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Design a Frequency Reconfigurable Microstrip Patch Antenna for Satellite Communication

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Abstract-A novel reconfigurable patch antenna with four diode switches for multi band applications is presented. The dual resonant mode of reconfigurable patch antenna is simulated by transmission line feeding. By varying the diode switching conditions of the patch, the resonant frequencies are varied. The reconfigurable patch has operating frequency of 18.50 GHz with return loss -17.80 dB, other resonant frequencies are 18.90GHz, 19.5GHz, 21.10GHz with return loss -20.77dB, -18.57dB, -14.29dB respectively. The simulated antenna has high radiation efficiency and good performance. The radiation patterns for resonance bands are realized at is 00 and is 900 in xz and yz plane. The co and cross polarization has been imparted and cross polarization is found below 20 dB at each angle of one plane and operating frequency. The simulation results have good consistency.

Keywords: Reconfigurable antenna, HFSS Tool, Concentric rectangular ring.

I. INTRODUCTION

The evolution of wireless radio networks has the phenomenal growth for last decades. As the number of new users flourishing, the new devices appear and the mobile traffic, there is a great appeal for high capacity communications supposing high transmission quality, better coverage and capable of utilizing the radio spectrum more efficiently. In this, the peculiar properties of reconfigurable antennas and the radio wave propagation at micro- and millimeter-wave frequencies are studied. The radio link performance can be enhanced by Reconfigurable antennas. Recently, several advancements took place in the design of the reconfigurable antennas for accomplishment of better performance for instance antenna bandwidth, resonant frequency, polarization, and radiation properties.

The reconfigurable antennas associated with the multi-band antennas are reconfigured at the desired frequency band, radiation pattern and polarization. Reconfiguration can be attained by deploying switching elements within the radiating patch of the antenna [1]. The interference that occurs from the unused adjacent bands can be reduced by reconfigurable antennas. They also reduce the filter of the

front end circuits, results in compact design [2]. The miniaturization and cost effectiveness features attracts to select the frequency reconfigurable antenna with wide band. Its better tuning capacity between the various frequency bands with no change in gain and stability of radiation pattern is another attracting feature. The number of PIN diodes required more to switch between the multiple frequency bands which increases the insertion loss and also leads to the biasing circuit complexity.

The rectangular patch antenna for dual band broadband with U and V shaped slots was proposed by Amit A Deshmukh. For the reconfigurable antennas for dual band frequency, the patch is cut into the slots either quarter wavelength or half wavelength, surface and current distributions are reviewed. The radiation patterns in two principle planes and operating frequencies are of second order orthogonal mode [3].

The reconfigurable ring slot mounted with four varactor diodes symmetrically which was fed by the coaxial feed in order to improve the circular polarization from 1.92GHz to 2.51GHz, efficiency of operating frequency from 47% to 61% and Omni-directional radiation pattern [4]. The resonant frequency variation and the radiation variation cylindrical reconfigurable bending antennas for wearable applications are studied [5]. A reconfigurable slotted patch is introduced with two different shaped patches with coplanar wave guide for dual band applications and slots are used for multi resonant frequency modes with good impedance bandwidth for both Ultra wide band and WLAN applications [6].

A U-shaped double planar reconfigurable antenna with a single PIN diode as switching element provides the two resonant modes of operation used in WiMAX and WLAN applications. The radiation pattern of the simple structured reconfigurable antenna is bi-directional in both the planes with an optimum gain and good potential for the wireless communication systems [7]. The proposed antenna models utilizes the novel frequency reconfigurable technique fed by transmission feed operates at multiple frequencies with better return loss.

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This multiple frequency bands have very much useful at radio frequency range in different applications.

