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A Hybrid Microstrip Patch Antenna with Parasitic Slot for WLAN Applications

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ABSTRACT

A compact dual band microstrip patch antenna (MPA) with slot for wireless local area network (WLAN) applications is proposed. The dual-band microstrip patch antenna with slot fed by a micro strip line is designed to achieve dual frequency operation. The proposed antenna structure consists of microstrip patch resonator and C-slot resonator. The C-slot is etched on the ground plane of the microstrip patch. By adjusting the structure parameters, the microstrip patch operates at higher band (5.5 GHz) and C-slot operates at lower band (2.4 GHz), both resonators are radiating with two different radiation patterns. In order to determine the performance of the proposed antenna, functional parameters such as return loss, bandwidth, voltage standing wave ratio (VSWR), and radiation pattern are observed by the simulation of the structure with high frequency structure simulator (HFSS). The proposed antenna structure is suitable for WLAN applications.

Key words: Local area networks, microstrip patch antenna, dual band operation, microstrip feedline.

1. INTRODUCTION

In the last few years, the development of wireless local area networks (WLAN) represented one of the principal interests in the information and communication field.

The demand for wireless LAN equipment has increased up to the mark. Wireless channels for frequencies operating bands of the targeted environment must be better understood before designing a new WLAN system [1]. The 2.4GHz ISM band is license free, that is the reason most of WLAN devices suffer interference from devices which use the same frequency band. This ISM band is utilized by IEEE 802.11b and 802.11g standards. 5.5 GHz is used by IEEE 802.11a standard which is cleaner to support high speed WLAN [2]. This means that it has interference free spectrum so its productivity increases. Thus, the current trend in commercial and government communication systems [3] has been to develop low cost, minimal weight, low profile antennas that are capable of maintaining high performance over a large spectrum of frequencies. This technological trend has focused much effort into the design of Microstrip patch antennas [4]. With a simple geometry, patch antennas offer many advantages not commonly exhibited in other antenna configuration. For example, they are extremely low profile, lightweight, simple and inexpensive to fabricate using modern day printed circuit board technology. In addition, once the shape and operating mode of the patch are selected, designs become very versatile in terms of operating frequency, polarization, pattern, and impedance. The variety in design [5] that is possible with Microstrip antenna probably exceeds that of any other type of antenna element.

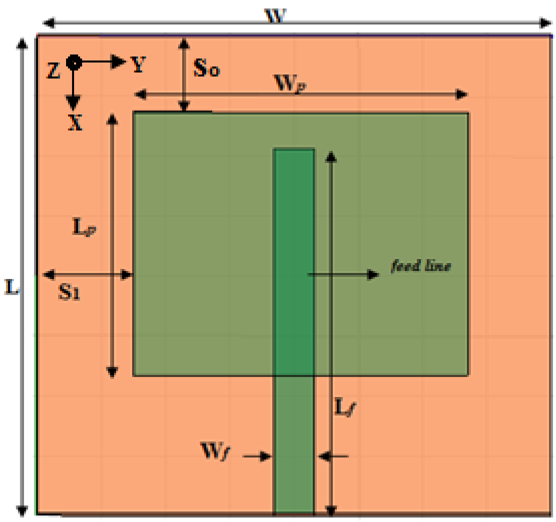
The use of microstrip patch [3] in feeding circuits requires accurate knowledge to couple the resonators and circuits. In order to match the microstrip patch to the feedline and to excite the desired mode in the resonator, the most common feeding technique is the microstrip feed line arrangement [4]. Recently, microstrip patch antennas have attracted extensive attention due to their dual-band as well as wideband operation without increasing antenna volume. The hybrid structure is considered as the combination of a microstrip patch antenna and another radiating resonator of the resonant feeding structure [5]. These two different radiating resonators [6] are tightly stacked together and resonate at two different frequencies. By arranging for the different radiating resonators' position, a compact dual-band [7] & [8], or frequency tunable [9] & [10] microstrip patch antenna can be designed. However, the resonant feeding structure adopted in these reported designs, such as microstrip-fed aperture-coupled, co-axial probe coupling, co planar slot feed, CPW-fed slot In this paper, in order to avoid via holes, the microstrip feed line arrangement offers more flexibility and is directly compatible with different mounting surfaces.

