Dual-Band Size Deducted Un-Equal Arm Y-Shaped Printed Antenna for Space Communications

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Abstract— **In recent years, with the continuous growth of communication service and the constant miniaturization of communication equipment, where printed antennas for their small volumes, low profiles, excellent integration and good performance, is higher demands for the volume of antennas and working band. A dual-band deducted un-equal arm Y-shaped printed antenna is thoroughly simulated in this paper. Resonant frequency has been reduced drastically consists of Y-shaped slot in middle point located from the antenna. More importantly, it is also shown that the differentially-driven microstrip antenna has higher gain of simulated 4.69 dBi at 6.23GHz and 4.18 dBi at 9.56GHz and beam width of simulated 170.38^0 at 6.23GHz & 166.131^{0}at 9.56GHz of the printed antenna. Compared to a conventional microstrip patch antenna, simulated antenna size has been reduced by 52.02% with an increased frequency ratio. The initial design and optimization of the printed antenna is operating in X band (8-12GHz).**

Keywords— *Compact, Patch, Slot, Resonant frequency, Bandwidth, Printed Antenna.*

I. INTRODUCTION

In recent years, demand for small antennas on wireless communication has increased the interest of research work on compact microstrip antenna design among microwave and wireless engineers [1-6]. Because of their simplicity and compatibility with printed-circuit technology microstrip antennas are widely used in the microwave frequency spectrum. Simply a microstrip antenna is a rectangular or other shape, patch of metal on top of a grounded dielectric substrate. Microstrip patch antennas are attractive in antenna applications for many reasons. They are easy and cheap to manufacture, lightweight, and planar to list just a few advantages. Also they can be manufactured either as a stand-alone element or as part of an array. However, these advantages are offset by low efficiency and limited bandwidth. In recent years much research and testing has been done to increase both the bandwidth and radiation efficiency of microstrip antennas [7-8].

Due to the recent interest in Y-shaped printed antenna was developed to meet the need for a cheap, low profile, broadband antenna. This antenna could be used in a wide range of applications such as in the space communications or satellite communication. Our aim is to reduce the size of the antenna as well as increase the operating bandwidth. The proposed antenna (substrate with $\varepsilon_r = 4.4$) has a gain of 4.18 dBi and presents a size reduction of 52.02% when compared to a conventional microstrip patch (10mm X 6mm). The simulation has been carried out by IE3D [14] software which uses the MoM method. Due to the small size, low cost and low weight this antenna is a good entrant for the application of C-Band of satellite communication and X-Band for microwave communication. Now this global Ku- band markets have become very expensive, and there is now we started look at X-band.

The C-band and X-Band defined by an IEEE standard for radio waves and radar engineering with frequencies that ranges from 4.0 to 8.0GHz and 8.0 to 12.0GHz[10] respectively. The X [11-13] band is used for short range tracking, missile guidance, marine, radar and air bone intercept. Especially it is used for radar communication ranges roughly from 8.29GHz to 11.4GHz .In this paper the microstrip patch antenna is designed for use in space communication satellites at 9.56GHz and satellite communication at 6.23 GHz. The results obtained provide a workable antenna design for incorporation in a space communication. When the three satellites located approximately 120 degrees apart in longitude than Deep Space Network (DSN) stations are capable of using the older and lower S-band deep-space radio communications allocations, and some higher frequencies on a more-or-less experimental basis, such as in the X-band. This X band communications includes the spacecraft landers for planet. [15].

II. ANTENNA DESIGN

The configuration of the conventional printed antenna is shown in Figure 1 with L=6 mm, W=10 mm, substrate (PTFE) thickness h = 1.6 mm, dielectric constant ε_r = 4.4. Coaxial probe-feed (radius=0.5mm) is located at W/2 and L/3. Assuming practical patch width W= 10 mm for efficient radiation and using the equation [6],

$$f_r = \frac{c}{2W} \times \sqrt{\frac{2}{(1+\varepsilon_r)}}$$

Where, c = velocity of light in free space. Using the following equation [9] we determined the practical length (L=6mm).

