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U-slot Circular Patch Antenna for WLAN Application

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Abstract

A dual-frequency microstrip patch antennas has been presented and used for 802.11WLAN applications. The antennas had been designed, simulated and parametrically studied in CST Microwave studio. By introducing u-slot, dual-band operation with its operating mode centered at frequency 2.4GHz, 3.65GHz and 5.2GHz had been obtained. The gain and directivity had been improved by adjusting the parameters of the antennas. The gain of the proposed designs was 6.019dBi, 4.04dBi and 6.22dBi and directivity was 6.02dBi, 4.05dBi and 6.22dBi at resonant frequencies 2.4GHz, 3.6GHz and 5.2GHz respectively. The patch antennas had been proposed to be used in portable devices that require miniaturized constituent parts.

***Keywords**: dual band, WLAN, circular patch, antenna*

1. Introduction

Multiband antenna are widely used in wireless communication systems like mobile phone, laptop etc. The size of these devices is becoming smaller rapidly due to the concept of miniaturization. Consequently the size of the antenna should be small to fit inside them. By introducing slots in circular patch antenna having single frequency band can be modified into multiband antenna. The size and position of slot are important in determining the resonance frequency. The shapes of the slots like C, E, F, H, L, V, U etc are being used for the desire performance. More than one slot of different shapes is used for different multiband applications. The u-slot was used in which the antenna performed wideband behavior and linearly polarized [1], but they have the disadvantages of large size and complications in fabrication.

Recently many design of dual band patch antenna have been analyzed. For example the antenna in [2] having rectangular patch and straight strips with different size. The antenna presented in [3], a microwave substrate was used having broad band characteristic, but the dimension of the ground (120mm × 100mm) was large for mobile devices. In [4] the high frequency performances have been improved by modified ground plane on the bottom layer. CPW fed monopole antennas have been presented in order to meet the dual band requirements like G-shaped [4]. The third band centered at 3.4 GHz useful for WiMAX has been achieved by triangular antenna having cross shape inside it [5]. Many researches show that the wide band characteristic of the antenna can be made as multiband by changing the flow of the surface current in the patch [6-8]. The pin diodes have been used in antenna for switching between linear and circular polarization with changing the size of the slot [9].Slots and notches loaded microstrip patch antenna for dual band operation [10], and a finger shaped antenna for wireless communication GSM/DCS/IMT [11]. It is the fact that multiband characteristics can be achieved by intelligent placement of slot in the patch antenna. The paper is composed of dual band u-slot circular path antennas. The resonance frequencies have been shifted by changing the size of slot. The dimensions and performance of the antenna have been carefully analyzed. The proposed antennas have the advantages of small size, light weight and ease of fabrication, which make the designs suitable for portable devices like mobile handset, laptop, gaming console etc. The bandwidth of the operating bands has sufficient to cover the IEEE802.11a/b/y standards of wide local area networks applications.

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2. Antenna Design

The value of dielectric constant (εr) of the substrate of the antenna A is 4.3 and B is 2.2. The length and width of the ground are same as that of substrate. The ground plane reflects the electromagnetic waves. The full ground plane creates directional radiation while partial ground plane produces omni-directional radiation pattern. The excitation of antenna is given through coaxial feed line. The capacitances due to u-slot cancelled the inductance produce by the coaxial probe. The characteristics impedance of coaxial cable 50ohm has matched with the input impedance of the patch antenna.