II. ANTENNA DESIGN GEOMENTRY OF PROPOSED MODELS

A. Design of E with Inverted U-Shape Patch

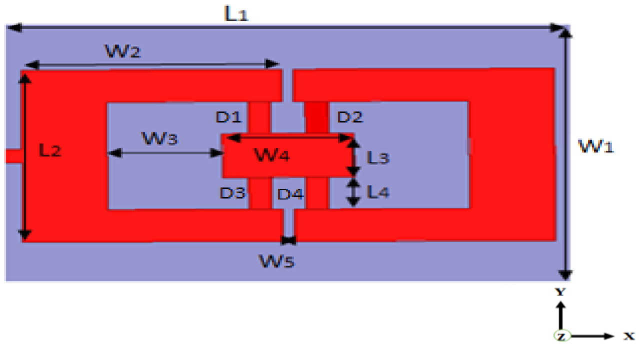
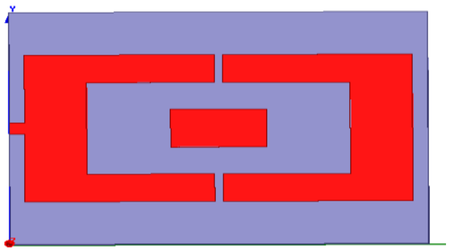


Fig. 1. Geometry of the proposed U-shape with inverted U-shape reconfigurable patch with transmission line feeding.

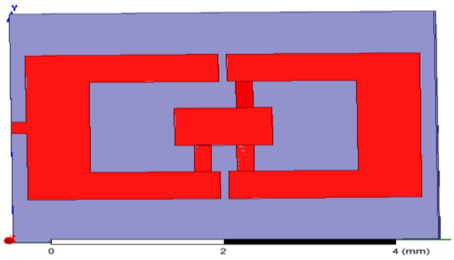
The rectangular reconfigurable patch fed by the transmission line feed for multi band applications is as shown in the Fig. 1.The substrate is designed with FR4 epoxy substrate with dimensions 5mm*4mm as length and width respectively. The thickness of the substrate is 1.5mm with dielectric constant of 4.4. The rectangular patch is mounted on the substrate using the fabrication material as copper whose tangent loss is 0.002 and relative permeability 1. The input impedance of 50ohms is connected to the rectangular ring patch antenna. The optimized parameter values are tabulated in TABLE I. The proposed antenna is capable of increased return loss due to placing the rectangular antenna. The design procedure of the proposed antenna with PIN diodes as switches is shown in Fig. 1. The Pin diode using for re-configurability is SMP1320011F whose ON state resistance is 0.75ohms and OFF state capacitance of 0.23pF.

TABLE-1:Dimensions of the Model-A reconfigurable patch antenna

Parameter	Dimension (mm)	Parameter	Dimension (mm)
L_1	5	L_3	2.27
W_1	4	W_3	0.65
L_2	2.27	L_4	1.15
W_2	2.53	H	1.5
L_5	0.2	W_4	0.475



(a)



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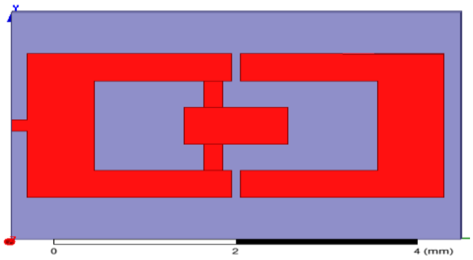

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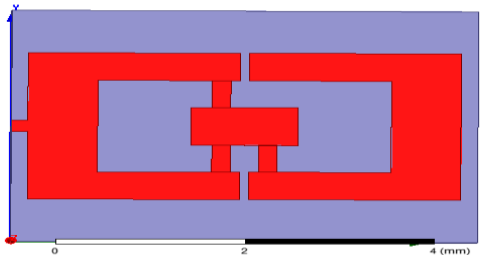
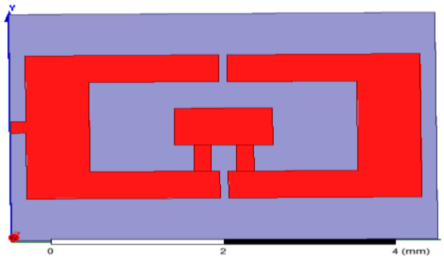


(d)



(e)

Fig. 2. Design procedure with different diode configurations (a) no diode (b)State-1 (c) State-2 (d) State-3 (e) State-4

Table.2: Configuration of Diodes

STATE	D1	D2	D3	D4	FREQUENCY(GHz)
1	0	1	1	1	18.50
2	1	0	1	0	21.10
3	1	0	1	1	18.90
4	0	0	1	1	19.50

The proposed antenna utilizes the re-configurability technique by the usage of four PIN diodes with different switching configurations as shown in the Table.2. Each configuration will operate with different frequency of operation with different return loss and performance.

