Broad Band U-Shaped PIFA with Dual Band Capability for Bluetooth and WLAN Applications

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Abstract: Nowadays, in modern mobile and wireless communication systems, there is an increased demand for compact, wide bandwidth and low-cost antennas with dual band capability. In this paper, two shapes for a low cost reduced size PIFA with wide bandwidth are investigated. The antenna substrate is from a cheap foam material with ε_r=1.07. The antenna is fed by single coaxial feed. Size reduction is achieved by cutting U-shaped slot on the radiating surface of the PIFA structure. The antenna size becomes (0.22λ x 0.18λ). Wide bandwidth is reached by making the U-shaped slot with two unequal arms. Moreover, dual operating frequencies are achieved by cutting either L-shaped or U-shaped slits on the coupled feeding part of the radiating surface. The antenna resonates in Bluetooth ISM band at 2.4 GHz as well as in WLAN band at 5.2GHz. The bandwidths are about 31% and 7.5% for the lower and upper bands, respectively. The proposed antenna is simple in structure compared to regular stacked or coplanar parasitic patch antennas that, makes it suitable for most mobile communication applications.

Key-words: U-shaped slot, Planar Inverted F-Antenna (PIFA), Wide bandwidth, Dual band, Bluetooth, WLAN.

1. Introduction

Microstsrip patch antenna are widely used in modern mobile and wireless communication systems, because of many advantages, such as low profile, light weight, etc., However, patch antenna has a drawback of narrow bandwidth. Research efforts have been made to overcome this problem. And many configurations have been presented to extend the bandwidth. The conventional method is using parasitic patches on the same layer or stacked on the top plate. However, these methods typically enlarge the antenna size, either in antenna's plane or antenna height. PIFA is a compact antenna design that reduces the size of antenna from $\lambda_o/2$ to $\lambda_o/4$ where λ_o is the free space wavelength [1]. A new type of PIFA with a dual-band is proposed in this paper. U-shaped PIFA antenna with two unequal arms is presented for a wide band capability [2]. L-slot or U- slot is added for dual-frequency operation at bluetooth ISM IEEE 802.11a and wireless LAN IEEE 802.11b.

2 Design Methodologies

In this paper, a U-shaped PIFA with two unequal arms is proposed to achieve compact size and broadband design. For the lower band (2.4GHz), two different-length arms of a U-shaped patch were used to excite two closely staggered resonant modes [2-3]. The two patches (U-shaped and the electromagnetically coupled coaxial-fed patch (T-shape or rectangular shape) are excited in the TM_{01} mode. The design achieves over 31% bandwidth in lower band with antenna thickness less than $0.08\lambda_o$ [4-5]. The U shaped PIFA is fed by another coaxially fed patch on the same layer. The fed patch can take the T-shape or the rectangular shape [2].

Dual frequency operation (Wireless LAN 5.2GHz) is achieved by etching L-slot on T-fed patch and etching U-slot on The rectangular fed patch, respectively. The fabrication masks of the two dual band antennas are shown in figure 1a and 1b, respectively. The measured antenna bandwidth is 31% and 7.5% in the lower and upper bands, respectively. The simulated analysis is done with HFSS® software package.

3 Antenna Geometry

The antennas as shown in figure1 have a radiating plate separated from the ground plane by a foam substrate with dielectric constant 1.07 and dielectric thickness 8mm. The T-coaxial fed patch with L-slot is with dimensions: W_{total} =28mm, W_1 = 5.5mm, W_2 = 7.5mm, W_3 = 4mm, W_4 =10.5mm, W_5 =15mm, L_1 =21mm, L_2 = 22.5mm, L_3 = 4mm, L_4 = 7.5mm and L_5 =15.5mm. The L-slot dimensions are W_{slot}, L_{slot} = (6mm, 7mm). The coaxial feed position is at distance 18.75mm from the shorting plate [6-7].

The dimensions of the rectangular coaxial-feed patch with U-slot is W_{total} = 30mm, W_1 = 5mm, W_2 = 3.5mm, W_3 = 13.5mm, L_1 = 26, L_2 = 24.25 and L_3 =15mm. The U-slot dimensions are W_{slot}, L_{slot} = (10mm, 7mm). The feed position is at distance 23.5mm from the shorting plate. The lower resonance is due to U-PIFA dimensions. We achieved broadband by using unequal arms [5]. The upper resonance frequency is due to L-slot or U-slot on the coupled fed patch [8]. The resonant frequency of lower band is depends on both the length of the two arms of the U-PIFA, while the upper resonance frequency depends on the dimensions of the inserted slot.