Table 1 shows the parameters of the proposed designs. All the dimensions are in mm and dielectric constant (ε_r) is unitless. The characteristics of the patch antenna have been analyzed by many parametric and simulation studies made by many researchers across the world [12-14]. But no empirical formulas have been reported yet. The design of microstrip circular patch antenna, the parameters such as dielectric constant (ε_r), resonance frequency (f_r), and height (h) are consider for determining the radius of the patch. The dimensions of circular patch antenna are calculated as;

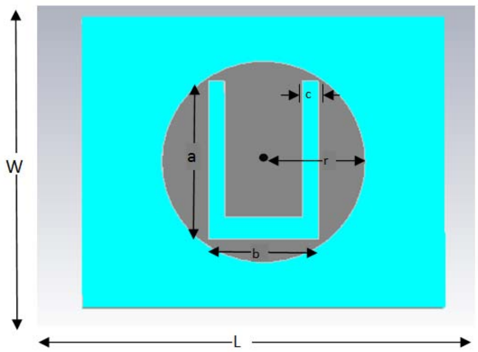


Figure 1. U-slot Patch Antenna with dimension variables

Table 1. Parameters of the proposed antennas

Designs	L	W	a	b	c	ε_r	r	h
Antenna A	53	43	17.2	14.2	2.6	4.3	16	5
Antenna B	53	43	23.4	16.16	2.38	2.2	14.9	4.3

$$a = \frac{F}{[1+\frac{2h}{\pi\varepsilon_r F}\{\ln(\frac{\pi F}{2h})+1.7726\}]^{\frac{1}{2}}} \quad (1)$$

$$F = \frac{8.791\times 10^9}{f_r\sqrt{\varepsilon_r}} \quad (2)$$

Where F is fringing effect which makes the patch electrically larger. The effective radius of the antenna is:

$$a_e = a\left[1+\frac{2h}{\pi\varepsilon_r a}\left\{\ln\left(\frac{\pi a}{2h}\right)+1.7726\right\}\right]^{\frac{1}{2}} \quad (3)$$

3. Results and Discussion

The simulations have been carried out using CST Microwave Studio. The reflection coefficient S_{11} of the antennas is calculated in dB. At port 1 where input to the antenna has applied the scattering parameter S_{11} gives reflection coefficient which should be less than -10dB.The return loss of the antennas is shown in the Figure 2. In all resonance frequencies the return loss of antenna A and B are less than -10dB. The impedance of the antennas are illustrated in Figure 4, which show that antennas have good impedance matching. Each curve cross -10dB is representing frequency band. The return loss of the antenna A is -15.68dB at resonant frequency 3.65GHz which indicates good impedance matching. In 5.2GHz the return loss of antenna B crossing -10dB, but the bandwidth is (5.10-5.40) = 300MHz, which is sufficient to match with IEEE802.11a standard. By changing u-slot broadness the second resonance frequency 5.25GHz can be shifted to 5.76GHz band. In case of antenna B this variation causes shifting of resonance frequency to 2.45GHz.

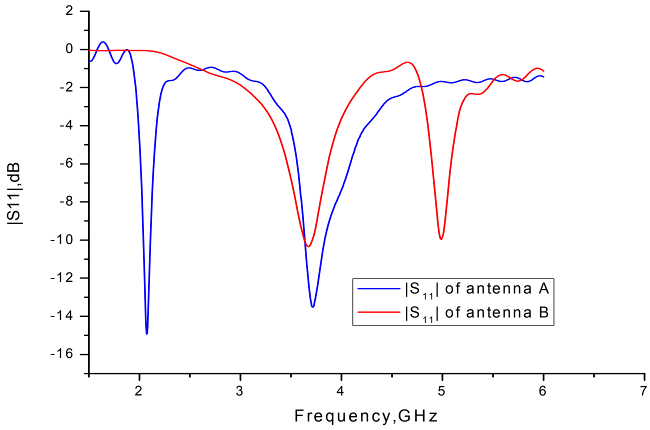


Figure 2. Reflection coefficient vs frequency plot of antenna A and antenna B

The Voltage standing wave ratio can be calculated by using the following equation.

$$\mathrm{VSWR} = \frac{1+|S_{11}|}{1-|S_{11}|} \tag{4}$$

S_{11} is known as reflection coefficient which is the complex number where the magnitude is used to determine Voltage standing wave ratio. At 2.4GHz antenna A has the VSWR value of 1.16 because of good impedance matching as compared to antenna B. At the resonance frequency 3.65GHz the antenna A has the VSWR value of 1.13 which does not show much variation.

