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Analysis of Different Shape Slotted and Re-configurable Pin Diode Based Microstrip Patch Antenna for x and ku Band Application.

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Abstract - *This paper is about the design of three different proposed microstrip patch antenna incorporating slots and pin diode as switch (ON-OFF mode) for frequency re-configurability and advancement in antenna parameters. Microstrip line feeding technique is used. The antenna has been designed using Ansoft HFSS 13.0 and fabricated with substrate FR4_epoxy of thickness 1.8 mm. 1st antenna is about single band with edge and center slotted that has return loss -20.3466 dB at resonant frequency 11.1224 GHz, 2nd one is about dual band frequency excluding one slot and incorporating a pin diode at the patch center in between the slot and has return loss -29.0333 dB at resonant frequency 13.8776 GHz and the 3rd antenna is about dual band frequency incorporating two pin diode at both ends in the slot on patch at the center and has return loss -35.2532 dB at resonant frequency 13.7755 GHz. Moreover other parameters like VSWR, Gain, and Directivity have also been measured and values are best suited for designed antennas and are suitable for X and Ku band application.*

Key Words: **Microstrip patch Antenna, Reconfigurable, Slots, Pin Diodes, X and Ku, Dual Band, HFSS.**

1. INTRODUCTION

Over the past few decades, Antenna Technology has been rapidly growing and involving innovative requirements in wireless communication system.[1][2][4] It has wide range of application like Wi-Fi, WLAN, Mobile Phone, GPS, Traffic Radar, Satellite, Biomedical, Military, Aerospace where antenna structure is the key part of the system.[3]

Microstrip patch antenna has drawn attention among others due to its noticeable advantages such as small size, low weight, small size, low manufacturing cost, ease of fabrication, ease of being integrated on the circuit.[6][7][10] Moreover it has dominant characteristics like low profile, multi band frequency, low radiation loss, integration with microwave integrated circuit and can be in any shape like rectangular, square, triangular, hexagonal, circular, elliptical and any others.[12][16]Furthermore microstrip patch antenna consists of a conducting ground plane at the bottom and metallic radiating patch at the top of comparatively thick dielectric substrate.[5][8]

In addition, Microstrip patch antenna structure can be described as sandwich of dielectric substrate in between two parallel conducting layers. [13][15] Out of various feeding technique microstrip line feed has a conducting strip which is directly connected with the patch.[5][7] Likewise slots with the radiating patch have been fruitful for increasing the parameters, multiband frequency of microstrip patch antenna. In addition to acquire multiband frequency and to improve the performance of microstrip patch antenna re-configurability has drawn the attention of many researchers in recent time.[2][9] Re-configurability has been achieved by incorporating pin diode as switch (ON-OFF mode) which can be placed either in the slotted area or on the radiating patch.[3][8] Multiband, higher frequency such as X and Ku band as per IEEE Standard frequency range (8 to12)GHz X band and (12 to 18)GHz Ku band are back to back and separate with one another.[14][15] In this paper quad edge different slotted with pin diode at the centre in the radiating patch reconfigurable.

2. PROPOSED ANTENNAS

Three different antenna with different configuration is proposed in the paper. The configuration of three antennas is described here in brief:

Antenna 1:

This antenna design is about quad edge and plus shape slotted center patch which gives single band of resonant frequency 11.1224 GHz. Figure 1(a) shows the design of proposed antenna 1.

Antenna 2:

This antenna design is about quad edge and rectangular shape slotted center patch with pin diode which gives resonant frequencies of 11.1224 GHz, 13.8776 GHz and13.9796 GHz. Figure 1(b) shows the design of proposed antenna 2.

Antenna 3:

This antenna design is about quad edge and plus shape slotted center patch with two pin diodes which gives resonant frequencies of 11.0204 GHz and 13.7755 GHz. Figure 1(c) shows the design of proposed antenna 3.

