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Simulation of Rectangular Slot-Ring Antenna Fed by Microstrip Line With Tuning Stub for WLAN/WIMAX Communication Applications

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Abstract

This research presents the simulations of rectangular slot-ring antenna fed by microstrip line with tuning stub for WLAN/WiMAX communication operations. The proposed antenna consists of a rectangular slot-ring shaped antenna cutting on the ground plane of the front side and microstrip feed line with tuning stub on the backside for excitation. This slot antenna is analyzed by using MoM method of IE3D software for study characteristics of the antenna. In this research are analyzed of return loss (S_{11} parameter), input impedance (Z_{in}), VSWR, current distributions, gain and far field radiation patterns, respectively. The simulated results of the proposed antenna can be obtained an impedance bandwidth of frequency band of 4.42 GHz, coverage frequency band from 2.17 to 6.59 GHz. Therefore, it can cover the requirement of the bandwidths of WLAN and WiMAX (2-6 GHz) communication systems. The average gain of the proposed antenna is 4 dBi, and the far-field radiation pattern in azimuth plane (xy-plane) of frequencies is omni-directional and elevation plane (xz-plane) of frequencies is bi-directional.

Keywords: Slot antenna, Wireless communication, Tuning stub

INTRODUCTION

Nowadays, wireless communication technology is most significance for wireless communication systems. For example, Wireless Local Area Networks (WLAN) technology operate at the frequency bands 2.4 GHz, 5.2 GHz (5.15-5.35 GHz), 5.8 GHz (5.725–5.85 GHz) are defined in IEEE 802.11a/b/g standard and Worldwide Interoperability for Microwave Access (WiMAX) technology operate at the frequency bandwidth from 2-6 GHz for mobile WWAN (Wireless Wide area Network: WWAN) is defined in IEEE 802.16e standard. The benefits of implementing WLAN and WiMAX are wireless connections can extend or replace a wired infrastructure, increased productivity for the mobile employee and easy access to the Internet in public places, respectively. Therefore, it should design and development of wireless device for supports this technology.

The slot antenna is device which can be used for transmitting-receiving of the signals. Because, the advantage of the antenna are low profile, small size, light weight and widely used in wireless and mobile communications systems. Thus, the researcher of the telecommunication research group are designed and development of the antenna for single frequency [1-2], dual frequency [3-4] and multi frequency [5-7]. These researches are design for supporting the only individual frequency. Besides, design of wideband slot antenna for WLAN applications [8-11] but the impedance bandwidth less than 3 GHz not coverage the frequency band of WLAN/WiMAX operations and design of wideband antenna by using tuning stub for enhance bandwidth [12-15] but the antennas are rather complex for make the photo type. Moreover, the researchers design the UWB antenna for UWB communication systems from the frequency band at 3 GHz to 10.6 GHz [16-18]. The antennas design for UWB systems which not support WLAN frequency band below 3 GHz. Then, it should be design used technique enhance bandwidth by using various tuning stub and shaped of the antenna for support the frequency band of WLAN/WiMAX operations.

In this paper presents design and development of rectangular slot-ring antenna fed by microstrip line with tuning stub for WLAN/WiMAX communication systems. The structure of proposed antenna consists of a rectangular slot-ring shaped antenna cutting on the ground plane for used as a radiator and microstrip feed line with hexagonal shaped with insert line slot of tuning stub on the backside for excitation. The slot antenna is analyzed of return loss (S_{11} parameter), input impedance (Z_{in}), VSWR, current distributions, gain and far field radiation patterns by using MoM method of IE3D software. From the simulation results of the proposed antenna can cover the impedance bandwidths of WLAN/WiMAX (2-6 GHz) communication systems.

