Design of Frequency Reconfigurable Symmetrical Rhombic Micro Strip Slot Antenna

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Abstract: A Symmetrical Rhombic Micro Strip Slot Antenna is proposed where its frequency is reconfigured by using two switches (PIN Diodes which are mostly used to achieve re-configurability). Based on the switching condition it allows various groups of resonance frequencies (1.8GHz, 3.3GHz, 4.6GHz and 4.8GHz).The antenna is fed by micro strip line feeding and an optimization technique is utilized for providing good impedance match with return loss (S11) less than -10dB at all its operating frequencies. The antenna design and simulated results of return loss (S11), VSWR, and radiation pattern are presented.

***Keywords* - Symmetrical Rhombic slot antenna, frequency reconfigurable, PIN Diodes (switches).**

I. INTRODUCTION

With the fast growth of wireless and mobile communication technology, conventional antennas are now required to be lighter in weight, lower in price, smaller in dimension and more diverse in their features. To clip the height of the Conventional antenna, a number of effective ways are possible such as using modulation techniques[1]. Although, there is a fact that the effective ways to drop the antenna height are not a good enough to provide effective communication, Micro Strip Antenna is the most beneficial antenna which may eventually defeat this kind of demand because of its essential features like thin profile, reasonable price, easy fabrication and versatile in regards with multi-band or multi-functional characteristics. [2]. Furthermore, antennas may be required to operate at different standards or for various applications. So, the Reconfigurable antennas are more preferable for efficient use of available spectrum. The electrical and radiation properties (resonance frequency, field-patterns and polarization) of the antenna can be altered dynamically using these antennas. Dynamic nature is brought in by placing the actuators such as p-i-n diodes, switches, varactor diodes, etc., in decisive locations of the antenna. The Micro Strip Antenna is a printed antenna usually composed of 4 elements namely radiating patch, substrate, ground and feed line. The dielectric substrate is placed in between the patch and ground plane [3]. There are various substrates such as Teflon, FR4 and Rodgers with relative permittivity of 2.0, 4.4 and 2.2 respectively which allows mechanical assistance for the antenna. A way of transferring power to radiating patch is called feeding [4]. There are different feeding techniques to supply power to the antenna. For example, micro strip feed line, co-axial feed line and proximity coupled micro strip line feed [5].In order to clip the antenna size, every parameters like height of substrate, dielectric material, defected ground structures, etc.., shows impact on the frequency response, VSWR, S11 and some other characteristics. Thick size dielectric material with lower dielectric constant will attain optimized characteristics and Selection of the feeding technique for a micro strip patch antenna is also an important decision for providing better efficiency, radiation properties and large operating bandwidth [6].

The Reconfigurable micro strip antennas have several advantages and capabilities compared to conventional antennas i.e. by using only one antenna, the RMA is used for various applications depending on which application the user wants to use. According to the parameters of an antenna, reconfigurable antennas are categorized as follows –frequency reconfigurable antennas, radiation pattern reconfigurable antennas, polarization reconfigurable antennas and combinations of all the three reconfigurable antennas [7]. Now-a-days Frequency reconfigurable antennas have adopted considerable attention prior to the development of high-technological wireless communication systems like Cognitive Radio which involves in sensing wide band spectrum and a reconfigurable narrow band to communicate [11].

II. DESIGN PROCEDURE

The architecture of the proposed frequency reconfigurable antenna is designed on a dielectric substrate material (Rogers RT/duroid 5880 (tm)") which reduces ripples in the return loss and the height of the substrate is h=0.75mm with the relative permittivity 2.2. The antenna is alimented by using micro strip line feeding or edge feeding as shown in the figure, where the feed point must be located at point on the edge in (YZ plane), with input impedance is 50ohms for the resonant frequency.
The design strategy of the antenna is analyzed from the following steps below:

Step 1: Calculation of the Width (W): The width of the Microstrip patch antenna is given by

$$W_p = \frac{c}{2f\sqrt{\frac{\epsilon_r + 1}{2}}}$$

Where c = velocity of light
f = resonance frequency
$\epsilon_r = 2.2$ (Substrate material- "Rogers RT/duroid 5880 (tm)")
W_p=0.0204457607m

= 20.44576mm

Step 2: Calculation of Effective dielectric constant **(** $\in_{reff}$ **):**

For $\frac{w}{h} \geq 1$

$$\in_{reff} = \frac{\in_r + 1}{2} + \frac{\in_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

