Twice -Band Microstrip Hexagonal Slotted Patch Antenna for Microwave Communication

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Abstract—A single layer, single feed compact slotted patch antenna is thoroughly simulated in this paper. Resonant frequency has been reduced drastically by cutting three equal slots which are same hexagonal structure at the upper right, upper left and lower left corner from the conventional microstrip patch antenna. It is shown that the simulated results are in acceptable agreement. More importantly, it is also shown that the differentially-driven microstrip antenna has higher gain of simulated 3.24 dBi at 9.91 GHz and 0.14 dBi at 13.61 GHz and beamwidth of simulated 163.19^0 at 9.91 GHz and 122.10^0 at 13.61 GHz of the single-ended microstrip antenna. Simulated antenna size has been reduced by 48.11% with an increased frequency ratio when compared to a Conventional microstrip patch antenna.

Index Terms — Compact, Patch, Slot, Resonant frequency, Bandwidth.

1. 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]. Microstrip antennas have many unique and attractive properties – low in profile, light in weight, compact and conformable in structure, and easy to fabricate to support the high mobility necessity for a wireless telecommunication device and for high resolution mapping for radar communication, a small and light weight compact microstrip antenna is one of the most suitable application. The development of antenna for wireless communication also requires an antenna with more than one operating frequency. This is due to many reasons, primarily because of various wireless communication systems and many telecommunication operators use various frequencies. In its most fundamental form, a Microstrip Patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side. Therefore one antenna that has multiband characteristic is more desirable than having one antenna for each frequency band.

Most effective technique is cutting slot in proper position on the microstrip patch. In this paper includes cutting three equal slots which are same hexagonal structure at the upper right, upper left and lower left corner from the conventional microstrip patch antenna, to increase the return loss and gain-bandwidth performance of the simulated antenna (Figure 2). The antenna has become a necessity for many applications in recent wireless communication such as radar, microwave and space communication. To reduce the size of the antenna substrates are chosen with higher value of dielectric constant [7-9]. Our aim is to reduce the size of the antenna as well as increase the operating bandwidth. The proposed antenna (substrate with ε_r = 4.4) has a gain of 3.24 dBi and presents a size reduction of 48.11% 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 X-Band microwave communication and Ku-Band RADAR communication.

The X band belongs to in the microwave radio region of the electromagnetic spectrum. It is defined by an IEEE standard for radio waves and radar engineering with frequencies that ranges from 8.0 to 12.0 GHz. The X 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 8.29 GHz to 11.4 GHz. The Ku-Band belongs to in the microwave radio region of the electromagnetic spectrum. It is defined by an IEEE standard for radio waves and radar engineering with frequencies that ranges from 12.0 to 18.0 GHz [10-11]. The Ku band [12] is used for high resolution mapping and satellite altimetry. Specially, Ku Band [13] is used for tracking the satellite within the ranges roughly from 12.87 GHz to 14.43 GHz.

2. 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],

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

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

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

where,

$$\frac{\Delta L}{h} = 0.412 \times \left[\frac{(\varepsilon_{reff}+0.3)\times(W/h+0.264)}{(\varepsilon_{reff}-0.258)\times(W/h+0.8)}\right] \qquad \ldots 3$$

$$\varepsilon_{reff} = \left(\frac{\varepsilon_r+1}{2}\right) + \frac{\varepsilon_r-1}{\left(2\times\sqrt{\left(1+12\times\frac{h}{W}\right)}\right)} \qquad \ldots 4$$

and

$$L_{eff} = \left[\frac{c}{2\times f_r\times\sqrt{\varepsilon_{reff}}}\right] \qquad \ldots 5$$