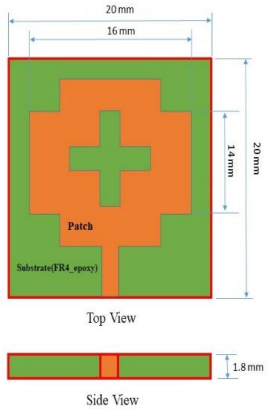

Figure 1(a) Antenna 1

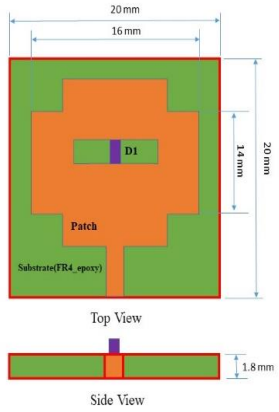

Figure 1(b) Antenna 2

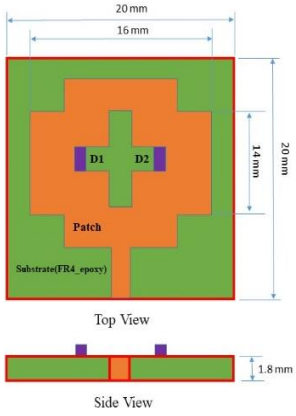

Figure 1(c) Antenna 3

2.1 CONFIGURATION FOR PROPOSED ANTENNAS

Three different microstrip patch antenna design has been proposed by incorporating slots and pin diodes in between slots. The antenna has been designed and tested by using Ansoft HFSS 13.0 software and the material selected for substrate is FR4_epoxy with thickness 1.8 mm having dielectric constant 4.4 and tangent loss 0.02. Microstrip line feeding technique has been used in these proposed antenna to excite the patch. Below mentioned table describes about detail configuration of the proposed antennas.

Table -1: Configuration for Proposed Antenna 1, 2 and 3

Parameters	Configurations
Substrate (x-axis X y-axis X z-axis)	Material=FR4_epoxy
	Length (L)=20mm
	Width(W)=20mm
	Height(H)=1.8mm
	Dielectric constant=4.4
	Dielectric loss tangent=0.02
Patch (x-axis X y-axis)	Length (L)=16mm
	width(W)=14mm
Feed Point (x-axis X z-axis)	X=2mm and Z=-1.8mm
4 Square slots in Patch (x-axis X z-axis)	Slots each 2.75mm X 2.75mm at corner
2 Rectangular slots in patch (x-axis X z-axis)	slot 8mm X 2 mm at center
	slot 2mm X 8 mm at center , (Note: Not Used in Antenna 2)
Pin Diode 1 (x-axis X y-axis X z-axis)	1mm X 2mm X 1mm
Pin Diode 2 (x-axis X y-axis X z-axis)	1mm X 2mm X 1mm, (Note: Not used in Antenna 2)

3. RESULTS AND DISCUSSION.

The results obtained from simulation of three antennas with different configuration is discussed in this section.

3.1 Antenna 1

This antenna gives single band resonant frequency of 11.1224 GHz which shows the balanced value of the antenna parameters like return loss -20.3466 dB, vswr 1.6744, Gain of 4.8678 dB and Directivity 7.2616 also from the current distribution for E-Plane, it is observed that the antenna produces omnidirectional radiation throughout all resonant frequencies with stable radiation pattern and circular polarization. Table 3.1 describes the observed parameters of the proposed antenna structure and likewise figure 3.1 (a), (b), (c), (d), (e) and (f) represent the graphical pattern for return loss, vswr, gain, directivity, radiation Pattern and current distribution.

Table 3 -1: Observed values for antenna 1.

Frequency [GHz]	Return loss	VSWR	Gain	Directivity
11.1224	-20.3466	1.6744	4.8678	7.2616

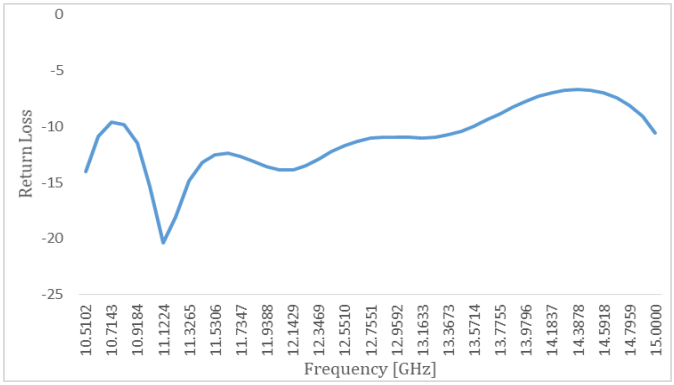

Figure -3.1 (a): Return Loss for Antenna 1.

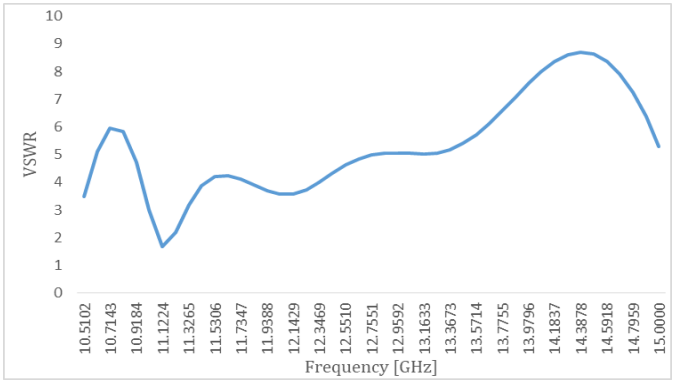

Figure -3.1 (b): VSWR for Antenna 1.