For $\frac{w}{h} \leq 1$

$$\in_{reff} = \frac{\in_r + 1}{2} + \frac{\in_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} + 0.041\left[1 - \sqrt{\frac{W}{h}}\right]$$

Where $\frac{w}{h} \geq 1$ W =20.44576mm, h= 0.75mm

27.26 ≥ 1

$\in_{reff}$ = 2.09494

Step 3: Calculation of the Effective length (L_{eff}):

$$L_{eff} = \frac{c}{2 f_0 \sqrt{\in_{reff}}}$$

=17.8680628mm

Step 4: Calculation of the length extension **(**ΔL)**:**

$$\Delta L = 0.412h \frac{(\in_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\in_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)}$$ =0.420966mm

Step 5: Calculation of actual length of patch **(L):**

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

=17.445mm

Step 6: Calculating the dimensions of ground plane (L_g and W_g):

The transmission line model is applicable to infinite ground planes only. However, for practical concern, it is required to have a finite ground plane and to reduce fringing effect, the ground plane should be greater than the patch dimensions by nearly six times the substrate thickness all around the circumference. Therefore the ground plane dimensions are given as:

L_g = 6h +L

=22.24705301mm

W_g = 6h + W

= 25.2457607mm

Step 7: Determining the position of feed point (X_f, Y_f):

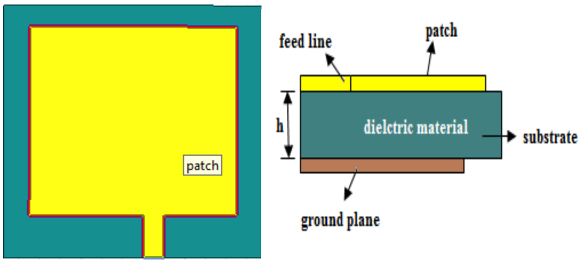
An Optimization Technique is utilized to locate the position of feed point. For different positions of the feed point, the return loss is simulated and compared to choose the feed point at which the return loss is more negative. Initially the feed line is taken at centre of width with width 2mm and after simulating, the line location is modified for better impedance matching.

III. ANTENNA DESIGN

The design procedure is outlined which shows the way for practical design and in order to get optimum characteristics (radiation properties, bandwidth and reduce side lobes), the parameter dimensions are approximated slightly and designed where the TABLE 1 shows the theoretical versus optimal parameter dimensions. Initially a rectangular patch antenna is designed with patch 18X20mm and feed line is assigned perfectly by using optimization technique for providing good impedance match. A Partially grounded structure (PGS) is considered where the length of the ground is reduced from 22mm to 18mm that improves the radiation properties and degree of efficiency [8]. Fig.1 shows the top view and bottom view of rectangular patch antenna

Table 1 Optimal Dimensions Of Parameters

Parameter	Patch width (mm)	Patch length (mm)	Effective dielectric constant (mm)	Ground width (mm)	Ground length (mm)
Theoretical dimension	20.445	17.8680	2.09494	25.24576	22.247053
Optimal dimension	20	18	-	25	18

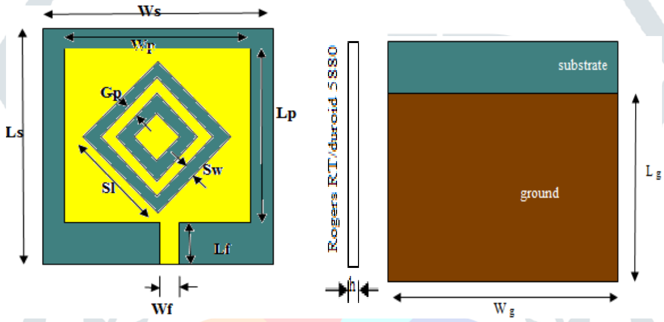


(a) (b)