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

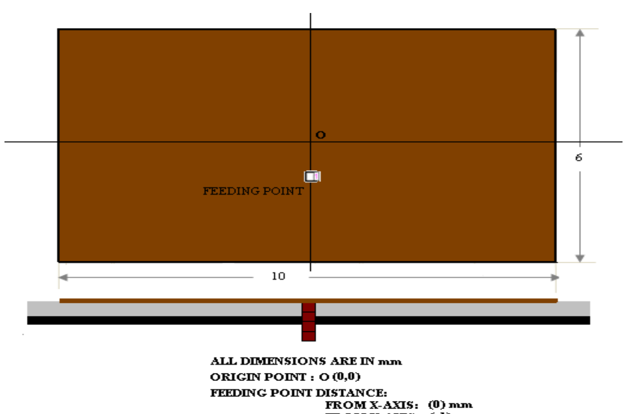

Figure 1: Conventional Antenna configuration

Figure 2 shows the configuration of simulated printed antenna designed with similar PTFE substrate. Three equal slots which are same hexagonal structure at the upper right, upper left and lower left corner from the conventional microstrip patch antenna and the location of coaxial probe-feed (radius=0.5 mm) are shown in the figure 2.

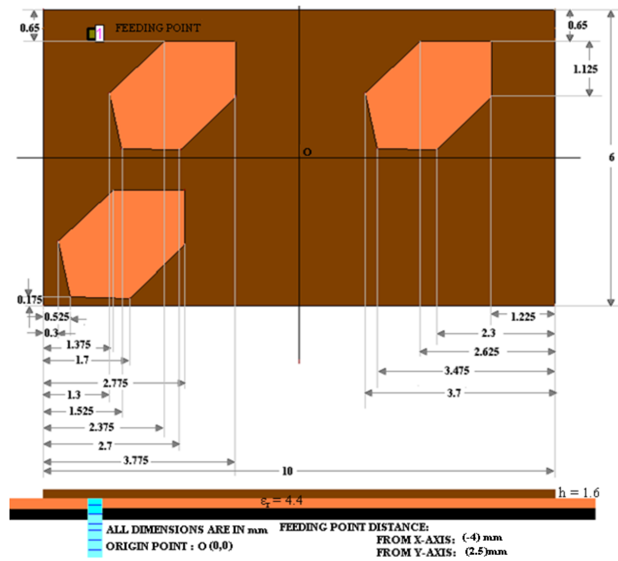

Figure 2: Simulated Antenna configuration

3. Results And Discussion

Simulated (using IE3D [14]) results of return loss in conventional and simulated antenna structures are shown in Figure 3-4. A significant improvement of frequency reduction is achieved with simulated antenna compared to its conventional antenna counterpart.

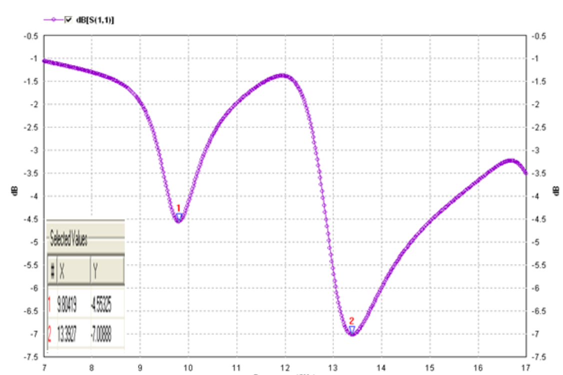

Figure 3: Antenna 1 Return Loss vs. Frequency (Conventional Antenna)

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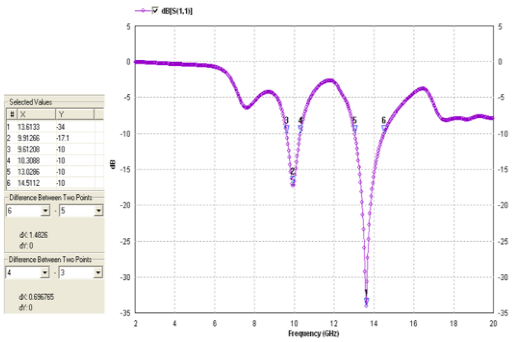

Figure 4: Slotted Antenna Return Loss vs. Frequency (Slotted Antenna)

In conventional antenna, return loss of about -7.0 dB is obtained at 13.39 GHz. Comparative analysis of Fig.3 &4 depicts that for the conventional antenna (fig.3), there is practically no resonant frequency at around 9.25 GHz with a return loss of around -6 dB. For the simulated antenna there is a resonant frequency at around 9.91 GHz with the return loss as high as -17.1 dB.

