A New Compact Slot Antenna for Dual-band WLAN Applications

Mahmood T. Yassen, Jawad K. Ali, Ali J. Salim, Seevan F. Abdulkareem, Ali I. Hammoodi, Mohammed R. Hussan

Abstract*— The design of a simple two patch slotted antenna with an offset microstrip feed line is presented as a candidate for use in 2.4/5.2 GHz wireless local area network, WLAN, applications. The first patch has been designed as a rectangular shape and the other has been designed as an inverted L shape with a protruding stub. The proposed antenna has been supposed to be printed on an FR4 substrate with a thickness of 0.8 mm and relative permittivity of 4.6. The resulting antenna has been found to have a compact size of 25.75x22 mm^2. The antenna offers dual –band characteristics with -10 dB return loss bandwidths of 2.3996 – 2.6309 GHz and 5.1335 – 5.8065 GHz for the lower and the upper resonating bands respectively. This dual-band resonant behavior makes the proposed antenna covering many communication services such as ISM, RFID, WLAN and WiFi applications. Modeling and performance evaluation of the proposed antenna have been carried out using a method of finite integration technique (FIT) based EM simulator, the CST MICROWAVE STUDIO.

***Index Terms*— Compact antennas, Dual band antennas, Slot antennas, Wireless applications, WLAN.**

I. INTRODUCTION

Many compact antennas with broadband and multiband or ultra wideband performances including dipole antenna, monopole antenna, and planar antenna configurations have been reported [1-6]. These are printed antennas with moderate radiating characteristics and can be operative at dual and multiple frequency bands. Moreover for the antenna fabrication and design, the slot structures require to provide a broad band and dual-band systems including the frequency ranges of ISM, WLAN, WiFi, and also the operating frequency of RFID.

Recently several interesting structures of slot antennas with diverse geometric configurations for the bandwidth enhancement and the size reduction functions have been widely studied [7-12]. These antennas are based on the slot design configurations and tunable antenna fabrications which have been developed to obtain wide impedance bandwidth and small size; but they have complex design structure. These slot antenna design structures have improved dual-band responses for wireless communications [13-18]. The feed of the slot antennas using a centered or an offset microstrip feed line have also been reported.

In this paper, a simple and compact dual slotted antenna with a microstrip line feed is proposed and discussed. The microstrip line is dislocated from the center of the antenna. The proposed antenna exhibits dual-band characteristics with the lower resonant band of (2.3996 – 2.6309) GHz and the upper band of (5.1335 – 5.8065) GHz. These bands are suitable to cover the Industrial Scientific Medical (ISM 2.4 – 2.484 GHz), Radio Frequency Identification (RFID 2.45GHz), Wireless Local – Area Network (WLAN 2.4 – 2.484 GHz), and Wireless Fidelity (WiFi 5.2 – 5.8 GHz).

II. THE PROPOSED ANTENNA STRUCTURE

The geometry of the proposed antenna is shown in Figure1. Figure1 (a) shows the layout of the antenna with respect to the coordinate system, while Figure1 (b) shows the front view of the structure which comprises two elements separated by a slot. The first element is designed as a rectangular shape with (Wp1×Lp1) dimensions, while the second element is designed as an inverted L shape consisting of Wp2, Lp2L and Lp2S dimensions and also contains a protruding stub of Wpst width and Lpst length at the lower edge of it which is located d away from the center of structure. The antenna is excited using an offset 50 ohm microstrip line as shown in Figure 1 (c) which represents the bottom view of the structure. The dimensions of the microstrip line are (Wf×Lf) where it is offset also by d from the center of structure and exactly beneath the protruding stub.

Figure 1 (c) also shows a reduced ground plane designed as L shape and conducted by the upper end of the microstrip line. The reduced ground plane consists of two parts connected to each other to form the L shape. The dimensions of the horizontal part of the ground plane are (Wgp1×Lgp1) while the dimensions of the vertical part are (Wgp2×Lgp2). The total size of the antenna is 25.75×22 mm^2, which is printed on an FR4 substrate with 0.8 mm thickness of and relative permittivity of 4.6. Table 1 summarizes the detailed dimensions of the antenna

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parameters as labeled in Figure 1.