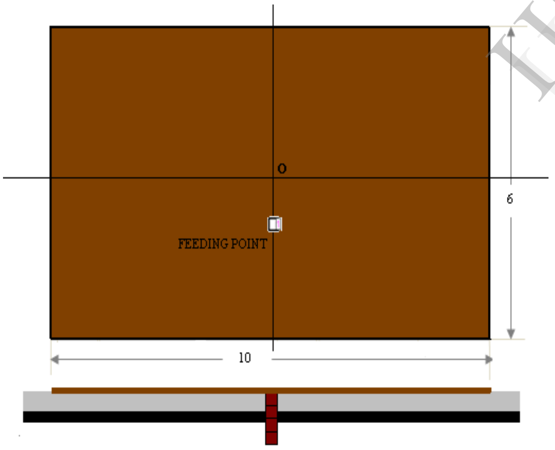
$$L = L_{eff} - 2\Delta L$$

Where, $\frac{\Delta L}{h} = \left[0.412 \times \frac{(\varepsilon_{reff}+0.3)\times(W/h+0.264)}{(\varepsilon_{reff}-0.258)\times(W/h+0.8)}\right]$

$$\varepsilon_{reff} = \left[\left(\frac{\varepsilon_r+1}{2}\right) + \frac{\varepsilon_r-1}{\left(2\times\sqrt{\left(1+12\times\frac{h}{W}\right)}\right)}\right]$$

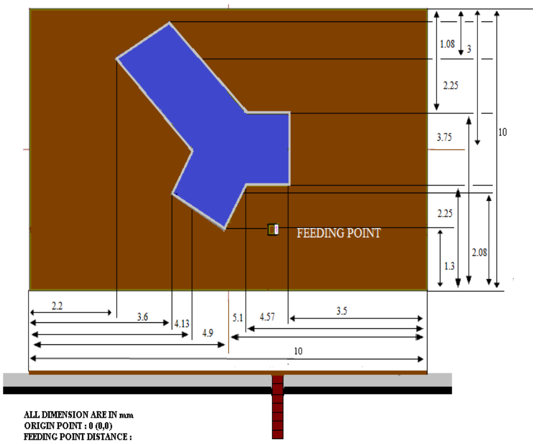
and $L_{eff} = \left[\frac{c}{2\times f_r \times \sqrt{\epsilon_{eff}}}\right]$

Where, L_{eff} = Effective length of the patch, ΔL/h =Normalized extension of the patch length, ε_{reff} = Effective dielectric constant.



ALL DIMENSIONS ARE IN mm
ORIGIN POINT : O (0,0)
FEEDING POINT DISTANCE:
FROM X-AXIS: (0) mm
FROM Y-AXIS: (-1) mm

Figure 1: Conventional Antenna configuration



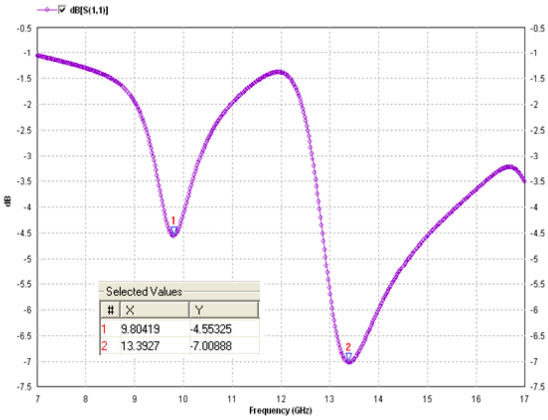
ALL DIMENSION ARE IN mm
ORIGIN POINT : 0 (0,0)
FEEDING POINT DISTANCE :
FROM X-AXIS : 1.1 mm
FROM Y-AXIS : -1.7 mm

Figure 2: Simulated Antenna configuration

Figure 2 shows the configuration of simulated printed antenna designed with similar PTFE substrate. The middle point Y-shaped the location of coaxial probe-feed (radius=0.5 mm) are shown in the figure 2.

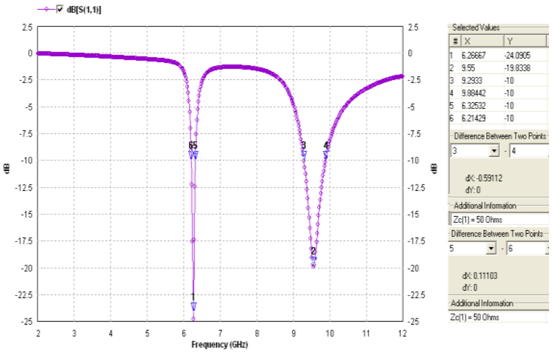
III. RESULTS AND DISCUSSION

Simulated (using IE3D [10]) results of return loss in conventional and simulated antenna structures are shown in Figure 3-4. A significant improvement of frequency reduction is achieved in simulated antenna with respect to the conventional antenna structure.



