MULTIBAND FOUR-STUB MONOPOLE ANTENNA FOR WIFI/WIMAX/WLAN/UWB/X-BAND APPLICATIONS WITH DGS

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Abstract:

This article demonstrates the four-stub multiband monopole antenna with Defected Ground Structure (DGS) for WiFi/WiMAX/WLAN/UWB/X-band applications. The dimensions of the proposed antenna are 30x28x1.6 mm^3 and modelled on the FR4 substrate. The simulated result shows three bands which ranges from (2.4 – 3.3)/2.8 GHz, (4.6 – 5.1)/4.9 GHz and (8.3 – 13.9)/9.2 GHz with the return loss of -32dB, -19dB and -31dB and the impedance bandwidth of 32.14%, 10.20% and 60.9% respectively. The antenna gains are 2.8dBi, 3.2 dBi and 2.9dBi respectively at 2.8 GHz, 4.9GHz and 9.2 GHz and it makes the antenna much suitable for WiFi, WiMAX, lower and upper WLAN, Ultra Wide Band(UWB) and X-Band satellite link applications. The S-parameters and the radiation patterns are simulated and validated on the ANSYS HFSS software.

Keywords: Multiband monopole antenna, Defected Ground Structure, WLAN, WiMAX, UWB.

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I. INTRODUCTION

The development of multiband operations in the wireless communication systems have increased to cater the demand for the compact, cheap in cost, multiband antennas for the wireless and mobile applications like 5G and future 6G applications. The miniaturisation of microstrip patch antenna due to the device miniaturisation has become a necessity now days. For this, the microstip antennas are much suitable as it is easy to fabricate, low profile and cheap. These microstrip patch antennas are much compatible as far as monolithic microwave integrated circuits are concerned. To use the antenna in RF and microwave technology, the Defected Ground Structure (DGS) is becoming advantageous and hence the size of the antenna has become compact or low profile [1]. The literature review concludes that the proposed antenna has a smaller size with better performances than those in the references reviewed. There are several dual- and multi-band applications' antennas are discussed in [2-17].

The prototype antenna is much compact in size than the compact monopole tri-band antenna with microstrip feeding for WLAN and WiMAX applications, [2]. The impedance bandwidth and the gain achieved of the prototype antenna is better than that of the reference antenna. In the reference [3], the antenna designed in E-Shaped Patch Antennas for High Speed Wireless Networks has the size much greater than the prototype antenna. In [4], A Compact Microstrip Slot Antenna for WLAN/WiMAX Applications is discussed producing three bands, is large in size than the proposed antenna. The prototype also gives a better impedance bandwidth than that of the reference one.The proposed antenna is much smaller in size when compared to microstrip patch antenna developed for generating dual band for WLAN/MIMO/WIMAX/AMSAT/WAVE applications, [5]. In this, the return losses and the impedance bandwidth are also very low than that of the prototype. The antenna of the reference [6], a slot antenna fed with microstrip feeding for multiband applications using the split-ring resonator is discussed which has got much greater size than the prototype and also has less impedance bandwidth with low gain achieved too. In [7], a low profile fed by CPW antenna generating three bands for wireless applications has been discussed which is also having large size than the prototype and low gain and less impedance bandwidth are also there than the prototype. In the references [8-17], the different techniques for designing and implementing the microstrip antennas for dual- and multiband applications are literature reviewed.

In this letter, the low-profile antenna proposed here is simulated on ANSYS HFSS using the FR4 material with the loss tangent of 0.02 and dielectric constant 4.4. 50 Ω microstrip transmission line feeding structure used in the proposed antenna. This antenna generates the frequency bands (2.4 – 3.3)/2.8 GHz, (4.6 – 5.1)/4.9 GHz and (8.3 – 13.9)/9.2 GHz much suitable for WiFi, WiMAX, Lower and Upper WLAN, Ultra Wide Band(UWB), International Telecommunication Union and X-Band Satellite Link applications using the four stubs on the rectangular patch with cut in the ground palne with the achievement of more bandwidth.

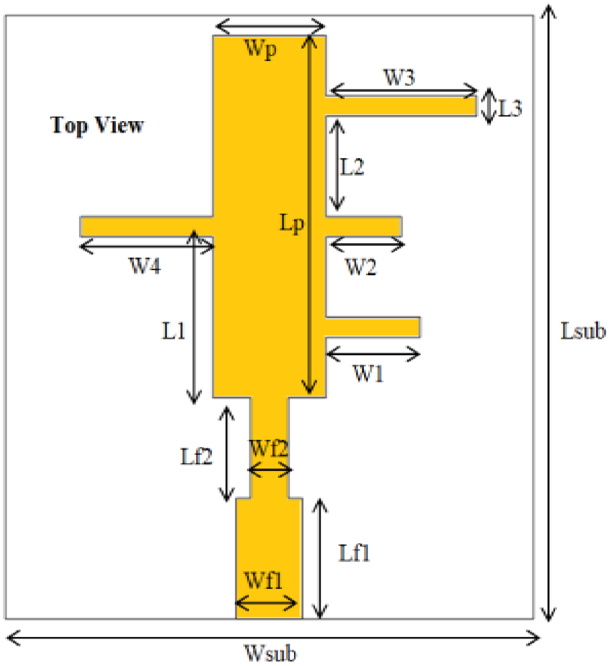

Figure 1: Proposed Antenna Geometry.