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= 9.91 GHz with return loss of about -17.1 dB and at f_2 = 13.61 GHz with return losses -34dB respectively. Corresponding 10 dB bandwidth is obtained for Antenna 2 at f_1 and f_2 are 696.80 MHz and 1.48 GHz, respectively.

The simulated E plane and H-plane radiation patterns are shown in Figure 5-12. The simulated E plane (Total) radiation pattern of simulated antenna for 9.91 GHz is shown in figure 5.

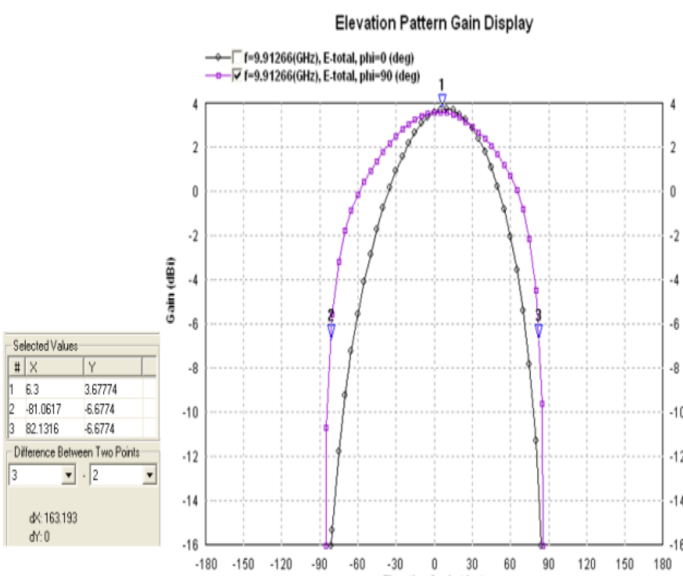

Figure 5: E-Plane (Total) Radiation Pattern for Slotted Antenna at 9.91 GHz

The simulated E plane (Total) radiation pattern (3D) of simulated antenna for 9.91 GHz is shown in figure 6.

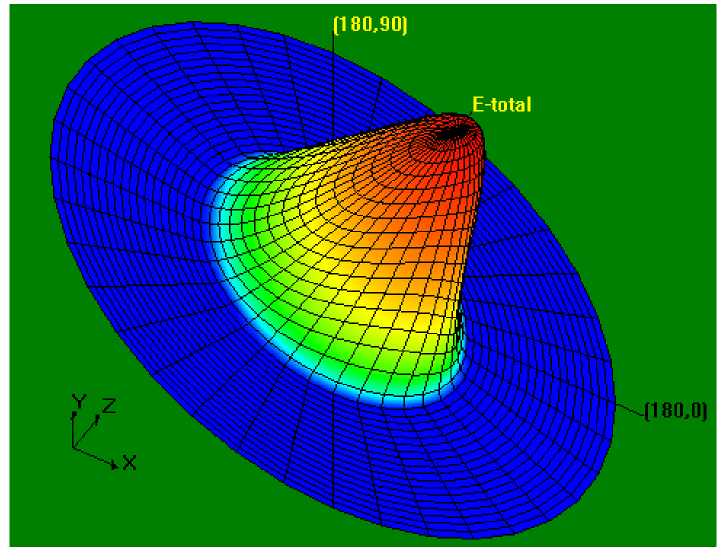

Figure 6: E-Plane (Total) Radiation (3D)Pattern for Slotted Antenna at 9.91 GHz

The simulated current distribution pattern of simulated antenna for 9.91 GHz is shown in figure 7.