4 Results and Discussion

For reference purpose, the conventional PIFA, with the same dimensions, is simulated. It has the following dimensions W, L are 28mm and 23mm, respectively. The obtained resonance frequency equals 2.5GHz with reflection coefficient –15dB. The bandwidth is 9% as shown in figure 2. The investigated antenna shown in figure 1(a) is first constructed by using a U-shaped PIFA with equal arms. The antenna fed is through electromagnetically coupled T-shaped coaxially fed patch. The dimensions are kept the same as reference PIFA for comparison purposes. The antenna resonance frequency is still at 2.5GHz, with return loss –15dB and bandwidth 12%. The results are shown in figure3. As third step, the proposed configuration with unequal arms U-slot is designed. The antenna resonance frequency shifts down to 2.4 GHz. The obtained return loss is -16dB and the bandwidth is 14% as shown in figure3. Finally the L-slot is etched on the T-patch. The antenna dimensions are as given in section 3. The simulated resonance frequencies are 2.35GHz and 5.25GHz with return losses of –20dB and –30dB, respectively. The antenna bandwidths are 31% and 7.5% at the lower and upper resonance frequencies, respectively. Comparison between the simulation results and experimental measurements is in figure 4. The antenna gain is 7dB. The E-plane and H-plane radiation patterns at 2.4GHz are as shown in figure 5. The proposed antenna is fabricated using photolithography technique. Scattering parameters and input impedance are measured using 8719ES network analyzer.

The second investigated antenna is in figure1 (b). The antenna is firstly constructed by using U-shaped PIFA with equal arms. The fed is through proximity coupled rectangular patch with coaxial-feed. The dimensions are kept the same as the original PIFA for reference purposes. The antenna resonance frequency is 2.45GHz, with return loss –13dB and bandwidth 10%. The results are shown in figure 6. In second step, the proposed configuration of U-shaped PIFA with unequal arms is designed. The antenna resonance frequency becomes 2.4 GHz. The obtained return loss is -17dB, and the bandwidth becomes 14%. Finally, the proposed configuration with etched U-slot on the rectangular feed patch is designed. The antenna dimensions are as given in section 3. The simulated resonance frequencies are 2.4GHz; 5.25GHz with return losses –13dB and –15dB, respectively. The bandwidths are 14.5% and 9.5% at the lower and upper resonance frequencies, respectively. The antenna results are as shown in figure 7. The antenna gain equals 6.5dB. The E-plane and H-plane radiation patterns at 2.4GHz are as shown in figure 8. The antenna is fabricated using photolithography and measured. Figure 7 shows the comparison between the simulated and measured scattering parameters. It is clear from figured 4 and 7 that there is very good agreement between the simulated and the measured data in the two proposed antennas, which verifies the designs.

5 Conclusions

Two newly dual band PIFA antennas are investigated in this paper. Wideband performance is obtained by inserting a U-shaped slot with unequal arms. A dual band capability is achieved by inserting L slot or U slot in the proximity-coupled patch. The second shape with inserted U-slot has a measured bandwidth of 31% and 7.5 % at resonance frequencies of 2.35GHz and 5.25GHz, respectively. The antenna has an overall length of less than $\lambda_0/4$ and thickness of $0.05\lambda_0$. Experimental results show good agreement with HFSS Simulation results in both antenna cases. However, there is a little increase in the measured bandwidth at the lower band than the simulation

