# Design of a Multiband Microstrip U-Shaped Planar Inverted F Antenna

B. Mansouri, Z.H. Firouzeh, R. Safian
Department of Electrical and Computer Engineering, Isfahan University of Technology (IUT), Isfahan, Iran
Email: b.mansouri@ec.iut.ac.ir, zhfirouzeh@ec.iut.ac.ir, rsafian@cc.iut.ac.ir

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**ABSTRACT**
In this paper, a new design of multiband microstrip U-shaped PIFA antennas is proposed. The antenna has a U-shaped patch on a substrate with dielectric constant of 3 and is shorted to the ground plane through two shorting walls. The antenna operates in three separated frequency bands including 1.16-1.24 GHz, 2.37-2.44 GHz and 3.65-3.75 GHz. That is suitable for wireless frequency bands applications. The first frequency band of antenna is used for wireless video links and wireless video transmitters. The second and third frequency bands are usable for Wi-Fi, Wireless Local Area Network (WLAN) and Bluetooth bands. A slot has been designed on the ground plane to improve radiations at 2.4 GHz and to enhance the bandwidth of the antenna at resonance frequencies.

**KEYWORDS:** Multiband PIFA Antenna, Bandwidth Enhancement, Wireless Applications.

## 1. INTRODUCTION

The planar inverted F antenna (PIFA) is a popular antenna used widely in wireless communication applications. Nowadays different frequency bands are widely used in portable cellular/non-cellular devices and multiband functionality. The PIFA is one of the antennas that is used dramatically to satisfy this requirement. In fact, the PIFA is a kind of monopole antenna where the top section has been folded down so as to be parallel with the ground plane. In a patch antenna shorting wall causes antenna to act as a quarter-wave structures. Therefore, the PIFA may resonate in the same resonance frequency of a patch antenna with about %50 reduction in size and it is a very good advantage especially in mobile phone handsets that the antenna size is critical. PIFA antennas have other advantages such as low profile, simple fabrication and attractive radiation patterns. However, the PIFAs suffer from narrow bandwidth. Various techniques have been employed to increase bandwidth of PIFAs. In these antennas, the size and geometry of ground plane are effective on the bandwidth. In addition, the geometry of the ground plane can be designed leading to the bandwidth increase. In [1]-[2] slots were added to the ground plane and have been caused bandwidth to improve. In [1], the Slot is tuned to resonate around 900MHz which acts as a parasitic element at high frequencies to achieve broad bandwidth. In another work, the length of slots are designed comparably to $\lambda/4$ at high frequency to act as a additional $\lambda/4$-resonator and to enhance the bandwidth at DCS 1800-1900 band [2]. The slots can be produced in the main radiating structure to increase the bandwidth of some bands of interest. A U-Slot on the patch is usually used to add different frequency bands and to work the antenna in dual- and multi-frequency bands [3]. Furthermore, the U-Slot can improve the frequency bandwidth of the antenna [4]. Another way to increase the bandwidth is to use a wide feed. This technique was employed in [5] to achieve a single and so broad bandwidth. Employing two shorting-walls influences on the bandwidth of PIFAs and it enhances frequency bands as well [6]. The location and distance between shorting walls are effective in bandwidth of the antenna. In addition, adding grooves in the dielectric substrate increases the frequency bandwidth [4].

In this paper a new design of a multiband PIFA antenna is proposed. The antenna resonates at three different frequencies of the 1.2GHz, 2.4GHz and 3.8GHz with good radiation characteristics. The antenna has various wireless applications in each frequency such as wireless video links and video transmitter at 1.2 GHz band, Bluetooth, Wi-Fi and wireless local area network (WLAN) bands at 2.4GHz frequency. To increase and improve the radiation pattern of the antenna at 2.4 GHz, a slot is added to the ground plane of the antenna. Results are obtained based on available finite element package HFSS software. In addition, CST Microwave Studio simulator is used to compare the results and finalize the design of the antenna structure. The remaining sections of this paper are organized as follows: Section 2 describes the design of the multiband antenna. The effect of slot addition on the ground plane of the antenna is considered in Section 3. Finally, the conclusion is given in the last section.

## 2. THE DESIGN OF MULTIBAND PIFA ANTENNA

Fig. 1 shows the structure of the designed antenna. The dimensions are depicted in Fig. 2 and their values are given in Table I.