II. ANTENNA DESIGN

Figure 1 shows the top and the bottom view of the prototype antenna with the different dimensions of feeds, patch and stubs used and also the defected ground structure in the ground with a rectangular slot. This simulation of the low-profile antenna is done on HFSS on FR4 material having the dielectric constant of 4.4 and 0.02 is the loss tangent. The substrate length and substrate width are shown by L_{sub}

and W_{sub} respectively. L_{f1} and W_{f1} are the length and width of feed 1 whereas L_{f2} and W_{f2} are the length and width of feed 2 respectively. L_p is the length of patch and W_p is patch width. W1, W2, W3 and W4 are the widths of stubs used and L3 is the length of the stubs which is 1.0 mm. These show the dimensions of the top view. Like this, L_g is the ground plane length with G1 and G2 as the length and the width of the cut in the ground. The total dimension of the proposed antenna is 30x28x1.6 mm^3.

The optimised geometrical parameters of the prototype are shown in Table: 1.

W_{Sub}	L_{Sub}	L_{f1}	W_{f1}	L_{f2}	W_{f2}	L_p	W_p	W1	W2
28 mm	30 mm	6 mm	3.5 mm	5 mm	2 mm	18 mm	6 mm	5 mm	4 mm
W3	**W4**	**L1**	**L2**	**L3**	**G1**	**G2**	**L_g**		
7.5 mm	7 mm	8 mm	5 mm	1 mm	2.5 mm	3 mm	8 mm		

Table 1: Dimensions of proposed antenna (in mm)

Figure 2 demonstrates the return loss of the proposed antenna with Defected Ground Structure which is indicative of occurrence of three bands at 2.8, 4.9 and 9.2 GHz in contrast to without DGS with insignificant band. The optimum parameter values and the return loss (S11≤ - 10dB) are provided in the Table: 1.

The three bands ranges from (2.4 – 3.3)/2.8 GHz, (4.6 – 5.1)/4.9 GHz and (8.3 – 13.9)/9.2 GHz with the return loss of -32dB, -19dB and -31dB and the impedance bandwidth of 32.14%, 10.20% and 60.9% are obtained respectively.

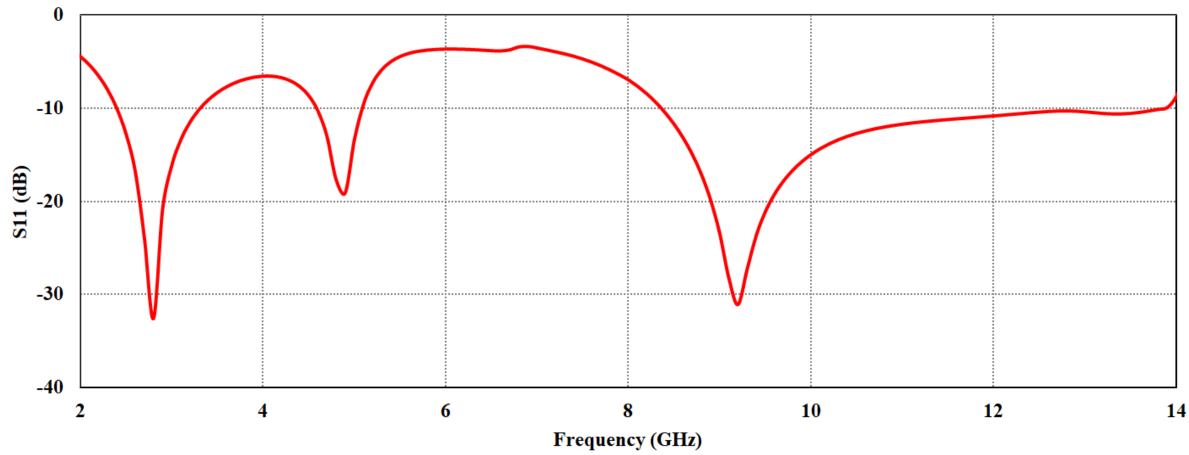

Figure 2: Return loss of the proposed antenna

III. ANTENNA CONFIGURATION

The figure 3 shows the proposed antenna with all possible configurations through which the better result is obtained. The final proposed antenna shown in the figure is Antenna 3. Antenna 1 is the simple rectangular patch with the feed line which gives the very less return loss with dual band only. Now, a stub is added onto the left of the patch right in the middle of rectangular patch shown by Antenna 2. This also generates dual band with some improvement in the return loss as compared to Antenna 1. After that, three more stubs are added of different width on right side of the rectangular patch as shown in the figure named Antenna 3. It now gives the three bands with much better return loss and a better impedance bandwidth is obtained.