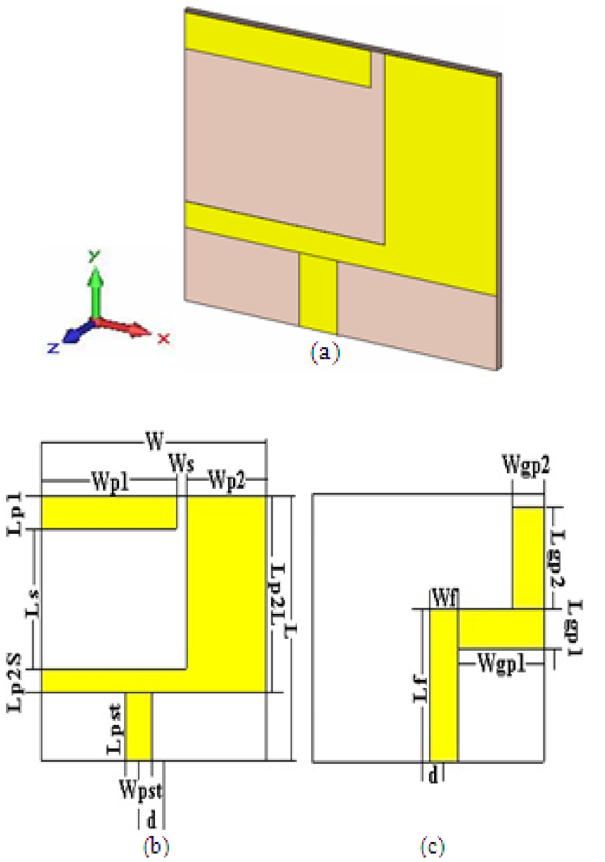

Figure: 1 (a) perspective view of the proposed antenna entire structure (b) front view (c) bottom view.

Table: 1 Summary of the Ref. Ant. dimensions, in mm

Wp1	*Lp1*	*Ws*	*Wp2*	*Lp2L*	*Lp2S*
15.5	2.75	1.15	9.1	16.35	2
Ls	***Wpst***	***Lpst***	***d***	***Wf***	***Lf***
11.6	3.15	5.65	-1.75	3.15	12.6
Wgp1	***Lgp1***	***Wgp2***	***Lgp2***	***W***	***L***
9.55	3.25	3.5	8.35	25.75	22

III. THE ANTENNA DESIGN

The proposed two patch slotted dual-band antenna has been designed to resonate with the lower frequency is located at 2.3996 GHz. After optimizing the different antenna parameters, the proper design has been chosen to get the required results with the dual-band characteristics.

During the design optimizations, it has been found that the dominant factors in the proposed antenna are the slot dimensions which form the internal edges of the two patches, (Wp1+Ls), in terms of the guided wavelength λg.

$$\lambda_g = \frac{\lambda_o}{\sqrt{\varepsilon_{eff}}} \qquad (1)$$

where ε_{eff} is the effective dielectric constant.

Then the lower resonant frequency, f_L, relative to the radiating elements edges is formulated by:

$$f_L \approx \frac{c_o}{2(L_s + W_{p1})\sqrt{\varepsilon_{eff}}} \qquad (2)$$

where c_o is the speed of light in free space.

IV. SIMULATION RESULTS AND DISCUSSION

The antenna structure of Figure 1, with the dimensions depicted in Table 1 has been modeled with the specified substrate. The resulting return loss response has been shown in Figure 2. The antenna has dual-band resonant behavior with bandwidths for return loss ≤ -10 dB extending from 2.3996 GHz to 2.6309 GHz for the lower band, and from 5.1335 GHz to 5.8065 GHz for the upper band respectively. This makes the proposed antenna suitable for ISM (2.4 – 2.484) GHz, RFID 2.45 GHz, WLAN (2.4 – 2.484) GHz, and WiFi (5.2 – 5.8) GHz wireless applications.

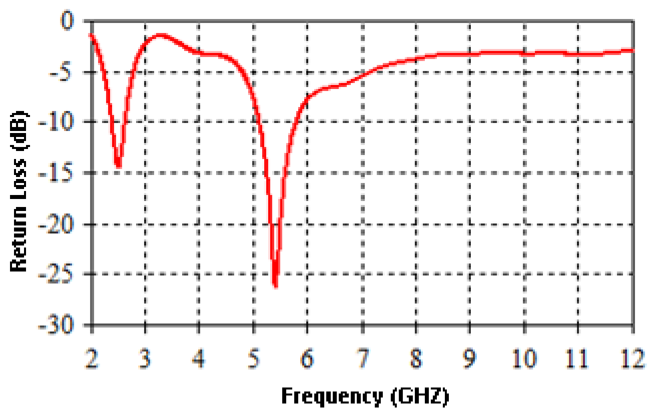

Figure: 2 Simulated return loss response of the modelled antenna.

