2nd Int'l Conf. on Electrical Engineering and Information & Communication Technology (ICEEICT) 2015
Jahangirnagar University, Dhaka-1342, Bangladesh, 21-23 May 2015

Investigation of Multiband Antenna for Wireless Communication

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***Abstract*—In this paper, design and analysis of a rectangular microstrip patch antenna with two U-shaped slots for multi operating bands of wireless communication systems have been presented. The proposed antenna is placed on the substrate of Taconic TLY-5 dielectric material and excited by 50Ω microstrip feed line. The operating bands are centered at 1.60GHz, 2.40GHz, 4.27GHz, 5GHz, 6GHz, 8.1GHz and 9.2 GHz. In this work, GEMS Simulator is used as the software environment in order to design and analyze the performance of antenna. In addition, the return loss of the designed antenna has been analyzed by varying slot width. Based on the results and analysis, it is noticed that the antenna shows better performance when the widths of the first and second slots are 5mm and 5.8mm respectively. Moreover, the directivity, gain and 3D radiation patterns of the designed antenna are acceptable for wireless communication.**

***Keywords*—Microstrip patch antenna, double U-slot, multiband.**

I. Introduction

With the rapid development of wireless communication systems, multiband antennas are playing important role for wireless service requirements. Nowadays, Bluetooth, Worldwide Interoperability for Microwave Access (WiMAX) and Wireless Local Area Network (WiLAN) wireless networking systems along with satellite communication have become more favorable due to tremendous improvement in microstrip patch antenna. In addition, microstrip patch antenna obtains much popularity due to low weight, low profile planar configuration, low fabrication costs and capability to integrate with microwave integrated circuits technology [1]. On contrary, the most serious limitation of the microstrip patch antenna is the narrow bandwidth of the basic element. During the past years, many methods have been proposed to enhance its bandwidth such as adding an impedance matching network, using stacked patches, using edge-coupled parasitic patches and using lossy materials [2]-[4]. The conventional single U-slot patch antenna achieves an input impedance bandwidth of

30% and its impedance characteristics are further improved with electromagnetic coupling using double U-slot or a L-probe and stacked rectangular patch which has a 44.4% bandwidth [5]. Moreover, the antenna is used for multiband operations with the variation of U-slot width. However, the microstrip patch antenna is very well suited for wireless applications which include wireless communication systems, cellular phones, pagers, radar systems and satellite communication systems [2,3]. In literature, researchers suggested a number of techniques for designing multiband antenna. In [6], a printed multiband antenna has been designed and fabricated for mobile and wireless communications using meandering strip technique but the designed antenna is not applicable for X-band. Moreover, in [7], a printed multiband MIMO antenna has been designed using planar technology but this antenna also apart from X-band applications. In [8, 9], a multiband antenna has been presented for WLAN/Cellular applications and the antenna shows acceptable return loss only for three bands. In [9, 10], a broadband double U-slot rectangular microstrip antenna has been designed for single industrial scientific and medical(ISM) band applications. Moreover, a double U-Slot loaded stacked microstrip patch antenna with 2×2 array has been presented in [11] for multiband operations. But, it shows greater return loss for X-band results in a poor radiation pattern.

In this paper, a double U-slot microstrip patch antenna has been presented for operating at multiband application of wireless communication system. In addition, it exhibits acceptable gain, directivity and radiation pattern along with minimum return loss for both ISM and X-band applications. Moreover, the performance parameters of designed antenna have been analyzed for three bands.

In this work, section I will describe the antenna design procedures using suitable dimension parameter. Then simulation results of the proposed antenna will be presented in section III which includes return loss, gain, directivity and 3D radiation pattern analysis. Finally, section IV will summarize the antenna performance.