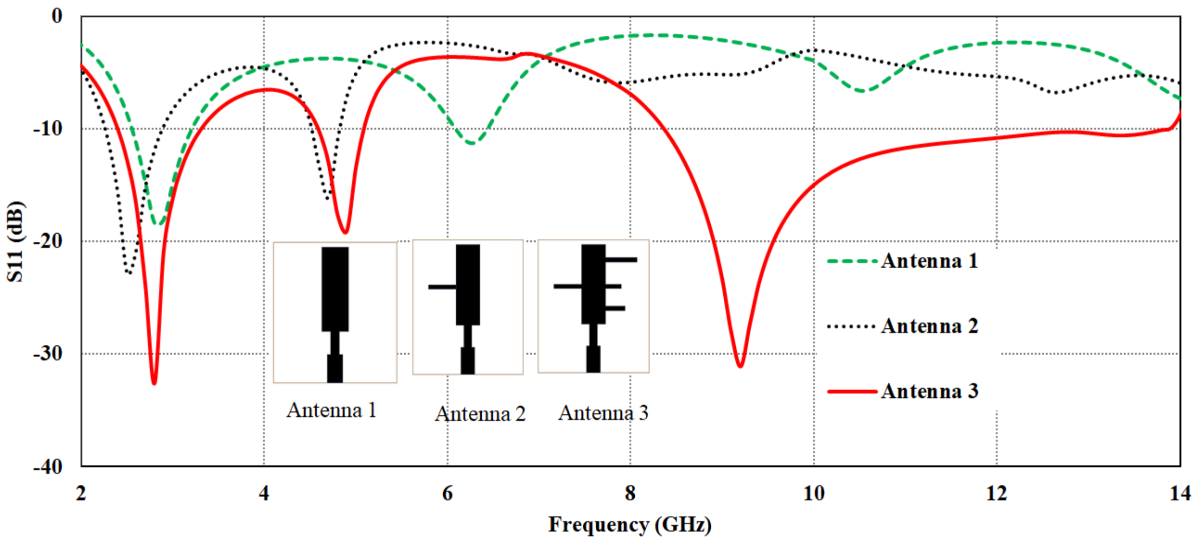

Figure 3: Configuration of the different antennas

IV. RESULT AND DISCUSSION

The proposed antenna has the size 30x28x1.6 mm^3 and has the better impedance matching and good return loss. The radiation pattern of the proposed antenna is omnidirectional and it is same as that of the monopole antenna with λ/4 ground plane and the range covered is (2.4 – 3.3)/2.8 GHz, (4.6 – 5.1)/4.9 GHz and (8.3 – 13.9)/9.2 GHz with the return loss of -32dB, -19dB and -31dB and the impedance bandwidth of 32.14%, 10.20% and 60.9% respectively are achieved.

Table 2 focusses on the comparative study of the proposed Four-stub Multiband Monopole Antenna with Defected Ground Structure (DGS) for 2.8/4.9/9.2 applications with the reference antennas. The reference antennas are bigger in size than that of the proposed antenna.

Table 2: Comparison between reference and proposed antennas.

Reference	Bands	Size of the Antenna	Gain (dBi)
[2]	3	35x45 mm^2	2.4/2.4/1.0
[3]	2	60x60 mm^2	6
[4]	3	30x35 mm^2	3.86/3.52/4.32
[5]	2	70x60 mm^2	6.1/8.0
[6]	3	40x50 mm^2	1.08/1.82/2.93
[7]	3	40x24 mm^2	1.62/2.34/2.53
Proposed Antenna	3	30x28 mm^2	2.8/3.2/2.9