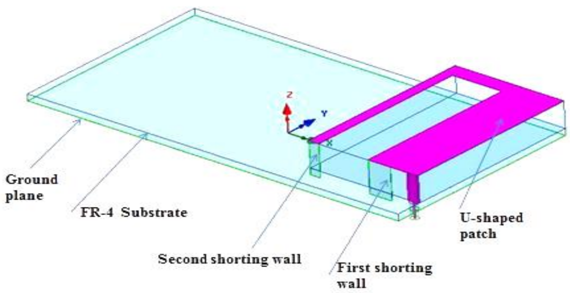



**Fig. 1** The structure of the proposed PIFA antenna

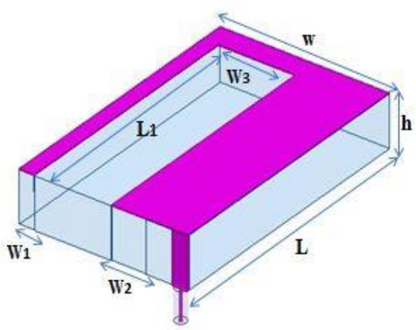



**Fig. 2 .**The dimensions of the radiator

**Table 1.** The values of the antenna dimensions

| Parameters | Value |
|---|---|
| L | 35 mm |
| W | 22mm |
| $L_1$ | 32mm |
| $W_1$ | 2mm |
| $W_2$ | 4.5mm |
| $W_3$ | 10mm |
| h | 6.1mm |

The size of the ground plane is 75×40 mm$^2$ and a FR-4 substrate with dielectric constant of 4.35 is used. A U-shaped patch with asymmetrical arms is placed on a dielectric holder is made of RO3003 with dielectric constant of 3. As shown in Fig.1, the U-patch is shorted to the ground plane through two shorting walls. The simulated reflection coefficient of the proposed antenna is presented in Fig. 3. It is observed that the antenna resonates in three different frequencies at 1.2GHz, 2.48GHz and 3.7GHz, respectively. The presence of the second shorting wall is effective to add the second resonance frequency and the first bandwidth of the antenna. This result can be seen from comparison Figs. 3 and 4 in which the reflection coefficient (S11) is simulated with and without the second shorting-wall in the antenna structure.

The variation of distance between two arms of the U-shaped patch, *i.e.* $W_3$ and also that of their lengths, *i.e.* $L_1$ is investigated on the resonance frequencies as shown in Fig. 4 and 5, respectively. Note that the first and third resonance frequencies are independent of $W_3$ and $L_1$. The change of $W_3$ only causes slightly the second resonance frequency to shift. However, 2.4 Ghz band is obtained by tuning $L_1$. This frequency band is practical in wireless applications. It can be changed in the range of 2.4 GHz band from 2.32GHz to 2.62 GHz by varying L1 from 30 to 34 mm.

Fig 7 presents the simulated radiation patterns of the proposed antenna centered at 1.2GHz, 2.48GHz and 3.7GHz. It is observed that that the peak gains are achieved 2.26dB, 4.49dB and 4.15 dB, respectively, from the first to third resonance frequencies.

As seen the radiation patterns of the antenna at 1.2GHz is omnidirectional with a uniform gain which is acceptable for wireless applications. Also the radiation pattern is not entirely omnidirectional at 3.7 GHz but the gain variation is not considerable. The antenna gain is not identical at 2.4GHz in Y-Z plane and it decreases for $\theta \geq 90$.