II. Antenna Design

The patch size of a microstrip patch antenna depends on several significant parameters which include resonant frequency f_r, dielectric constant of substrate material ϵ_r, substrate height (h), effective dielectric constant ϵ_{reff}, extended length ΔL and Light Velocity (c). Among these parameters only resonant frequency, dielectric constant and light velocity form a relation which is used for calculating patch width (W) of the proposed antenna. However, the patch length (L) is determined using related parameters from equation (4).

$$W = \frac{c}{2f_r\sqrt{\frac{\epsilon_r + 1}{2}}} \tag{1}$$

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \tag{2}$$

$$\Delta L = 0.421h\frac{(\epsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\epsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \tag{3}$$

$$L = \frac{1}{2f_r\sqrt{\epsilon_{reff}}\sqrt{\mu_0\epsilon_0}} - 2\Delta L \tag{4}$$

TABLE I

DIMENSION PARAMETERS OF PROPOSED ANTENNA

Antenna Elements	Dimensions in mm
Patch Width, W	45.6
Patch Length, L	38.1
Length of Feed Line, L5	21.8
Width of Feed Line, W5	1
Width of First U-Shape, W1	35
First U-Slot Length, L6	33
Width of Slits 1 ,W6	5.3
Width of second U-Shape, W2	15
Length second U-Slot, L2	14.1
Width of slits 2, W3	5
Effective Length of First U-Slot, L1	27
Effective Length of Second U-Slot, L3	9.4
Width of Port, W4	4.9
Length of Port, L4	2
Width of Substrate	75
Length of Substrate	75
Thickness of Substrate	1.58

Fig. 1 shows the general configuration of proposed microstrip patch antenna where a copper patch with two U-shaped slots is placed over the substrate of Taconic TLY-5 dielectric material and a ground plane is printed on the other side of the patch. The dielectric constant of the substrate material is 2.2. Moreover, the proposed antenna is excited by a 50Ω microstrip feed line which is connected to the feeding pin.

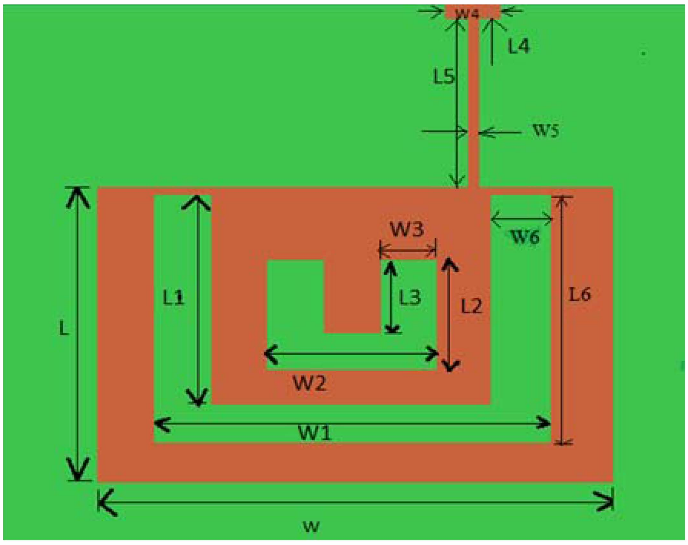


Fig. 1: Structure and detail dimensions of proposed antenna.

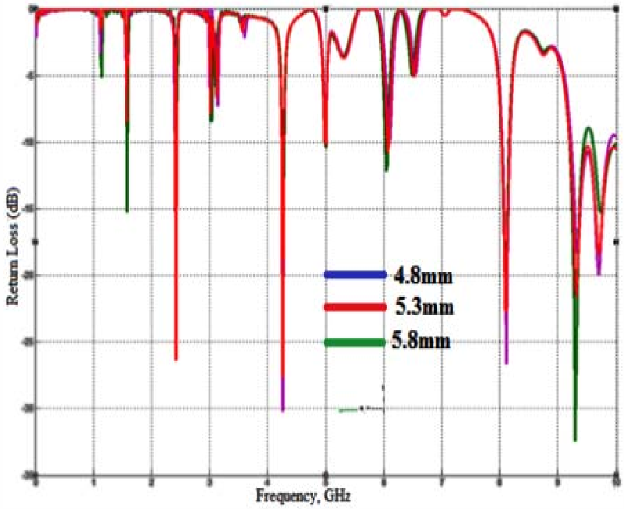
III. Simulation Results And Analysis

In this section, the performance parameters which include return loss, gain, directivity and radiation patterns of proposed antenna have been analyzed sequentially.