ANTENNA DESIGN

Figure 1 shows the geometry and configuration of the rectangular slot-ring antenna fed by microstrip feed line with rectangular tuning stub and with line slot insertion on the tuning stub. The proposed slot antenna consists of a rectangular slot-ring shaped antenna etching out from the ground plane for used as a radiator, with a rectangular shaped tuning stub and with line slot insertion on the tuning stub in other side for excitation is shown in Figure 1. The slot antenna is designed for WLAN/WiMAX communication systems. In this design of the proposed slot antennas and feeding structures are made on FR4 substrate with thickness (h) of 1.6 mm, relatively permittivity (ε_r) of 4.5 and loss tangent of 0.02, respectively.

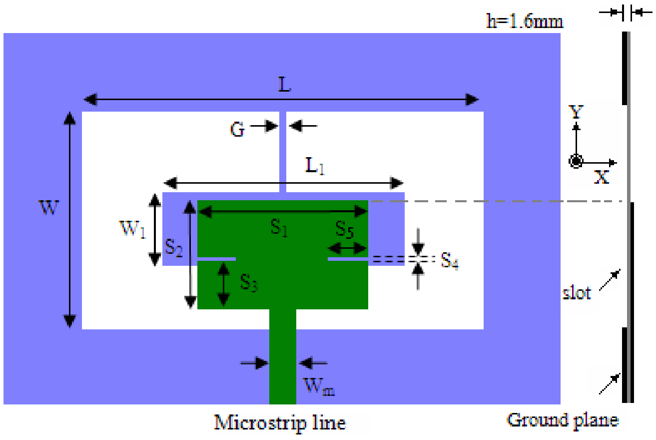

Figure 1: Geometry and configuration of the rectangular slot-ring antenna fed by microstrip feed line with rectangular tuning stub and with line slot insertion on the tuning stub

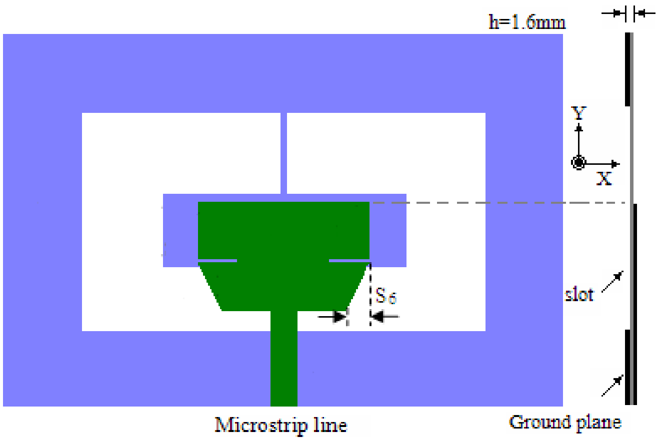

Figure 2: Geometry and configuration of the rectangular slot-ring antenna fed by microstrip feed line with hexagonal tuning stub and with line slot insertion on the tuning stub

The configuration of the proposed slot antenna are: outer length of the slot-ring shaped (L), outer width of the slot-ring shaped (W), inner length of the slot-ring shaped (L_1), inner width of the slot-ring shaped (W_1), width of gap etching out from the slot-ring shaped (G), length of the tuning stub (S_1), width of the tuning stub (S_2), width below of the tuning stub (S_3), size of the line slot insertion on the tuning stub (S_4), width of the line slot insertion on the tuning stub (S_5), as shown in Figure 1. In addition, it extended the slot antenna from Figure 1 by cutting rectangular tuning stub to be hexagonal tuning stub in Figure 2 for enhance bandwidth. Thus, this antenna added one parameter is length of cutting rectangular tuning stub to be hexagonal tuning stub (S_6).

The guide wavelength (λ_g) [19] at 2.4 GHz is given by

$$\lambda_g = \frac{c}{f\sqrt{\varepsilon_{eff}}} \tag{1}$$

where

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W_m}\right]^{-1/2} \tag{2}$$

and f is the design frequency, light velocity c = 2.998 × 10^8 m/s, ε_{eff} is effective dielectric constant of the substrate, ε_r is relatively permittivity of the substrate, h is thickness of the microstrip antenna and W_m is width of the microstrip feed line.