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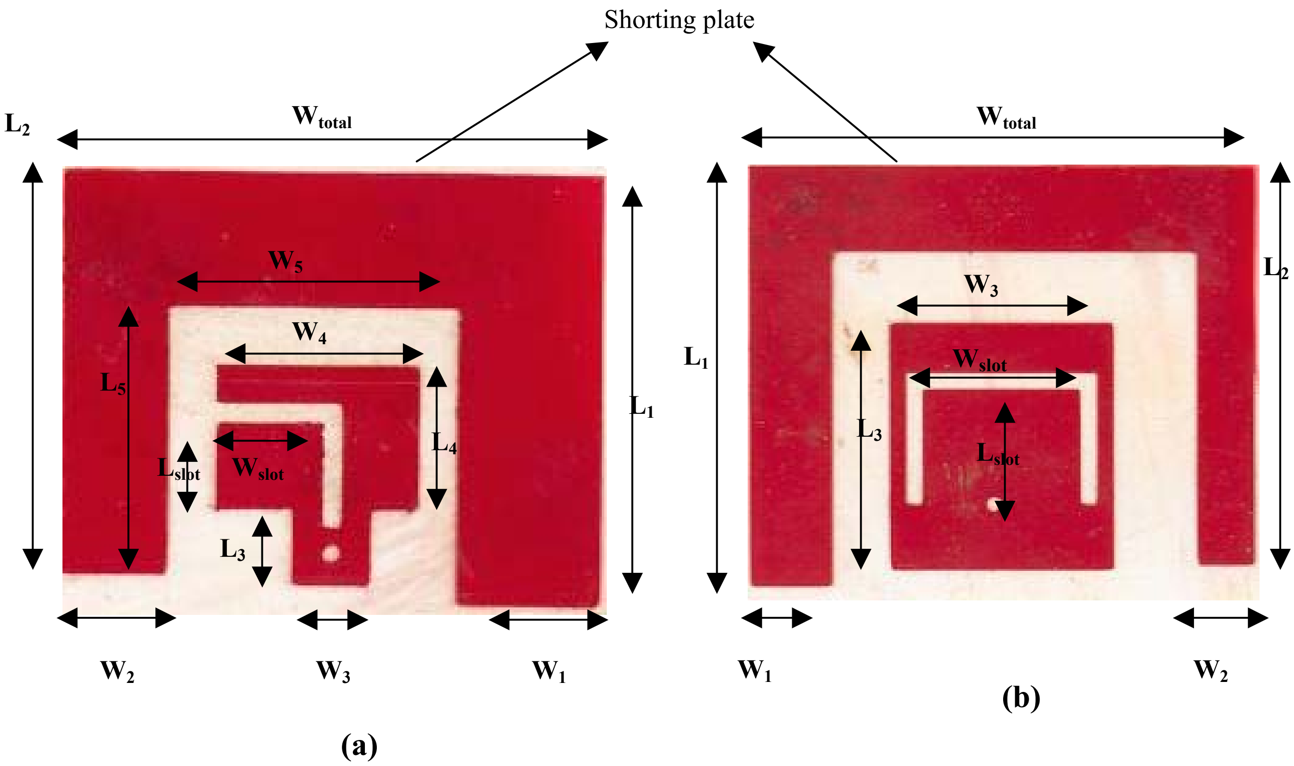


Fig. 1: Fabrication mask of the proposed antennas (a) U-shaped PIFA with T-coaxially fed patch with inserted L-slot, (b) U-shaped PIFA with rectangular-coaxially fed with inserted U-slot