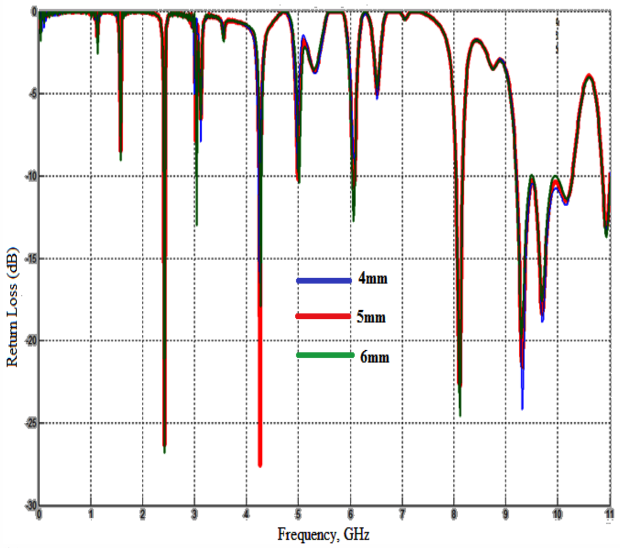
A. *Return Loss Analysis*

Fig. 2(a) shows that the return loss response for multiband antenna with the variation of Width of Slits 1 (W6) along with considering Width of slits 2 (W3) value 5mm. In this analysis, antenna shows the minimum return loss about -32.5dB at 9.2GHz for 5.8mm first slot width. Moreover, it is also shown that the return loss values for 4.8mm, 5.3mm and 5.8mm slot widths have become acceptable for several bands which include 1.6GHz, 2.4GHz, 4.27GHz, 5GHz, 6GHz and 8.1GHz. On the contrary, the proposed antenna exhibits return loss above -10dB for 1.2GHz, 3GHz and 6.5GHz bands which are not applicable for wireless communication. However, the antenna shows the better performance at 5.3mm Width of Slits 1 whereas 2.4GHz, 4.27GHz and 8.1GHz bands are considered as the most effective bands from perspective to return loss.

Fig. 2(b) shows that the effect of Width of slits 2 (W3) on return loss for multiband antenna along with considering Width of slits 1 (W6) value 5.3mm. Among three analyses, the return loss for 5mm shows the minimum value about -24.2dB at 8.1GHz. Moreover, several acceptable bands (2.4GHz, 3GHz, 5GHz, 6GHz, 8.1GHz and 9.2GHz) arise for both 4mm and 5mm slot widths. On contrary, the proposed antenna shows poor performance for 6mm slot width due to return loss above -10dB for several bands which have become applicable for previous slot sizes. However, for W3, 5mm is the critical size for achieving better performance.



(a)



(b)

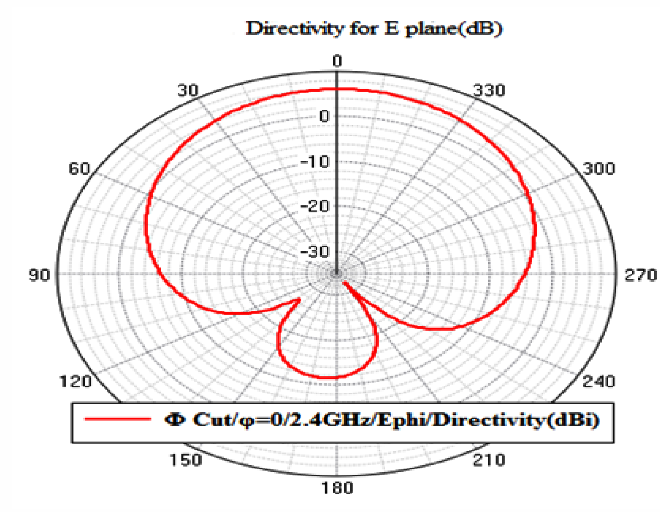
Fig. 2: Return loss with the variation of (a) first U-slot width, W3 and (b) second U-slot width, W6.