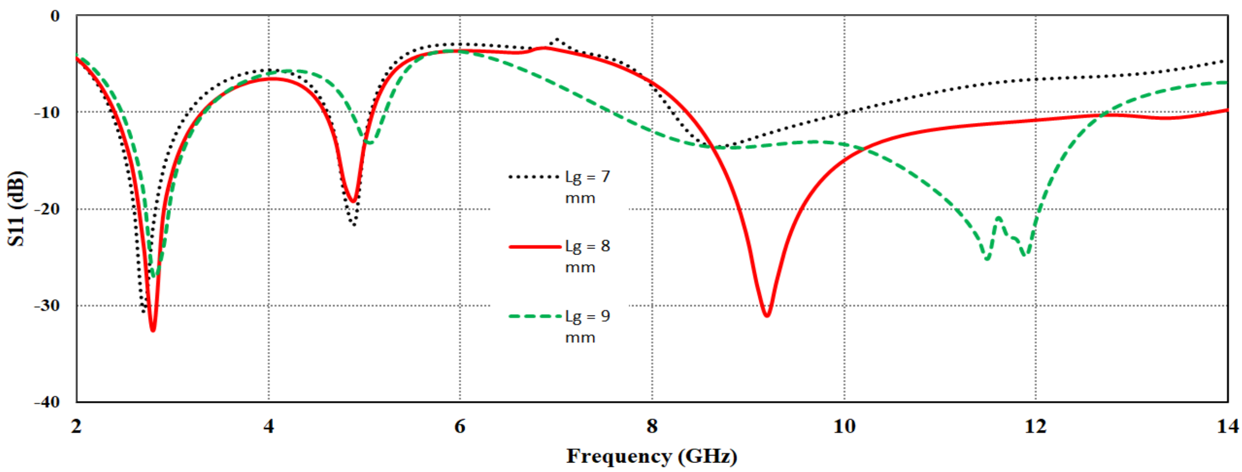

Figure 4: Length of the ground plane Lg varying from 7-9mm

In the Figure 4, the curves are shown when the length of the ground plane (L_g) is varying from 7-9 mm. when the L_g is taken 7 mm the antenna resonates only two times with low resonance. After that, L_g is given the value 9 mm, this generates three bands but with less resonances. But when the L_g has the measurement of 8 mm the antenna is generating triple bands with a better resonances and wide coverage of frequencies. Hence L_g with 8 mm is the optimum value for the better result.

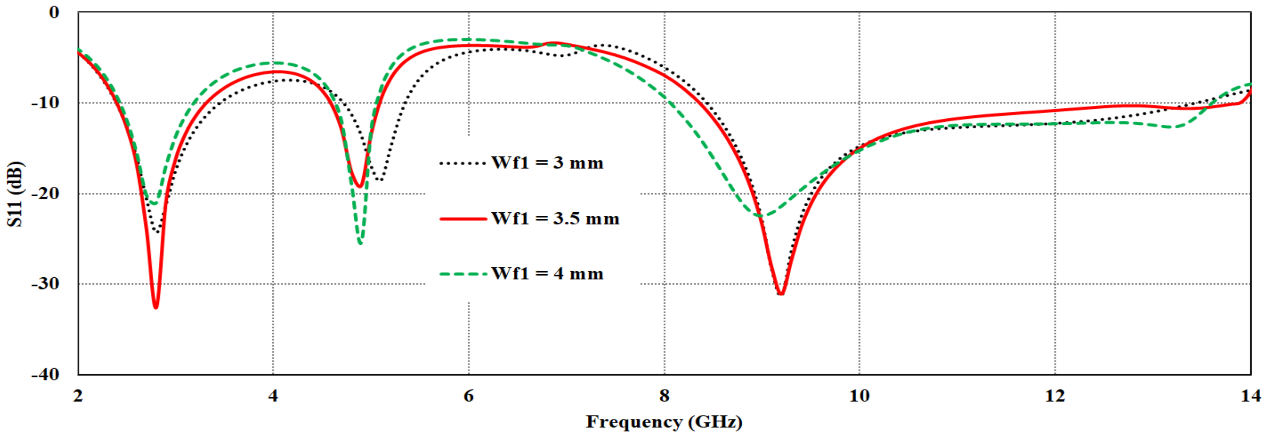

Figure 5: Width of feed Wf1 varying from 3-4mm

Figure 5 shows the curves when the width of feed Wf1 is varying from 3-4 mm. At Wf1 equals 3 mm, the antenna generates three bands with less resonances. After this, when the width Wf1 is given the value 4 mm then also it generates three bands with much low resonances. But when the value to Wf1 is given as 3.5 mm, the antenna generates three bands with better and sharp resonances and wide coverage of frequencies. Hence, Wf1 of 3.5 mm is optimum value for better results.

