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A New Compact WLAN 2.4 GHz CPW-fed Slot Antenna with Inverted-F Shaped Tuning Stub

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Abstract

In this paper, a new compact planar inverted-F antenna (PIFA) applicable to WLAN 802.11 b/g and bluetooth applications is proposed. The proposed antenna is a CPW-fed slot antenna with inverted-F shaped tuning stub on a FR-4 substrate, which is compact, cost-effectively and precisely to manufacture, with an omni-directional pattern and a sufficient bandwidth for all of above mentioned WLAN and bluetooth standards. The experimental results of the constructed prototype are presented, and are also compared with commercial software tool.

1. Introduction

The use of the 2.4 GHz industrial, scientific, and medical (ISM) band is be coming an important means of wireless communications including WLAN 802.11 b/g and buletooth applications. These demands have stirred significant renewed interest in antenna design particularly at the ISM bands. Therefore, the development of appropriate antenna designs is imperative. Many antenna structures for ISM bands have been presented. [1]-[2]. An antenna printed on a substrate has some advantages compared to other antennas, like the planar inverted-F antenna (PIFA). It is usually cheaper and more precisely to manufacture.

In recent years, the demand for compact handheld communication devices has grown significantly. Devices having internal antennas have appeared to fill this need. Antenna size is a major factor that limits device miniaturization. In the past few years, new designs based on PIFA antennas have been used for handheld wireless devices because these antennas have low-profile geometry and can be embedded into the devices. Several antennas for mobile and WLAN communications devices are based on PIFA [3]-[6]. These kinds of inverted-F antennas printed on a dielectric substrate are shorted to the ground plane on the other side of the dielectric substrate. In this case, such inverted-F strip antennas can not be easily integrates in the printed circuit board of the system. In this paper, a slot antenna with inverted-F shaped tuning stub printed on a FR-4 dielectric substrate and fed by a coplanar waveguide line is proposed. By using the inverted-F shaped tuning stub in a single layer, the proposed antenna no via hole is required in short circuiting the inverted-F strip to the ground plane. Furthermore, the opened and shorted sections of inverted-F tuning stub are fed toward center by feed line, which decreases the required area for the proposed design. Details of the design considerations of the proposed antenna and experimental results of the constructed prototype are presented.

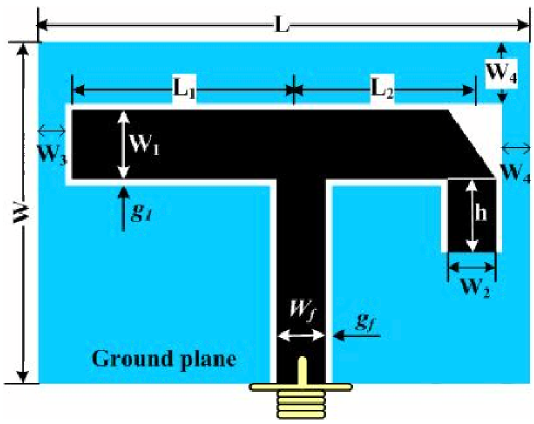

Figure 1: Geometry of the proposed CPW-fed slot antenna with inverted-F shaped tuning stub.

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Table 1: Resonant frequency, input impedance, and bandwidth characteristics as a function of the geometrical parameters

Parameters	W_1↑	W_2↑	W_3↑	W_4↑	L_1↑	h↑
Resonant Frequency	↓	↓	↑	↑	↓	↓
Input impedance	↑	↑	↓	↓	↑	-
Bandwidth	-	↑	-	↓	↑	-

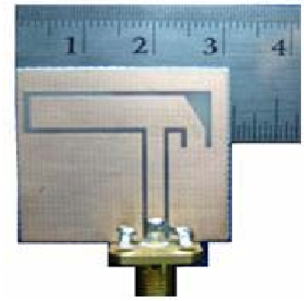


Figure 2: Photograph of the fabricated prototype antenna.

2. Antenna Design and Discussion

The configurations of the new compact CPW-fed slot antenna with inverted-F shaped tuning stub are depicted in Figure 1. In this study, an inexpensive FR-4 substrate of thickness 1.6 mm and relative permittivity 4.4 was used for the dielectric substrate. The inverted-F tuning stub has a width of W_1, a length of L_1 for open section, and consists of a vertical shorting strip width and length of W_2 and h, respectively. A 50-Ω CPW feed line, having a signal strip of width W_f and a gap of distance g_f, is used to excite the slot. The spacing between the inverted-F tuning stub and edge of the ground plane is g_1. The miter of shorting strip is used to avoid right angle microstrip bend, which results in a poor current flow on tuning stub. The antenna has overall dimensions (W×L) of 28.3 mm× 30.1 mm.