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Table 3: Comparison Table For Model-A

Parameter	Reference [1]	Proposed Model-A
Feed	Coaxial feed	Lumped port
Spacing between 2 U-shapes	-	0.1mm
Spacing between centre patch & U-shapes	0.95mm*1.49mm	1mm*0.45mm
U-shape patches	3.15mm*1.58mm	2.53mm*2.27mm

Table 4: Operation Comparison For Model-A

D_1	D_2	D_3	D_4	Base-Paper Frequency(GHz)	Proposed Model-A Frequency(GHz)
1	1	0	0	16.40	19.50
1	1	0	1	19.50	18.50
0	1	1	1	-	18.50
1	0	1	0	-	21.10
1	0	1	1	-	18.90
0	0	1	1	-	19.50

B. Design Of E - With Inverted E-Shape Patch:

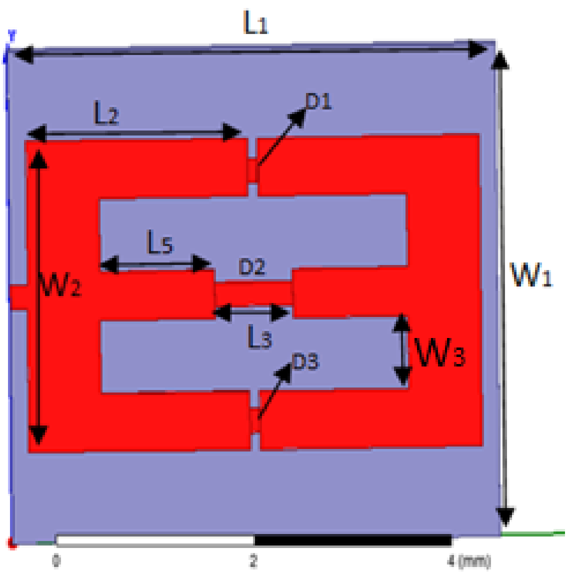
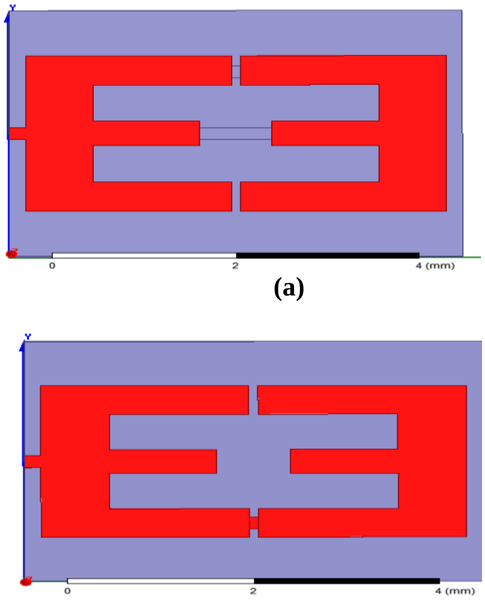


Fig.3. Geometry of the E-shape with Inverted E-shape

Table-5: Dimensions of Model-B reconfigurable patch antenna

Parameter	Dimension (mm)	Parameter	Dimension (mm)
L_1	5	W_1	4
L_2	2.27	W_2	2.53
L_3	0.8	W3	0.59
L_4	0.1	W_4	0.47
L_5	1.175		



(a)

(b)

Fig.4. Design procedure for E-shapes (a) Single Diode ON (b) Double Diode ON

Table-6: Configuration of Diodes for E-shapes.