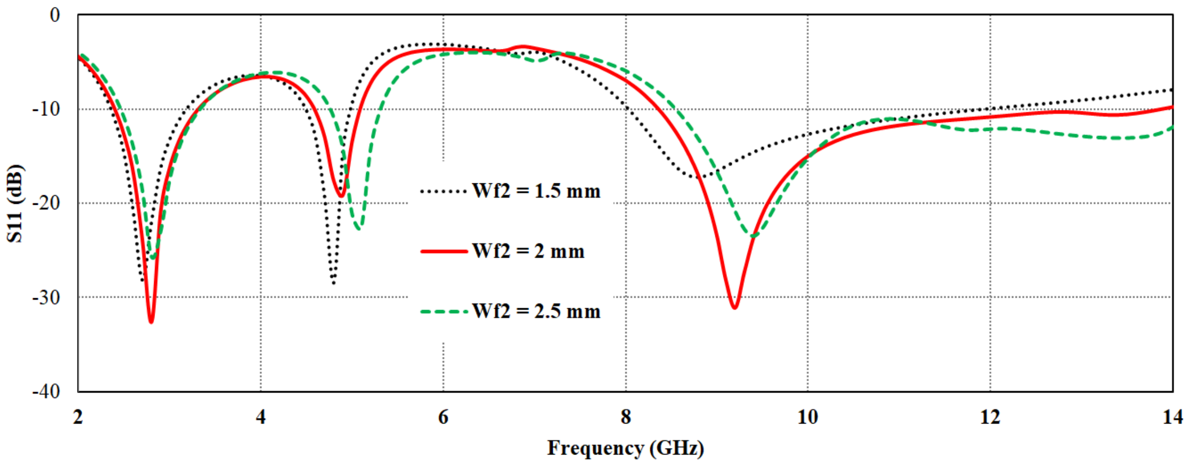

Figure 6: Width of feed Wf2 varying from 1.5-2.5mm

In the Figure 6, the curves for the width of feed Wf2 is demonstrated when it is varying from 1.5-2.5 mm. When the Wf2 is taken 1.5 mm, the antenna generates dual bands only with less resonance. After that, when Wf2 is given the value of 2.5 mm, antenna generates three band but with low resonances. But when Wf2 is taken 2 mm, this time also antenna generates three bands but with better resonances and wide coverage of frequencies.Therefore, Wf2 of 2 mm giving the optimum results.

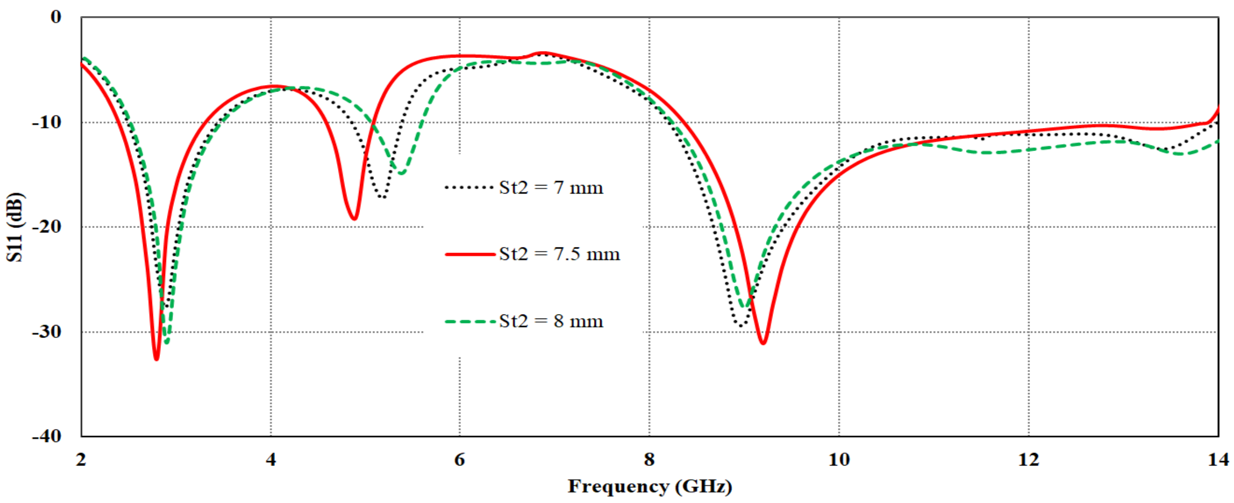

Figure 7: Width of stub W3 varying from 7-8mm

Figure 7 demonstrates the curves for stub when its width W3 is varied from 7-8 mm. at W3 equals 7 mm, antenna generates three band but with less resonance. When W3 is taken 8 mm, this time too antenna generates three bands but much less resonance. But, when the value to W3 is given 7.5 mm, antenna generates three bands with good resonances and wide frequency coverage. Hence, W3 with 7.5 mm is giving optimum result.