In the study, the antenna of the proposed design for application in the WLAN 2.4 GHz band was studied. The design center frequency was chosen at 2.45 GHz, the center frequency of the WLAN 2.4 GHz band (2400-2483.5 MHz) or about 84 MHz. With the desired center operating frequency known, the total length L_1+ L_2+h of the inverted-F tuning stub can be first determined to be approximately one-quarter wavelength of the center operating frequency. For this reason, the total length of the inverted-F tuning stub was adjusted to be 21.04 mm. Also note that, in this design, the length of the shorting strip was selected to be 3.29 mm only (about 0.027λ) to achieve a lower height for the proposed antenna. Then, by the tuning the length L_1 of the open section of the inverted-F tuning stub and adjusting the width W_1, good impedance matching over wide frequency range can be achieved for the proposed design. To achieve the best matching and enhance bandwidth performance, the length, width, and height of the inverted-F tuning stub and ground plane parameters are optimized. The trend of resonant frequency, input impedance, and bandwidth characteristics of each frequency is analyzed as a function of geometry parameters, as given in Table I. By observing from Table I the influence of various parameters on antenna performances, it can be seen that all parameters affect the resonant frequency of the antenna. As W_1, W_2, L_1, and h increased, the resonant frequency decreased, and vice versa. This was expected, since the height, h, and the length L_1, affect the total length of the PIFA. On the other hand, as W_4 increased, the resonant frequency so increased. Three parameters of the antenna including W_2, W_4, and L_1 affect the bandwidth of the proposed antenna. The size of the ground plane (W, L, W_2, W_3, and W_4) to a great extent also affects the resonant frequency, impedance matching, and radiation patterns. In addition, the calculated dimensions were also obtained by IE3D simulation software. The proposed antenna can be further enhances by adjusting those parameters.

The optimized design parameters for the proposed antenna are W_f = 2.73 mm, W = 28.3 mm, L = 30.1 mm, W_1 = 5.6 mm, W_2 = 3 mm, W_3 = 2.1 mm, W_4 = 1.5 mm, L_1 = 18.18 mm, L_2 = 2.86 mm, h = 3.29 mm, g_f = 0.3 mm, and g_1 = 0.6 mm.

3. Simulation and Experimental Results

In the study, a prototype of the optimal design for application in WLAN/bluetooth band was constructed as shown in Figure 2. The characteristics impedance of the antenna were measured by an HP8510C network

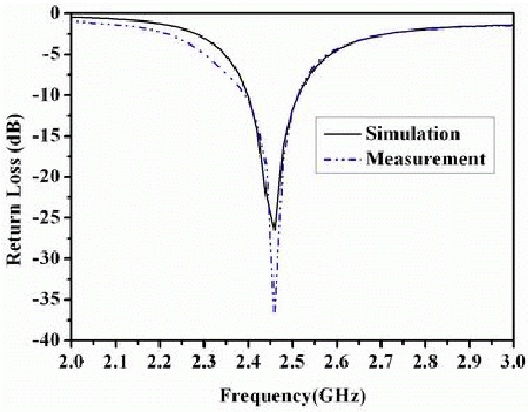
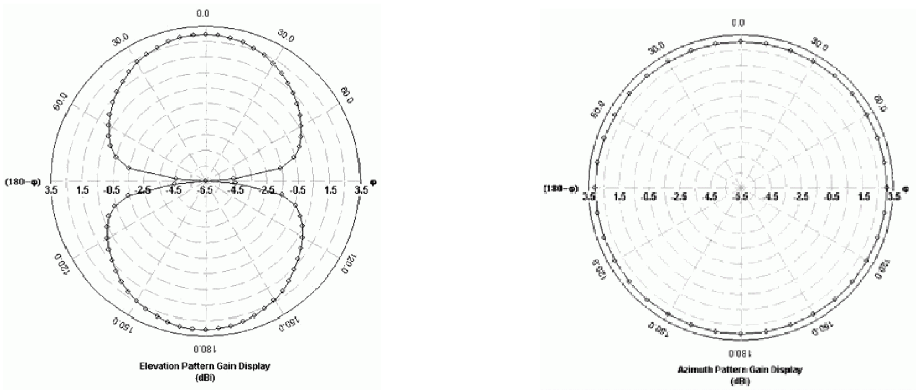


Figure 3: Measured and simulated return losses for the proposed antenna with W_f = 2.73 mm, W = 28.3 mm, L = 30.1 mm, W_1 = 5.6 mm, W_2 = 3 mm, W_3 = 2.1 mm, W_4 = 1.5 mm, L_1 = 18.18 mm, L_2 = 2.86 mm, h = 3.29 mm, g_f = 0.3 mm, and g_1 = 0.6 mm.