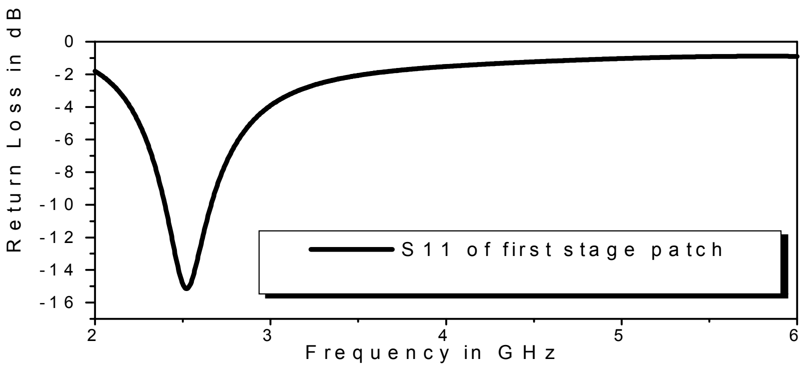


Fig. 2: The return loss of the conventional PIFA for reference

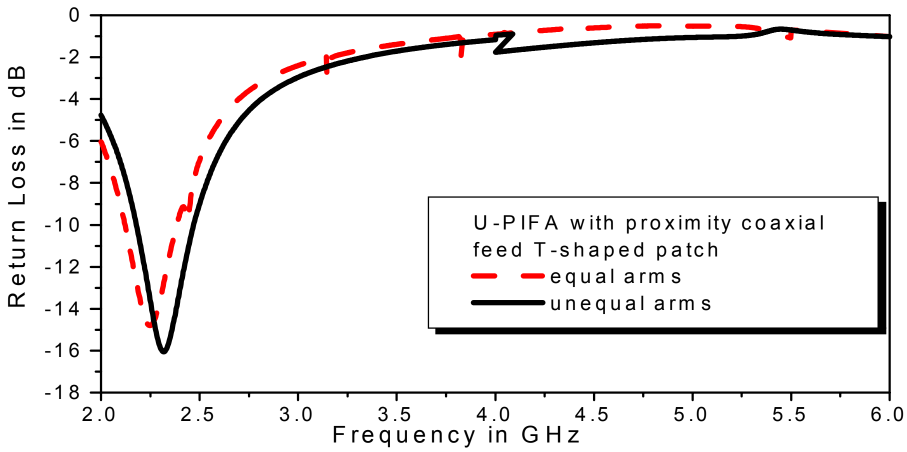


Fig. 3: The return loss of U-shaped PIFA with equal and unequal arms with electromagnetically coupled T-shaped patch

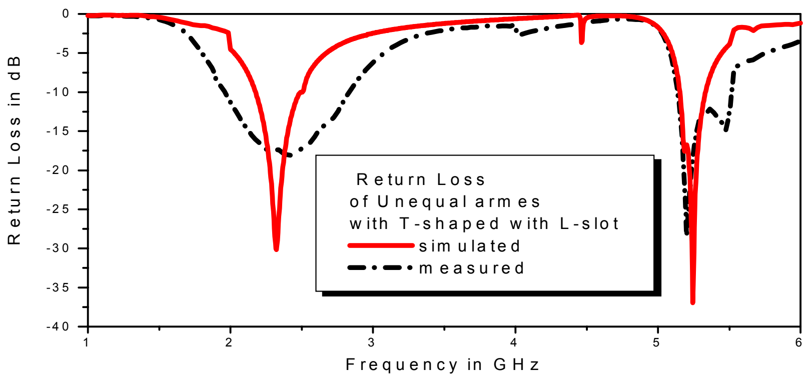
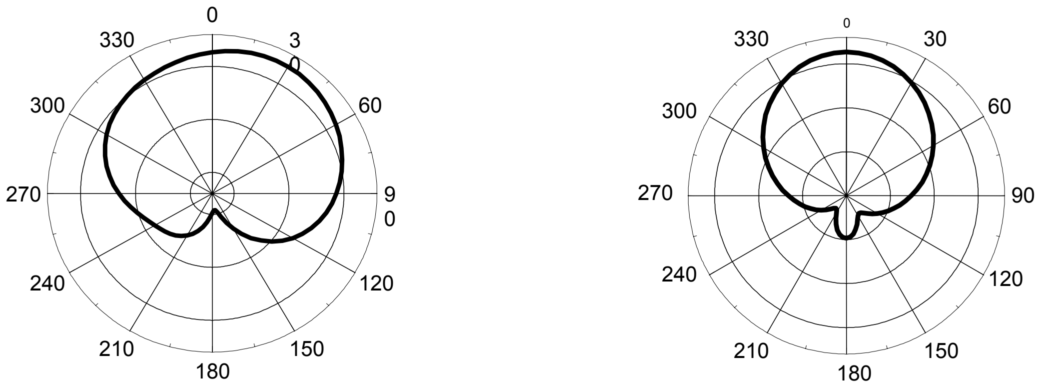


Fig. 4: Comparison between the simulated and measured return loss of the proposed dual-band PIFA by using electromagnetically coupled T shaped patch with coaxial feeding and inserted L-slot



7(a) E-Plane 7(b) H-Plane

Fig. 5: The radiation pattern of U-shaped PIFA with T shaped-coaxially-fed patch and inserted L-slot at the lower resonance frequency (2.4GHz)