In this paper, in order to avoid via holes, the microstrip line feed to MPA is proposed [11]. It is the simplest method to energize MPAs. In this method, a microstrip line printed on the same substrate excites a microstrip patch that could be placed directly over the microstrip line or nearby over the dielectric substrate. An advantage of microstrip feed is that it is easier to fabricate, match and model.

To demonstrate the idea, the proposed hybrid dual-band antenna is designed for wireless local area networks. It consists of upper (5.5 GHz) and lower (ISM) frequencies of the dual band antenna are primarily controlled by the MPA and C-slot respectively. This design has the advantage of compact size, simple structure and can achieve dual band with different radiating patterns. A parametric study of the antenna was carried out, and the effect of the various parameters performance is discussed.

2. ANTENNA CONFIGURATION

The proposed dual band microstrip patch antenna structure is as shown in Figure 1. The dual band microstrip patch antenna with slot is consist of two different resonators one is microstrip patch which is printed on the FR – 4 substrate and another resonator is C-slot [12] which is etched on the ground plane, these radiating resonators are tightly stacked together and resonate at upper and lower frequencies, respectively. The feed line is etched on the substrate at center position. The proposed antenna has the dimensions of 40 mm × 40 mm × 1.75 mm, and a FR-4 dielectric with a relative permittivity of $\varepsilon_r = 4.4$ and substrate thickness is 1.6 mm.



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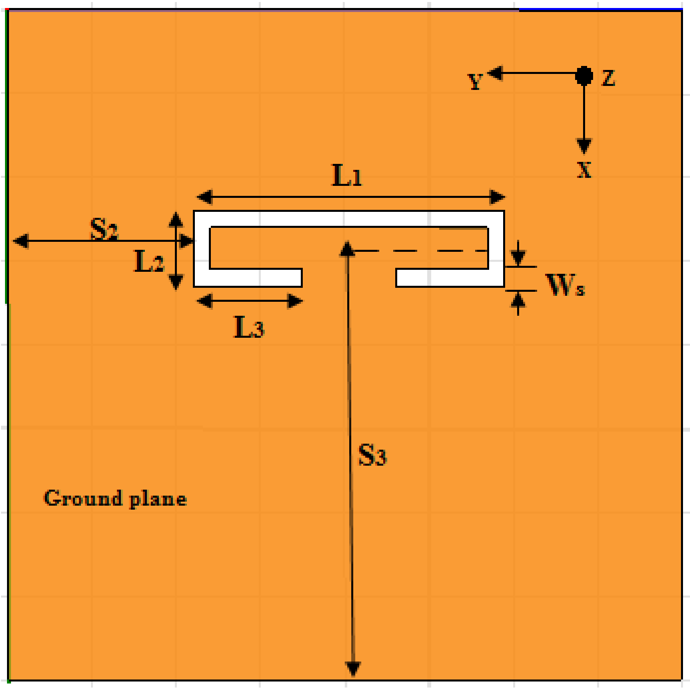

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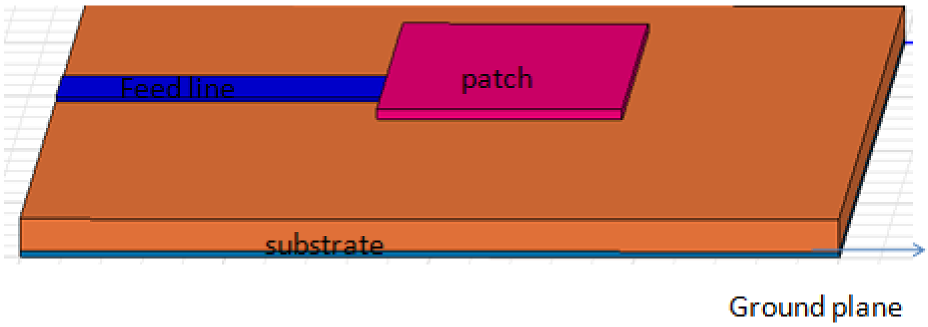


