Analysis of Hexagonal Shaped Antenna: Frequency Reconfiguration by using PIN Diode

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Abstract: - The proposed antenna is designed with hexagonal shape. In this novel antenna at upper side L shaped Patch is connected to hexagonal patch by using one PIN diode (SMP 1320) and two square slots at two corners. Design frequency for this antenna is 5.2 GHz. The side length (a) of Hexagon decides the frequency of hexagonal patch antenna and to achieve expected frequency for this antenna a=9mm is selected. FR4 substrate is preferred. Frequency reconfiguration is done by making PIN diode ON & OFF. In OFF state, 5.2 GHz frequency is provided by antenna and -17.61 dB return loss with 5.8 antenna gain, 70 MHz bandwidth. In ON state, 3.61 GHz frequency is provided by antenna and -14.88 dB return loss with 3.2 antenna gain, 110 MHz bandwidth. Simulation is performed with HFSS software. For this antenna nearly similar simulation and testing results achieved.

Keywords: - Frequency Reconfiguration, PIN diode, Return Loss, Bandwidth,

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I. Introduction

In current era, it is expected that a single electronic device can fulfill all the requirements of number of applications. From this point of view, reconfigurable antennas are more important in wireless communication. Reconfiguration of antenna means to control number of parameters of that antenna e.g., Resonant Frequency, etc. [1] To achieve this reconfiguration number of components are used e.g., PIN diode, MEMS [2]

Rasool & et.al. proposed a simple & compact reconfigurable antenna having CPW feed line with complementary split ring resonator antenna [3]. Tanuj Garg explained L slotted Hexagonal shaped antenna for which RT duroid substrate is preferred. Garg concludes that as per the horizontal length of L slot changes, frequency of antenna will also change. Garg achieved two band frequencies 4.94 GHz & 8.02GHz for L=1.9cm [4].

To improve the performance of reconfigurable antenna, defected ground structure method is also useful [9-10]. Jaswinder Kaur & et.al. described swastik shape DGS for zigzag MPA.

S. Kannadhasan & et.al. described a simple DGS MPA for 5G WCS for which he preferred FR4 substrate.

The rest of the paper contents are as follows: In section II proposed antenna geometry is given. Section III explains Design Procedure of proposed antenna. In section IV frequency switching techniques are given. Simulation Results are given in section V and Testing Results are given in section VI. Section VII concludes the paper.

II. Antenna Geometry

The structure of Hexagonal shaped reconfigurable antenna is shown in figure1. For this proposed Hexagonal shaped antenna FR4 substrate with microstrip line feed method is preferred. The proposed antenna contains hexagonal patch with two square slots at two corners and L shaped Patch at upper side connected to hexagonal patch through one PIN diode. Frequency reconfiguration is to be done by using PIN diode (SMP1320) having different ON state and OFF state RLC values.