The width of the microstrip feed line for corresponding to the characteristic impedance of 50 ohms transmission line [19] is given by

$$Z_0 = A(C - B) \tag{3}$$

where

$$A = \frac{119.9}{\left[2(\varepsilon_r + 1)\right]^{1/2}} \tag{4}$$

$$B = \left[\ln\left(\frac{\pi}{2}\right) + \frac{\ln(4/\pi)}{\varepsilon_r}\right]\frac{\varepsilon_r - 1}{2(\varepsilon_r + 1)} \tag{5}$$

$$C = \ln\left\{\frac{4h}{W_m} + \left[\left(\frac{4h}{W_m}\right)^2 + 2\right]^{1/2}\right\} \tag{6}$$

SIMULATION RESULTS AND DISCUSSION

The Geometry and configuration of the rectangular slot-ring antenna fed by microstrip-fed with tuning stub is shown in Figure 1. The proposed slot antenna is fabricated on an inexpensive FR4 substrate with thickness (h) of 1.6 mm, relatively permittivity or dielectric constant (ε_r) of 2.2, loss tangent of 0.02. The microstrip feed line is designed with the conductor strip line (W_m) of 3.0 mm corresponding to the characteristic impedance of 50 ohms transmission line. The antennas are analyzed by using IE3D [20] software which is based on the Method of Moments (MOM).

The return loss or reflected loss (S_{11}) is a parameter of antenna for represents the reflected wave return from load. This parameter is given as follows

$$S_{11} = \frac{\Im\left[V_{ref}(t)\right]}{\Im\left[V_{inc}(t)\right]} e^{2\gamma L} \quad (7)$$

When $\Im$ represents a Fourier Transform and L is the length between an observing point and a reference point.

The propagation constant γ can be defined by

$$\gamma = \alpha + j\beta \quad (8)$$

where α and β are attenuation and phase constant.

The first proposed design can be further enhanced by adjusting width of tuning stub S_1, S_2, S_3, S_4, S_5, and S_6, respectively. In this paper, it will show the effect of adjusting six parameters by fixing the value of other parameters: L, W, L_1, W_1, G, h, W_m are as follows: L= 50 mm, W=27 mm, L_1=30 mm, W_1=9 mm, and G=0.5 mm, h=1.6 mm, W_m = 3.0 mm, respectively.

A. Effect of Adjusting Length of the Tuning Stub (S_1)

First, shows the effect from adjusting the length of the tuning stub (S_1) and S_1 is adjusted to 20 mm, 21 mm and 22 mm by fixed S_2= 13.5 mm, S_3= 6 mm, S_4= 3 mm, S_5= 0.4 mm, and S_6= 4 mm, respectively. The simulation results of return loss (S_{11}) in adjusting S_1, is shown in Figure 3.

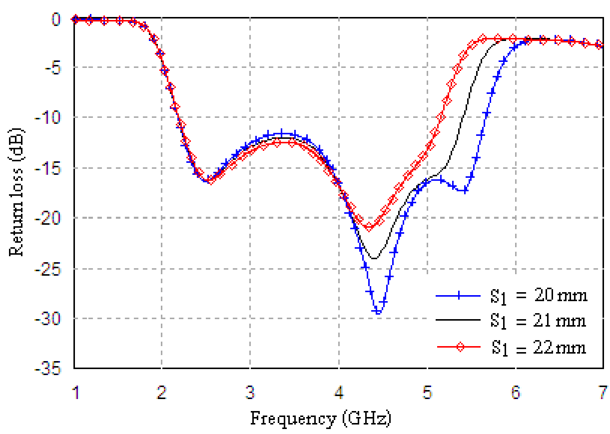

Figure 3: The return loss (S_{11}) in the case of adjusting S_1

From Figure 3, it is shown that the simulation results of return loss (S_{11}) in three adjusting the length of the tuning stub (S_1), it will affect on the return loss in high frequency band from 5.2 GHz to 5.7 GHz which has the good matching impedance for enhance wide bandwidth. The optimal length of the tuning stub (S_1) is 20 mm and use this value for study other parameters in the next topic.