B. *Directivity Analysis*

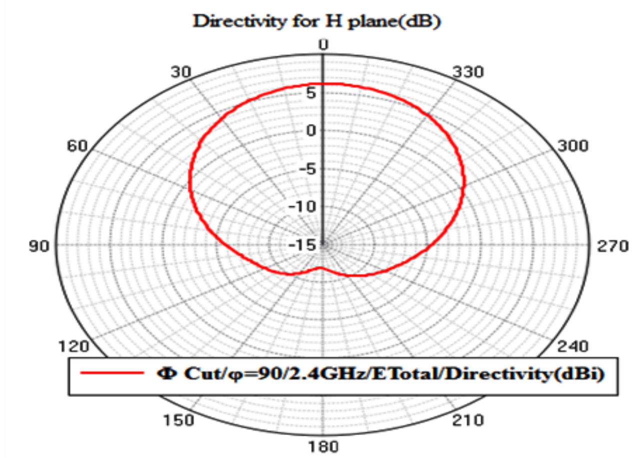
In figs. 3(a) and 3(b), the directivity for E plane and H plane have been presented for 2.4GHz. Although the maximum radiation for both cases 6.10dB but H plane radiation patterns are more directive than E plane due to back lobe exists in E plane.

Figs. 4(a) and 4(b) show the directivity for E plane and H plane patterns at 4.27GHzwhere maximum radiation at 8.86dB and 8.96dB respectively. It is shown that the directivity for both planes nearly the same radiation pattern along with back lobe removes from radiation patterns.

Moreover, the directivity for E plane and H plane has been presented in the figs. 5(a) and 5(b) for 8.1GHz. In this case, two major lobes with side lobes form the E plane pattern and maximum radiation is 10.01dB at 41 degree. Moreover, HPBW is comparatively narrower than previous bands. On contrary, H plane pattern has divided into three major lobes and maximum directivity is 4.62dB.

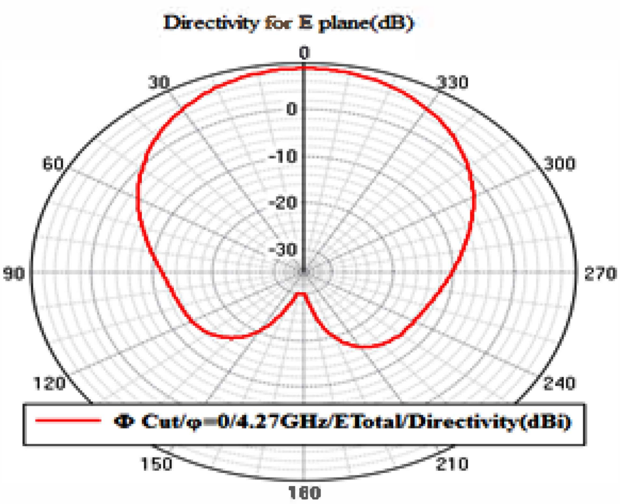


(a)

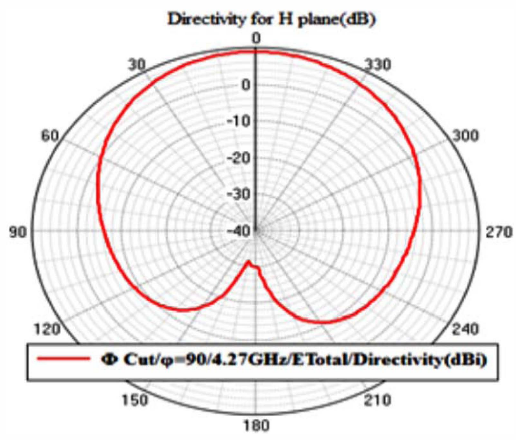


(b)

Fig. 3: Directivity for (a) E plane and (b) H plane at 2.4GHz.