The surface current distribution has been studied using simulation tool and is illustrated in Figure 3. Figure 3 (a) shows the surface current on the surfaces of the front and rear sides of the proposed antenna at 2.5152 GHz. The current is concentrated at the lower edge of the rectangular patch and at the internal edge of the other patch in front view but in rear view the current is concentrated at the horizontal part of the ground plane and also at the right edge of the vertical part.

Figure 3 (b) shows the surface current also for the front and rear sides of the proposed antenna but at 5.4385 GHz. The current is mainly concentrated at the horizontal part of the inverted L patch and the protruding stub in front view while in rear view the current is concentrated at the horizontal part of the ground plane and at the right edge of the vertical part like in rear view of Figure 3 (a). It is clear that the lower resonant frequency has been attributed by longer current path as depicted in Figure 3(a).

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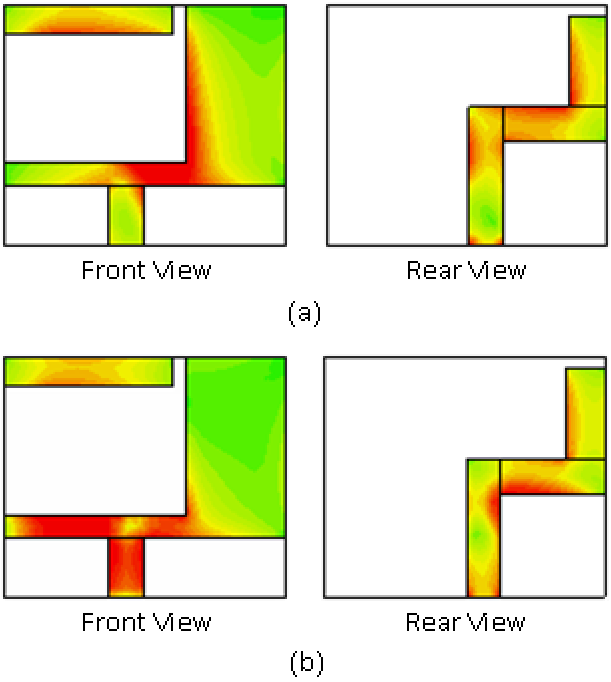
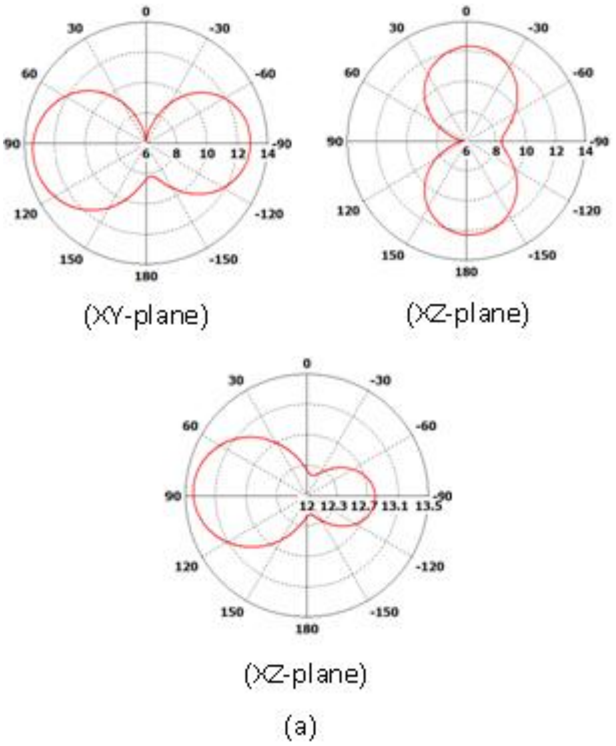


Figure: 3 Simulated current distributions on the surface of the proposed antenna at (a) 2.5152 GHz, (b) 5.4385 GHz.