(c)

Figure 1: Proposed dual band MPA with C-slot: (a) Top view; (b) Bottom view; (c) Side view

The ground plane is printed on the FR4 substrate with a dimension of 40x40(LxW) mm^2. The MPA with copper material has a dimension of 22x26(L_PXW_P) mm^2 as shown in Figure 1. The microstrip patch is placed above the substrate with an offset distance S_0 = 6.5 mm and S_1 = 7.5 mm which is used to adjust the coupling energy between the microstrip-fed line and microstrip patch. The 50-Ω feeding line has a length of L_f =30.5 mm and a width of W_f=3.0 mm.

In this letter, a new approach that utilizes a parasitic C-slot etched in the ground plane is investigated experimentally. The C – slot is as shown in Figure 1, it is consists of three parts of a rectangular slot of length L_1, L_2, L_3 and a fixed width of W_s=0.5 mm, the design of C-slot on the ground plane with offset distances S_2 and S_3. In addition, the parasitic slot dimension was found to be effective in controlling the resonant frequency of the slot mode. In order to reduce experimental cut-and-try design cycles, the simulation software HFSS is used to guide fabrication. By carefully adjusting the parasitic C-slot dimension, the proposed antenna can operate in two bands, and a good impedance match for the operating frequencies can be easily obtained.

3. PARAMETRIC STUDY

In reference to Figure 1, there are a number of parameters that influence the antenna characteristics. To achieve optimum antenna performance, a parametric study is carried out to investigate the characteristics of the MPA.

For the design in this study, the MPA is printed on the FR4 (ε_r=4.4) on the height of substrate is 1.6 mm, the initial parameters are chosen L_P=22 mm, W_P=26 mm, S_0=6.5 mm, S_1=7.5 mm, L_1=18 mm, L_2=4 mm, L_3=6 mm, S_2=11 mm, S_3=26 mm and W_S=0.5 mm. The width and length of the microstrip feed line W_f and S_f are chosen to be 3 mm and 30.5 mm, respectively.

In order to obtain the upper frequency 5.5 GHz, the microstrip patch is designed on the substrate FR4. The upper excited band is due to the microstrip patch with dimensions of L_P=22 mm, W_P=26 mm.

The theoretical resonant frequency of the C–slot is calculated by the following equation [12] and equal to 2.4 GHz which is well suited for industrial, scientific, medical(ISM).

$$f = \frac{c}{(2L_1 + 4L_2 + 4L_3 - 6W_S)\sqrt{\quad}_{eff}}$$

Where c is speed of the light in free space, f is fundamental frequency of the slot resonator, and □$_{eff}$ is effective dielectric constant. In this case the value of ε_{eff} is about 0.69ε_r(2.9).

The design consideration for the lower excited C-slot antenna is consists of five rectangular slots with different length and fixed width W_S=0.5 mm as shown in Figure 1, the C-slot on the ground plane deign consideration is S_2 = 11 mm, S_3=26 mm, different rectangular slot lengths are L_1=18 mm, L_2=4 mm, L_3=6 mm as shown in Figure 1.