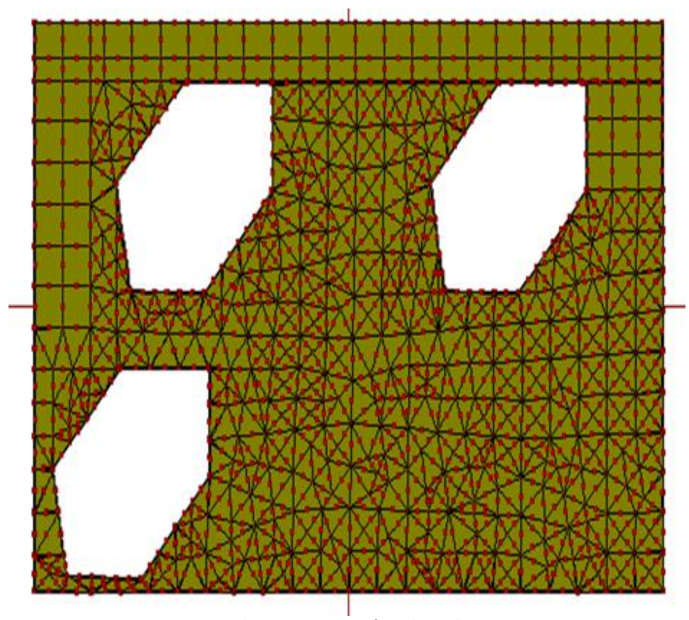

Figure 7: Current Distribution Pattern for Slotted Antenna at 9.91 GHz

The simulated E plane radiation pattern of simulated antenna for 9.91 GHz is shown in figure 8.

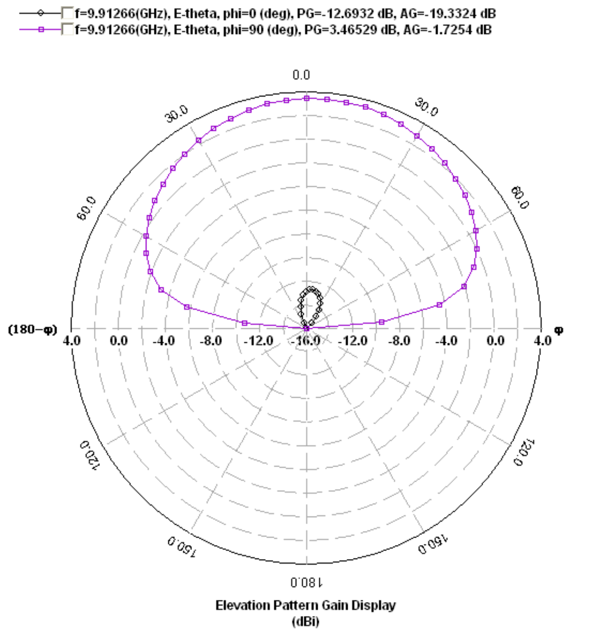

Figure 8: E-Plane Radiation Pattern for Slotted Antenna at 9.91 GHz

The simulated H plane radiation pattern of simulated antenna for 9.91 GHz is shown in figure 9.