#	X	Y
1	9.80419	-4.55325
2	13.3927	-7.00888

Figure 3: Return Loss vs. Frequency (Conventional Antenna)



#	X	Y
1	6.26667	-24.0905
2	9.55	-19.8338
3	9.2933	-10
4	9.88442	-10
5	6.32532	-10
6	6.21429	-10

Difference Between Two Points
3 - 4
dX: -0.59112
dY: 0
Additional Information
Zc(1) = 50 Ohms
Difference Between Two Points
5 - 6
dX: 0.11103
dY: 0
Additional Information
Zc(1) = 50 Ohms

Figure 4: Return Loss vs. Frequency (Slotted Antenna)

In the conventional antenna return loss of about -7.01 dB is obtained at 13.39GHz. Comparing fig.3 and fig.4 it may be observed that for the conventional antenna (fig.3), there is practically no resonant frequency at around 6.23GHz with a return loss of around -6 dB. For the simulated antenna there is a resonant frequency at around 6.23GHz, where the return loss is as high as -24.725.

Due to the presence of slots in simulated antenna resonant frequency operation is obtained with large values of frequency ratio. The first and second resonant frequency is obtained at f_1= 6.23GHz with return loss of about -24.725dB and at f_2 = 9.56GHz with return losses -19.8438 dB respectively.

Corresponding 10dB band width obtained for Antenna 2 at f1, f2 are 111.0 MHz and 591.1MHz respectively. The simulated E plane and H-plane radiation patterns are shown in Figure 5-16. The simulated E plane radiation pattern of simulated antenna for 6.23GHz is shown in figure 5.

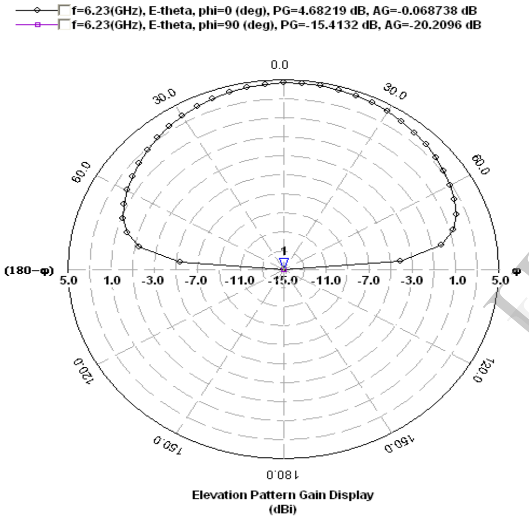


Figure 5: E-Plane Radiation Pattern for Slotted Antenna at 6.23 GHz

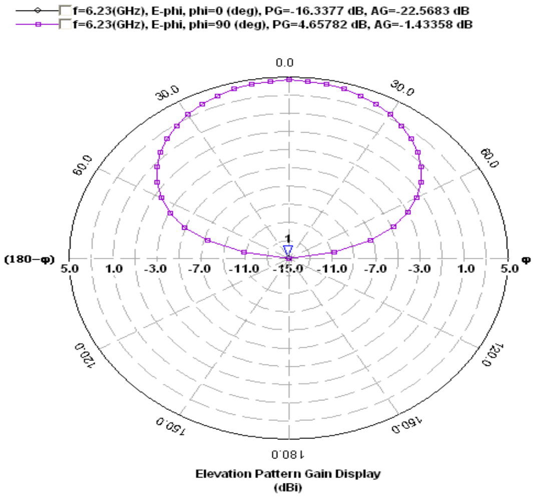


Figure 6: H-Plane Radiation Pattern for slotted Antenna at 6.23 GHz

The simulated H plane radiation pattern of simulated antenna for 6.23 GHz is shown in figure 6.The simulated E plane radiation pattern of slotted antenna for 9.56 GHz is shown in figure 7. The simulated H plane radiation pattern of slotted antenna for 9.56 GHz is shown in figure 8.