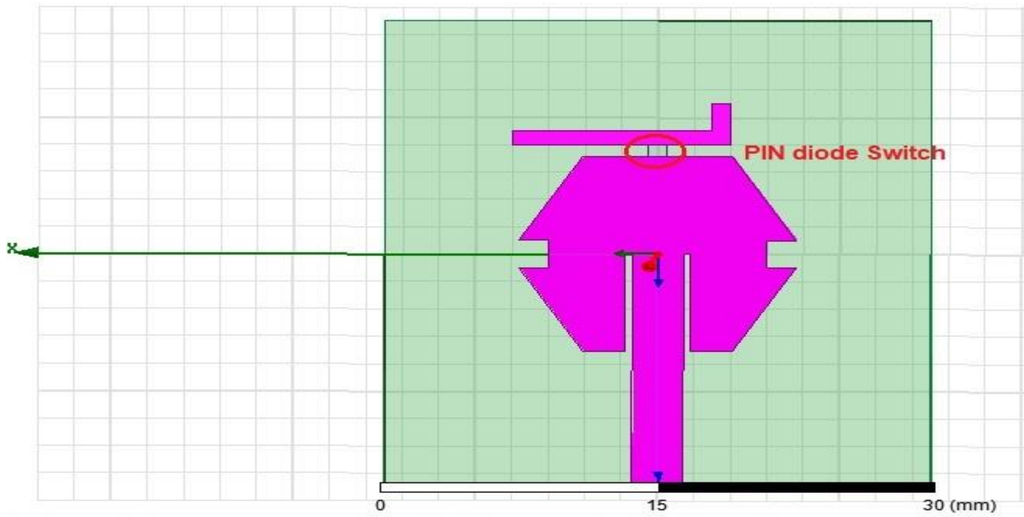

Figure 1: Front view of antenna

III.Antenna Design Procedure

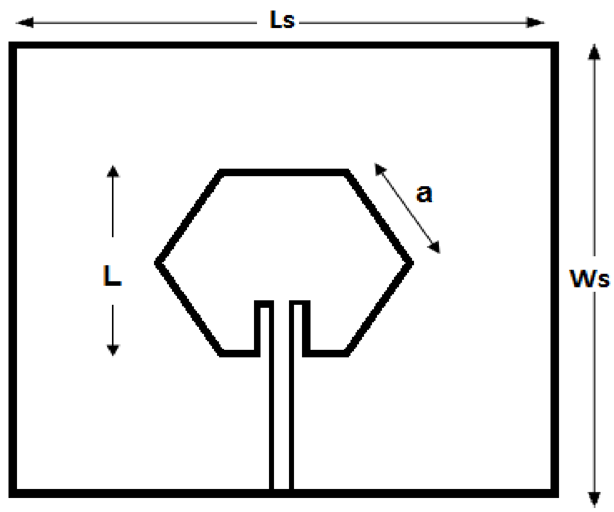

Figure 2: Structure of proposed antenna

The resonant frequency of the proposed antenna is selected as 5.1 GHz. All dimensions are calculated by using formulae given below:

Step 1: Calculation of Lambda (λ)-

Lambda (λ)=c/f=3x10^8/5.2x10^9

(λ)=57.8mm at 5.2 GHz

Step 2: Calculation of side length of Patch (a)-

The fundamental mode resonant frequency of such antenna is given by

$$fr = \frac{2c}{6*a*\sqrt{\varepsilon r}} \quad (1)$$

Where, c is speed of light , ε_r is relative permittivity of substrate,

and a is side length of hexagonal patch.

$$a = \frac{2c}{6*fr*\sqrt{\varepsilon r}} \quad (2)$$

$$a = \frac{2\times3\times10^{\wedge}8}{6\times5.2\times10^{\wedge}9\sqrt{4.4}}$$

a=9mm

Step 3: Calculation of Length of Patch (L)-

The Resonant length is given as

$$L = \frac{\lambda}{2\sqrt{\varepsilon r}} \quad (3)$$

Where, L = resonant Length

λ = wavelength in free space

εr = dielectric constant

L= 13.8mm

Step 4: Calculation of Substrate dimension-

For this design substrate dimension would be

Ls=L+2*6h=14+2*6*1.6=33mm

Ws=W+2*6h=17+2*6*1.6=35mm

The parameter dimensions of the proposed antenna are given in Table 1. For this proposed antenna substrate and ground dimensions should be the same of length 33mm and width 35mm. Length of hexagon side should be represented by 'a' of 9mm.

Table 1. Parameters of the proposed antenna

Sr.No	Parameters	Calculated Dimensions(mm)
1.	L	13.8
2.	a	9.0
3.	Ls	33.0
4.	Ws	35.0

II. Frequency switching techniques

Reconfigurable antenna classification is shown in figure 3. Reconfiguration means to change either antenna radiation pattern or resonant frequency or Polarization etc. Frequency reconfiguration is to be done by number of methods e.g., by varying size of Patch, by varying values of Lumped elements etc. [5]. M. S. Shakhirul & et.al. discussed different frequency switching techniques [6].

For reconfiguration of antenna RF switches are preferable, suggested switches are PIN diodes, MEMS etc. Switch is nothing but a component which works as a circuit maker or circuit breaker for configuration of antenna. The function of switch is to control RF current and hence to achieve proper configuration of antenna RF switch positioning is material. PIN diodes are most preferable as compared to MEMS because it is cost efficient & high handling competency [7-8]. At microwave frequencies, it provides pure resistance from few Ω to few KΩ. For ON state, small current means near about 10 mA current is required.