STATE	D 1	D 2	D 3	FREQUENCY(GHz)
1	1	1	0	11.90GHz
2	0	0	1	20GHz

C. Design Of Double Planar U-Shape Patch:

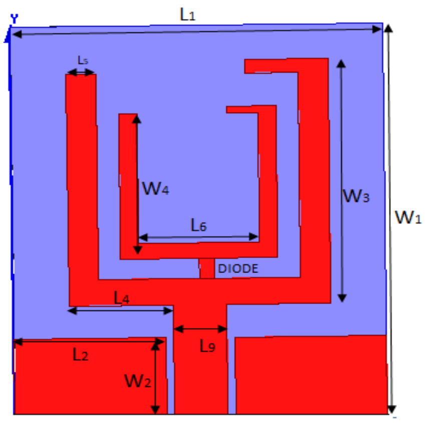


Fig.5. Geometry of Double planar U-shape

Table7: Dimensions of Model-B reconfigurable patch antenna

Parameter	Dimension(mm)	Parameter	Dimension(mm)
L_1	25	L_9	3.6
L_2	10.2	W_1	30
L_3	3.6	W_2	6.25
L_4	7	W_3	17.6
L_5	2	W_4	11.06
L_6	8.16	W_5	0.5
L_7	1.2	W_6	1
L_8	2.08		

Table-8: Comparison Table For Model-C

Parameter	Reference [2]	Proposed Model-C
Centre Patch considered as	Ground Plane	Radiating Patch
Feed	CPW	Lumped port
Diode ON: Frequency (GHz)	5.2,5.8	18.60,20.20
Diode OFF: Frequency (GHz)	3.2	19.70

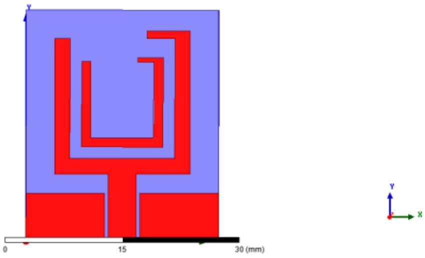


Fig.5 (b). Double planar U-shape with Diode OFF State

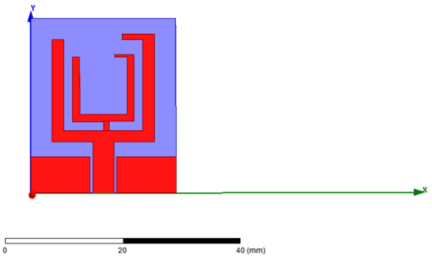


Fig.5 (c). Double planar U-shape with Diode ON State

Table-9:Model-3 Diode Configurations:

State	Diode	Frequency (Ghz)
OFF	0(OFF)	19.90GHz
ON	1(ON)	18.60GHz,20.20GHz

III. SIMULATION RESULTS

A. Model-A Results

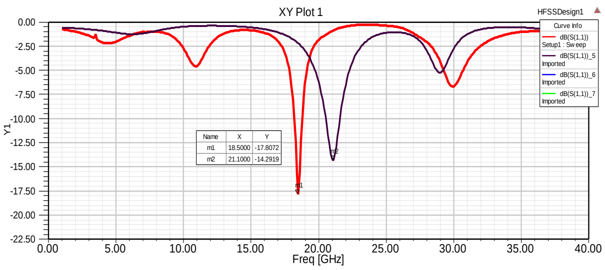


Fig.6 Return loss at 18.50GHz & 21.10GHz

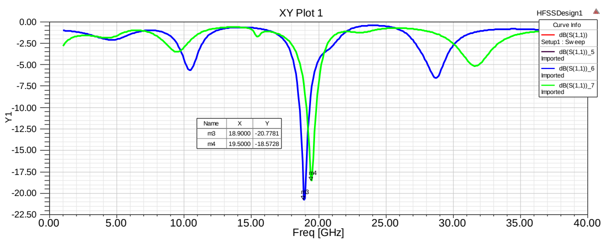


Fig.7. Return loss at 18.90GHz & 19.50GHz

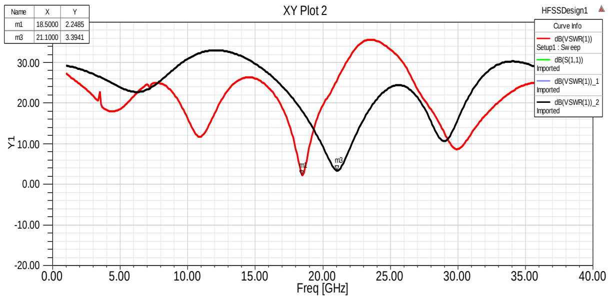


Fig.8. VSWR at 18.50GHz & 21.10GHz

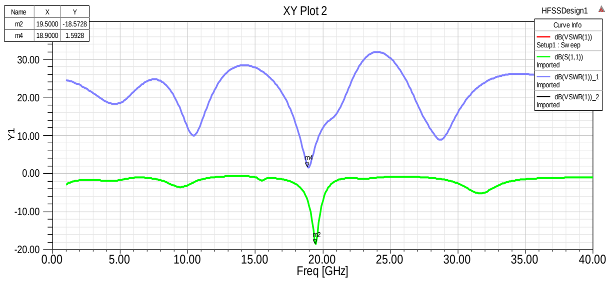
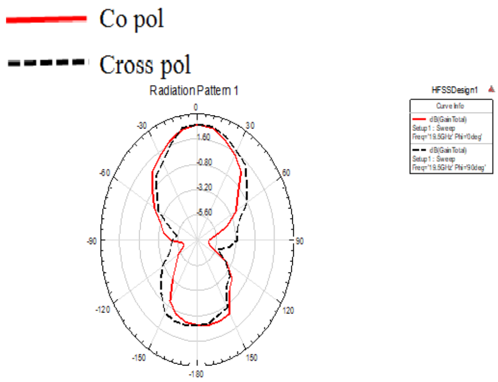
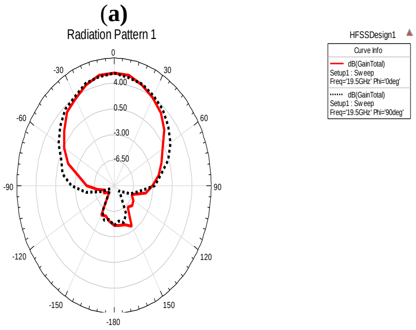


Fig.9. VSWR at 18.50GHz & 21.10GHz

The High frequency structure simulator (HFSS) is used to design and simulate the proposed antenna model. The fabricated antenna is fed through lumped port with an impedance of 50ohms. The return loss and VSWR of the proposed rectangular ring patch antenna operating at resonant frequencies is displayed in Fig. 3 The observed resonant frequencies of the proposed antenna operates at frequency is 18.50GHz with return loss -17.45 dB and resonant frequencies are 18.90GHz,19.50GHz with return loss -20.77dB, -18.57dB, -14.29dB respectively.



(a)



(b)

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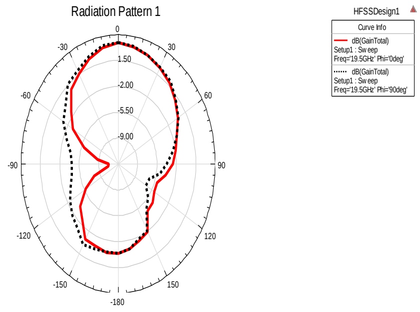

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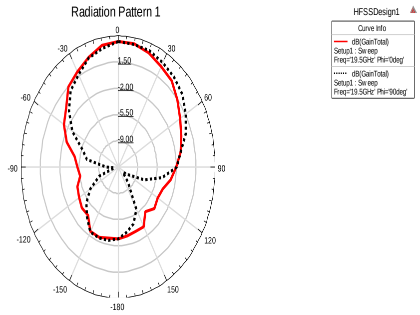
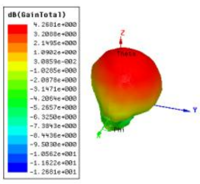