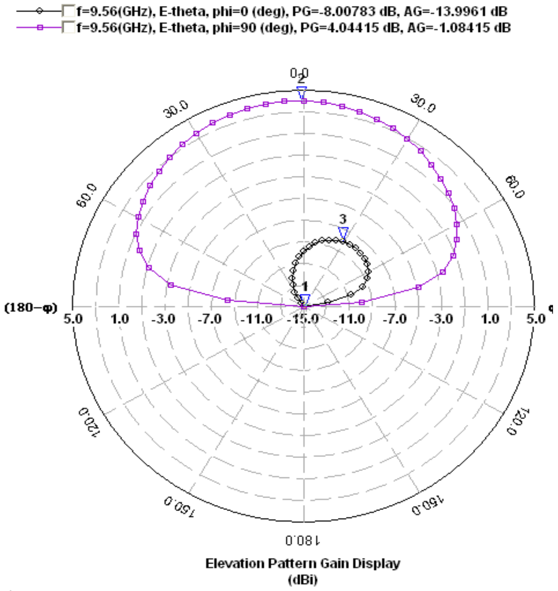


Figure7: E-Plane Radiation Pattern for slotted antenna at 9.56 GHz

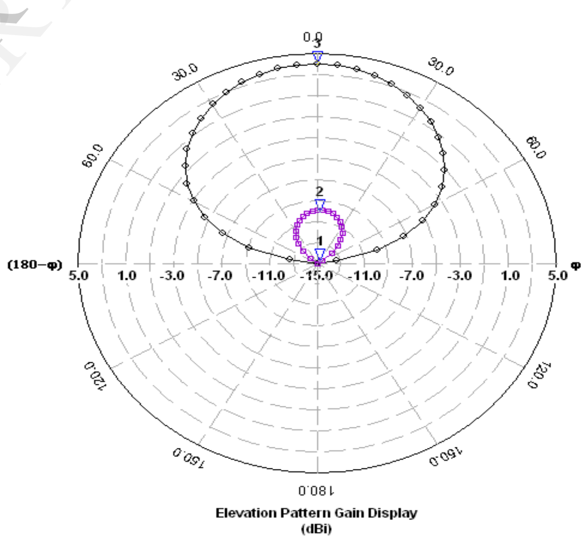


Figure 8: H-Plane Radiation Pattern for slotted antenna at 9.56 GHz

The simulated E plane & H-plane radiation pattern (3D) of simulated antenna for 6.23 GHz is shown in figure 9 & figure 10.

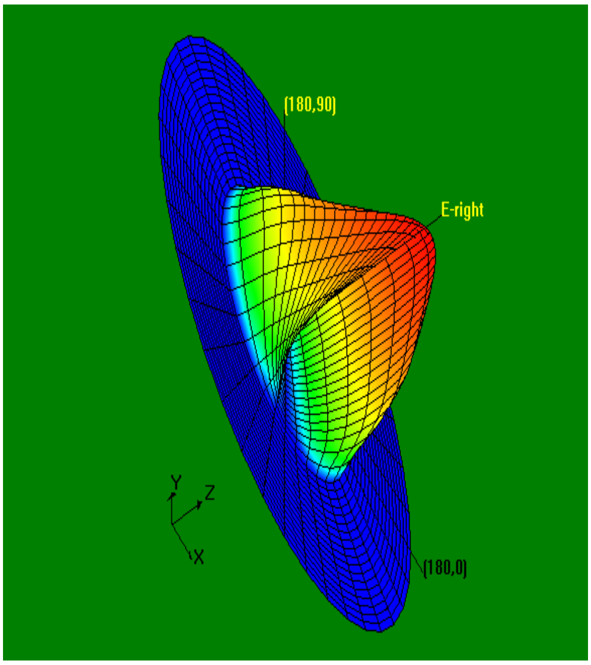


Figure 9: E-Plane Radiation Pattern (3D) for slotted antenna at 6.23 GHz

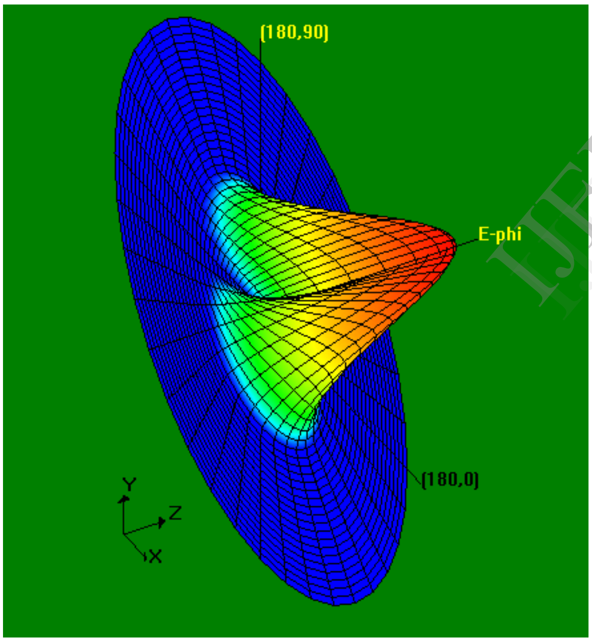


Figure 10: H-Plane Radiation Pattern (3D) for slotted antenna at 6.23 GHz

The simulated E -plane & H-plane radiation pattern (3D) of simulated antenna for 9.56 GHz is shown in figure 11 & figure 12.