For this proposed antenna we preferred frequency reconfiguration by using PIN diode (SMP 1320) which has different RLC values for ON & OFF states.

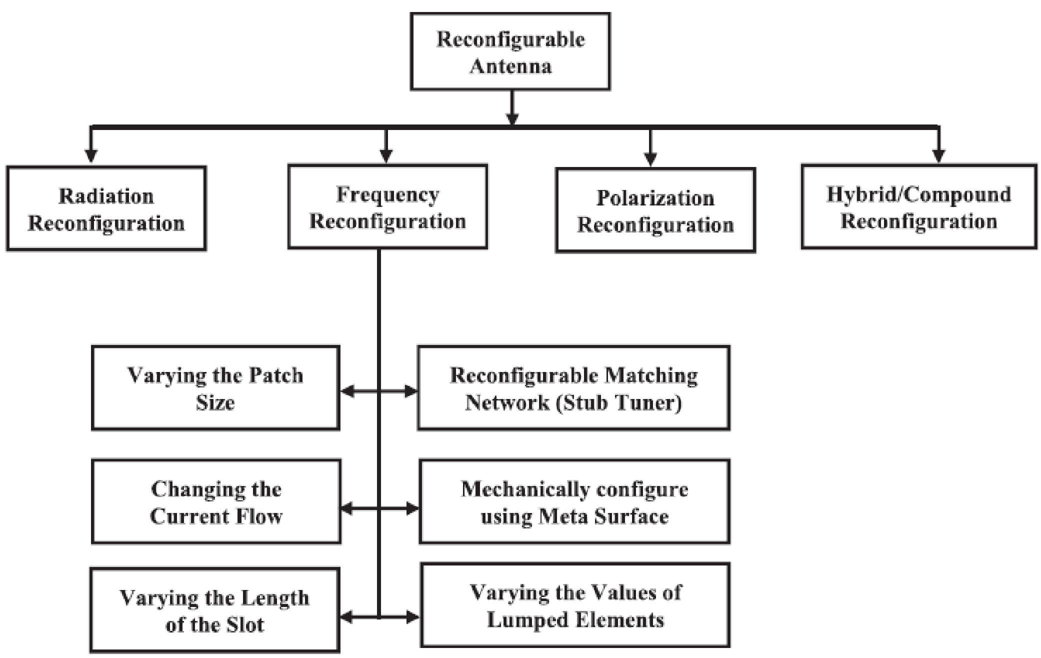

Figure 3: Classification of Reconfigurable antenna

III. Switching Mechanism

As per the ON/OFF state of diode, it can provide frequency reconfiguration, because there is change in its RLC values. For ON state L= 0.7nH. For this state Rf & L are in series connection whereas for OFF state Rr & C are in Parallel Connection, for this state Rr=0.9 Ω & C=0.3pF,L= 0.7nH.

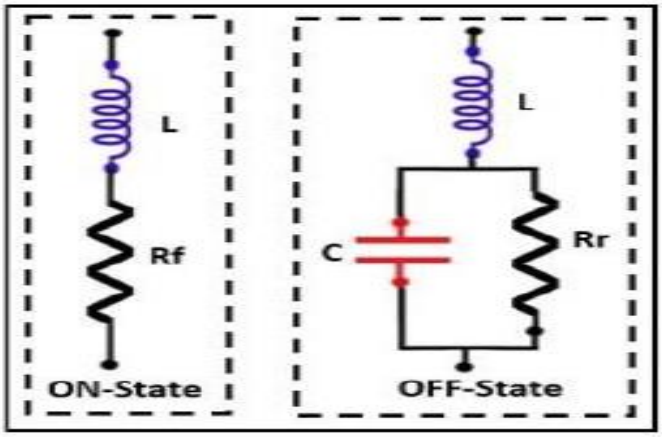

Figure 4: ON & OFF states of PIN diode

IV. Simulation Results

The proposed antenna is simulated by using ANSYS HFSS software. We simulated this antenna for two states of diode, first one is ON state of Pin diode and second is Off state of diode. For On state we are getting S11 value should be -16.91 dB at frequency 3.67 GHz. S11 value graph is shown in figure 5.

