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Design of Dual Band Microstrip Antenna for Wi-Fi and WiMax Applications

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Abstract

In this paper, a dual band rectangular microstrip patch antenna with microstrip line is presented. The proposed antenna is designed on FR4 substrate with thickness 1.5 mm and relative permittivity 4.3. The antenna is designed to operate at 2.4/5.8 GHz bands for Wi-Fi/WiMax applications. The obtained return loss is -32.77dB at 2.4 GHz with 7.4% bandwidth and -25.955 dB at 5.8 GHz with 8.17% bandwidth. The practical and simulation result are computed. It is noted that there is a good agreement between the simulation and measured result (using vector network analyzer (VNA).

Keywords*: dual band, microstrip antenna, Wi-Fi, WiMax*

1. Introduction

Microstrip antennas are considered as one of the most used and preferred antennas compared with regular microwave antennas, and that is due to the fact that these sorts of antennas are low volume, light weight and thin profile arrangements, which can be made conformal. The cost of fabrication is likewise low. As a result of these features, they can be made in extensive amounts. For the polarization sorts, it can bolster both circular and linear polarization relying upon the radiation design. Microstrip antennas additionally are equipped for double and even triple frequency operations which is very desirable [1].

Nowadays, wireless communication systems such as WLAN/Wi-Fi or WiMax require compact and low cost antennas; therefore, microstrip antennas are widely used in these systems. In spite of their advantages, microstrip antennas have a main limitation in its narrow bandwidth. A valid solution to widen the bandwidth is dual band operation antennas [2].

There are many dual band antennas proposed for WiFi/WiMax applications. A dual band inverted-L antenna at 3.5 GHz and 5 GHz was presented in [3]. This antenna has a simple structure and a single feed aimed for mobile WiMAX and Wi-Fi operation. The overall dimensions of the antenna was 20×30 mm^2 fed by a coaxial connector and ground plane of 60×60 mm^2.

Similarly a dual band microstrip antenna patch antenna for WiMAX and Wi-Fi at a resonant frequencies of 3.5 GHz and 5.2 GHz was proposed in [4]. Epoxy FR-4 substrate having a dielectric constant of 4.3 with overall size of 49 ×53 1.67 mm^3. A microstrip patch antenna with dual U slot for WLAN/WIMAX applications was proposed in [5]. FR4 substrate having 4.4 dielectric constant with 1.6 mm thickness and patch dimension of 40×47 mm^2.

Likewise, A 9 Slots dual band microstrip patch antenna for wireless applications was proposed in [6]. The antenna was fed with coaxial feed and used FR4 material as substrate with 4.4 dielectric constant and dimensions of 80x120x3.4 mm. A human shaped microstrip patch antenna for Wi-Fi and WiMAX applications was proposed in [7]. The designed antenna used air as substrate with 3.2 mm thickness and 1.0006 permittivity with size of 120×100×3.2 mm^3.

Also, a horse-shoe shaped stacked microstrip patch antenna for WLAN, WiMAX and IMT applications was proposed in [8]. The antenna had a horse-shoe shaped patch placed on the upper surface of the rigid substrate with an overall dimensions of 40×50 mm^2. A a tri-band microstrip patch antenna aimed at GSM, UMTS and WiMAX applications was presented in [9]. FR-4 substrate was used for the proposed antenna that have 4.4 dielectric constant and 0.02 loss tangent with 1.6 mm thickness and overall size of 44×44×1.6 mm^3.

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A planar Multiband Antenna for GPS, ISM and WiMAX Applications was propsed in [10]. The antenna's entire area is 59.5x47 mm^2 and is printed on an FR-4 substrate and fed by a 50 Ohm microstrip line. Inset Feed Toppled H-Shaped Microstrip Patch Antenna for PCS/WiMAX Application was proposed in [11]. H-shaped microstrip patch antenna with grounded plane is investigated for triple band operation. Theproposed antenna of dimension 40×40 is designed on FR4 substrate with dielectric constant εr=4.4 and height h=1.60 mm.

