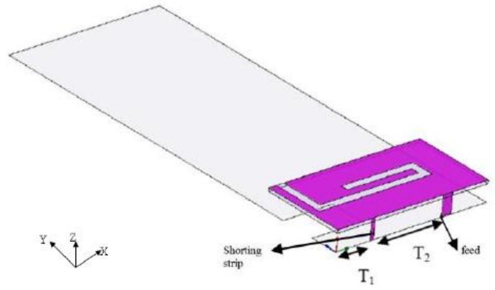


(c)

Fig. 1. Geometry of the proposed multiband PIFA (a) top view (b) bottom view (c) 3-D view

The thickness between the basic PIFA radiating element and the ground plane is h=5 mm that is attractive for slim handset antennas. The slot on the ground plane is shown in Fig. 1 (b). In this paper, the location and the dimensions of the slot in the ground plane are optimized in order to increase the bandwidth to an acceptable value. The radiator element of PIFA is grounded with a shorting strip. The antenna impedance matching is achieved by controlling the distance between the feed-line and shorting strip. Optimized dimensions of the antenna are given in the Table I.

TABLE I: Dimensions of the proposed antenna

PARAMETER	VALUE (mm)	PARAMETER	VALUE (mm)
L_1	40	S_6	9
L_2	21	G_1	7
L_3	100	T_1	9
S_1	11	T_2	18
S_2	28	W_1	2
S_3	4	Shorting strip width	1
S_4	19	Feed width	2.5
S_5	13	Slot width	2

III. Result and Discussion

High Frequency Structure Simulation (HFSS) have been used to obtain simulation results [10]. In this simulation, we assumed perfect electric conductor for the radiation element, the ground plane, shorting strip and feed line. The proposed antenna structure is tuned to provide enough impedance bandwidths to cover DCS-1800/PCS-1900/UMTS/WiBro/ Bluetooth/S-DMB/WiMAX/WLAN frequency bands with return losses less than or equal to -6 dB (SWR≤3) and with acceptable radiation patterns. Fig. 2 shows the simulated return losses of three various cases for the proposed antenna. When dielectric is located below the radiating element of antenna, the lower resonant mode is shifted to about 2 GHz. Also next resonant frequencies are shifted toward low frequencies. Creating slot on the ground plane causes increasing the bandwidth with good impedance matching at about 2 GHz. The simulated bandwidth of the first band is as large as 1 GHz. Also bandwidths of the second and the third resonant modes have been increased 160 MHz, 220 MHz respectively and bandwidth of the fourth resonant mode remains constant. Effects of the two slots length in the proposed antenna are indicated in Fig. 3 and Fig. 4. As seen in Fig. 3, by varying the length of S_1 from 8 mm to 14 mm, the impedance matching in the lower band is degraded and in the upper band is improved. Results obtained by varying the length of S_2 from 24 mm to 32 mm are shown in Fig. 4. In this case, the impedance matching on the lower band is not highly sensitive to the parameter S_2 while the impedance matching on the upper bands is improved by increasing S_2.

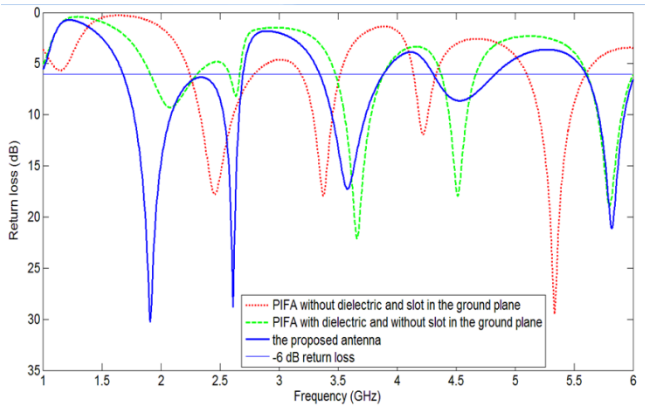


Fig. 2. Simulated return losses of the proposed antenna

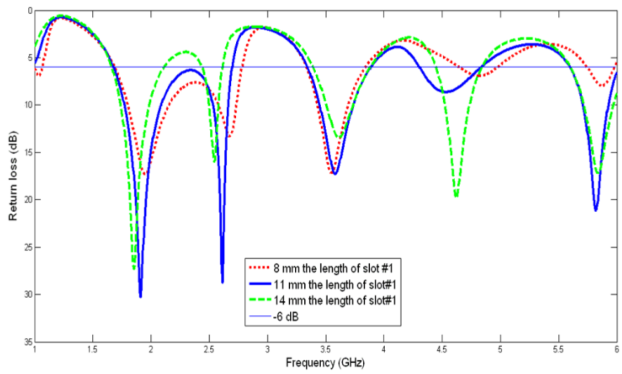


Fig. 3. Simulated return losses of the proposed antenna for different lengths of slot #1 (S_1)