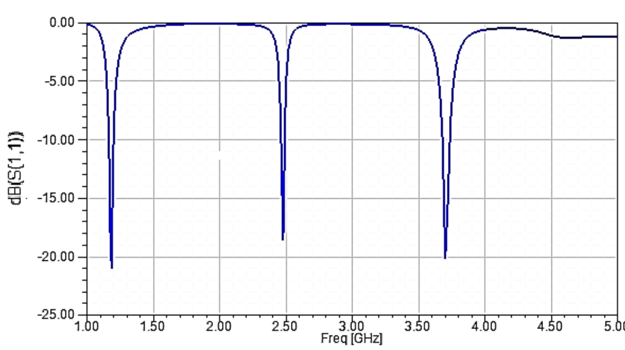



**Fig. 3. The simulated reflection coefficient of PIFA antenna**

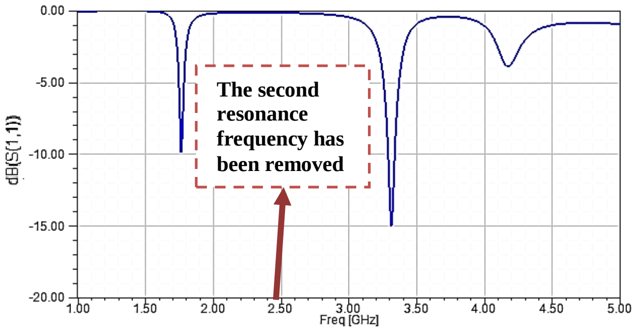



**Fig. 4.** The effect of the second shorting-wall on the reflection coefficient

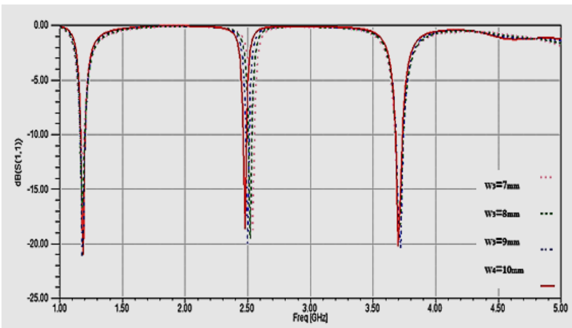


**Fig. 5.** The effect of different values of W3

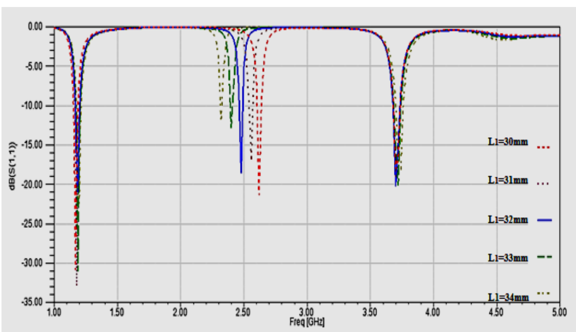
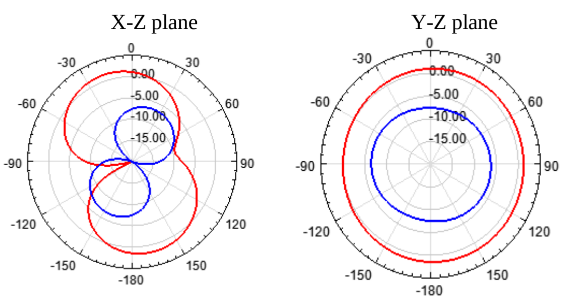
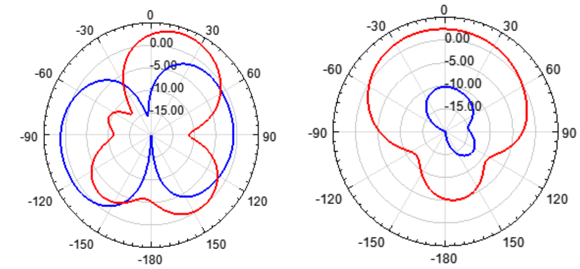


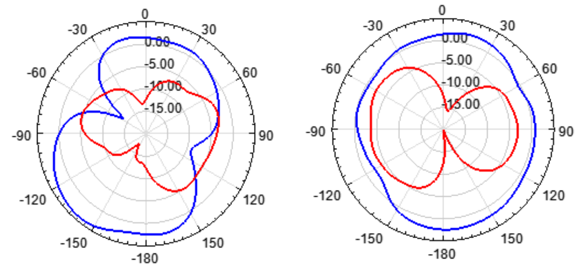
**Fig. 6.** The effect of different values of L1




(a)



(b)



(c)

**Fig. 7.** The simulated radiation patterns in X-Z and Y-Z planes at (a) 1.2GHz (b) 2.48GHz (c) 3.7GHz

## 3. THE EFFECT OF SLOT ADDITION ON THE GROUND PLANE OF THE ANTENNA

It is previously mentioned the gain of the proposed antenna in Y-Z plane suffers from a lot of variation at 2.48GHz; consequently, it is not uniform in this plane. An alternative technique to improve the radiation pattern in Y-Z plane at 2.48GHz is manipulating the ground plane. As e result, the combined radiation pattern of the ground plane effect and PIFA antenna would be better than before. The addition of a slot to the ground plane causes the resonance frequency of the ground plane to decrease. It can be tuned to resonate near the resonance frequency of the PIFA. Firstly, the surface current on the ground plane is simulated at 2.48GHz and depicted in Fig. 8. Then, two proper locations are explored to add the slots. The intensity and density of the surface current are noticeable in these areas. After adding the slots individually and simulating each case, it is concluded that the first place shown in Fig. 9 is suitable to put the slot. The length and width of the slot has been optimized to satisfy three goals as follows. Firstly, the antenna saves multi bands at frequencies near the previous resonance frequencies. Next, the bandwidth does not decrease at the resonance frequencies but also increase. Finally, the radiation pattern of Y-Z plane at 2.4 GHz is improved.