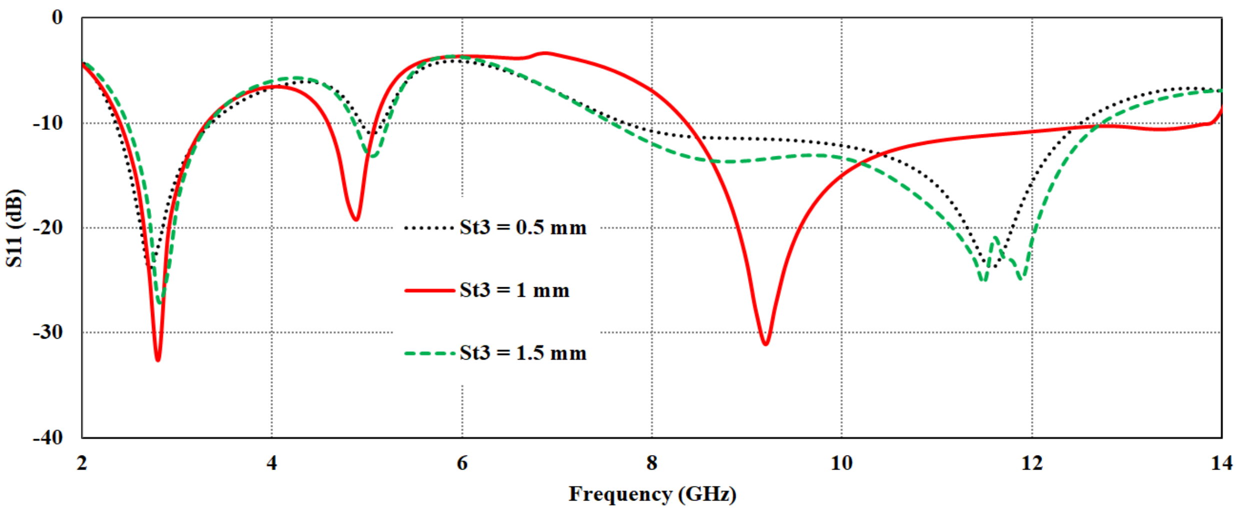

Figure 8: Length of stub L3 varying from 0.5-1.5mm

Figure 8 shows the curves for the length of stub L3 placed in the mid of rectangular patch on left side varying from 0.5-1.5 mm. When L3 is taken 0.5 mm the antenna generates dual bands with less resonance. After that, when L3 is taken 1.5 mm also generates dual bands with some improved resonance from earlier. But, when L3 is given the value 1 mm, the antenna generates triple bands with better resonance and wide range coverage. Hence, the L3 with 1 mm giving the optimum results.