In this paper, a rectangular dual-band microstrip antenna for WiFi/WiMax applications in 2.4/5.8 GHz bands is presented. The antenna consists of a rectangular patch that contains five rectangular and a rectangular slot in ground plane. The slot in the ground enhances the gain and bandwidth while the slots in the patch improves the return loss. The proposed antenna is simulated using CST microwave studio 2016 and the obtained radiation characteristics of the antenna are presented.

2. Antenna Design

The geometry of the proposed antenna is illustrated in Figure 1, it consists of a rectangular patch whose width and length are 18.2 mm and 22 mm respectively. The dielectric material selected for the design is FR-4 which has a dielectric constant 4.3 and a thickness h=1.5 mm. The antenna is fed by a 50Ω microstrip line with a width 3.7 mm for impedance matching. Five rectangular slots are etched on the patch which helps achieve dual band radiation at the desired frequencies. The patch and ground plane are made of copper with thickness 0.035 mm. A rectangular slot is introduced in ground which has dimension of 40×40 mm. Tables and Figures are presented center, as shown below and cited in the manuscript.

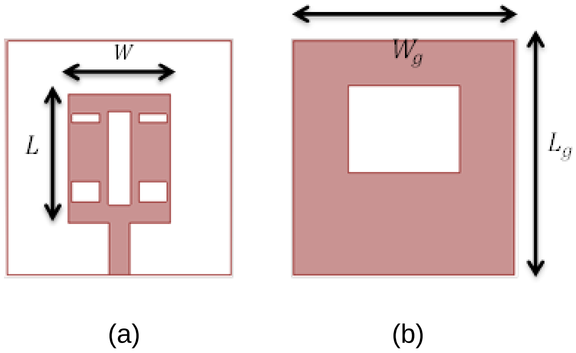


Figure 1. Geometry of the proposed antenna: (a) front view (b) back view

Table 1. Design Parameters of the Proposed Antenna

Antenna Parameters	Value (mm)
Length and width of ground ($L_g \times W_g$)	40 ×40
Length and width of substrate ($L_s \times W_s$)	40×40
Patch width (W)	18.2
Patch length(L)	22
Feeder width(W_f)	3.7
Feeder length(L_f)	9

The following equations are used to calculate the dimensions of microstrip antenna [1]. The width of patch is found by:

$$w = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (1)$$

where C is the velocity of light , f_0 is the resonant frequency and ε_r is the dielectric constant of substrate. The following equations gives effective dielectric constant of substrate and length extension ΔL:

$$\varepsilon_e = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+12\frac{h}{w}\right)^{-\frac{1}{2}} \quad (2)$$

where h is high of substrate.

$$\Delta L = \frac{h}{\sqrt{\varepsilon_r}} \quad (3)$$

The length of the patch is found from:

$$L = \frac{h}{2\, f_0 \sqrt{\varepsilon_r}} - \Delta L \quad (4)$$

the length and width of the ground are given by the following equations:

$$L_g = L + 6h \quad (5)$$

$$w_g = w + 6h \quad (6)$$

feeder length L_f and feeder width w_f for the microstrip feed line are obtained by the following equations:

$$L_f = \frac{6h}{2} \quad (7)$$

$$z_0 = \frac{87}{\sqrt{\varepsilon_r + 1.41}} \ln \frac{5.98h}{0.8 w_f} \quad (8)$$

3. Parametric Study

A parametric study is done for obtaining the best parameters for the antenna. The effect of changing the width, length of patch and width of transmition feed to the return loss are studied as shown in Figure 2, Figure 3 and Figure 4.

As seen from Figure 2, Figure 3 and Figure 4, changing width of patch effects on the 5.8 GHz frequency mostly. As the value of W increases, the 5.8 GHz frequency is shifted to the left. W=18.2 mm is chosen for having the best compromise between return loss and bandwidth. On the other hand, changing patch length affects the 2.4 GHz frequency more. As the value of L increases, the 2.4 GHz shifted to left and 5.8 GHz shifted to right. L=22 mm is chosen to obtain radiation at 2.4 GHz and 5.8 GHz. As for the effect of feeder width, its value affects the impedance matching of microstrip feed to the impedance. W_f=3.7 mm is chosen as the best value where a good impedance marching is obtained at the two frequencies.