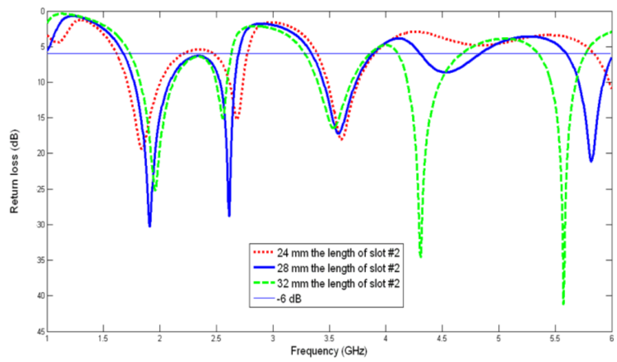
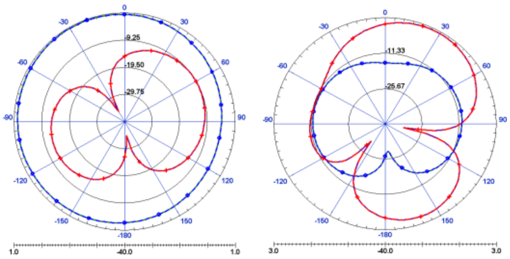


Fig. 4. Simulated return losses of the proposed antenna for different lengths of slot #2 (S_2)

We simulated radiation patterns of the proposed antenna in the two principal planes; x-z plane and y-z plane. Simulated radiation patterns at different resonant frequencies are shown in Fig. 5. From these figures, it can be seen that gain patterns in xz-plane are almost omnidirectional and the cross-polarization level is much lower than co-polarization at low frequencies but at high frequencies co-polar and cross-polar will be approximately at the same level. Also in yz-plane, directive gain patterns can be observed.

In order to achieve good operation of the antenna in mobile communications, it is reasonable to have increased level of the cross-polarization, because the orientation of the mobile phone is not fixed.



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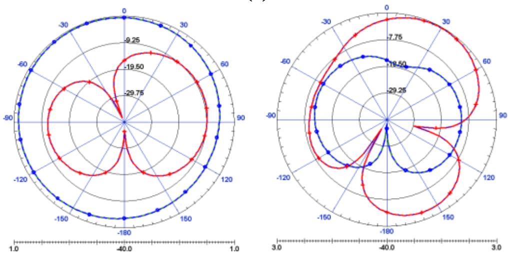

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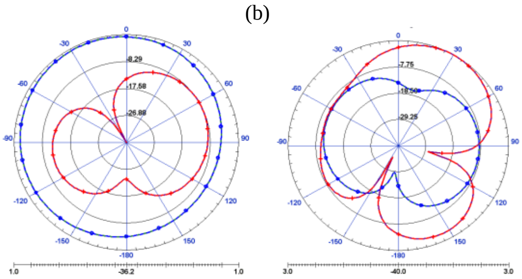

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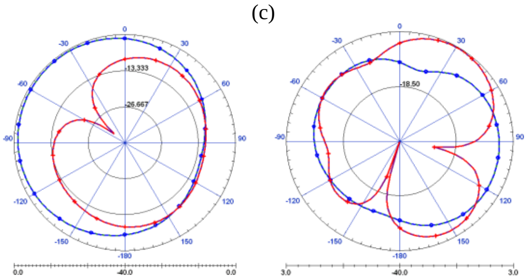

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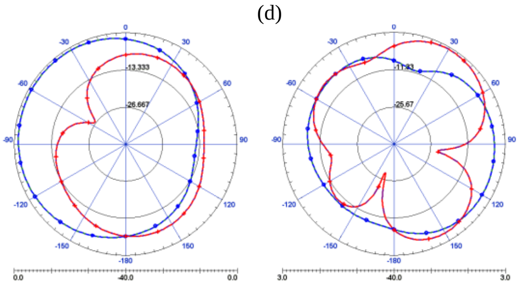

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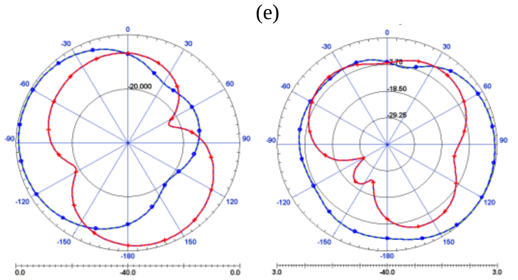