B. Effect of Adjusting Width of the Tuning Stub (S_2)

Second, shows the effect of the slot antenna by adjusting the width of the tuning stub (S_2). The parameter of S_2 is adjusted to 12.5 mm, 13.5 mm and 14.5 mm by fixed S_1= 20 mm. The simulation results of return loss (S_{11}) in adjusting S_2, is shown in Figure 4.

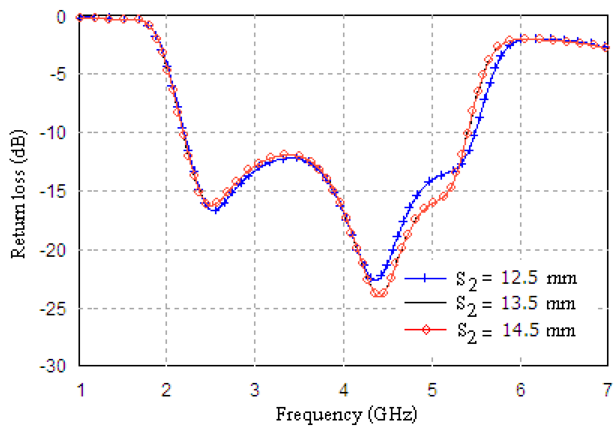

Figure 4: The return loss (S_{11}) in the case of adjusting S_2

The simulation results of return loss (S_{11}) in three adjusting S_2 are shown in Figure 4. It is shown that the width of the tuning stub (S_2), mainly affect on the return loss at high frequencies band which has the optimized impedance bandwidth when S_2 is 12.5 mm and use this value for study other parameters.

C. Effect of Adjusting Width Below of the Tuning Stub (S_3)

Third, study characteristic of return loss adjust the width below of the tuning stub (S_3). The parameter of S_2 is adjusted to 5 mm, 6 mm and 7 mm by fixed S_1= 20 mm and S_2= 12.5 mm. The simulation results of return loss (S_{11}) in adjusting S_3, is shown in Figure 5.

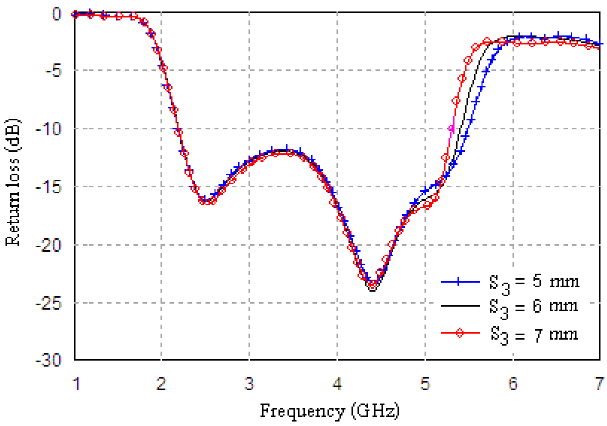

Figure 5: The return loss (S_{11}) in the case of adjusting S_3

Figure 5 shows the simulation results of return loss (S_{11}) in case adjusting three value of the tuning stub (S_3). It can see that the tuning stub (S_3) will affect the return loss at high frequency band and increase of the bandwidth. The optimal value of S_3 is 5 mm.

D. Effect of Adjusting Size of the Line Slot Insertion on the Tuning Stub (S_4)

Fourth, size of the line slot insertion on the tuning stub (S_4) is adjusted to 0.5 mm, 1 mm and 2 mm by fixed S_1= 20 mm S_2= 12.5 mm, and S_3= 5 mm. The simulation results of return loss by adjusting S_4 are shown in Figure 6.