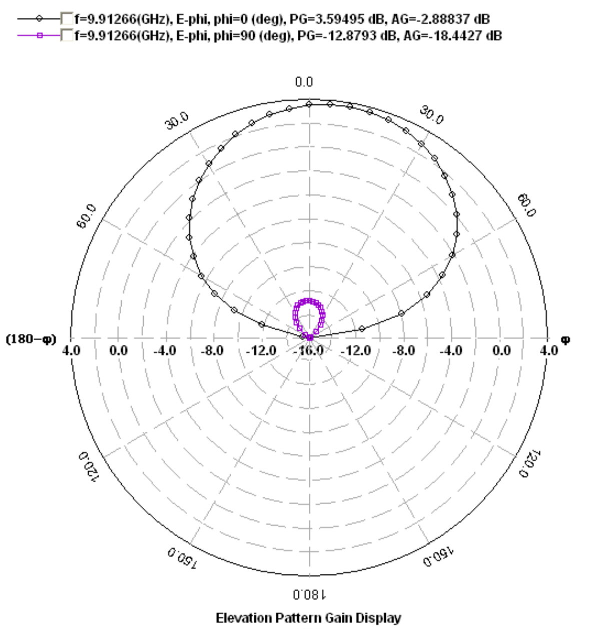

Figure 9: H-Plane Radiation Pattern for slotted Antenna at 9.91 GHz

The simulated E plane radiation pattern (3D-view) of Slotted Antenna for 9.91 GHz is shown in figure 10.

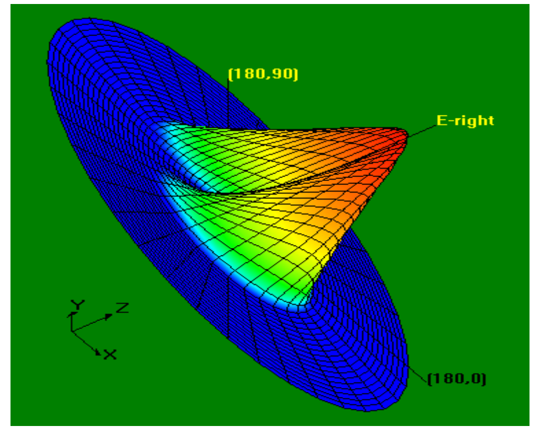

Figure 10: E-Plane Radiation Pattern (3D) for slotted antenna at 9.91 GHz

The simulated H plane radiation pattern (3D-view) of slotted antenna for 9.91 GHz is shown in figure 11.

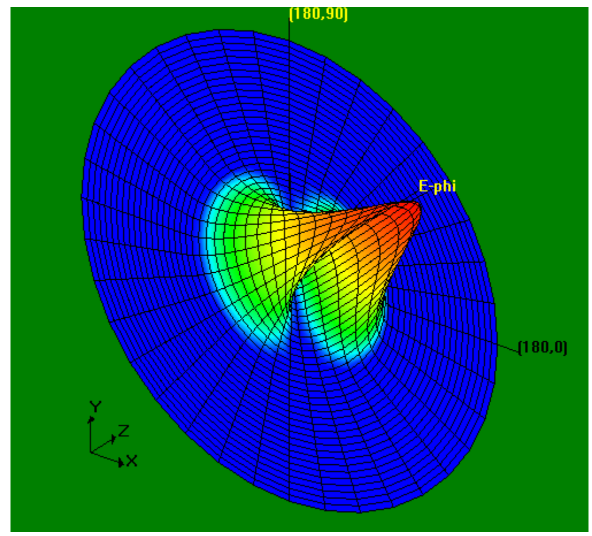

Figure 11: H-Plane Radiation Pattern (3D) for slotted antenna at 9.91 GHz

The simulated E plane (Total) radiation pattern of simulated antenna for 13.61 GHz is shown in figure 12.

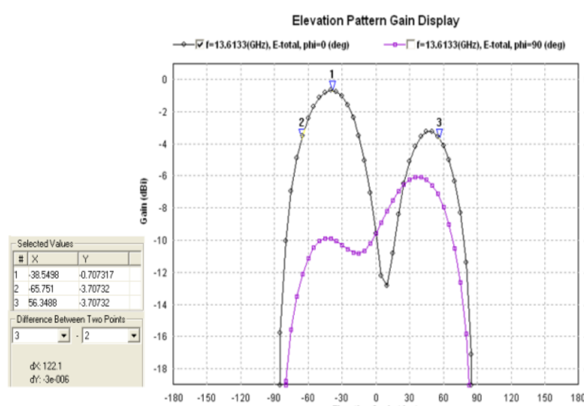

Figure 12: E-Plane (Total) Radiation Pattern for slotted antenna at 13.61GHz

The simulated E plane (Total) radiation pattern (3D) of simulated antenna for 13.61 GHz is shown in figure 13.