The gain and directivity of proposed designs are shown in figure 3. Antenna B has lower gain and directivity as compare to antenna A.The gains of antenna A at resonance frequency 2.45GHz and 3.65GHz are 6.02dBi and 4.05dBi respectively. At resonance frequencies 5.25GHz the gain of antennas B is 6.22dBi. Likewise the directivity of antenna A and B are 6.019dBi and 4.046dBi at resonance frequencies 2.4GHz and 3.65GHz respectively and at resonance frequencies 5.25GHz; the directivity of the antenna A is 6.22dBi.

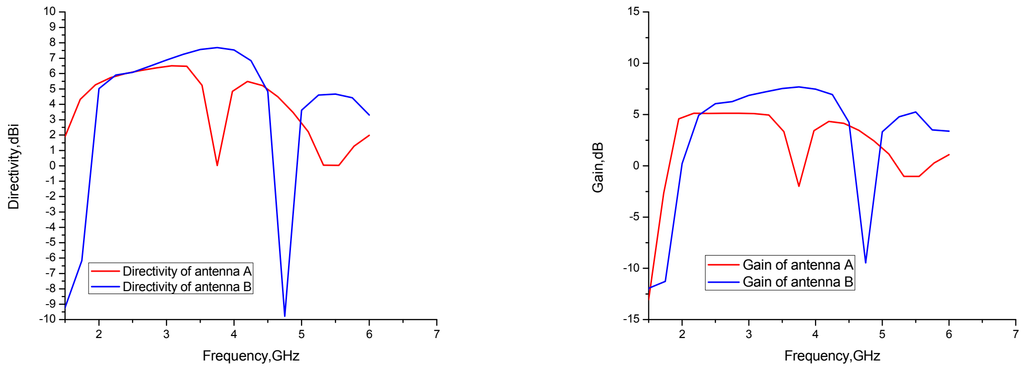


Figure 3. Directivity and Gain of antenna A and antenna B

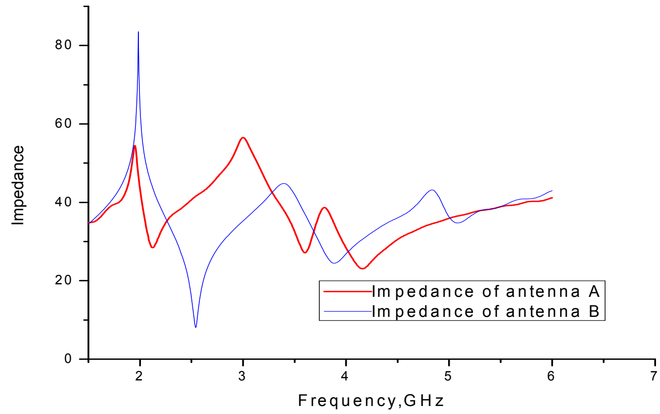
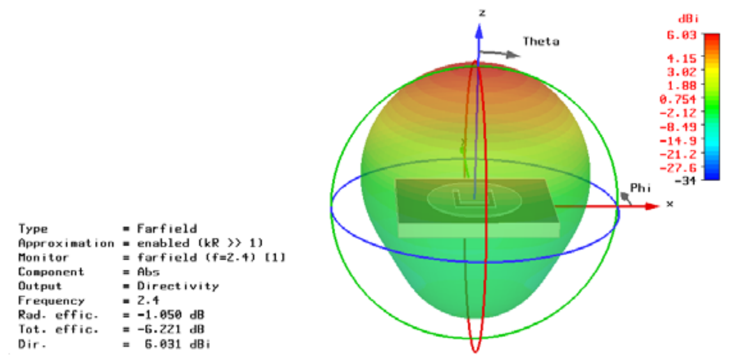
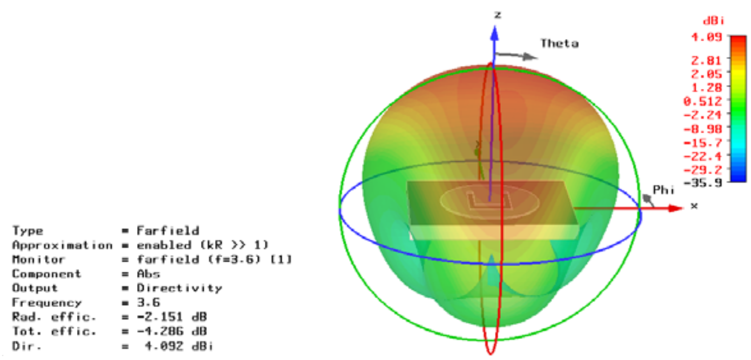