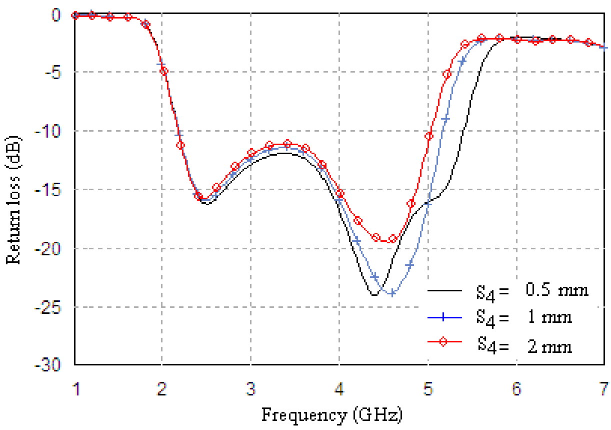

Figure 6: The return loss (S_{11}) in the case of adjusting S_4

Figure 6 shows the simulation results of return loss (S_{11}) in case adjusting parameter S_4, will affect of the return loss at high frequency band and make enhance bandwidth. The optimal of S_4 is 5 mm and uses this value for study characteristic of parameters S_5 in the next section.

E. Effect of Adjusting Width of the Line Slot Insertion on the Tuning Stub (S_5)

Fifth, study effect of the antenna by adjusting width of the line slot insertion on the tuning stub (S_5) is adjusted to 4 mm, 5 mm and 6 mm by fixed S_1= 20 mm S_2= 12.5 mm, S_3= 5 mm. and S_4= 5 mm. The simulation results from adjusting S_5, are shown in Figure 7.

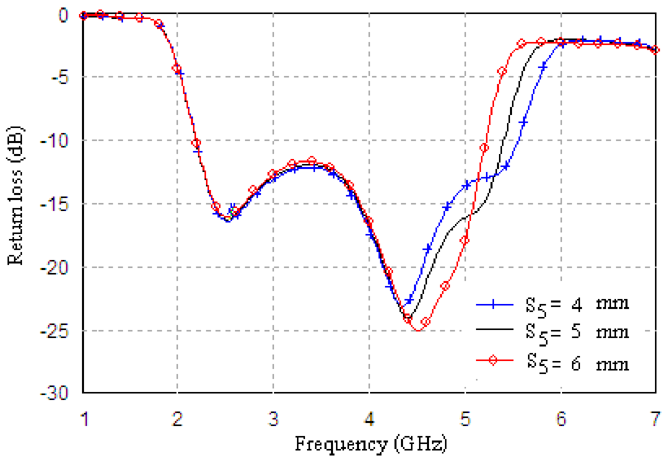

Figure 7: The return loss (S_{11}) in the case of adjusting S_5

The simulated return loss of the slot antenna in case adjusting width of the line slot insertion on the rectangular shaped tuning stub (S_5). It can see that the width of the tuning stub S_5, mostly affect on the return loss at high frequencies band and enhance bandwidth which has the optimized impedance bandwidth when S_5 is 4 mm.

F. Effect of Adjusting Length of Cutting Rectangular Tuning Stub to be Hexagonal Tuning Stub (S_6)

Finally, it will adjust length of cutting rectangular tuning stub to be hexagonal tuning stub (S_6) to 2 mm, 3 mm and 4 mm by fixed S_1= 20 mm S_2= 12.5 mm, S_3= 5 mm. S_4= 5 mm and S_5= 4 mm, respectively. The simulation results of return loss by adjusting S_6 are shown in Figure 8.

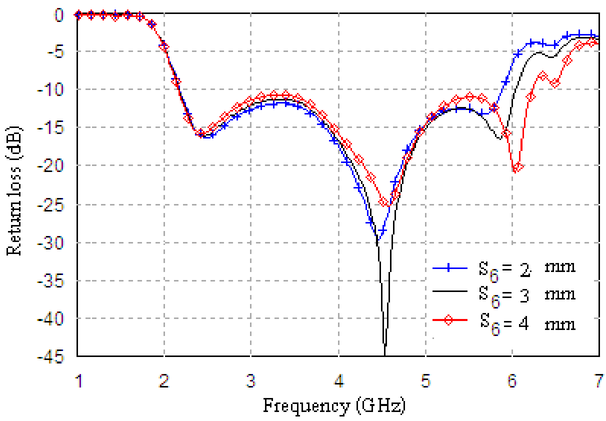

Figure 8. The return loss (S_{11}) in the case of adjusting S_6

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The simulation results of return loss (S_{11}) in adjusting length of cutting rectangular tuning stub to be hexagonal tuning stub (S_6) may affect on return loss in high frequency band as shown in Figure 8. It can see that when adjusting parameter S_6, it can be increase the impedance bandwidth of the slot antenna. The optimized impedance bandwidth when lengths of cutting rectangular tuning stub to be hexagonal tuning stub (S_6) of 4 mm.