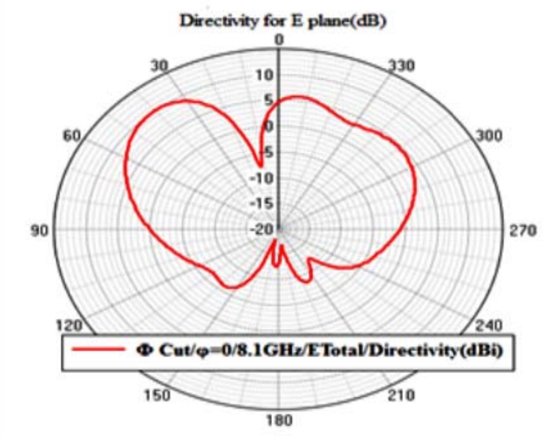


(a)

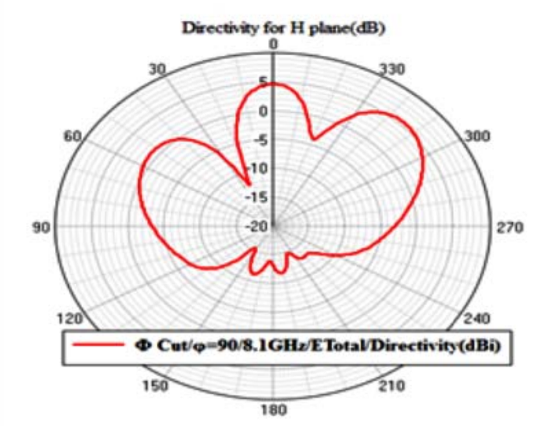


(b)

Fig. 4: Directivity for (a) E plane and (b) H plane at 4.27GHz.



(a)



(b)

Fig. 5: Directivity for (a) E plane and (b) H plane at 8.1GHz.

C. *Gain Analysis*

Fig. 6 shows the gain characteristics for the proposed multiband antenna. From perspective to gain several bands which include 2.4GHz, 4.27GHz, 5GHz, 6.1GHz, 6.5GHz and 8.1GHz are acceptable for wireless communication. In this case, the maximum gain for the proposed antenna is 9.23dB at 8.1GHz. Based on return loss and gain analysis, it is shown that the band 6.5GHz is not effective for wireless application.

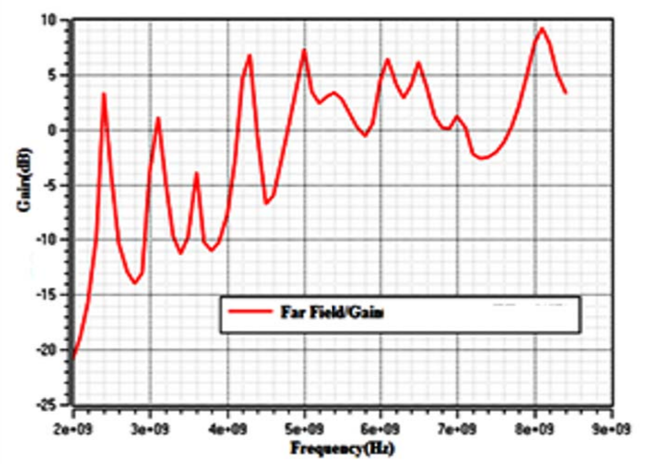
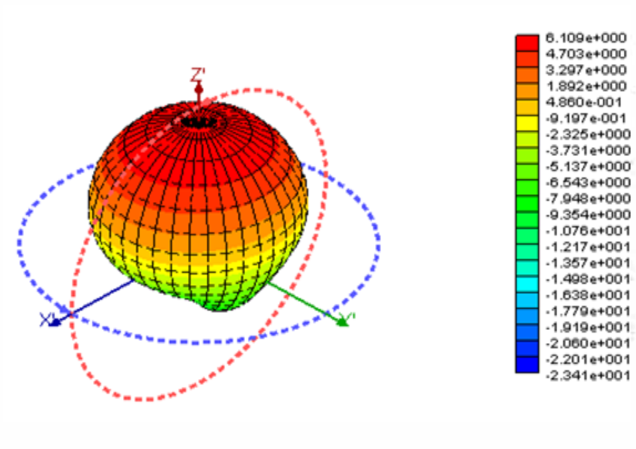