4. SIMULATED RESULTS AND DISCUSSIONS

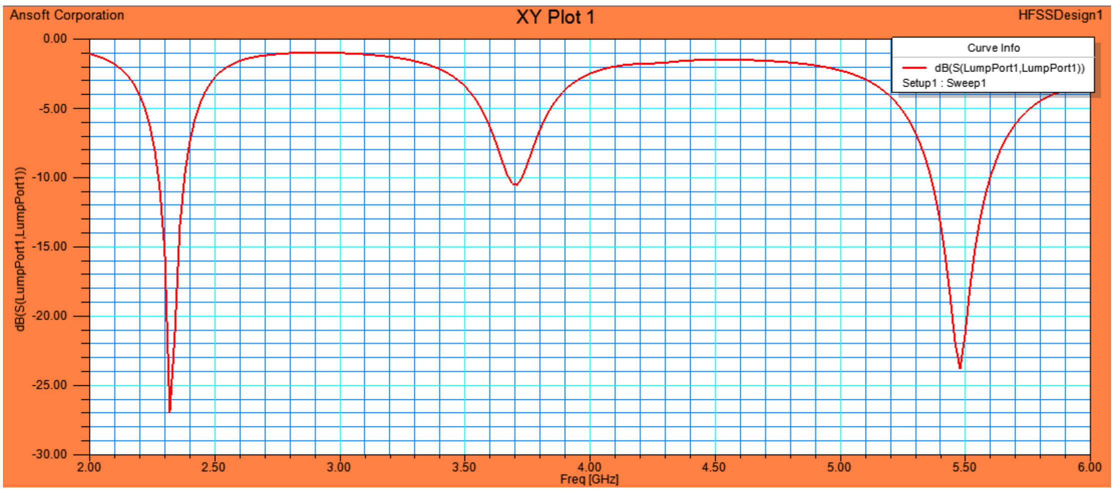


Figure 2: Simulated return loss at 2.4 GHz and 5.5 GHz

Figure 2 shows the simulated return loss of the proposed hybrid MPA. The lower excited band is due to the C-slot while the higher band is due to the microstrip patch. As observed in Figure 2, the return loss of the proposed antenna at two different frequencies 2.4 GHz and 5.5 GHz

It is observed-27 dB return loss at 2.4 GHz and-24 dB return loss at 5.5 GHz. As a result, a simulated lower band achieves an impedance bandwidth of 5.41 % (for S_{11} <-10 dB) ranging from 2270 to 2410 MHz with respect to the centre frequency at 2.4 GHz and the simulated bandwidth for the higher band reaches about 4.03 % (for S_{11} <-10dB) corresponding to the centre frequency at 5.5 GHz. Note that there are no frequencies to be excited without the presence of microstrip patch, that is, the resonant slot mode is caused by the microstrip patch.