The simulated far field radiation patterns for the total electric field of the proposed antenna at 2.5152 GHz and 5.4385 GHz are shown in Figure 4. Based on the results of the radiation patterns at XZ – plane, YZ – plane, XY – plane respectively, it can be seen that at 2.5152 GHz for XZ – plane the radiation pattern is close to figure eight.



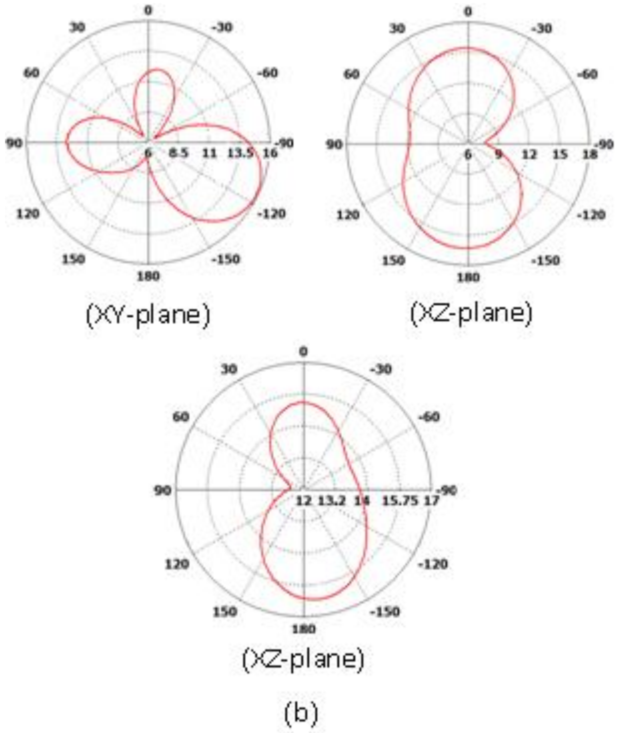


Figure: 4 Simulated far field radiation patterns for the total electric field at (a) 2.5152 GHz (b) 5.4385 GHz.

For YZ – plane and XY – plane the radiation patterns are close to rotated figure eight. At 5.4385 GHz a Capital B like shape is observed at XZ – plane. For YZ – plane an elliptical shape is obtained. At XY – plane, there are a few nulls in the radiation pattern but the overall omnidirectional characteristics are retained. The 3D radiation patterns corresponding to 2.5152 GHz and 5.4385 GHz are shown in Figure 5.

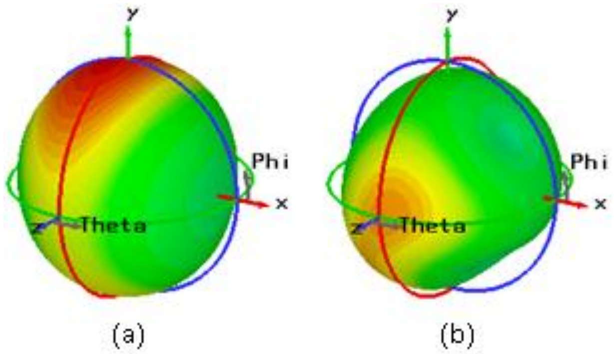


Figure: 5 Simulated total 3D electric field patterns of the proposed antenna at (a) 2.5152 GHz, (b) 5.4385 GHz.

The peak gain values in the two bands have been evaluated, as shown in Figure 6. In the lower frequency band, the peak gain plotted in Figure 6(a) is as large as 0.7 dBi. The gain versus frequency, for the upper band, is plotted in Figure 6(b), where the maximum gain of copolarization is found to be of about 1.3 dBi. Also the gain of the antenna remains almost constant throughout the two operating bands as illustrated in Figure 6.