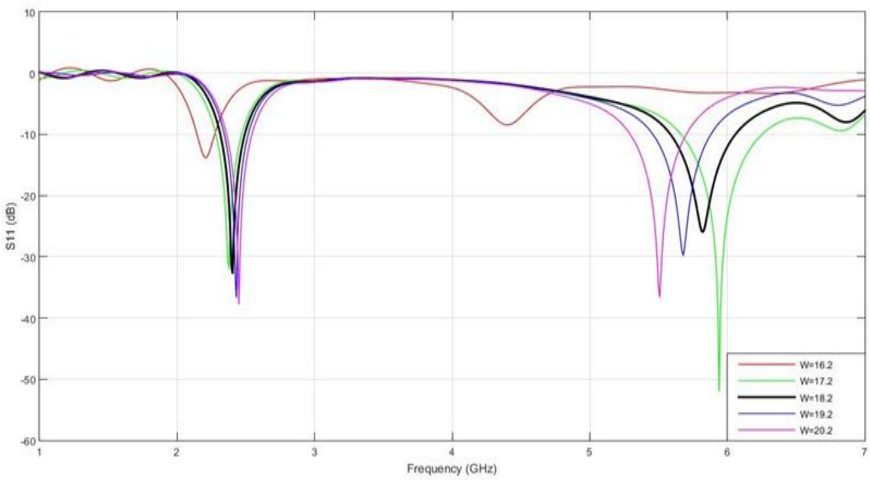


Figure 2. Effect of changing patch width to the reflection coefficient

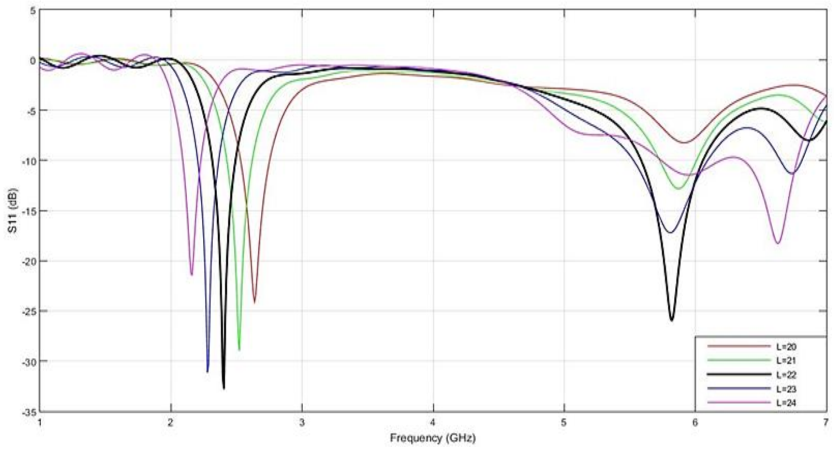


Figure 3. Effect of changing patch length to the reflection coefficient

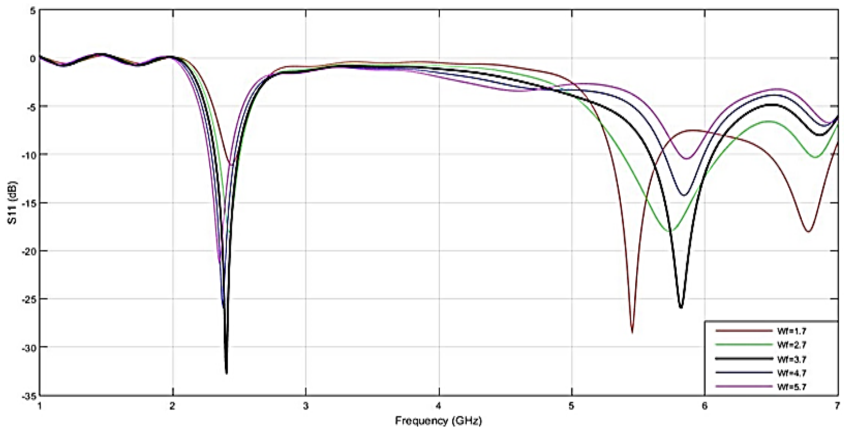


Figure 4. Effect of changing feeder width to the reflection coefficient

4. Results and Discussion

The return loss vs. frequency of the proposed antenna is shown in Figure 5. The return loss is found at 2.4 GHz and 5.8 GHz 32.77 dB and -25.955 dB respectively. The band width obtained at these frequencies are 7.4% in the range (2.3 GHz-2.492 GHz) and 8.17% in the range (5.586 GHz-6.06 GHz).