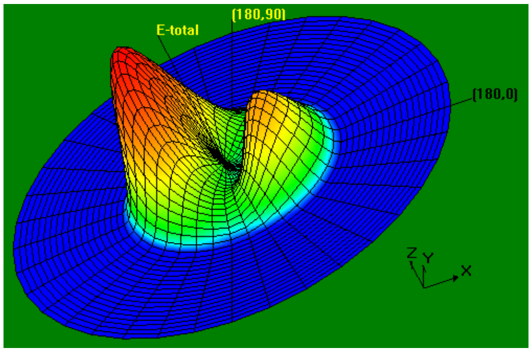

Figure 13: E-Plane (Total) Radiation Pattern (3D) for slotted antenna at 13.61 GHz

The simulated current distribution pattern of simulated antenna for 13.61 GHz is shown in figure 14.

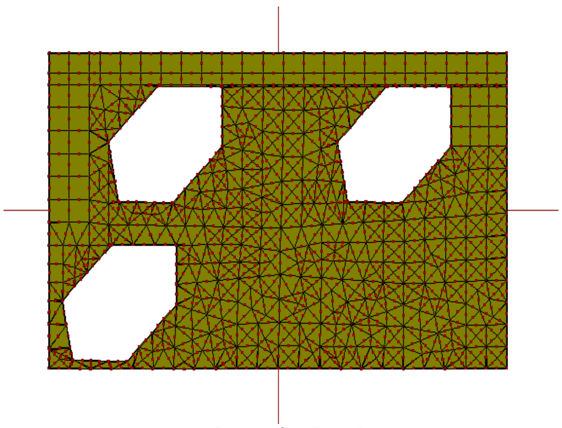

Figure 14: Current Distribution for slotted antenna at 13.61 GHz

The simulated E plane radiation pattern of simulated antenna for 13.61 GHz is shown in figure 15.

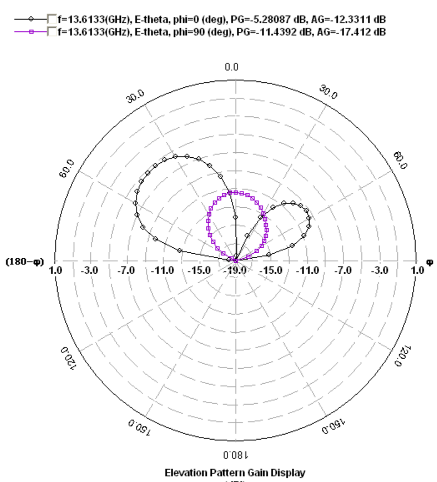

Figure 15: E-Plane Radiation Pattern for slotted antenna at 13.61GHz

The simulated H plane radiation pattern of slotted antenna for 13.61 GHz is shown in figure 16.