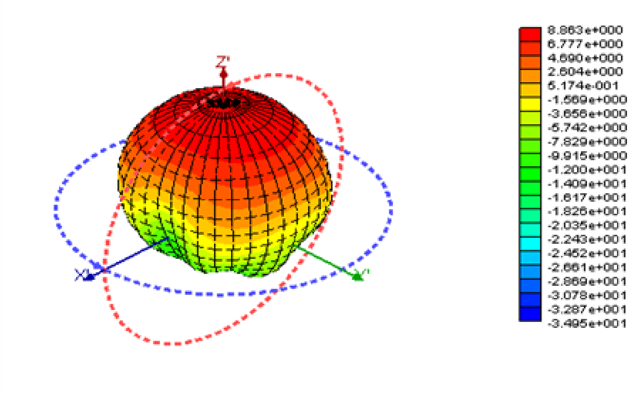
Fig. 6: Gain characteristics for proposed antenna.

D. *3D Radiation Pattern Analysis*

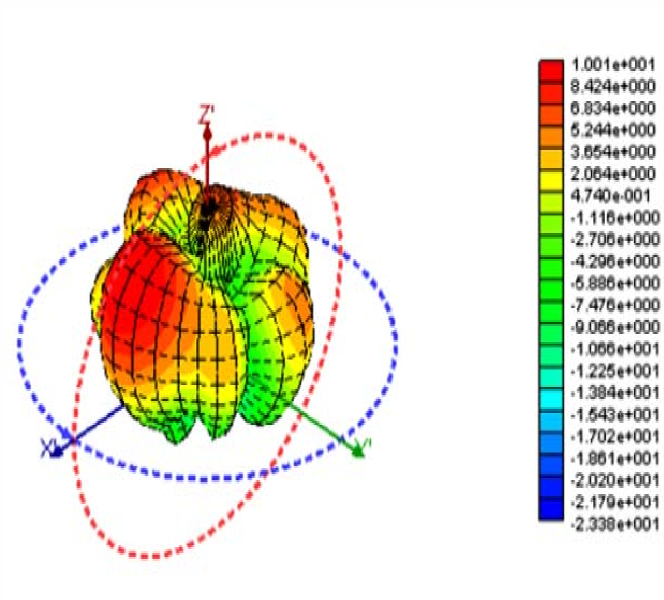
Figs. 7(a), 7(b) and 7(c) show the 3D radiation patterns for three distinct prominent bands which include 2.4GHz, 4.27GHz and 8.1GHz. From figs. 7(a) and 7(b), it is noticed that the radiation patterns along the z direction have become maximum for 2.45GHz and 4.27GHz at 6.10dB and 8.86dB respectively. On the other hand, radiation pattern has displaced from z direction for 8.1GHz and the antenna shows maximum radiation at 10.01dB.



(a)



(b)



(c)

Fig. 7: 3D radiation patterns for (a) 2.45GHz, (b) 4.27GHz and (c) 8.1GHz.

IV. Conclusion

In this paper, design and analysis of a multiband antenna have been presented. From design, it is demonstrated that the size of the proposed antenna and substrate is very small enough to be placed on the internal area of practical mobile handsets as well as other wireless applications for multiband operations. The designed antenna has been analyzed on the basis of various parameters which include return loss, gain, directivity and 3D radiation pattern. From perspective to return loss antenna shows better performance and obtains more than five acceptable bands with the variation of slot width. Although gain, directivity and 3D radiation patterns have been presented along with verified the directional characteristics only for the frequencies of 2.4GHz, 4.27GHz and 8.1GHz, but the designed antenna also supports for the other bands. Consequently, the proposed multiband antenna is compact, efficient and suitable for versatile wireless applications.

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