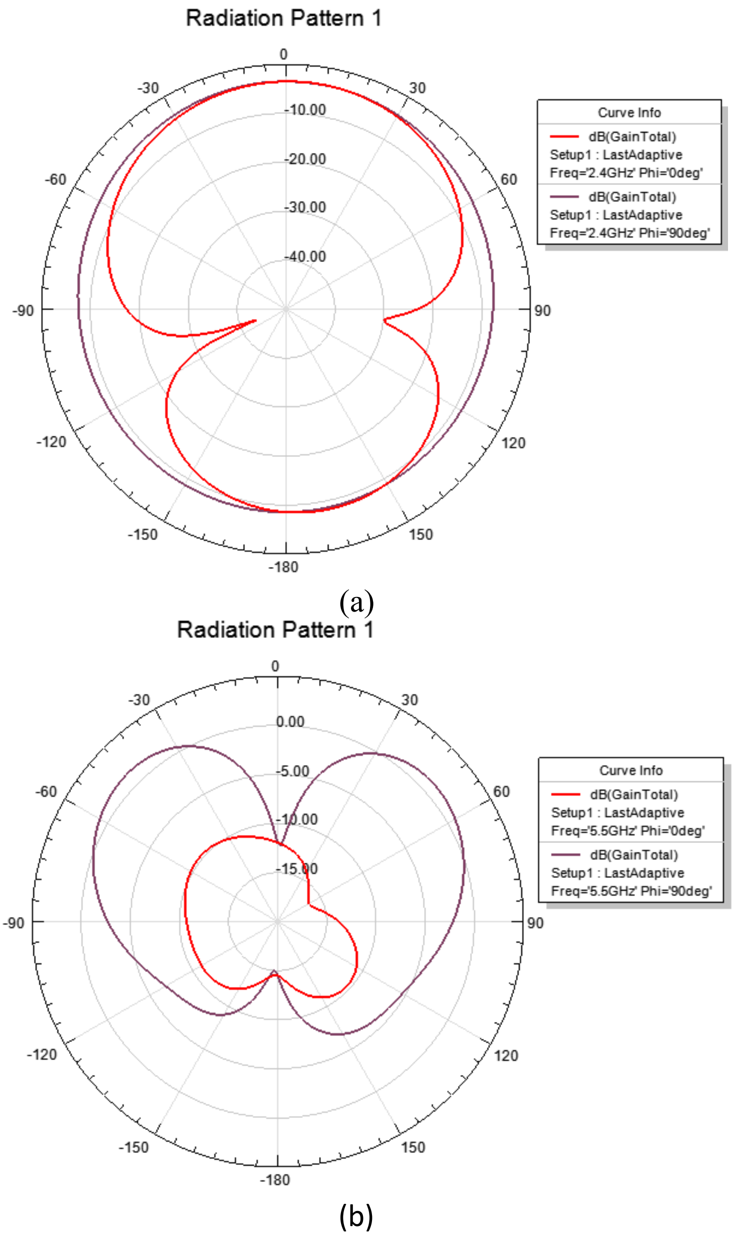
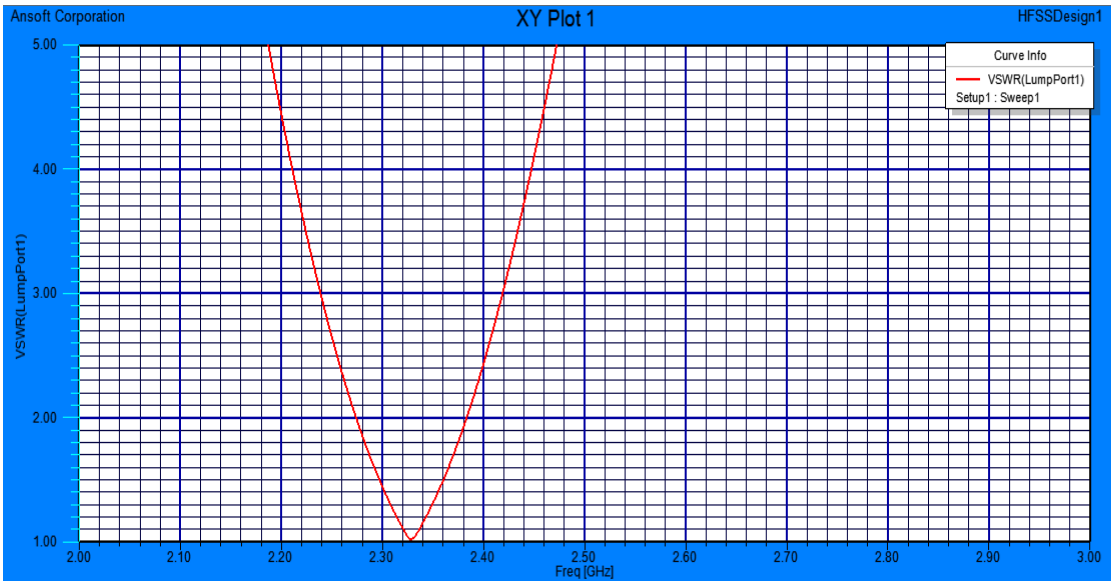
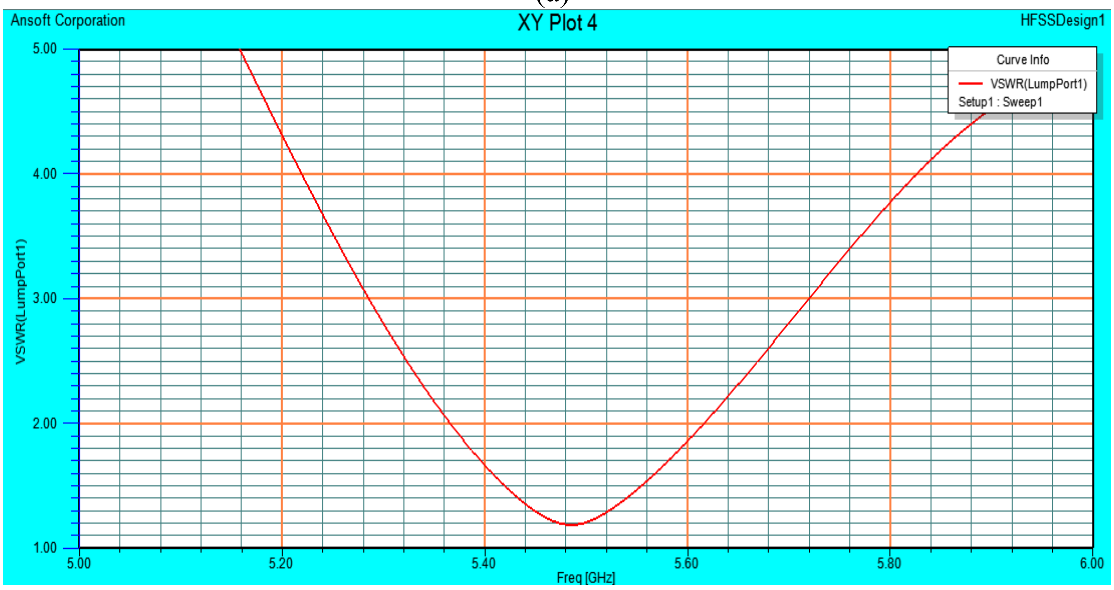