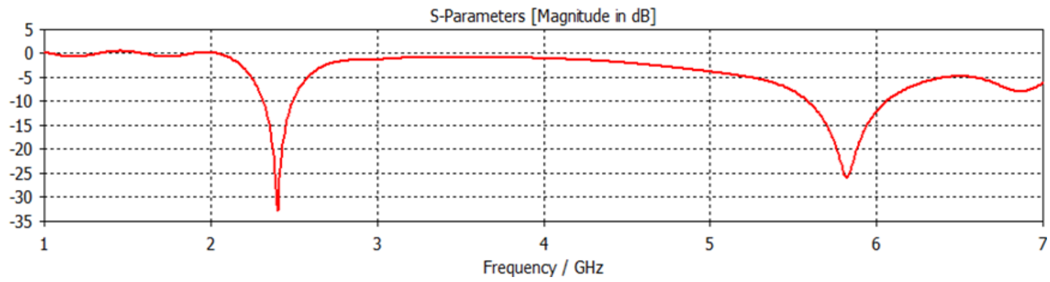


Figure 5. Return loss vs frequency of proposed antenna

Figure 6 shows the graph of VSWR at center frequencies for the proposed antenna less than 2. VSWR (voltage standing wave ratio) or standing wave ratio as a function of reflection coefficient, which explains power reflected from antenna.

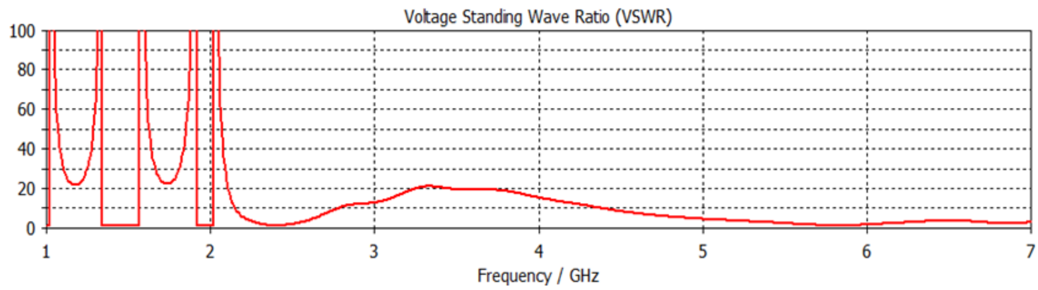
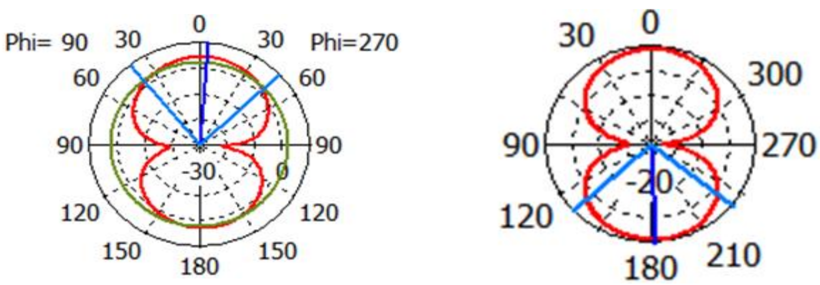


Figure 6. VSWR vs frequency of proposed antenna

$$\text{VSWR} = \frac{\Gamma+1}{\Gamma-1} \quad (9)$$

VSWR is always real and positive value for practical applications. Small value of VSWR means that the antenna is matched with the transmission line. Antenna is ideal at VSWR value equal to be 1. When antenna and feed are not matched, some electric energy cannot transfer to the antenna (i.e. reflection occurs). The polar plots for the directivity characteristic for the two frequencies are shown in Figure 7. The Gain of the proposed antenna for the two frequencies is shown in Figure 8. The 3D-radiation pattern for the proposed antenna for the two frequencies is shown in Figure 9. Figure 10 shows the current distribution for the proposed antenna at the designed frequencies.