Figure 6 shows VSWR graph. For this antenna we are getting VSWR value should be 1.33 and gain of 3.35 dBi for the same frequency 3.67 GHz (ON state). For this on state of Pin diode we are getting Bandwidth of 110 MHz.

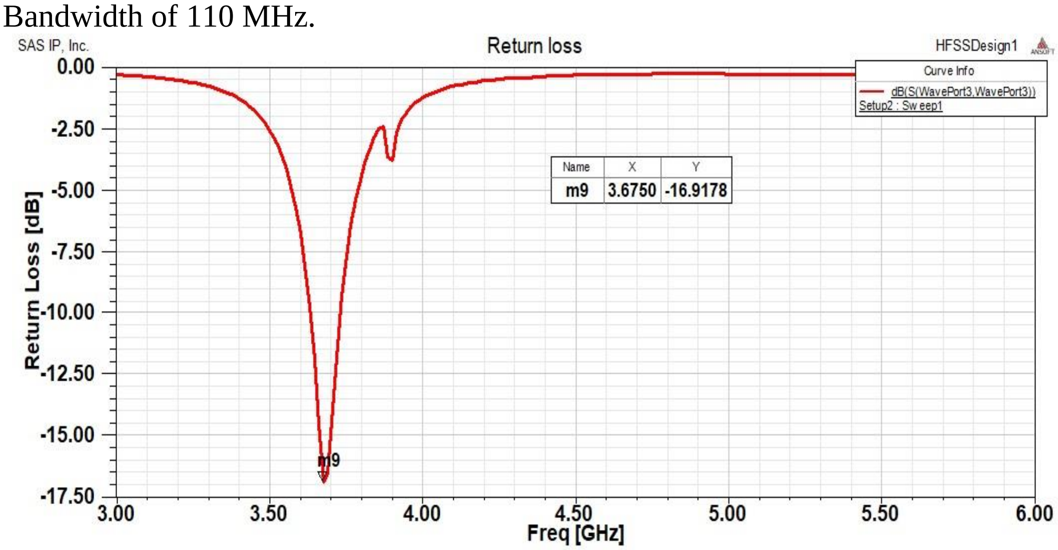

Figure 5: S11 value for ON state

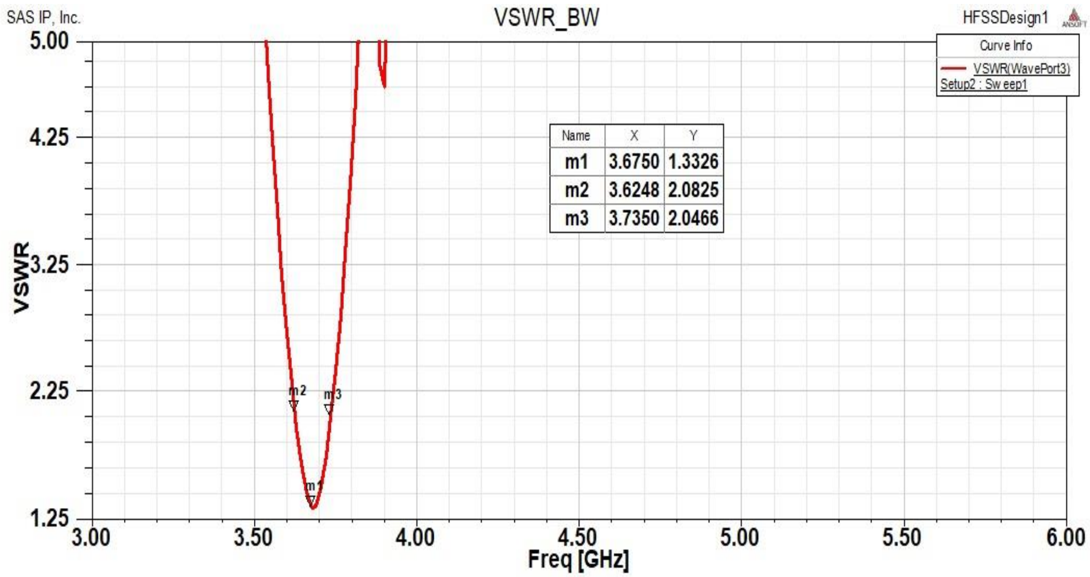

Figure 6: VSWR value for ON state