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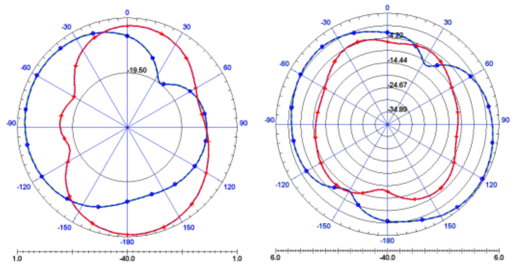

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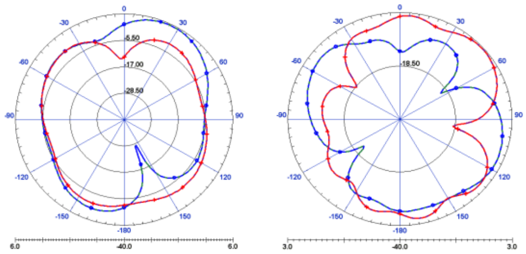
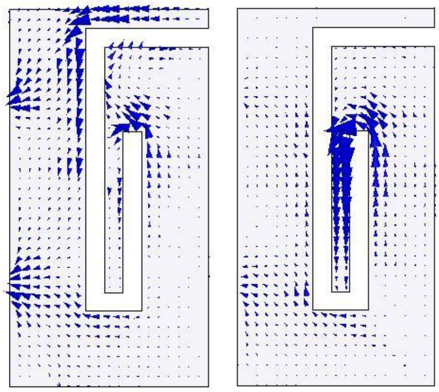


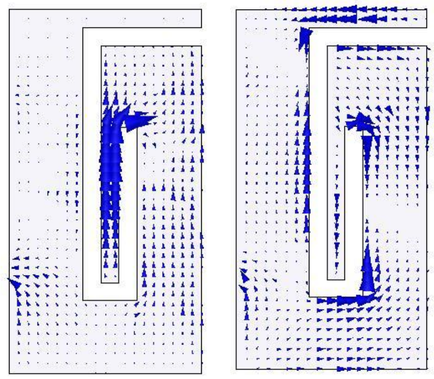
(h)

Gain(phi)
Gain(theta)

Fig. 5. Simulated 2-D radiation patterns at phi=0 (left patterns) and phi=90 (right patterns) (a)DCS-1800 (b)PCS (c)UMTS (d)WiBro (e)Bluetooth (f)S-DMB (g) WiMax (h) WLAN



(a) (b)



(c) (d)

Fig. 6. Surface current distribution on the radiating patch at (a) 2 GHz (b) 2.5 GHz (c) 3.5 GHz (d) 5.7 GHz

To get physical insight, the current distribution on the patch antenna and the ground plane are simulated. This information is important to understand why the slots are useful. The simulated current distributions are shown at different frequencies on the patch antenna and the ground plane in Fig. 6 and Fig. 7, respectively. According to results of simulation, the current density on the patch is concentrated exclusively around the meandered slot. It is also should be noted that the shorting strip affects on the current distribution of the radiator patch at low frequencies. Effect of the slot on the ground plane is observed at the lower band because it can resonate at around 2 GHz and increases the bandwidth of the antenna. The slot on the ground plane has not considerable effect on the bandwidth of the upper bands, which are mainly caused by uniform current distribution on the ground plane as shown in Fig. 7 (b).

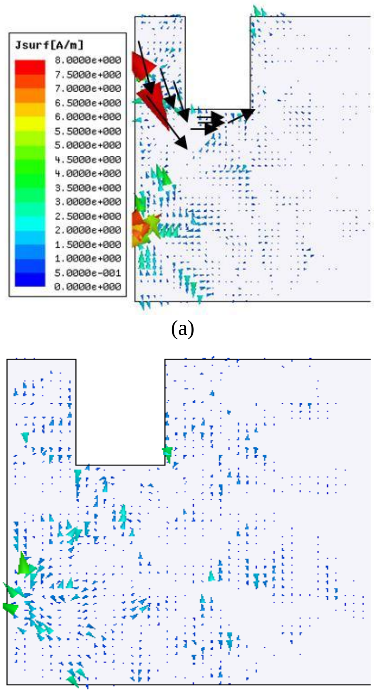


Fig. 7. Simulated current distribution on the ground plane around slot at (a) 2 GHz (b) 3.5 GHz

IV. Conclusion

In this paper, a new multiband planar inverted-F antenna has been presented to be useful for personal communication handset applications. The proposed antenna has a simple configuration and is simply printed on FR4 substrate. Improving the bandwidth has been obtained by adding a slot on the ground plane of this antenna. The effects of the slot on the ground plane and varying the length of two slots in the radiating patch have been investigated on the return loss. This antenna can operate within the DCS, PCS, UMTS, WiBro, Bluetooth, S-DMB, WiMax, WLAN and an additional frequency band, and provides good radiation patterns over these operating bands.

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