Fig.1 Rectangular Micro Strip Patch Antenna (a) Top view (b) side view

IV. SYMMETRICAL RHOMBIC SLOT ANTENNA

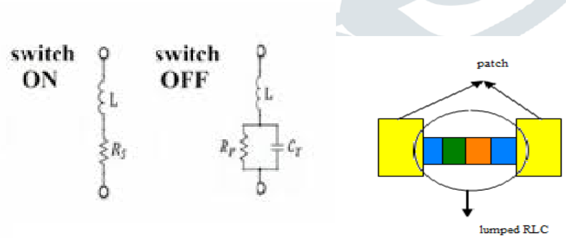
A Symmetrical Rhombic shaped slots are made on the patch with the gap (G_p) between the two slots of side length (Sl), thickness of slot (Sw) and the proposed antenna's geometry is shown in fig.2 with top view and bottom view. BAR64-3W is a pin diode that has low capacitance of 0.17pf and low forward resistance (2.1 ohms at 10mA) as shown in Fig3 (a). The PIN diode is simulated with HFSS as a lumped port (with R and C).The resistor and capacitor values are attested from the data sheet or from measurement of the PIN diode in a transmission line.



(a) (b)

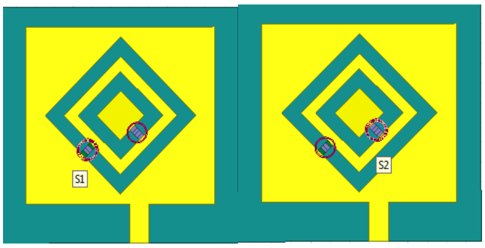
Fig. 2 Geometric pattern of the proposed reconfigurable antenna: (a) top view, (b) bottom view.

An equivalent circuit of PIN Diode is inserted by placing a small rectangular strips and assigning boundary (Fig 3(b)) in HFSS. DC blocking capacitors are placed on both the sides of the PIN diode with 0.1uf that reduces distortion in radiating energy due to dc biasing switches. Incase when switch is "on" it will have some resistance and when switch is "OFF" it will have some capacitance. PIN Diodes which act as switches (S1 and S2) are employed to realize the antenna's reconfiguration in its frequency where S1 is placed at outer slot and S2 at inner slot as shown in Fig.4.



(a) (b)

Fig.3 PIN Diode (a) equivalent circuit; (b) lumped RLC in HFSS



(a) (b)

Fig.4 proposed antenna design with switches S1&S2 (a) Switch S1 at outer slot; (b) Switch S1 at outer slot

V. RESULTS AND INTERPRETATION

The present antenna is simulated with defined configurations using HFSS simulator tool and characteristics are generalized with reference to return loss, VSWR, bandwidth, gain and radiation characteristic etc. Return loss is a suitable approach to draft the input and output signal sources. S11 depicts how much power is reflected from the antenna. If S11=0 dB, it shows that total power is reflected from the antenna with zero radiated power. Larger the negative return loss indicates more power being radiated by the antenna which in turn expands the gain of the antenna. In another way of saying, as the S11 increases, antenna attains better reflection coefficient and the load receives power with minimum loss [5]. For practical applications a maximum threshold value of 2 is tolerable for VSWR and in accordance with the return loss less than -9.54 dB. The narrow bandwidth of the micro strip antenna attains most grievous limitation in its applications. The bandwidth could be defined as "the range of usable frequencies within which the performance of the antenna with respect to some characteristics conforms to a specific standard." The bandwidth is also defined as the sweep of all the frequencies on both sides of the center frequency where the antenna characteristics are close to those values which have been obtained at the center frequency. Bandwidth is presented more concisely as a percentage [9]

$$BW_{\text{broadband}}(\%) = \frac{F_H}{F_L}$$

$$BW_{\text{ narrowband}}(\%) = \frac{F_H - F_L}{F_r}$$

Table 2

Operating states of the designed antenna

S1	S2	F r (GHz)	Return loss(dB)
OFF	OFF	4.6	-25.8673
ON	OFF	4.8	-22.0589
OFF	ON	4.6	-25.8373
ON	ON	1.8 3.3 4.8	-20.8755 -15.8820 -20.7334

Fig.5, shows the simulated return loss (s11) of the rectangular antenna with resonance frequency 4.7GHz, return loss -23.014 dB and the bandwidth is very small with narrow bandwidth typically 9.1489%. The simulated results indicate that the suggested antenna allows various groups of resonance frequencies with switching conditions (S1, S2) as shown in TABLE 2. When both switches are "OFF" the resonance frequency is 4.6GHz (C band (IEEE), a radio frequency band from 4 to 8 GHz) with return loss -25.8673 dB and bandwidth 10.8695%. In case when switch S1 is "ON" & S2 is "OFF" the resonance frequency is 4.8GHz with return loss -22.0589 dB and bandwidth 12.5%. In other case, when both switches are "ON", three resonance frequencies 1.8GHz,3.3GHz and 4.8GHz are obtained with return losses -20.8755dB,-15.8820dB and -20.7334dB. When switch S1 is OFF and S2 is ON then current is not feed to the inner rhombus because S1is off. So the resonance frequency is same as when both switches are OFF with -25.8373 dB return loss. The simulated return losses for all the four switching conditions are shown in the Fig 6-8. The simulated VSWR for different operating states are also shown in figure 9-12.