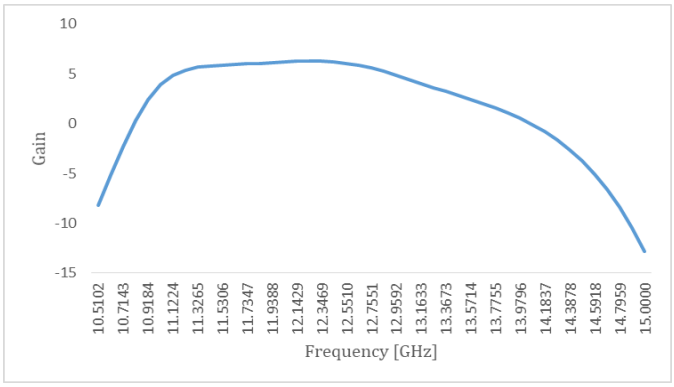

Figure -3.1 (c): Gain for Antenna 1.

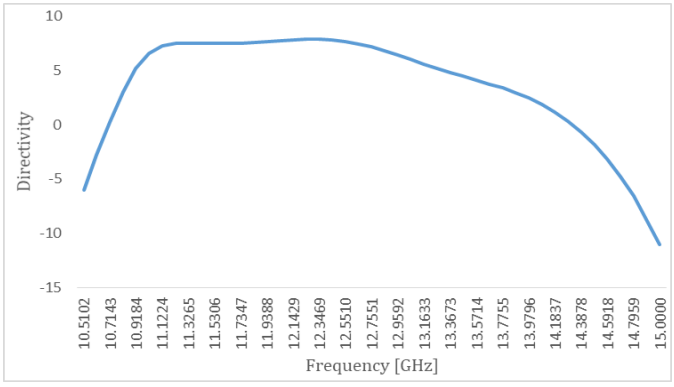

Figure -3.1 (d): Directivity for Antenna 1.

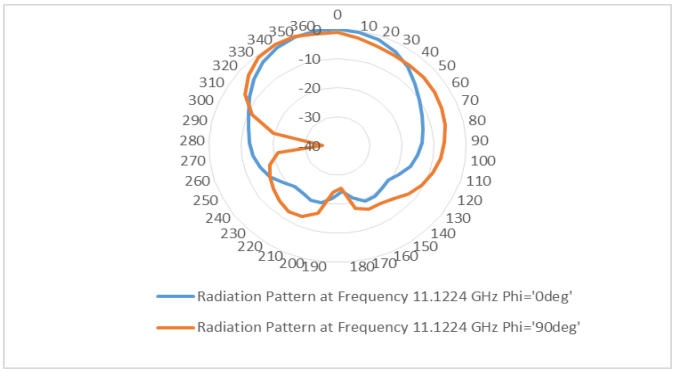

Figure -3.1 (e): Radiation Pattern for Antenna 1.

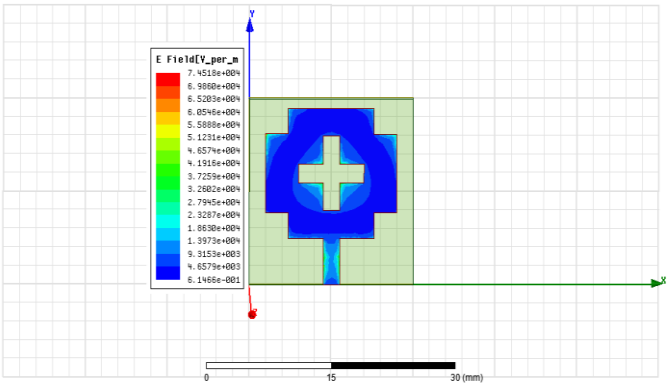

Figure -3.1 (f): Current Distribution for Antenna 1.

3.2 Antenna 2

Antenna 2 operation is based on the pin diode performance that is switching condition (ON-OFF). When the diode is at ON condition, the antenna gives the band of resonant frequency 11.0204 GHz and 13.9797. Similarly, during the OFF condition of diode the antenna gives resonant frequency of 11.0204 GHz and 13.8776 GHz. The observed values for return loss, vswr, gain, directivity for different frequencies at diode ON and OFF condition is summarized in table 3.2. From the current distribution for E-Plane, it is observed that the antenna produces omnidirectional radiation throughout all resonant frequencies with stable radiation pattern and circular polarization. The graphical pattern for return loss, vswr, gain, directivity, radiation pattern and current distribution is shown in the figure 3.2 (a),(b),(c),(d),(e) and (f) respectively.