G. The Proposed Slot Antenna Fed by Microstrip Line with Tuning Stub for WLAN/WiMAX Applications

Characteristics of slot antenna from adjusted six parameters (S_1, S_2, S_3, S_4, S_5, and S_6) which will effects on matching impedance over the entire for increase wide bandwidth. Finally, the optimal value are S_1= 20 mm S_2= 12.5 mm, S_3= 5 mm. S_4= 5 mm, S_5= 4 mm and S_6= 4 mm for good matching in wideband coverage WLAN/WiMAX applications. The simulation result of the proposed slot antenna is shown in Figure 9.

The maximum impedance bandwidth of 4.42 GHz, it can coverage frequency band from 2.17 to 6.59 GHz as shown in Figure 9. Figure 10 is shown the voltage standing wave ratio (VSWR) of proposed slot antenna. The VSWR of this antenna may be considered at VSWR $\leq$ 2, coverage the frequency band from 2.17 to 6.59 GHz.

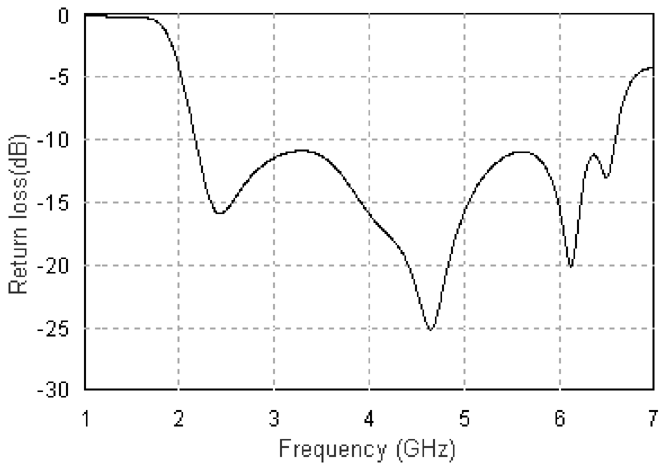


Figure 9. The return loss (S_{11}) of the proposed slot antenna

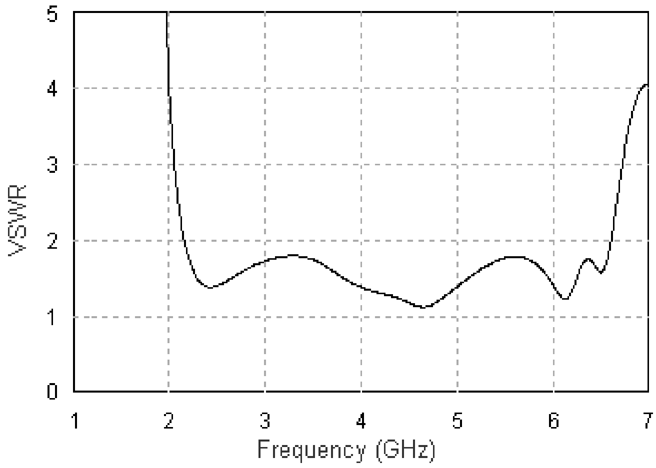


Figure 10. VSWR of the proposed slot antenna

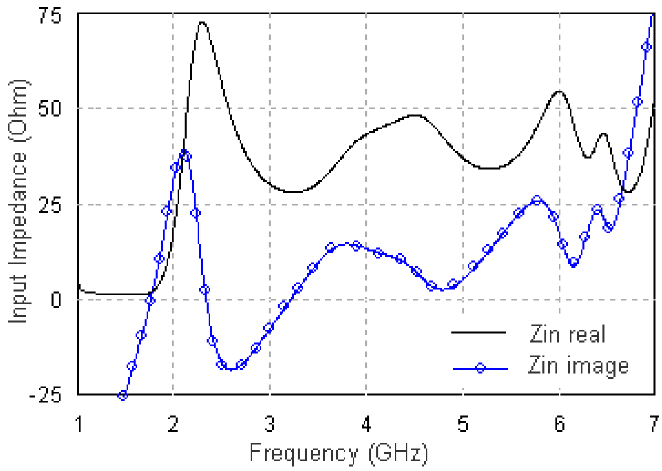
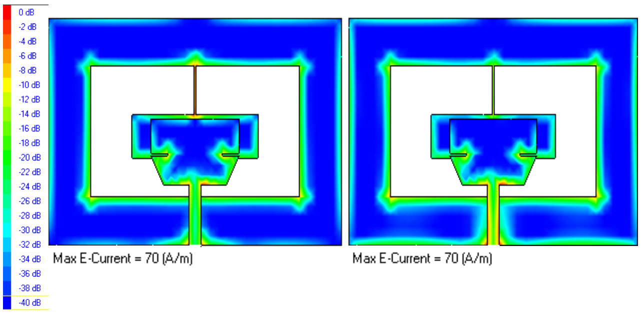


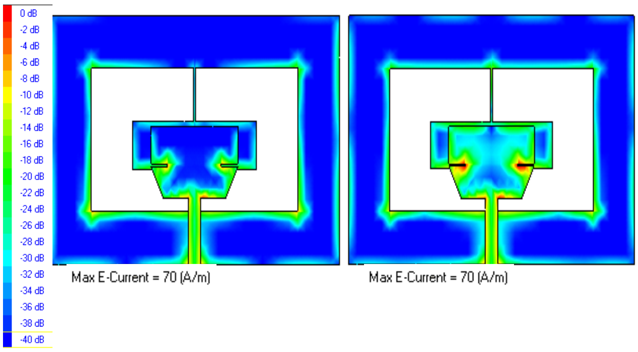
Figure 11. Input impedance (Z_{in}) of the proposed slot antenna

The input impedance Z_{in} is the complex number, which find out by using the parameter S_{11} and characteristic impedance Z_0 of the microstrip line. The input impedance [19] is given as follows:

$$Z_{in} = \left\lfloor \frac{1+(S_{11})}{1-(S_{11})} \right\rfloor \quad (9)$$



(a) frequency at 2.5 GHz (b) frequency at 3.5 GHz



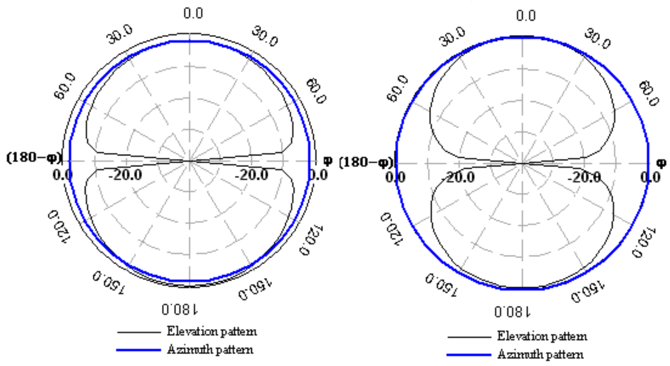
(c) frequency at 5 GHz (d) frequency at 6 GHz