Figure 4. Impedance of antenna A and antenna B

The proposed antennas have directional radiation patterns. The main lobes having maximum power radiate directly above the patch, shown in each plot in the Figure 5 and 6. The half power beam width in the elevation plan is indicated in the plots. The half power beam width depends on the directivity which is decreasing with increasing directivity of the antenna. The three dimensional radiation patterns of the proposed designs demonstrate that the maximum radiation occurs from the top of the patch surface.The maximum power in the main lobe is directed above the patch. The directivity and gain of the antenna are also shown in the 3D radiation pattern.



(a)



(b)

Figure 5. 3D Radiation patterns of antenna A (a) 2.45GHz (b) 3.65GHz

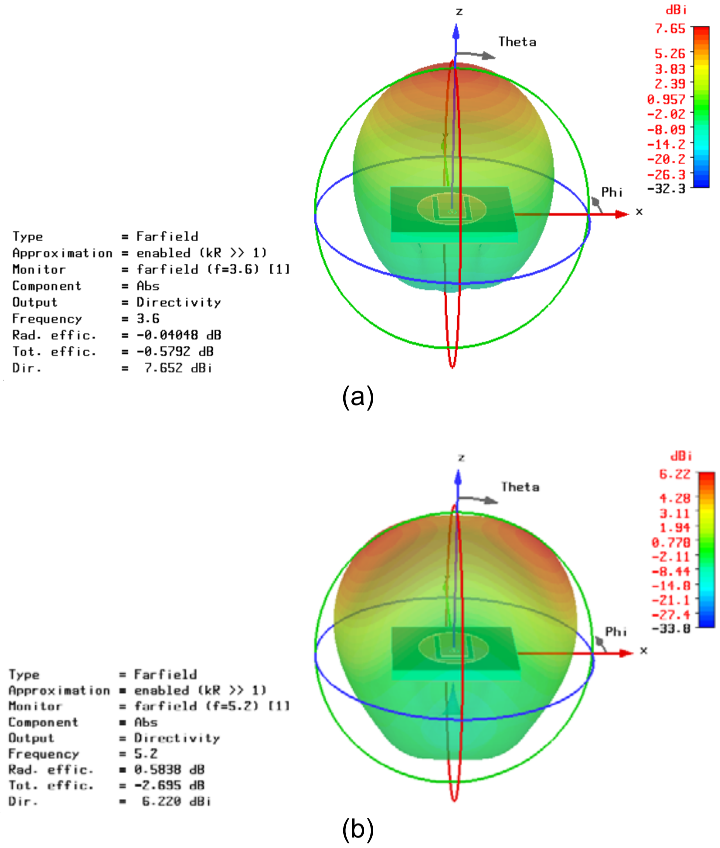


Figure 6. 3D Radiation patterns of antenna B (a) 3.6GHz (b) 5.2GHz

4. Conclusion

Two dual band u-slot circular patch antennas have been designed for WLAN application. The dimensions of these antennas are small and have remarkable performance characteristics. The antennas have good return loss and radiation patterns at the resonance frequencies of 2.5GHz, 3.67GHz and 5.2GHz. The resonance frequencies depend on the parameters of the patch, material and thickness of the substrate. By adjusting the parameters of the antenna the gain and directivity have improved.

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