Table -3.2: Observed values for antenna 2 for Pin Diode ON and Pin Diode Off.

Diode OFF				
Frequency [GHz]	Return loss	VSWR	Gain	Directivity
11.0204	-23.1313	1.2133	3.501	6.4415
13.9797	-17.9164	2.2201	2.6863	5.5881
Diode ON				
Frequency [GHz]	Return loss	VSWR	Gain	Directivity
11.0204	-21.4086	1.4807	3.6512	6.5597
13.8776	-29.0333	0.6143	3.568	6.2234

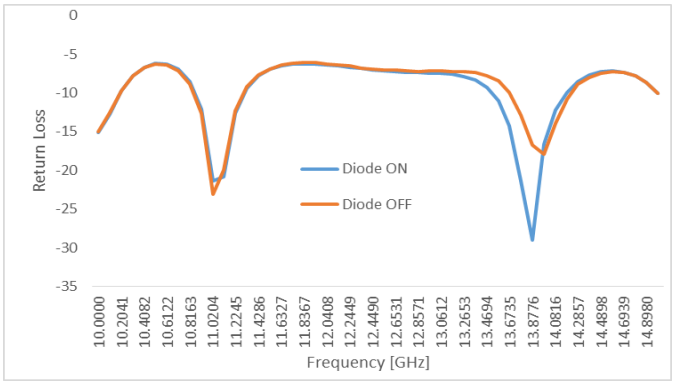

Figure -3.2 (a): Return Loss for Antenna 2.

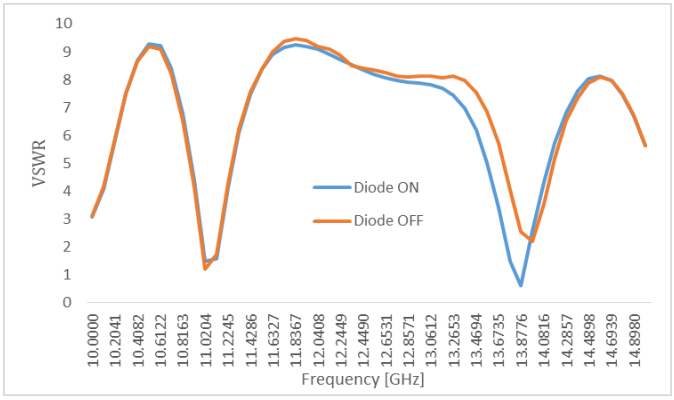

Figure -3.2 (b): VSWR for Antenna 2.

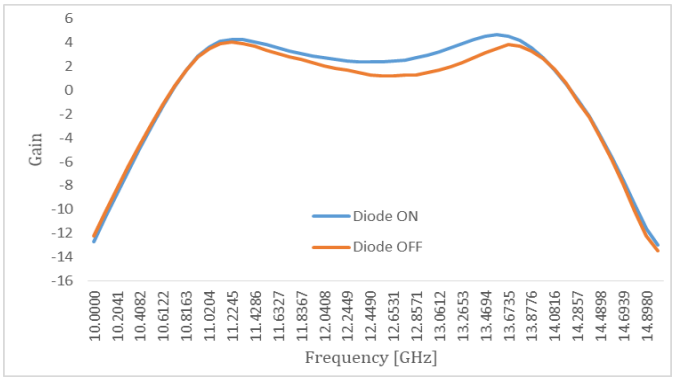

Figure -3.2 (c): Gain for Antenna 2.

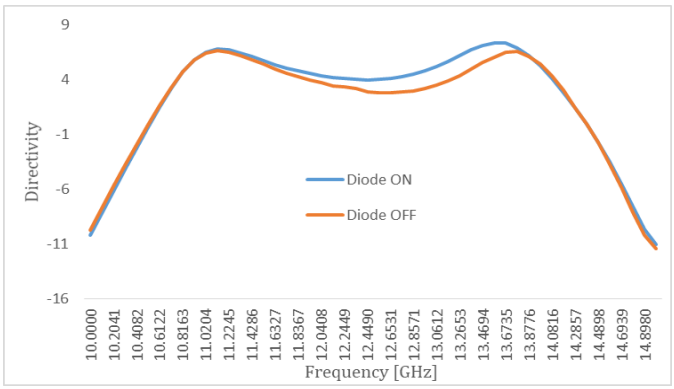

Figure -3.2 (d): Directivity for Antenna 2.