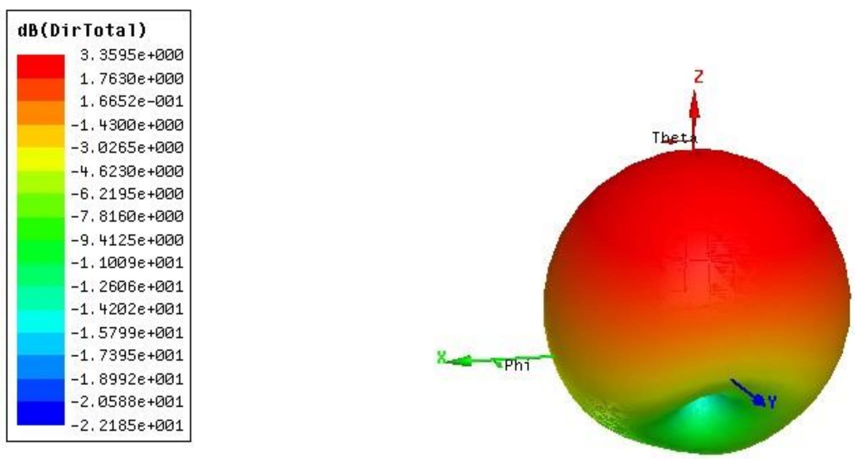

Figure 7: Gain value for ON state

For Off state we are getting S11 value should be -19.01 dB at frequency 5.07GHz. S11 value graph is shown in figure 8.

Figure 9 shows VSWR graph. For this antenna we are getting VSWR value should be 1.25 and gain of 5.89 for the same frequency 5.07 GHz (Off state). For this Off state of Pin diode, we are getting Bandwidth of 70 MHz.