Figure 12. Current distributions of the proposed slot antenna

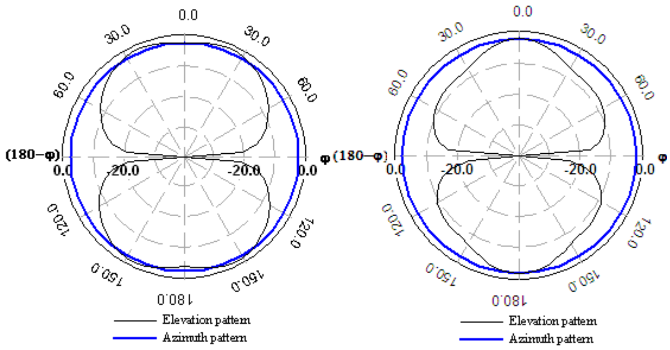
Figure 12 shows the simulated surface current distribution of the proposed slot antenna at 2.50 GHz, 3.5 GHz, 5 GHz and 6 GHz, respectively. It can be observed that the surface current increases on the width of gap etching out from the slot-ring shaped (G) and below of the hexagonal tuning stub at 2.50 GHz, as shown in Figure 12(a). The surface current distribution markedly increases on below of hexagonal tuning stub, as shown in Figure 12(b). Similarly, the impedance more acutely increases at below of hexagonal tuning stub at 5 GHz, as shown in Figure 12(c). Moreover, Figure 12(d) shows the surface current distributed most increase markedly on of hexagonal tuning stub and line slot in tuning stub at 5.80 GHz. It can independently control the frequency in the wideband by varying the length and width of hexagonal tuning stub and with line slot insertion on the tuning stub, respectively.

The radiation patterns of the proposed slot antenna at 2.5 GHz, 3.5 GHz, 5 GHz and 6 GHz is shown in Figure 13.

The simulation radiation pattern of the slot antenna on x-y plane (azimuth pattern) and x-z plane (elevations pattern) at 2.5 GHz, 3.5 GHz, 5 GHz and 6 GHz are omni-directional on x-y plane and bi-directional on x-z plane, as shown in figure 13.



(a) frequency at 2.5 GHz (b) frequency at 3.5 GHz



(c) frequency at 5 GHz (d) frequency at 6 GHz

Figure 13. Radiation patterns of proposed slot antenna

The simulation results of gains of the proposed antenna for WLAN/WiMAX communication as shown in Figure 14.

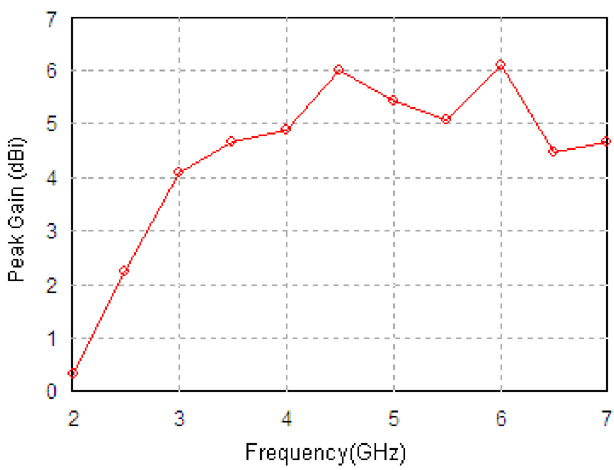


Figure 14. Gain of proposed slot antenna

From Figure 14, it is shown that the maximum gain of 6 dBi at 4.5 GHz, and 6 GHz and the average gain of the proposed antenna is 4 dBi.

Therefore, this proposed antenna can be used for WLAN/ WiMAX communication systems.

CONCLUSION

In this paper presents the simulations of slot antenna fed by microstrip line with tuning stub for WLAN/WiMAX operations. The proposed antenna consist a wide slot-ring shaped antenna cutting on the ground plane of the front side and microstrip feed line with tuning stub on the backside for excitation. This slot antenna is analyzed by using MoM method of IE3D software. The simulated results of the proposed antenna can be obtained an impedance bandwidth of frequency band of 4.42 GHz, coverage frequency band from 2.17 to 6.59 GHz for WLAN and WiMAX operations. The average gain of the proposed antenna is 4 dBi, and the far-field radiation pattern in azimuth plane (xy-plane) is omni-directional and elevation plane (xz-plane) is bi-directional

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