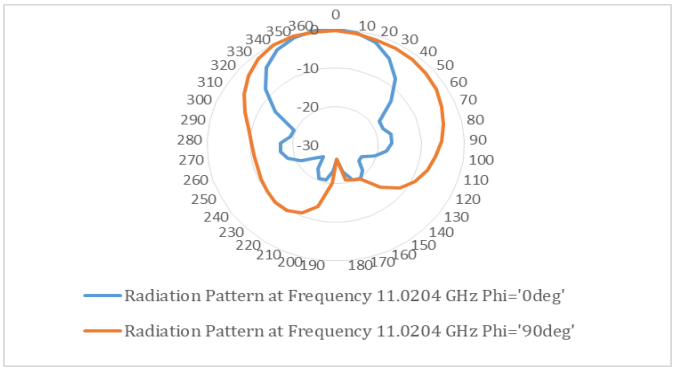

Figure -3.2 (e): Radiation Pattern for Antenna 2 at Frequency 11.0204 GHz.

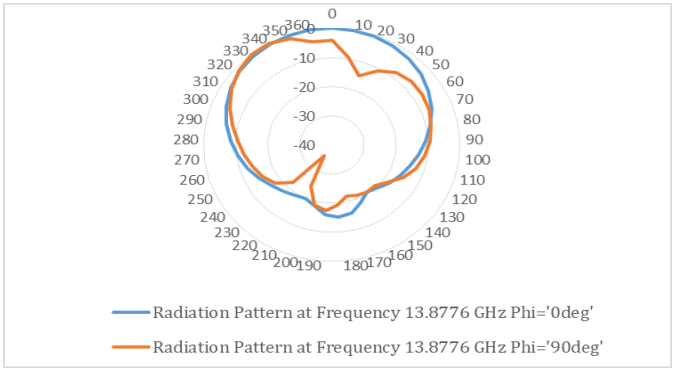

Figure-3.2 (e): Radiation Pattern for Antenna 2 at Frequency 13.8776 GHz.

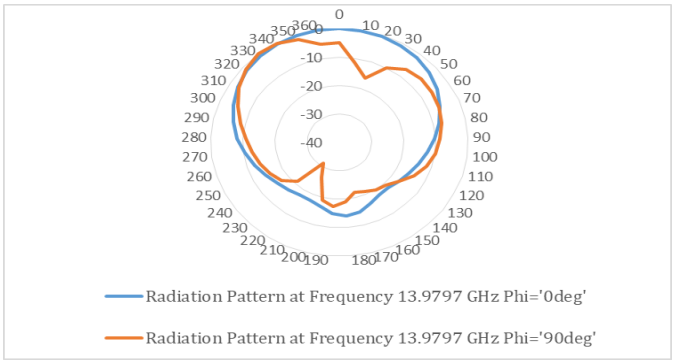

Figure-3.2 (e): Radiation Pattern for Antenna 2 at Frequency 13.9797 GHz.

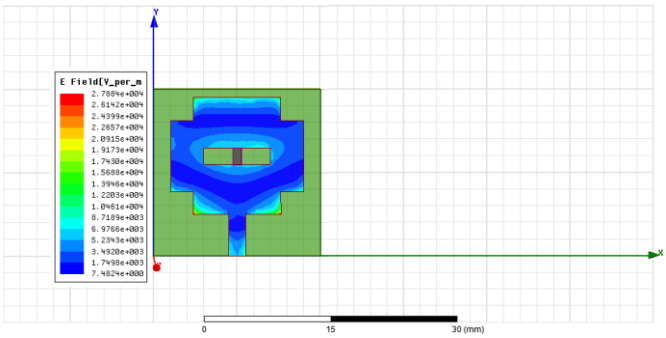

Figure-3.2 (f): Current Distribution for Antenna 2.

3.3 Antenna 3

This antenna 3 activities is based on the operation of two pin diode, i.e. pin diode 1 (D1) and pin diode 2 (D2) at switching condition (ON-OFF). At the initial condition when both the diode is OFF (D1 OFF and D2 OFF), the antenna gives the resonant frequencies of 11.0204 GHz and 13.8776 GHz. In addition, when the diode 1 (D1) is ON and diode 2 (D2) is OFF the antenna gives resonant frequencies of 11.0204 GHz and 13.7755 GHz with slight increase in the values of antenna parameters. Similarly when diode 1 (D1) is ON and diode 2 (D2) is OFF the antenna gives the same resonant frequencies of 11.0204 GHz and 13.7755 GHz with considerable improvement in the antenna parameter values. Finally when both the diode 1 (D1) and diode 2 (D2) are ON, the antenna gives the resonant frequencies of 11.0204 GHz and 13.6735 GHz with remarkable improvement in the values of the antenna parameters. The observed values of antenna parameters like return loss, vswr, gain and directivity for different condition of diode1 (D1) and diode 2 (D2) are summarized in the table 3.3. Current distribution for the E-Plane observed that antenna produces omnidirectional radiation throughout all resonant frequencies with stable radiation pattern and circular polarization.