After optimization, 9.5mm and 2mm are obtained for the slot length and width, respectively. As seen in Fig. 9, the surface current by the slot is forced to pass a longer electrical path. The simulation of S11 is depicted for this new structure in Fig. 10. The antenna resonates at three frequencies: 1.2GHz, 2.4 GHz and 3.7 GHz. The addition of the slot influences on the bandwidth of three frequencies, especially the third resonance frequency at 3.7GHz. Note that it is expected due to the slot length which is comparable with one quarter wavelength at 3.7GHz in substrate medium. As a result, the slot operates as a λ/4-resonator at this frequency.

The radiation patterns of Y-Z plane at 2.48GHz and 2.4 GHz are simulated for the antenna with and without the slot and depicted and compared in Fig. 11. The slot has the appropriate effect on the radiation pattern at 2.4GHz. The gain variation is less than the antenna without the slot on the ground plane. The radiation patterns of both X-Z and Y-Z planes are not changed for 1.2GHz and 3.7GHz when the slot is used in the ground plane.

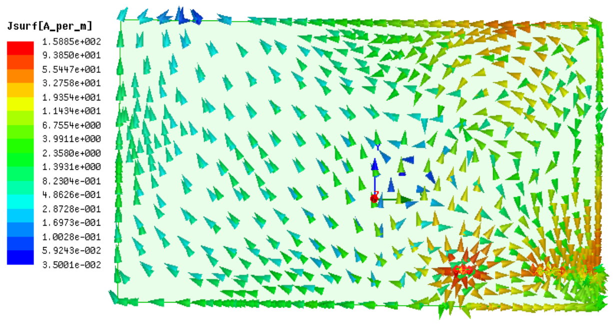



**Fig. 8 .**The simulated distribution of the surface current on ground plane

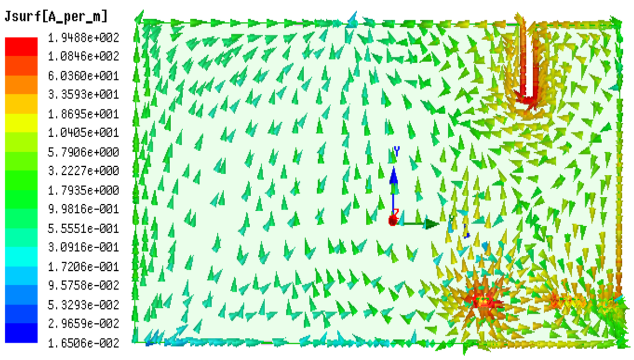



**Fig. 9 .**The simulated current surface distribution on ground plane of PIFA antenna with the slot

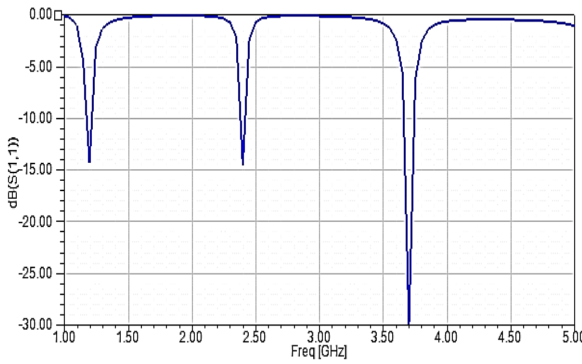
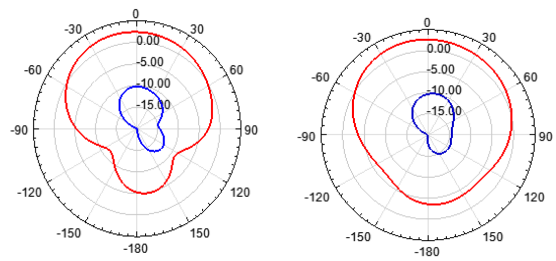



**Fig. 10 .**The reflection coefficient of the antenna with the slot on the ground plane




(a) (b)

**Fig. 11 .**The radiation pattern of Y-Z plane at (a) 2.48GHz and (b) 2.40GHz

## 4. CONCLUSION

A new multiband microstrip PIFA antenna has been proposed. Two shorting walls have been used in the antenna structure. In the preliminary design, the antenna resonates at three frequencies including 1.2GHz, 2.48GHz and 3.7GHz. The effect of the second shorting-wall on the resonance frequencies has been studied and considered. In the final design, a slot has been added on the ground plane. The slot has caused the surface current on the ground plane to pass a longer path; consequently, the resonance frequency of ground plane decreases. As a result, the slot increases the bandwidth at all three frequencies and improves the antenna radiation patterns at 2.4 GHz. The proposed antenna is usable and practical for Wi-Fi, Wireless Local Area Network (WLAN) and Bluetooth bands.

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