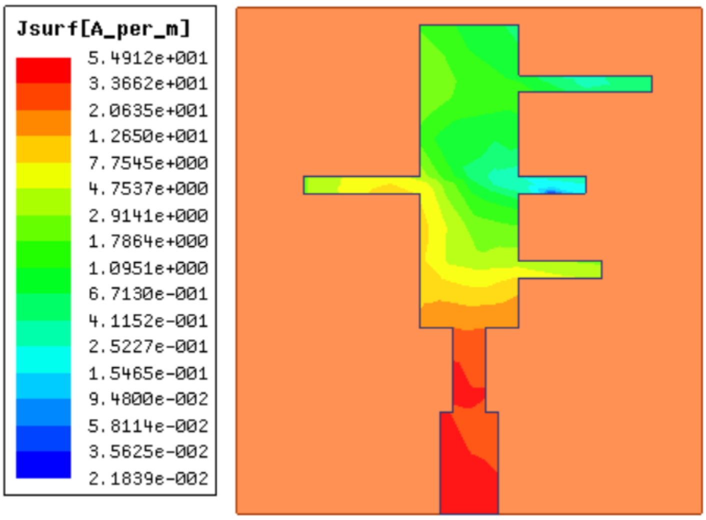

Figure 9: Current distribution of proposed antenna at 2.8 GHz

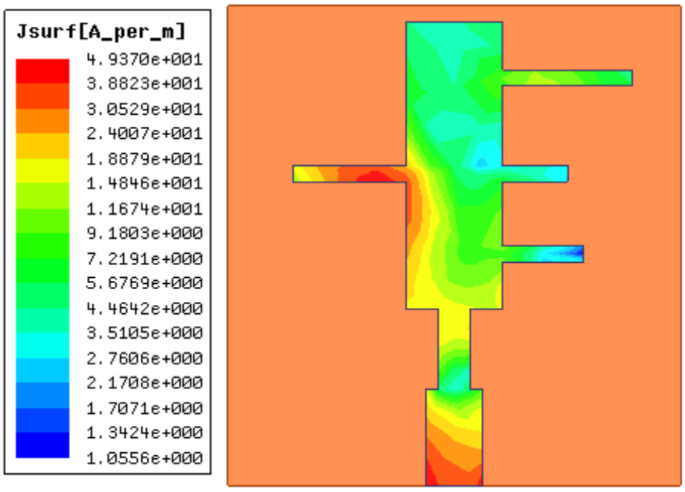

Figure 10: Current distribution of proposed antenna at 4.9 GHz

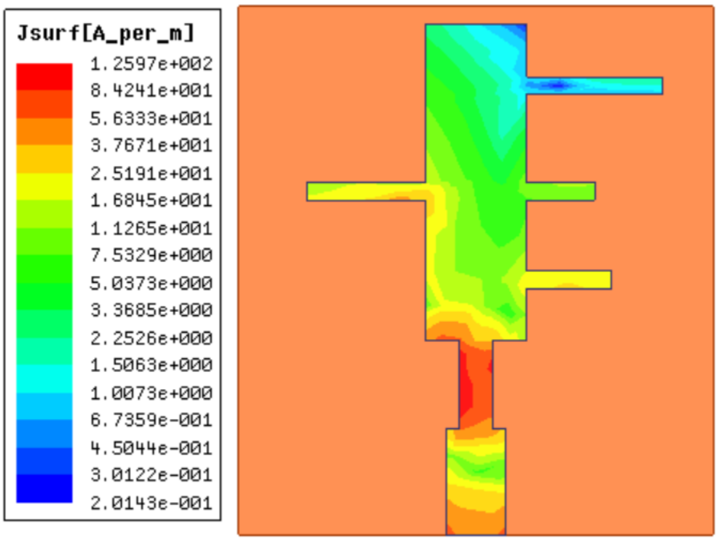

Figure 11: Current distribution of proposed antenna at 9.2 GHz

Figures 9, 10 and 11 are demonstrating the surface current distribution of the proposed antenna at 2.8, 4.9 and 9.2 GHz respectively. The red indication in the figures shows the higher current distribution.