Table-3.3: Observed values for antenna 3 for both Pin Diode1 (D1) and Pin Diode2 (D2) at (ON-OFF) condition.

D1 OFF and D2 OFF				
Frequency [GHz]	Return loss	VSWR	Gain	Directivity
11.0204	-22.8154	1.2584	3.611	6.3837
13.8776	-25.8827	0.8832	3.973	6.483
D1 OFF and D2 ON				
Frequency [GHz]	Return loss	VSWR	Gain	Directivity
11.0204	-21.0595	1.5417	3.6394	6.3964
13.7755	-35.2532	0.3001	4.45	6.8784
D1 ON and D2 OFF				
Frequency [GHz]	Return loss	VSWR	Gain	Directivity
11.0204	-20.6512	1.6163	3.6441	6.3802
13.7755	-33.1656	0.3816	4.445	6.8867
D1 ON and D2 ON				
Frequency [GHz]	Return loss	VSWR	Gain	Directivity
11.0204	-19.3833	1.8722	3.6822	6.4205
13.6735	-21.8228	1.4114	4.8811	7.2693

The graphical pattern for return loss, vswr, gain, directivity, radiation pattern and current distribution are shown in the figure 3.3 (a),(b),(c),(d),(e) and (f) respectively.

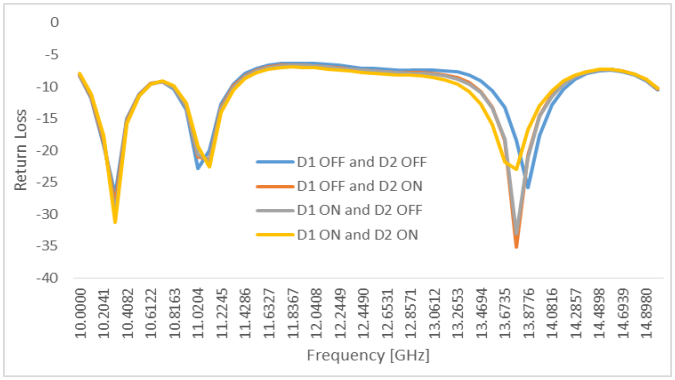

Figure- 3.3 (a): Return Loss for Antenna 3.

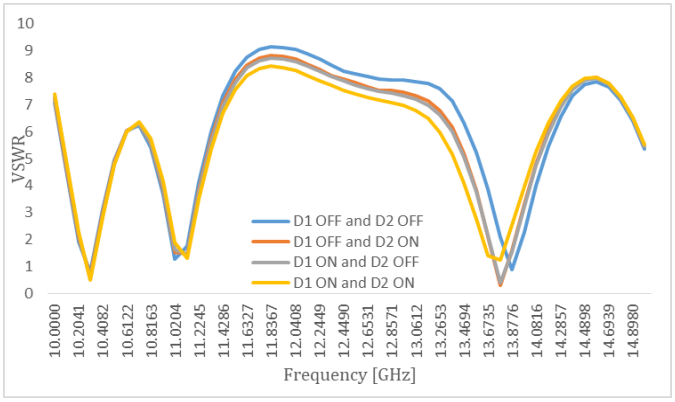

Figure-3.3 (b): VSWR for Antenna 3.

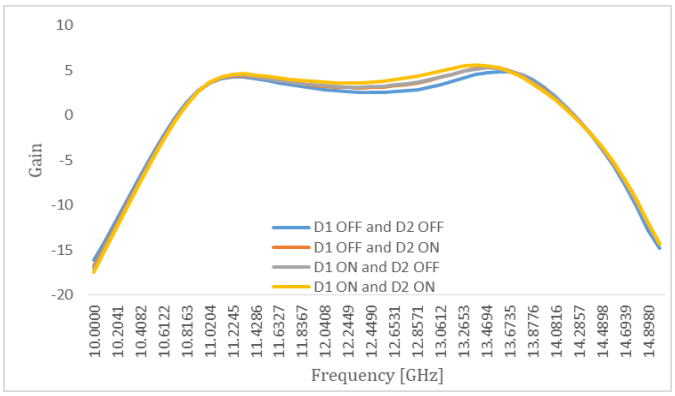

Figure-3.3 (c): Gain for Antenna 3.