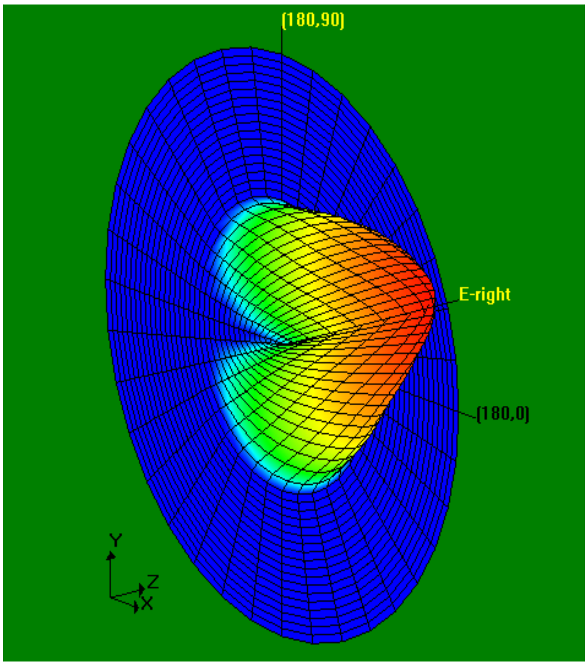


Figure 11: E-Plane Radiation Pattern (3D) for slotted antenna at 9.12 GHz

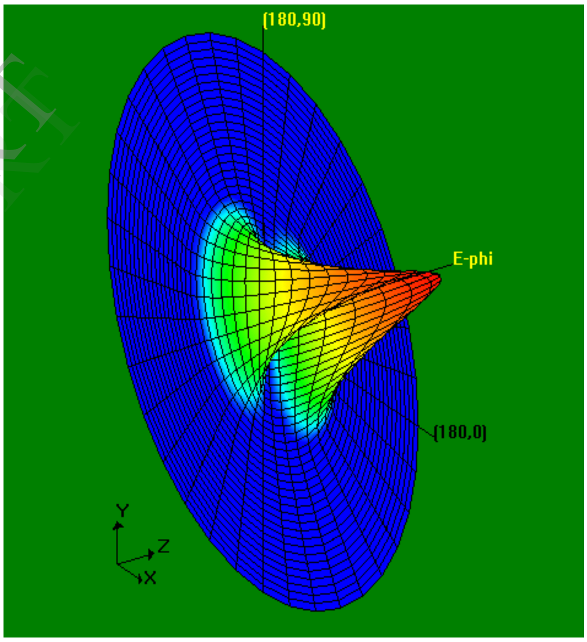


Figure 12: H-Plane Radiation Pattern (3D) for slotted antenna at 9.12 GHz

The simulated smith chart and VSWR of simulated antenna shown in figure 13 & figure 14.

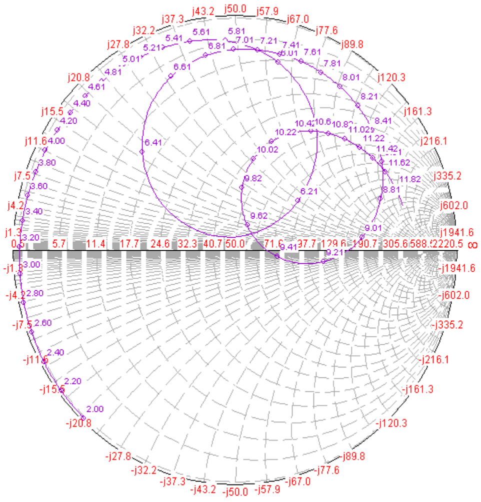


Figure13: Simulated Smith Chart for slotted antenna

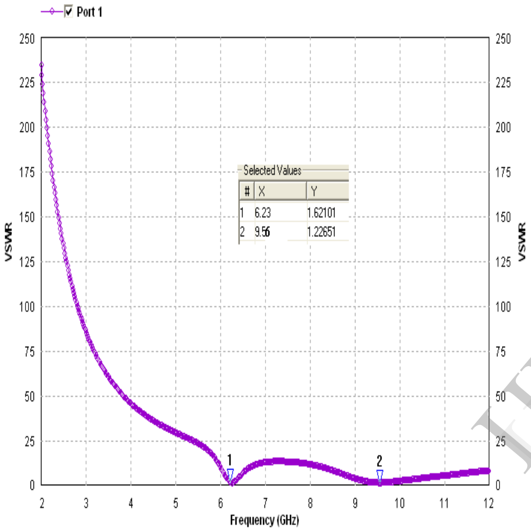


Figure 14: Simulated VSWR for slotted antenna

The simulated E -plane & H-plane radiation pattern (2D) of simulated antenna for 9.56 GHz is shown in figure 15 & figure 16.