(d)

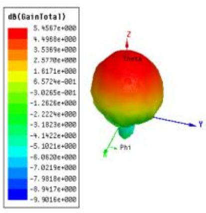
Fig. 10. Rradiation pattern for U- & inverted U-shape re-configurable patch antenna for multiple frequencies as shown in Table.1

The suggested antenna radiation patterns characteristics at operating frequency and the resonant frequencies are plotted as co polarization (solid red) and cross polarization (dotted black) as is shown in Fig. 4.The bi directional radiation pattern of co polarization in E plane and the Quasi Omni directional radiation pattern at H plane.

The gain is observed at different frequencies and the maximum gain noted at two resonant frequencies are 19.5 GHz and 21.10GHz with gain values are 4.26dB, 5.45dB shown in Fig. 5. The maximum radiation radiates in a particular direction as indicated with red color which was shown in the three dimensional view of the gain.



(a)



(b)

Fig. 11. Maximum gain (a) 21.10 GHz (b) 19.50 GHz

B. Model-B Results

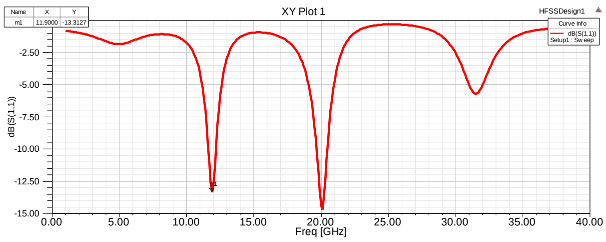


Fig.12. Return Loss at 11.90GHz

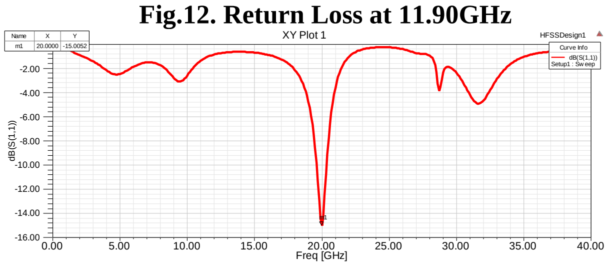


Fig.13. Return Loss at 20GHz

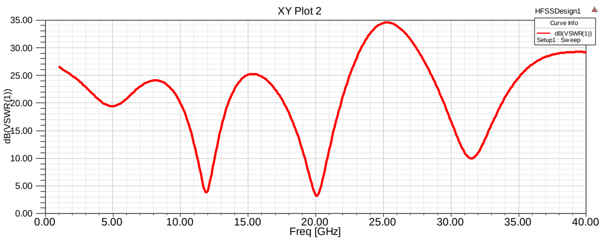


Fig. 14. VSWR at 11.90GHz

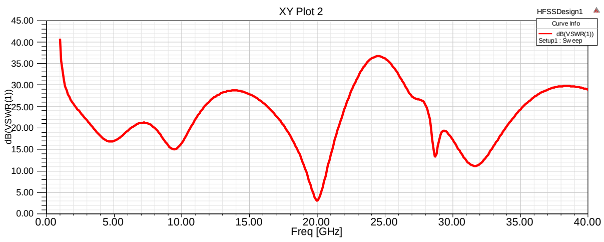


Fig. 15. VSWR at 20GHz

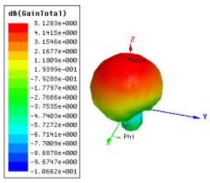


Fig.16. Gain at 11.90GHz

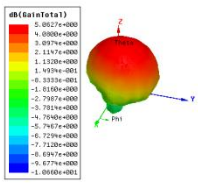


Fig.17. Gain at 20GHz

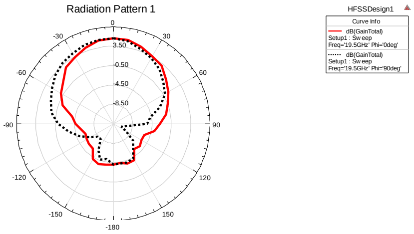


Fig.18. Radiation Pattern at 11.90GHz

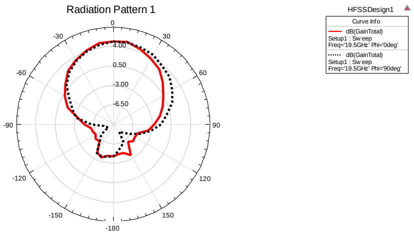


Fig.19. Radiation Pattern at 20GHz

C. Model-C Results

Fig.20. Return Loss when Diode OFF state.