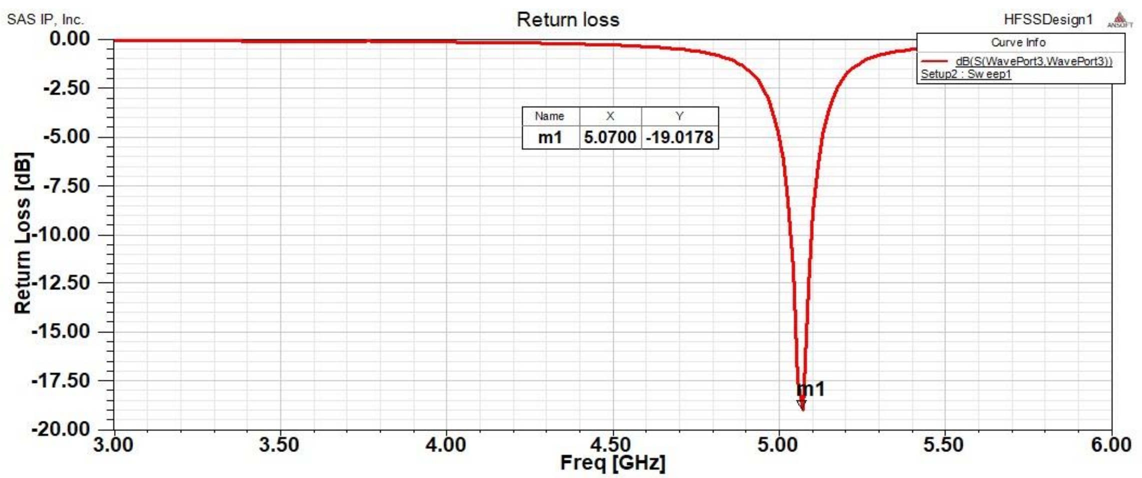

Figure 8: S11 value for OFF state

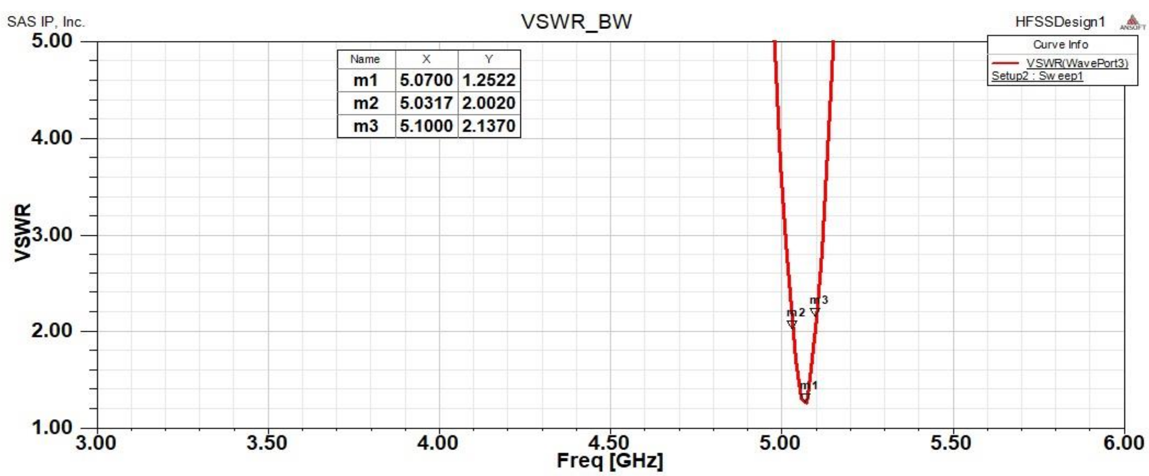

Figure 9: VSWR value for OFF state

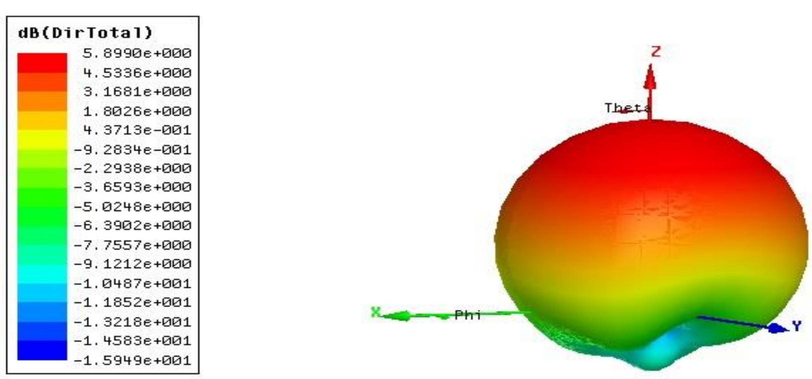

Figure 10: Gain value for OFF state

Table 2. Comparison Table of Simulation Results

Sr. No.	Simulated Results	Freq (GHz)	Return Loss(dB)	VSWR	Bandwidth (MHz)	Gain (dBi)
1.	Switch OFF reconfigurable Antenna Results	5.07	-19.01	1.25	70	5.8
2.	Switch ON reconfigurable Antenna Results	3.67	-16.91	1.33	110	3.3