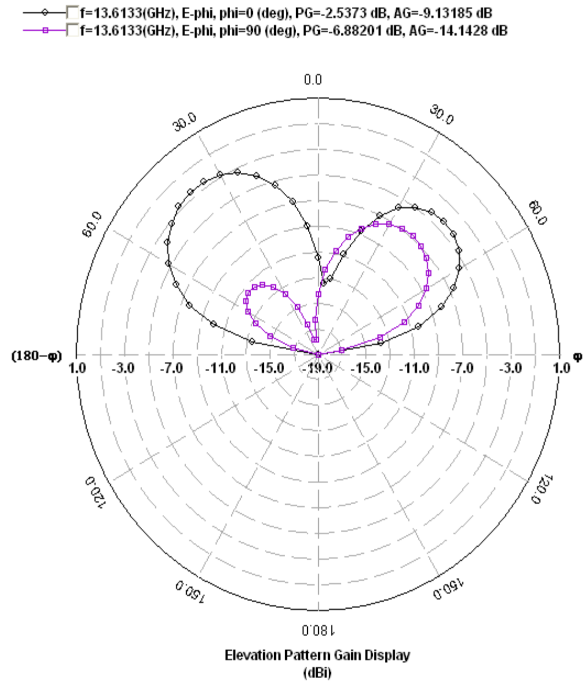

Figure 16: H-Plane Radiation Pattern for slotted antenna at 13.61GHz

The simulated E plane radiation pattern of slotted antenna (3D-view) for 13.61 GHz is shown in figure 17.

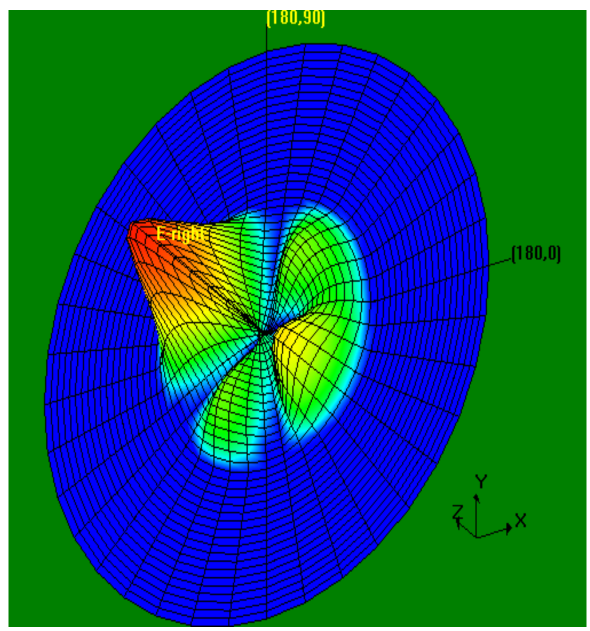

Figure 17: E-Plane Radiation Pattern (3D) for slotted antenna at 13.61 GHz

The simulated H plane radiation pattern of slotted antenna (3D-view) for 13.61 GHz is shown in figure 18.

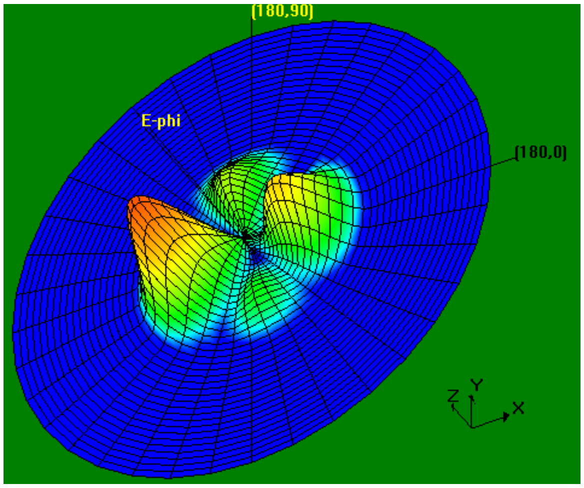

Figure 18: H-Plane Radiation Pattern (3D) for slotted antenna at 13.61 GHz

The simulated frequency vs. real part of the function for slotted antenna is shown in figure 19.

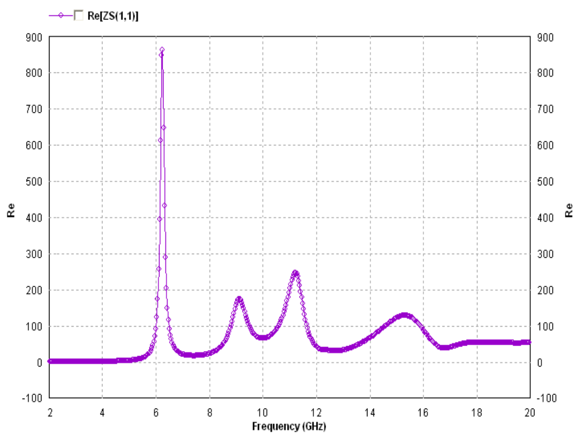

Figure 19: Frequency vs. real function for slotted antenna

The simulated frequency vs. VSWR for slotted antenna is shown in figure 20.