Fig.21. Return Loss when Diode ON state.

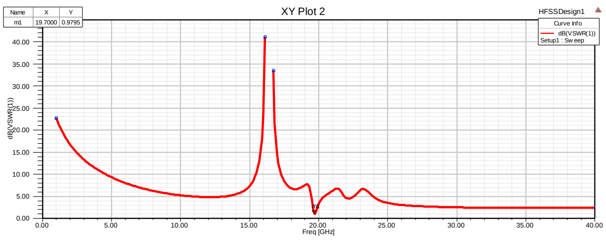


Fig.22. VSWR at Diode OFF state

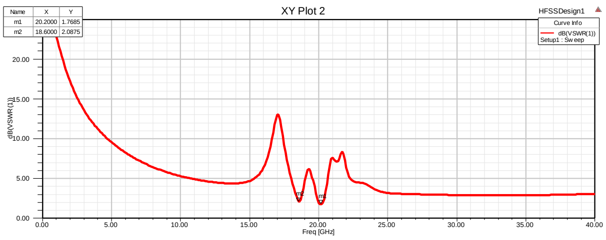


Fig.23. VSWR at Diode ON state

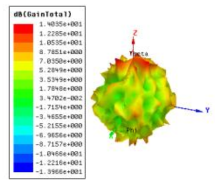


Fig.24. Gain at Diode OFF state

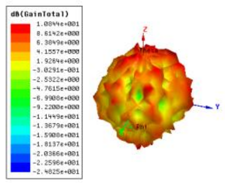


Fig.25. Gain at Diode ON state at 18.60GHz

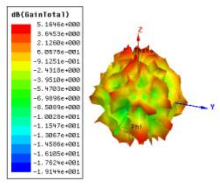


Fig.26 Gain at Diode ON state at 20.20GHz

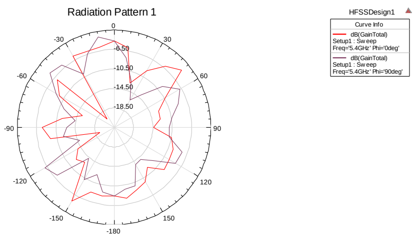


Fig.27 Radiation pattern at Diode OFF state

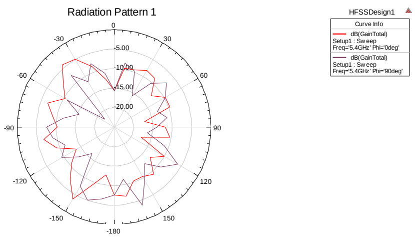


Fig.28 Radiation pattern at Diode ON state at 18.60GHz

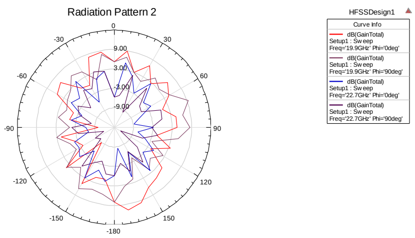


Fig.29 Radiation pattern at Diode ON state at 20.20GHz

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IV. CONCLUSION

In this paper, 3 Models of reconfigurable patch antennas are designed with PIN diodes switching for multiple frequency bands. These antennas will work for different frequency bands with desired Bandwidth. The proposed antenna works for satellite communication systems. The co polarization and cross polarization of proposed antenna are measured. To improve the impedance bandwidth, reduce the cross polarization the diodes are used in this antenna.

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