V. Testing Results

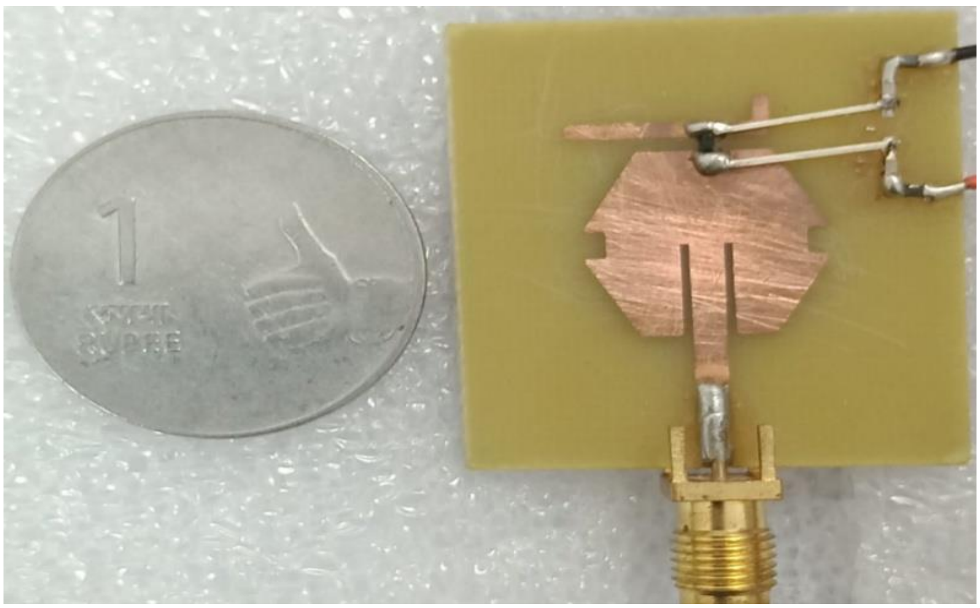

Figure 11: Front view of antenna

Fabricated micro-strip patch antenna is tested by using VNA instrument. For this proposed antenna we have preferred FR4 as substrate. FR stands for flame/fire retardant material. For this antenna substrate and ground dimensions should be the same, only there is change in height of substrate and ground (Hs=1.5 mm & Hg=0.1mm).

Figure 12: Analyser set up for Antenna testing

After testing of this antenna, we are getting very similar results. For testing also, we are using two states of PIN diode. For off state, we are getting S11 parameter value should be -17.65 dB at the frequency 5.2 GHz. We are getting VSWR parameter value should be 1.3 and gain of 5.7 dBi. The antenna achieves bandwidth of 70 MHz.

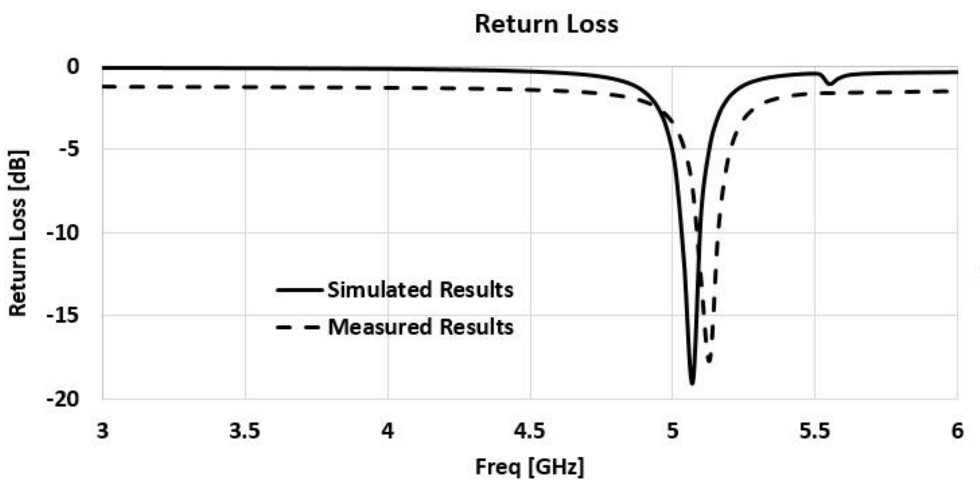

Figure 13: Measured Return Loss curve for OFF state

For On state, we are getting S11 parameter value should be -14.88 dB at the frequency 3.61 GHz. We are getting VSWR parameter value should be 1.43 and gain of 3.2 dBi. The antenna achieves bandwidth of 110 MHz.