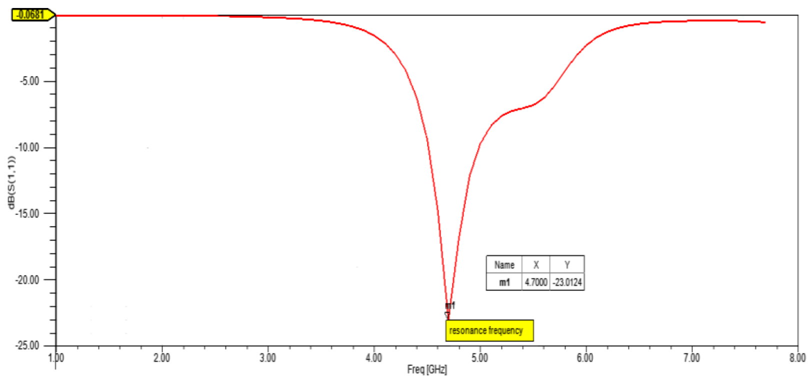


FIG.5 simulated return loss of rectangular patch antenna

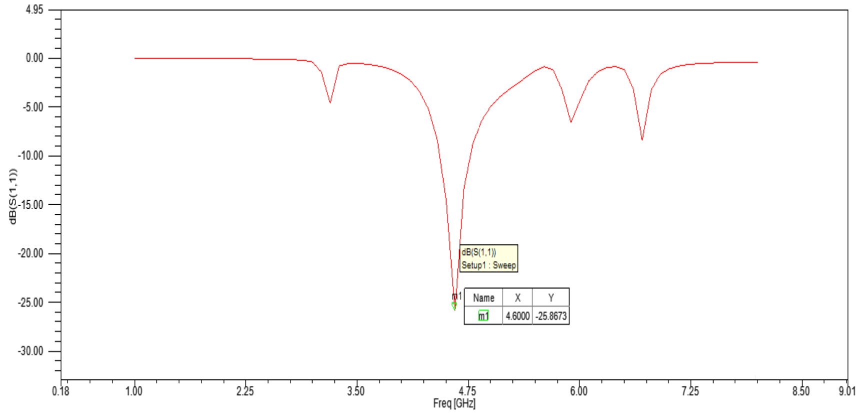


FIG.6 simulated S_{11} of symmetrical rhombic slot antenna when both switches (SI & S2) are OFF

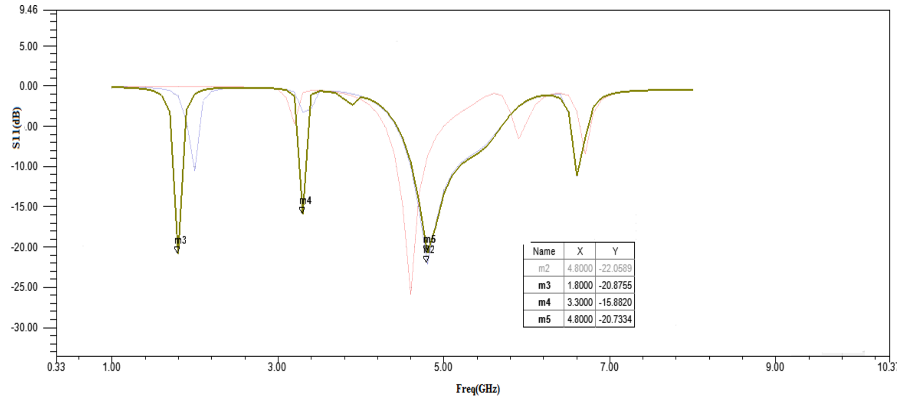


FIG.7 Comparing S_{11} when switches (SI & S2) are OFF with S_{11} when switches (SI & S2) are ON

