Significance of Ground Plane Size and Height in Small PIFA

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1. Introduction

Planar Inverted-F Antennas are widely used in a variety of communication systems especially in mobile phone handsets due to low profile, light weight, easy integration and easy to manufacture [1].

The ground plane of PIFA is an important factor and can play an important role to enhance the performance of the antenna as discussed in [2]. However, if the ground plane is acted as an antenna, the effect of the user hand is likely to degrade the antenna performance when the antenna is placed inside the mobile phone as well as causing several practical engineering problems [3]. In some designs, the location of the antenna on the substrate is also important to be considered as it can enhance the bandwidth of the antenna to few more percentages as shown in a recent study [4].

In this paper, a relatively small and thin PIFA that can support three frequency bands at 2.09 GHz, 3.74 GHz and 5 GHz with achievable bandwidths of 10%, 8.8% and 11% respectively is first presented. Then the effect of different ground plane dimensions and the significance of the physical height of the antenna from the ground plane are studied. The measured return loss, radiation patterns, gain and radiation efficiency are characterized.

2. Design Configuration

Fig. 1 demonstrates the structure of the proposed antenna. It consists of the main radiated parts, a rectangular slot, shorting pin, shorting wall, and a ground plane. The dielectric material selected for the design is FR-4 which has dielectric constant of 4.4, a loss and height of dielectric substrate is 1.57 mm. The proposed antenna is very small in size and physically thin. The total dimensions of the radiated parts occupy 25 x 26 x 3.57 mm^3 while the overall size of the antenna including the ground plan is 40 x 40 x 3.57 mm^3. High Frequency Structure Simulator (HFSS) V.11.4 package is used for full wave analysis of the antenna structure.

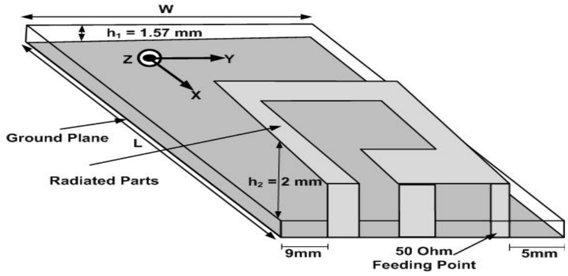
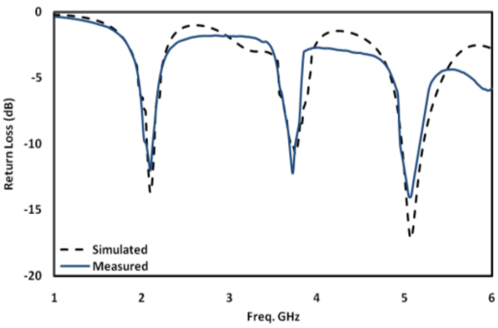


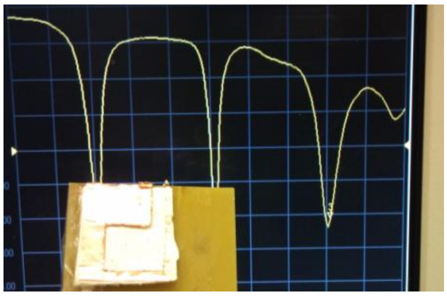
Fig. 1 The layout of the proposed antenna

3. Simulated and Measured Results

3.1 Return Loss (S_{11})

In order to validate the simulated results, the proposed antenna was fabricated on FR-4 substrate 4.4 with thickness of 1.57 mm and loss tangent 0.02. The width of the copper used in the prototype is 0.15mm. The simulated and measured return loss (S_{11}) of the proposed antenna is presented in Fig 2(a) and the prototype antenna under test is shown in Fig. 2(b). The return loss shows that three bands can be generated at 2.09 GHz, 3.74 GHz and 5 GHz. The simulated and measured results are in good agreements; the small changes between the simulated and measured results might be attributed to many factors such as the soldering proficiency and accuracy of cutting the edges of the copper. The corresponding bandwidth defined by -6 dB for the three bands is 11% (1978 MHz – 2200 MHz) for the 2.09 GHz band, 8.84% (3571 MHz – 3900 MHz) for the 3.74 GHz band and 10% (4887 MHz – 5391 MHz) for the 5 GHz band. Thus, the bandwidth can satisfy the requirements for most of the wireless applications.