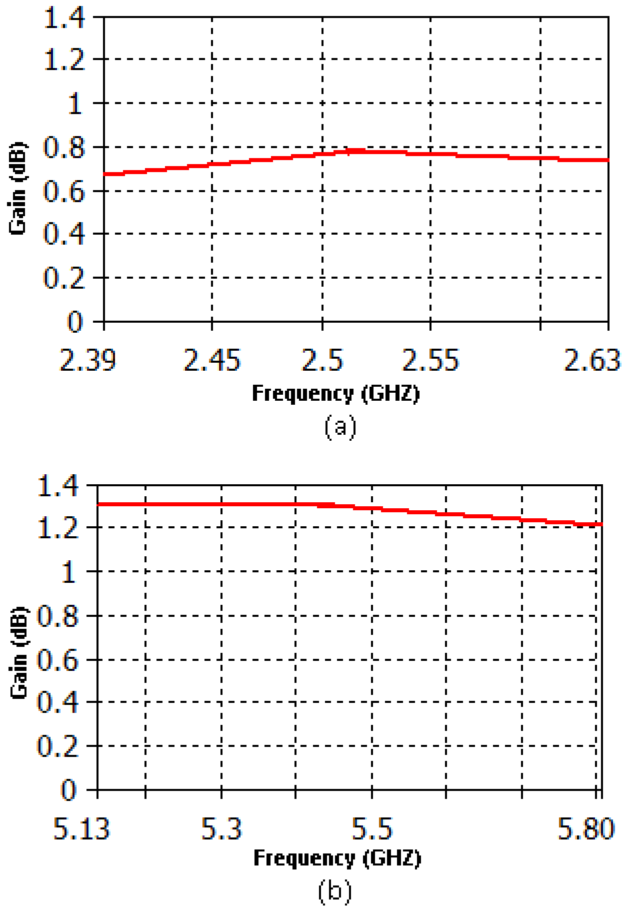


Figure: 6 The simulated gain of the proposed antenna at: (a) the lower band, and (b) the upper band.

V. PARAMETRIC STUDY

The effects of the feed line and the protruding stub location on the antenna performance have been investigated in this section. The distance between the structure center and the protruding stub center called d in Figure1 (a) of the proposed antenna. The distance has been varied from 0 to -1.75 mm. The observed reflection coefficients are shown in Figure 7. As d decreases from 0 to -1.75 mm, it can be clearly observed that both the resonant frequencies centered at 2.5152 GHz and 5.4385 GHz increase. For the both frequencies, as the distance between the two centers varied the values of reflection coefficient also vary.

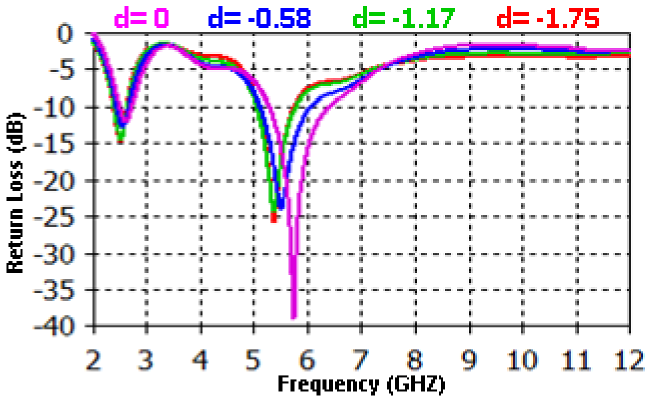


Figure: 7 Simulated return loss responses of the modeled antenna for different protruding stub positions.

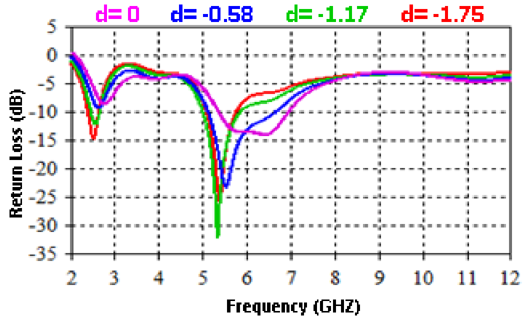


Figure: 8 Simulated return loss responses of the modeled antenna with the feed line position is a parameter.

VI. CONCLUSION

A compact two patch slotted antenna fed by an offset microstrip line is proposed in this paper as a candidate for dual-band WLAN applications. The proposed antenna has been analyzed and its performance has been evaluated using a method of finite integration technique based EM simulator, CST MWS. Simulation results showed that the antenna offers dual-band response covering the operating bandwidths for ISM, RFID, WLAN and WiFi operations. In spite of the compact size, the simple antenna demonstrates acceptable reflection coefficient, close to omnidirectional patterns over the two operation bands. The nearly omnidirectional radiation is suitable for wireless communication applications. A parametric study has been conducted to explore the effects of the location of protruding stub and the effects of the location of the microstrip feed line on the resonant frequencies and the values of their reflection coefficients.

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