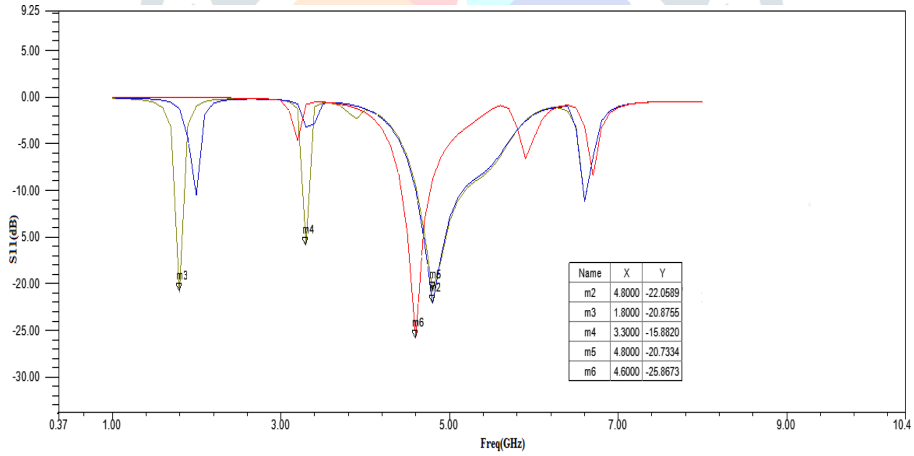


FIG.8 Comparing simulated S_{11} results of all 4 operating states

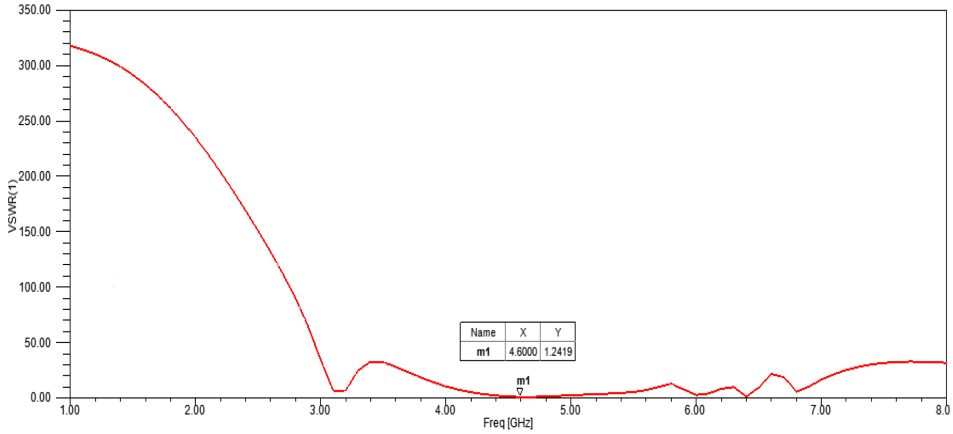


FIG.9 Simulated VSWR whenboth switches (SI & S2) are OFF

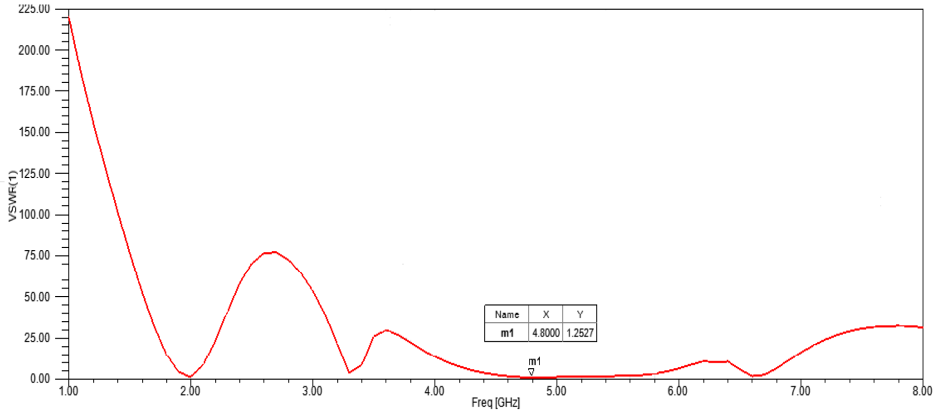


FIG.10 Simulated VSWR when switch SI (ON) & S2 (OFF)