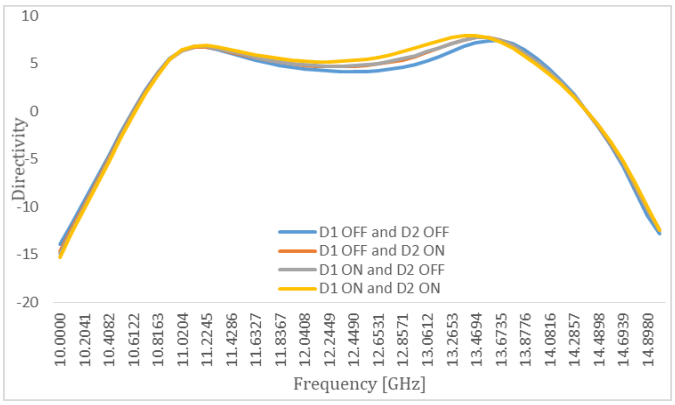

Figure-3.3 (d): Directivity for Antenna 3.

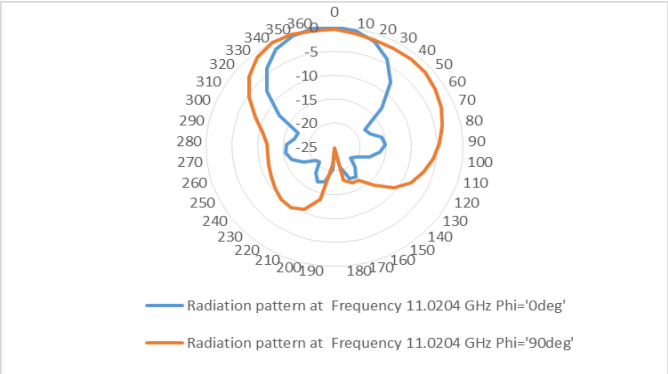

Figure-3.3 (e): Radiation pattern for Antenna 3 at frequency 11.0204 GHz.

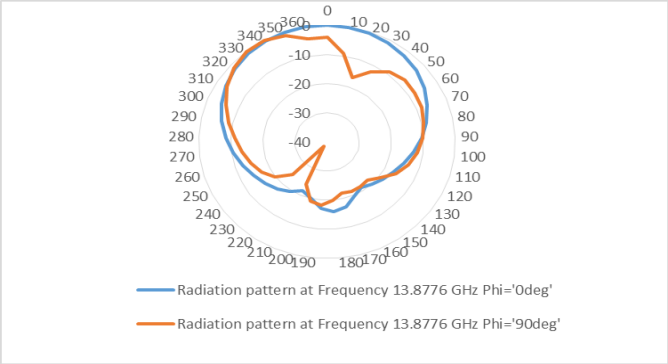

Figure-3.3 (e): Radiation pattern for Antenna 3 at frequency 13.8776 GHz.

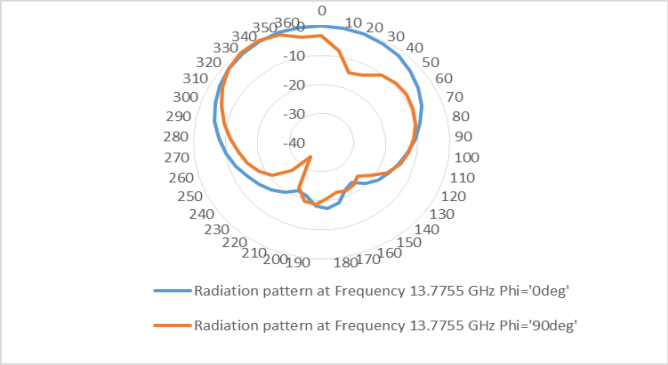

Figure-3.3 (e): Radiation pattern for Antenna 3 at frequency 13.7755 GHz.

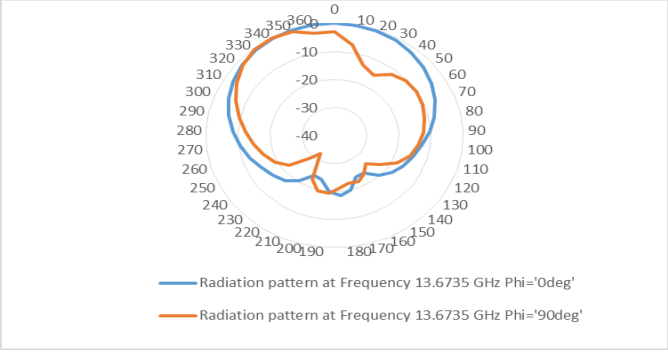

Figure-3.3 (e): Radiation pattern for Antenna 3 at frequency 13.6735 GHz.