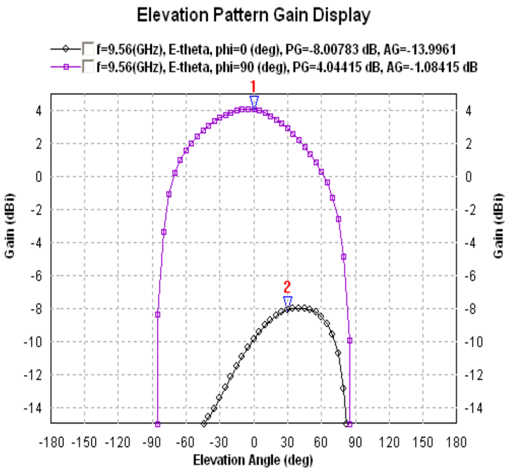


Figure15: E-Plane Radiation Pattern (2D) for slotted antenna at 9.56 GHz

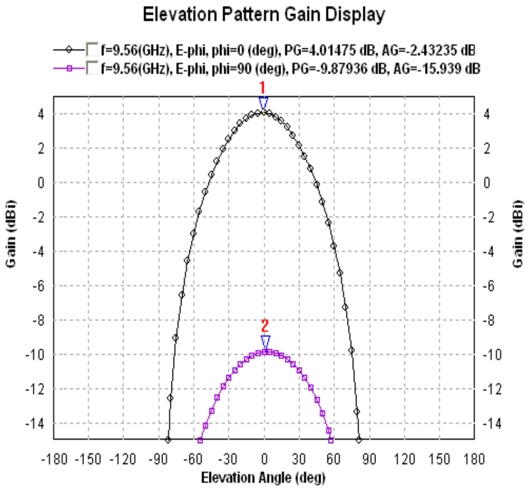


Figure 16: H-Plane Radiation Pattern (2D) for slotted antenna at 9.56GHz

All the simulated results are summarized in the following Table1 and Table2.

TABLE I: SIMULATED RESULTS FOR ANTENNA 1 AND 2 w.r.t RETURN LOSS

ANTENNA STRUCTURE	**RESONANT FREQUENCY (GHz)**	**RETURN LOSS (dB)**	**10 DB BANDWIDTH (GHz)**
Conventional	f_1= 9.80	-4.55	NA
	f_2= 13.39	-7.00	NA
Slotted	f_1= 6.23	-24.725	0.1110
	f_2 = 9.56	-19.8438	0.5911

TABLE II: SIMULATED RESULTS FOR ANTENNA 1 AND 2 w.r.t RADIATION PATTERN

ANTENNA STRUCTURE	**RESONANT FREQUENCY (GHz)**	**3DB BEAMWIDTH (^{0})**	**ABSOLUTE GAIN *(dBi)***
Conventional	f_1= 9.80	NA	NA
	f_2= 13.39	NA	NA
Slotted	f_1= 6.23	170.38	4.6974
	f_2 =9.56	166.131	4.1869
Frequency Ratio for Conventional Antenna			f_2 / f_1 = 1.366
Frequency Ratio for Slotted Antenna			f_2 / f_1 = 1.535

IV. CONCLUSION

This paper focused on the simulated design on differentially-driven microstrip antennas. Simulation studies of a single layer monopole hexagonal microstrip patch antenna have been carried out using Method of Moment based software IE3D. Introducing slots at the edge of the patch size reduction of about 52.02% has been achieved. The 3dB beam-width of the radiation patterns are 170.38° (for f_1), 166.131° (for f_2) which is sufficiently broad beam for the applications for which it is intended.

The resonant frequency of slotted antenna, presented in the paper, designed for a particular location of feed point (1.1mm, -1.7mm) considering the centre as the origin. Alteration of the location of the feed point results in narrower 10dB bandwidth and less sharp resonances.

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