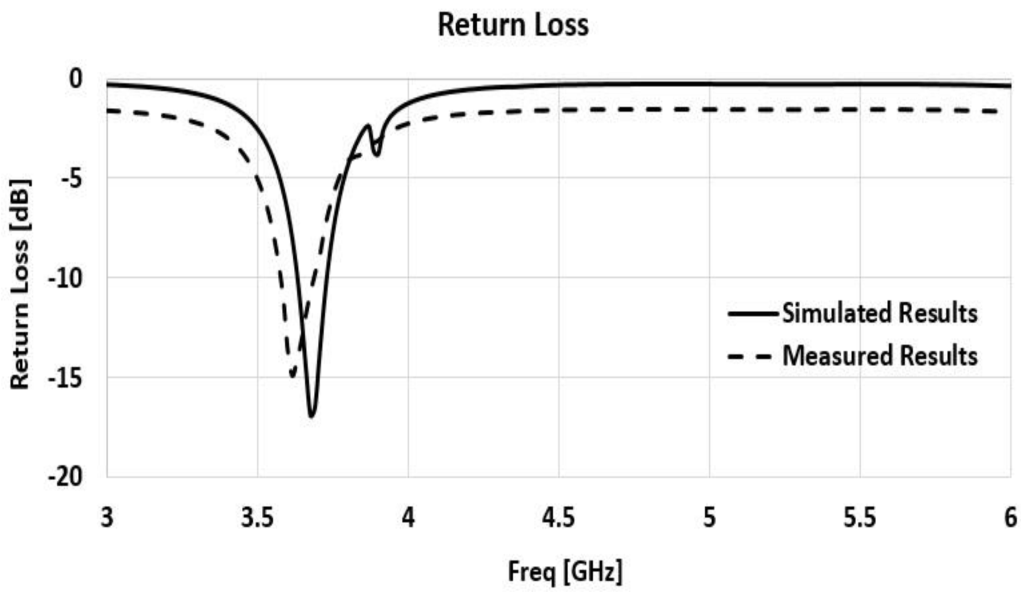

Figure 14: Measured Return Loss curve for ON state

Table 3. Comparison table of Testing Results

Sr. No.	Measured Results	Freq (GHz)	Return Loss(dB)	VSWR	Bandwidth (MHz)	Gain (dBi)
1.	Switch OFF reconfigurable Antenna Results	5.2	-17.65	1.30	70	5.7
2.	Switch ON reconfigurable Antenna Results	3.61	-14.88	1.43	110	3.2

Table 4. Comparison of Proposed antenna with previous reported reconfigurable structures

Ref.	Size (mm^3)	Operating Freq. (GHz)	Substrate	No. of PIN diodes
[11]	55x30x1.0	2.45,5.3	FR4	4
[12]	130x130x1.575	2.31,2.35,2.38	Rogers 5870	48
[13]	120x120x3.175	1.83-2.65	Rogers 5880	16
[14]	58x58x1.53	5.1,5.45,6.3,6.5	Neltec	5
[15]	25x25x1.6	4.94,5.35,6.25,6.83	FR4	2
[16]	30x30x0.762	3.8,4.5,5,5.9	Neltec	2
[18]	33.9x38x1.6	3.3-7	FR4	4 (Varactor)
[19]	40x32x1.6	1.8-6.5	FR4	4
[20]	58X48X1.6	2.2,2.3,2.5	FR4	2
[21]	50X45X1.6	2.2-6	FR4	2
This work	34x30x1.6	5.2, 3.61	FR4	1

VI. Conclusion

A compact reconfigurable antenna is designed and analyzed. In this compact antenna at upper side L shaped Patch is connected to hexagonal patch by using one PIN diode (SMP 1320) and two square slots at two corners. For this antenna nearly similar simulation and testing results achieved. From the achieved frequencies of this proposed antenna, we can conclude that this antenna is suitable for WLAN applications. As per the state of PIN diode changes, antenna gives frequency reconfiguration. For off state 5.2 GHz frequency is achieved with -17.61 dB return loss, 5.8 antenna gain and 70 MHz bandwidth. For ON state 3.61 GHz frequency is achieved with -14.88 dB return loss, 3.2 antenna gain and 110 MHz bandwidth. In future, we will try to increase gain of the frequency reconfigurable antenna.

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