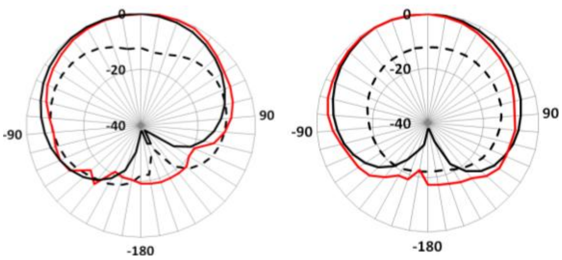
(a) (b)

Fig. 2 (a) The simulated and measured return loss S_{11} (b) The fabricated prototype of the proposed antenna connected to the network analyser.

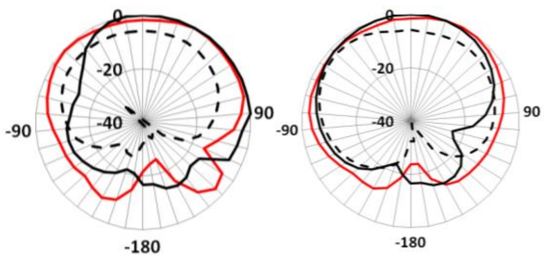
3.2 Radiation Patterns and Gain

The simulated and measured co and cross polarizations for E-plane and H-plane radiation patterns are plotted as shown in Fig. 3 (a)-(d). It can be observed from the radiation patterns that there is stable response throughout the UMATS, m-WiMAX and WLAN bands.

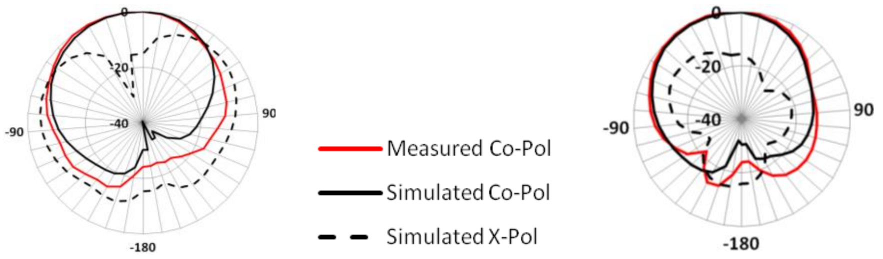
The simulated peak gain is 2.14 dBi for the 2.09 GHz band, 2.4 dBi for the 3.74 GHz band and 5 dBi for the 5 GHz band whereas the measured peak gain for the three bands is 2.05dBi, 2.32dBi and 4.42dBi respectively as shown in Fig.4. The measured radiation efficiency for the three bands is 70.12 %, 60.29 % and 66.24% respectively as shown in Fig. 4.



(a)



(b)



(c)

Fig. 3 The Simulated and measured E and H planes Co and X-pol radiation patterns for the proposed antenna (a) The orientation of the antenna (b) 2.09 GHz (c) 3.74 GHz and (d) 5 GHz.