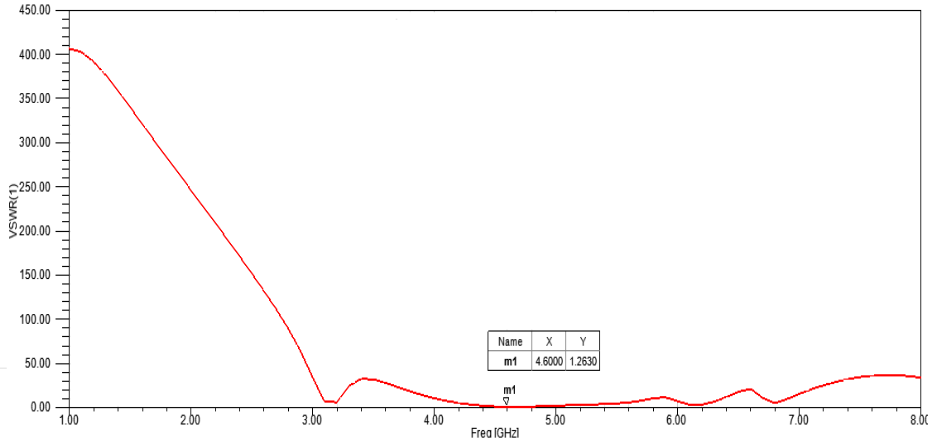


FIG.11 Simulated VSWR when switch SI (OFF) & S2 (ON)

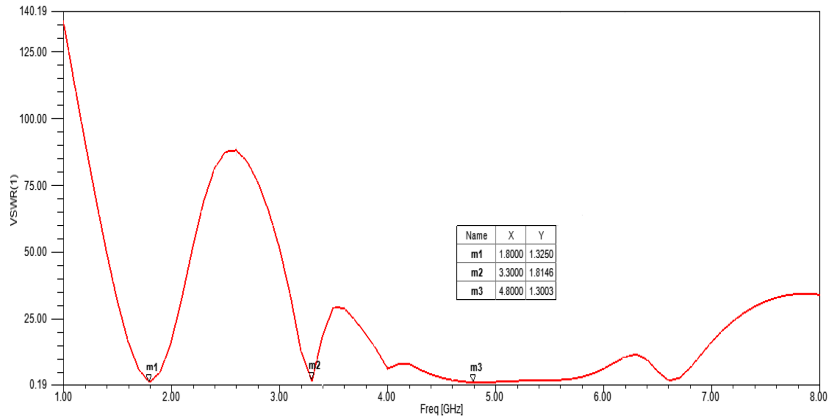


FIG.12 Simulated VSWR when both switches (SI & S2) are ON

The energy radiated by an antenna is represented by the Radiation figure of the antenna. Radiation Patterns are the graphical indication of the antenna's propagated energy into space. The graph shows that the radiation pattern changes in accordance with the angular position and radial distance from the antenna [10]. Fig.13 shows the simulated radiation pattern in 2-D and Fig 14 shows the simulated 3-D polar plot of gain.

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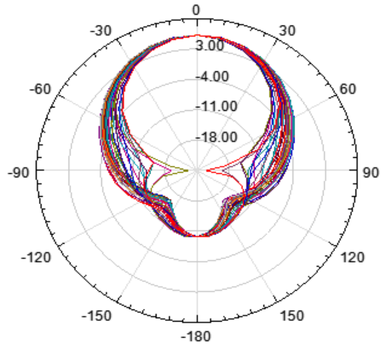

FIG.13 simulated Far field 2D Radiation pattern

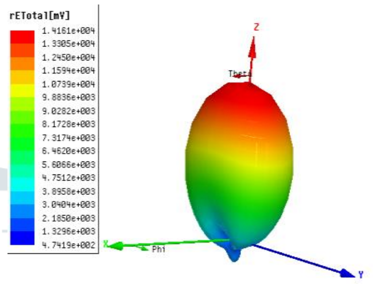

FIG.14 Gain in 3-D Polar plot

VI. CONCLUSION

The designed and simulated proposed antenna efficiently resonate different frequencies with good return loss, gain, acceptable 2D radiation pattern and VSWR values for different operating states of two PIN diodes. The frequencies which are obtained are used for multi frequency or multi band application.

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