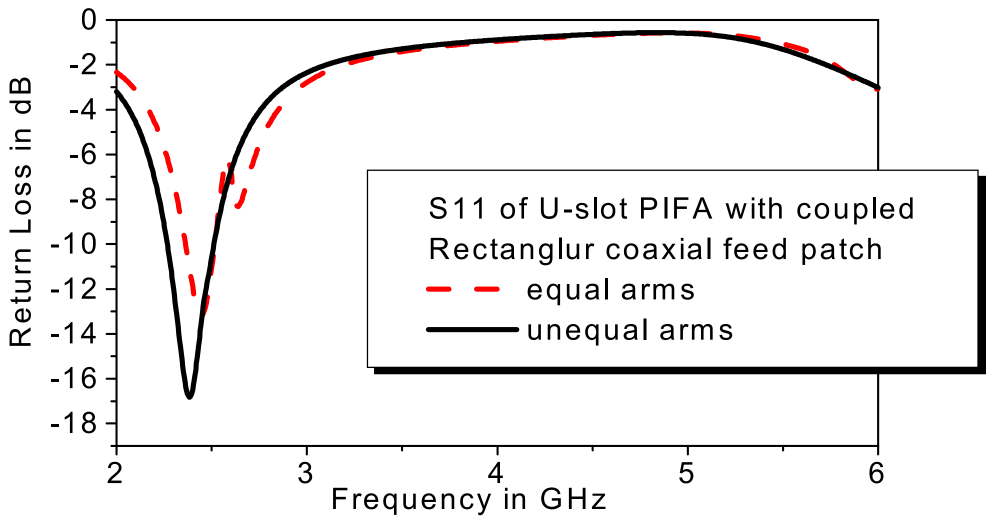


Fig. 6:The return loss of U-shape PIFA with equal and unequal arms with electromagnetically coupled rectangular patch with coaxial-feeding

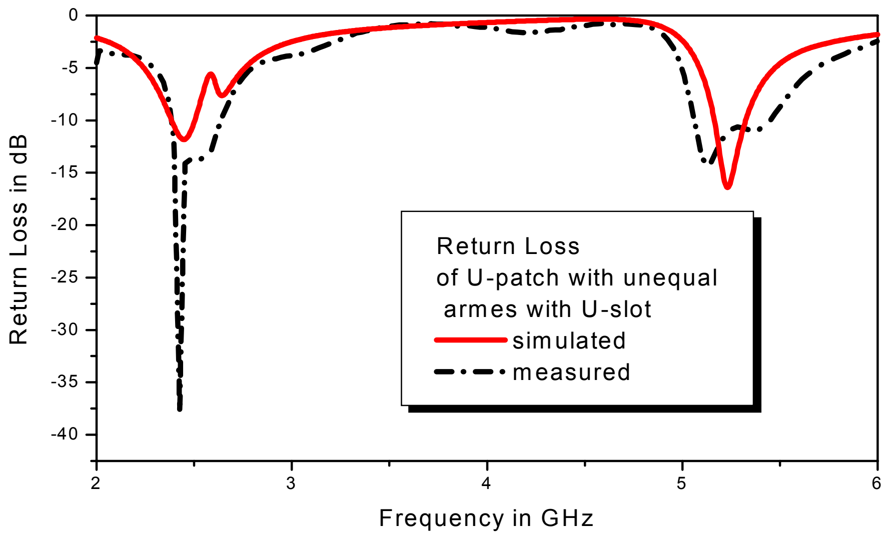


Fig. 7: Comparison between the simulation and measured reflection coefficient of the dual-band PIFA with proximity coupled rectangular patch and inserted U shaped-slot

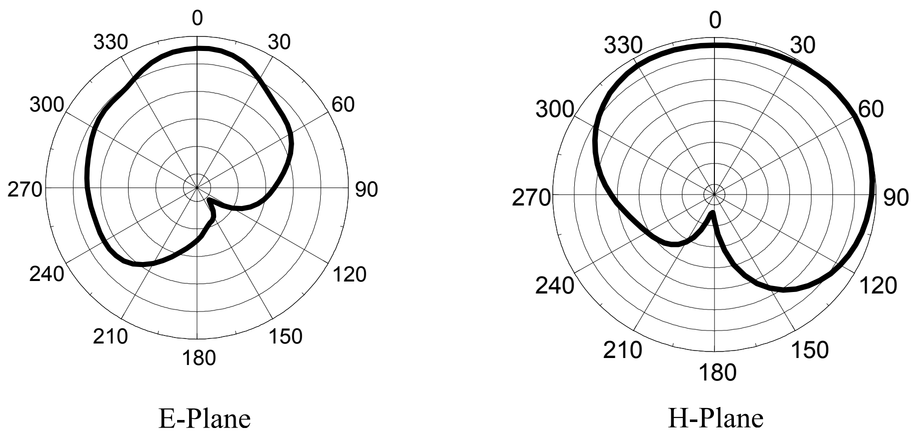


Fig. 8: The radiation pattern of the U-shaped PIFA with coupled rectangular-coaxially fed patch and inserted U-slot at the lower resonance frequency (2.4GHz)