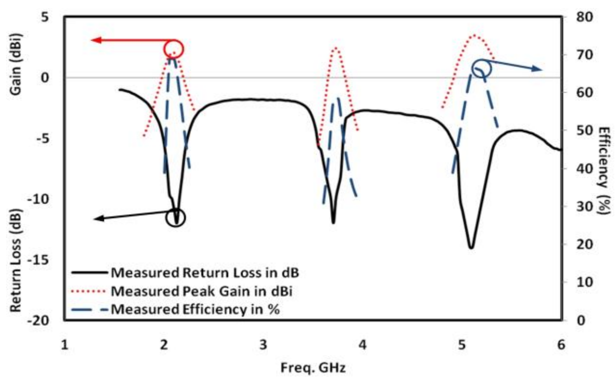


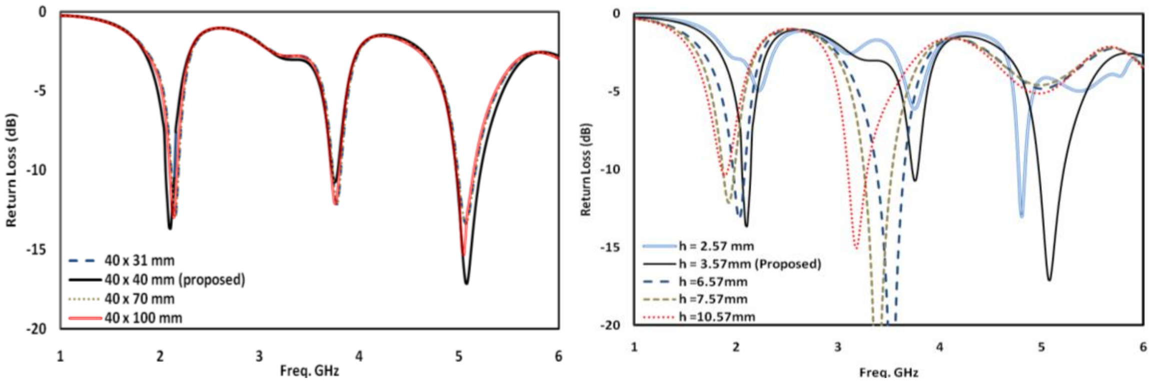
Fig. 4 The measured return loss, gain and total radiation efficiency against frequency for the proposed antenna

4. The Significance of the Ground Plane and the Physical Height

It is a well known that the ground plane size of PIFA can affect the performance of the antenna. For example in [5] the addition of the slots in the ground plane has significantly contributed in obtaining the wideband performance. Not only is the geometrical structure affecting the performance of the antenna but also the size of the ground plane. For example in [6] by varying the size of the ground plane the return loss (S_{11}) can be affected. The ground plane might lead to an apparent advantage when bandwidth alone is considered but has many drawbacks for system performance when the user holds the phone in different positions and drawbacks when multiple antenna integration is required. For this reason, the performance of the antenna should be obtained mainly from the structure alone not the surrounding elements

In the proposed antenna, the effects of varying the length of the ground plane from 40 x 40 to 40 x 70 and to 40 x 100 mm did not affect the matching nor the bandwidth of the antenna as shown in Fig. 5 (a). With this attractive feature, the antenna can be applied to the mobile phone with various possible ground plane lengths. In addition it reduces the isolation distance required between the antenna and the nearby conducting elements or electronic components in the mobile phone. The shapes of the radiation pattern remain principally unchanged when varying the size of the ground plane.

Moreover, in some designs, the physical height of the PIFA from the ground plane can enhance the bandwidth by few percentages. In the proposed antenna, by decreasing the height of the radiated parts ($h_2 + h_1$), the antenna's first, second and third mode is greatly affected and can no longer be excited. This behaviour is largely because, for small height values of h, radiated parts will be too close to the substrate base to be of any effect. This can prevent the currents from traveling longer distances which result in mismatching of the three bands as shown in Fig. 5 (b).



(a) (b)

Fig. 5 The effect some parameters on the S_{11} performance (a) The ground plane size (b) The physical height of the PIFA from the ground plane.

Conclusion

This paper has focused on the development of a compact multiband Printed Inverted-F Antenna (PIFA). The ground plane of the antenna has shown no effect on the antenna performance which helped to keep the total volume of the antenna to be small. The antenna has a planar configuration and cost effective. A prototype antenna has been fabricated and characterized for return loss, gain, radiation efficiency and radiation performances where the simulated and measured results were in good agreements.

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