Figure 3: Simulated radiation patterns at: (a) 2.4 GHz; (b) 5.5 GHz

The radiation patterns of the simulated antenna structure at 2.4 GHz and 5.5 GHz with phi=0 (deg) and phi = 90 (degree) are shown in Figure 3. The proposed antenna radiates a maximum in the broadside direction at 5.5 GHz, which corresponds to the far-field radiation from the resonant mode of the MPA and as shown in Figure 3. The slot resonator is radiating the patterns in bidirectional at 2.4 GHz.



(a)



(b)

Figure 4: Simulated VSWR at 2.4 GHz and 5.5 GHz

The voltage standing wave ratio (VSWR) of the proposed structure is as shown in Figure 4, than the VSWR of the proposed structure is close to 1.6 at 2.4

GHz. As it is less than 2 it can be said that the antenna offers good impedance matching characteristics for the ISM (2.4 GHz) band. As well as for the proposed structure simulated VSWR at 5.5 GHz is very close to 1.4, as it is less than 2 as shown in Figure 4 and it will said that proposed upper band antenna offers good impedance matching characteristics.

5. CONCLUSION

A miniature dual band microstrip patch antenna with a c-slot fed by a microstrip line has been proposed. The lower and upper bands of the dual-band antenna are provided by the c-slot and MPA modes, respectively. A parametric study is carried out to investigate the antenna functional and design parameters. The prototype has been simulated and it is observed that a bandwidth and return loss of 5.41%, 4.03% and-27 dB,-24 dB at the resonant frequencies of 2.4 GHz and 5.5 GHz respectively. The proposed structure takes a small volume, and simple shape. The microstrip coupling used in the design is efficient, simple and easy to be implemented and adequate operational bandwidth, such that it is suitable for wireless local area networks.

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