(a) (b)

Figure 7. Polar plots for the directivity characteristic of the proposed antenna: (a) at 2.4GHz (b) at 5.8GHz

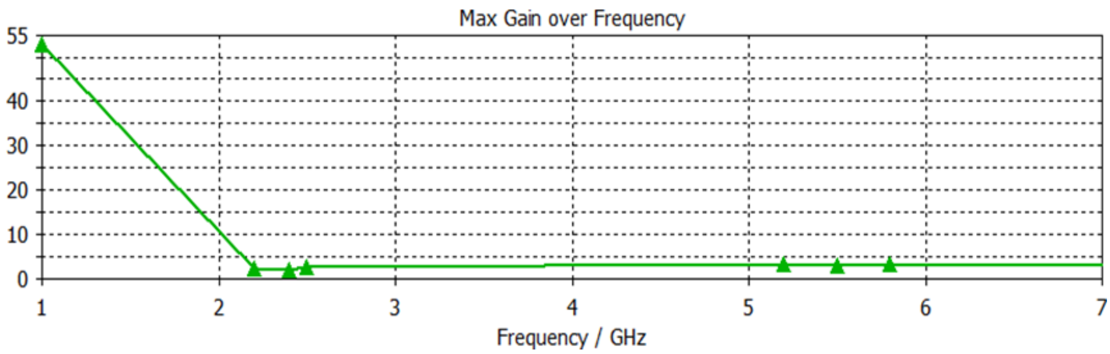
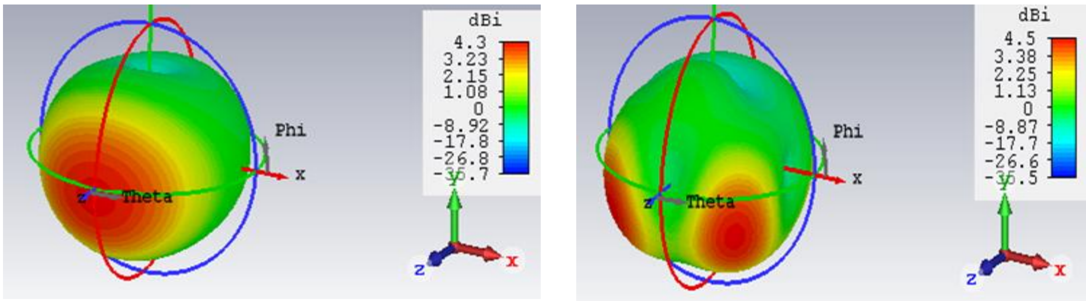
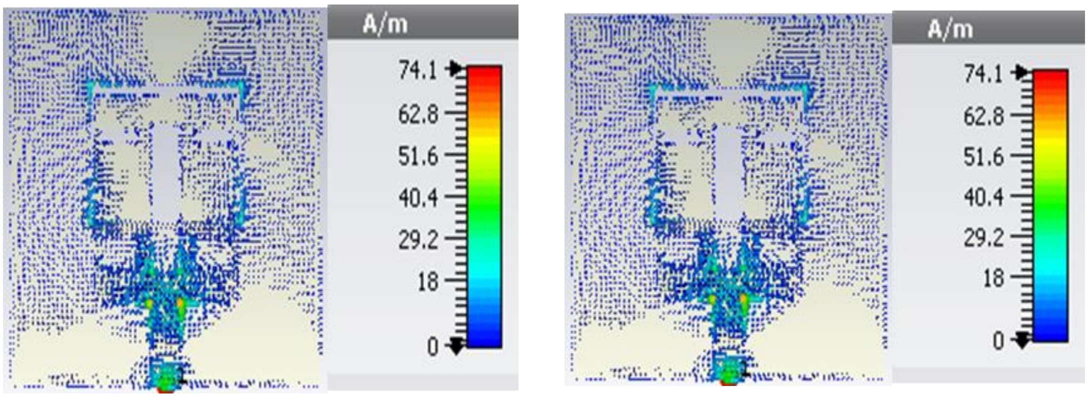