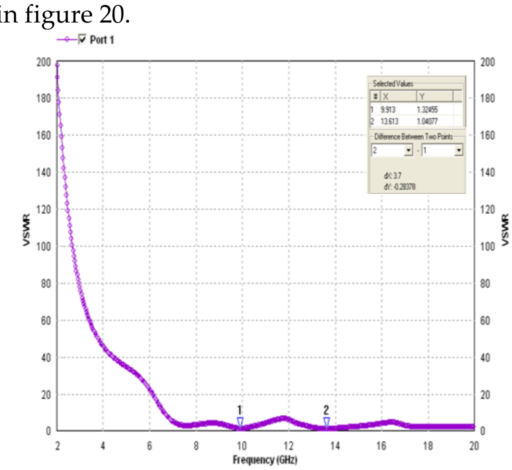

Figure 20: VSWR for slotted antenna

The simulated Smith Chart for slotted antenna is shown in figure 21.

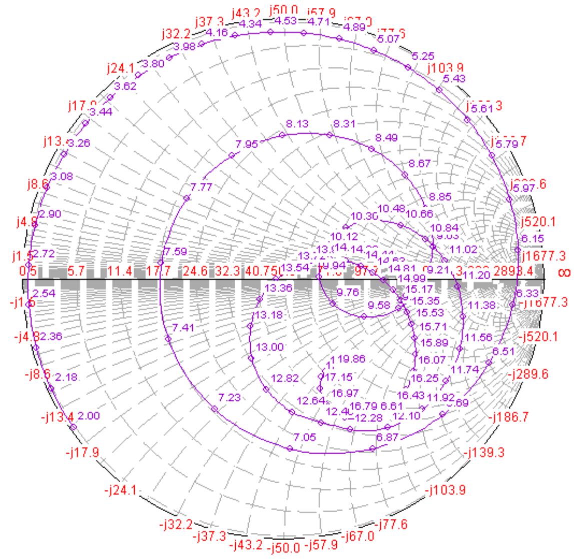

Figure 21: Smith Chart for slotted antenna

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

TABLE I:
SIMULATED RESULTS FOR ANTENNA 1 AND 2

ANTENNA STRUCTURE	RESONANT FREQUENCY (*GHz*)	RETURN LOSS (*dB*)	10 DB BAND-WIDTH (*GHz*)
Conventional	f_1= 13.39	-7.00	NA
Slotted	f_1= 9.91	-17.1	0.6968
	f_2= 13.61	-34	1.4826

TABLE II:
SIMULATED RESULTS FOR ANTENNA 1 AND 2

ANTENNA STRUCTURE	RESONANT FREQUENCY (*GHz*)	3 DB BEAM-WIDTH (^{0})	ABSOLUTE GAIN (*dBi*)
Conventional	f_1= 13.39	NA	NA
Slotted	f_1= 9.91	163.19^0	3.24
	f_2= 13.61	122.1^0	0.14
Frequency Ratio for Slotted antenna			**f_2/ f_1= 1.373**

4. CONCLUSION

This paper focused on the simulated design on differentially-driven microstrip antennas. Simulation studies of a single layer single feed micro strip printed antenna have been carried out using Method of Moment based software IE3D. Introducing slots at the edge of the patch size reduction of about 48.11% has been achieved. The 3dB beam-width of the radiation patterns are 163.19° (for f_1), 122.10° (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 (-4mm, 2.5mm) 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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