(a) (b)

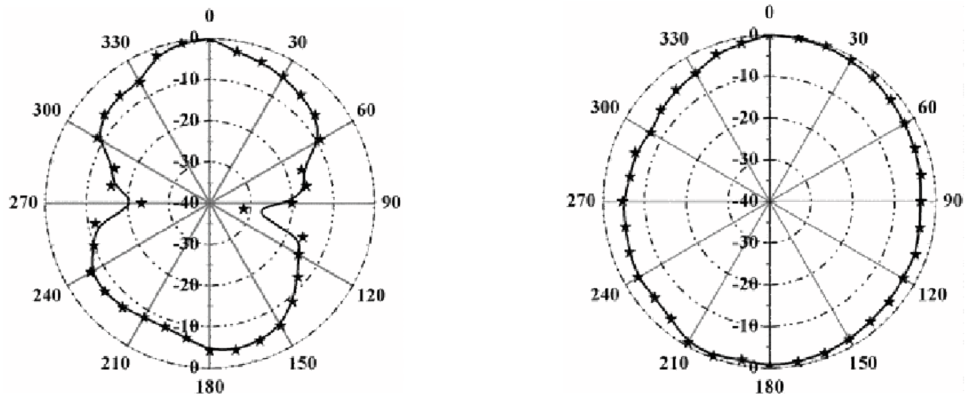
Figure 4: Simulated radiation patterns of the proposed antenna at 2.45 GHz in (a) elevation plane and (b) azimuth plane.

analyzer. Figure 3 presents the comparison of the measured and simulated return loss S_{11} against frequency. From the obtained results, it is clearly seen that the bandwidth for WLAN 2.4 GHz band is obtained. We can see a very good agreement of the simulation and measurement results. The measured 10-dB bandwidth is about 100 MHz from 2400 to 2500 MHz.

The radiation characteristics of the proposed antenna have also been studied. Figure 4 plots the simulated radiation patterns at 2.45 GHz. It is noted that the pattern in the azimuthal plane is omni-directional, which makes the proposed antenna have large radiation coverage in practical applications. The simulation results show that it is possible to build the proposed antenna, which does not only a compact size but furthermore fulfills the demand on bandwidth, impedance and radiation pattern. Other radiation pattern parameters of the proposed antenna as simulated are presented in Table II. Figure 5 shows the measured radiation patterns at 2.45 GHz for the proposed antenna. Good omni-radiation pattern is observed in azimuth plane. The measured antenna gain for operating frequencies within the WLAN band is also presented in Figure 6. The proposed antenna shows a peak antenna gain of 2.55 dBi at 2.45 GHz.

Table 2: The radiation parameters of the new compact CPW-fed slot antenna with inverted-F shaped tuning stub

Radiation Parameters	2.4 GHz	2.45 GHz	2.4835 GHz
Directivity (dBi)	3.45	3.44	3.44
Gain (dBi)	2.49	3.03	2.92
Efficiency (%)	80.2	90.8	88.7



(a) (b)

Figure 5: Measured radiation patterns of the proposed antenna at 2.45 GHz in elevation plane and (b) azimuth plane.

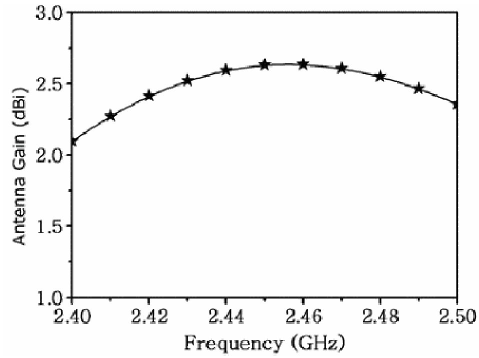


Figure 6: Measured antenna gain for operating frequencies within the WLAN band.

4. Conclusion

In this paper, a new compact CPW-fed slot antenna with inverted-F shaped tuning stub that covers the WLAN 802.11 b/g and bluetooth applications is proposed. And a prototype suitable for WLAN/bluetooth applications has also been constructed and studied. The constructed prototype meets the bandwidth requirement of the WLAN/bluetooth 2.4 GHz band, and good radiation characteristics have also been observed. In addition, the proposed antenna is compact, efficient, easy and cost-effective to manufacture.

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