Figure 8. Gain of the proposed antenna: (a) at 2.4GHz and (b) at 5.8GHz



(a) (b)

Figure 9. 3D-radiation pattern for the proposed antenna: (a) at 2.4GHz and (b) at 5.8GHz



(a) (b)

Figure 10. Current distribution for the proposed antenna: (a) at 2.4GHz and (b) at 5.8GHz

Figure 11 shows the simulation and the measured results. It is noted that there is a slight different between the measured and simulation result. This different is attributed to the manufacturing errors which consist of variation of ε_r with the frequency, fringing effect and due to discontinuity. Fabricated antenna of front view and back view as shown in Figure 12.

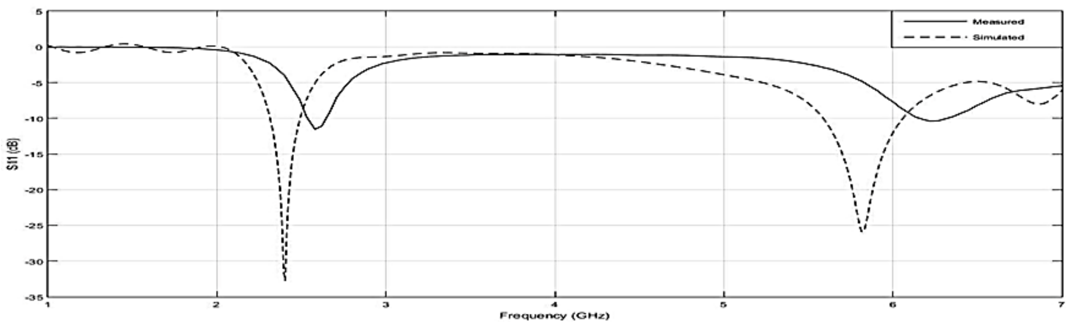
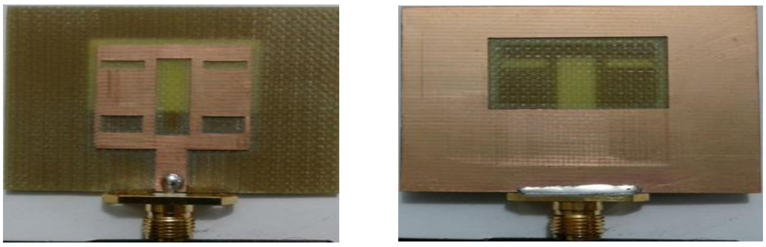


Figure 11. Measured and simulated reflection coefficient versus frequency

Table 2 shows a comparison among the proposed antenna and antenna in refrence in term of antenna size, resonant frequency and porpose of antenna. As we seen from this table that the proposed antenna is smaller in size and sutable for dual band.



(a) (b)

Figure 12. Fabricated antenna (a) front view (b) back view

Table 2. A comparison Among the Proposed Antenna and Antenna in Reference

Antenna	Antenna size (mm^2)	Resonant frequency GHz	Antenna porpose
Proposed antenna	40 × 40	2.4/5.8	Dual band
[3]	60 × 60	3.5 /5	Dual band
[4]	49 × 53	3.5/5.2	Dual band
[9]	44 × 44	1.8/2.1/3.5	Tri-band
[10]	59.5x47	1.56/2.45/3.53	Tri-band

5. Conclusions

In this paper, a dual band rectangular microstrip antenna at 2.4 GHz/5.8 GHz bands for Wi-Fi/WiMax applications is presented. The antenna consists of a rectangular patch with five slot in and a rectangular slot in ground. The result shows acceptable return loss, bandwidth and gain making it suitable for Wi-Fi/WiMax. The proposed antenna has two bands (2.314-2.492) GHz and (5.586-6.06) GHz in which the reflection coefficient is less than -10 dB.The proposed antenna was fabricated and simulated result (using CST) and measured result (using VNA) are obtained and compared.

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