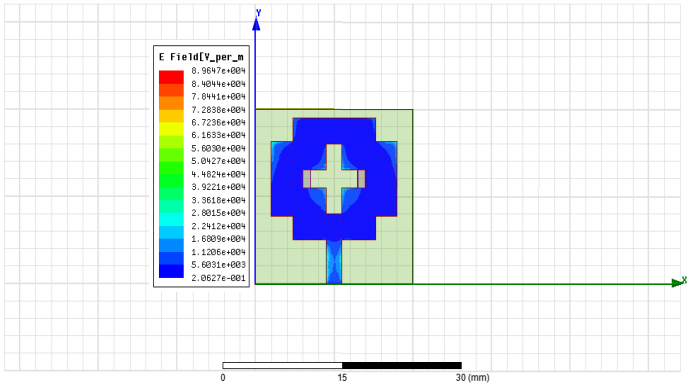

Figure-3.3 (f): Current Distribution for Antenna 3.

4. FABRICATION

This portion explains the fabrication of microstrip patch antenna 1, which was designed and simulated in above section. The dimensions used for the fabrication is obtained from simulation. Material used for fabrication is substrate FR4_epoxy and SMA connector. Figure 4.1 and 4.2 shows the top and bottom view of the antenna.

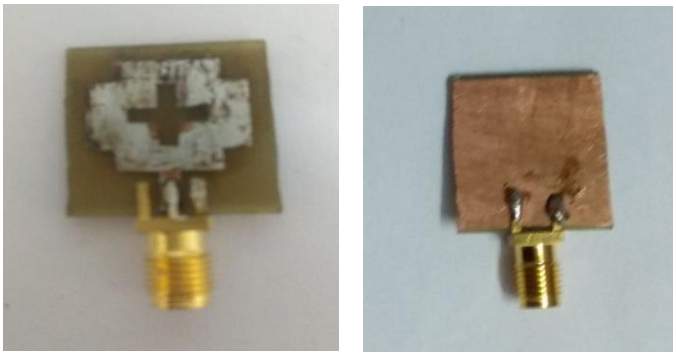

Figure-4.1: Antenna 1 prototype (top and bottom view) and Antenna 3 without Diode D1 & D2.

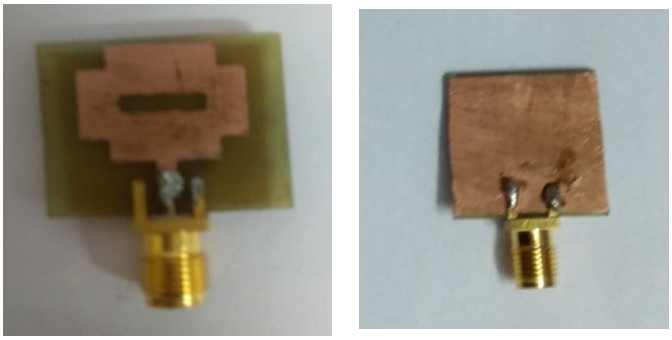

Figure-4.2: Antenna 2 prototype (top and bottom view) without Diode D1.

5. CONCLUSION

The proposed three antennas are simple, low cost and designed using microstrip line feed technique with patch on HFSS 13.0 and fabricated with substrate FR4_epoxy. These are suitable for X and Ku band application. The simulated

results for the slotted and frequency reconfigurable antennas have been discussed in this paper. In addition, it has been observed that with slots of different shapes and size, the radiating area of the patch decreased slightly but the performance of antennas increased. Slots and pin diodes were introduced for both frequency and antenna parameters re-configurability, the diodes have been incorporated over the patch at the center in between slotted area.

The above results have made clear that the slotted antenna 1 works for single band resonant frequency 11.1224 GHz and has attractive values of return loss, vswr, gain, directivity and radiation pattern. It has been analyzed that by introducing slots and pin diodes for frequency re-configurability, the values in return loss, vswr, gain and directivity significantly increase without affecting the results. Furthermore, by using the single pin diode in antenna 2 with only one slot at the center of the patch the antenna works for dual band resonant frequencies of 11.0204 GHz, 13.8776 GHz and 13.9797 GHz during diode OFF-ON condition and also by incorporating two pin diodes, the antenna works for different resonant frequencies of 11.0204 GHz, 13.6735 GHz, 13.7755 GHz and 13.8776 GHz during different diode OFF-ON condition. It has also been observed that the designed antennas produce omnidirectional radiation throughout all operating band of resonant frequencies with stable radiation pattern and circular polarization. These proposed antennas have potential to be used in different areas of application like satellite communication, broadband communication, radar, space, aeronautical radio navigation, mobile satellite.

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