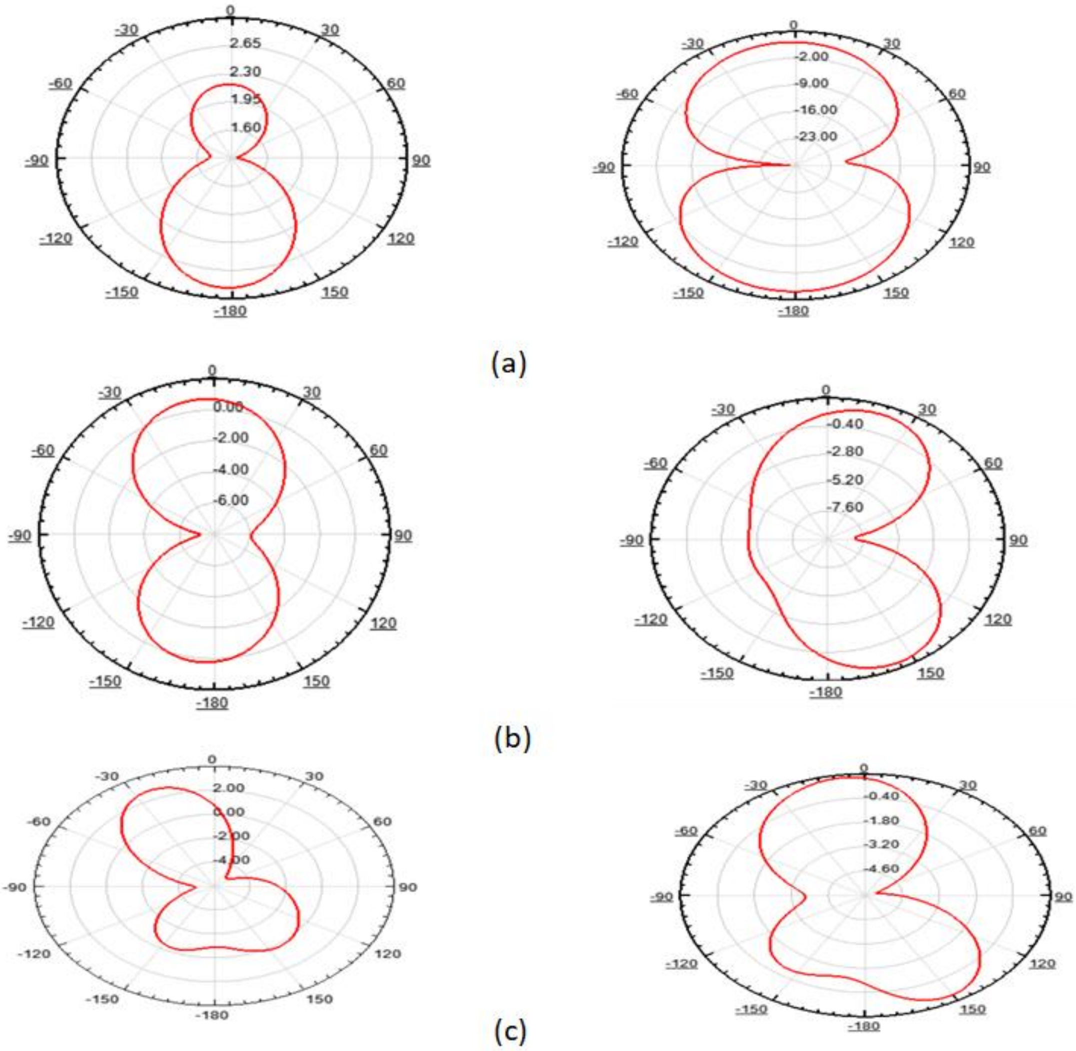

Figure 12: Radiation pattern of proposed antenna at (a) 2.8 GHz, (b) 4.9 GHz and (c) 9.2 GHz

Figure 12 shows the radiation pattern of the proposed antenna at 2.8, 4.9 and 9.2 GHz at 0 and 90 degrees which are same as that of the omnidirectional antenna.

The gain of the proposed antenna is shown in Figure 13. This antenna generates three bands with good resonance with wide coverage and improved gain. The gain achieved at (2.4 – 3.3)/2.8 GHz, (4.6 – 5.1)/4.9 GHz and (8.3 – 13.9)/9.2 GHz is 2.8 dBi, 3.2 dBi and 2.9dBi respectively.

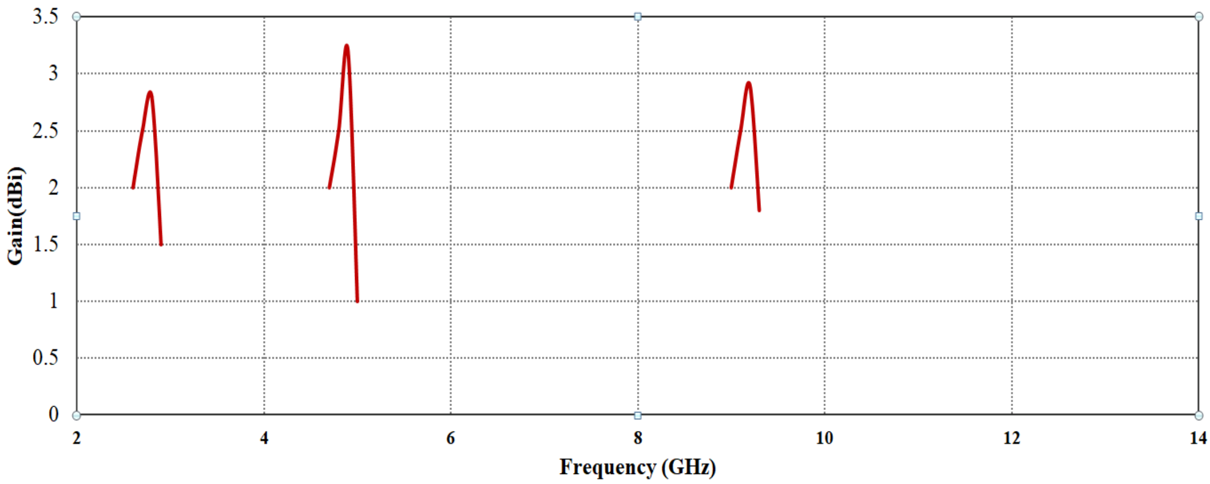

Figure 13: Gain of proposed antenna

V. CONCLUSION

The proposed microstrip patch antenna with defected ground structure in this paper is compact in size when compared to the reference antennas. Then bandwidth achieved is much better and improved. The radiation pattern is omnidirectional and the gain is also enhanced, i.e., at (2.4 – 3.3)/2.8 GHz, (4.6 – 5.1)/4.9 GHz and (8.3 – 13.9)/9.2 GHz is 2.8dBi, 3.2 dBi and 2.9dBi respectively with size of the antenna as 30x28x1.6 mm^3. This antenna generates the frequency bands (2.4 – 3.3)/2.8 GHz, (4.6 – 5.1)/4.9 GHz and (8.3 – 13.9)/9.2 GHz much suitable for WiFi, WiMAX, Lower and Upper WLAN, Ultra Wide Band(UWB), International Telecommunication Union and X-Band Satellite Link applications. The impedance bandwidth of 32.14%, 10.20% and 60.9% is achieved on the basis of return loss ($S_{11} \leq$ -10dB). The antenna is simulated on ANSYS HFSS with FR4 material, dielectric constant 4.4 and loss tangent of 0.02.

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