Design of Frequency and Pattern Reconfigurable Antennas by using E-Shaped structure

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Abstract--- The paper here is to presents the design of Frequency and Pattern Reconfigurable Antenna which is one of the essential requirements for the Cognitive radio. This is designed at 2.45GHz of frequency using FR-4 Epoxy (ε_r =4.4) substrate having a height of 1.6mm. The patch size of the proposed antenna is 30 X 4 mm^2 and three rectangles having same lengths and same widths as 11 X 5 mm^2 are interconnected with three PIN Diodes (HPND 4005). Frequency reconfigurability is achieved by using E-shape patch with different electrical lengths. In this design all the diodes are verified for all the combinations and as we placed three diodes we obtain eight combinations and resonates at different frequencies. This design is useful for cognitive radio applications.

Key words--- Frequency reconfiguration, Radiation pattern reconfiguration, Reflection Coefficient, VSWR

I. Introduction

The essential requirement in wireless communication systems are Microstrip Antennas. A Reconfigurable microstrip antenna offers multifunction operations whereas a single antenna incorporates only a particular radiation characteristic. Reconfigurable antennas can be mainly used for frequency reuse and are designed for single frequency which radiates mainly for linear polarization.

The major design issues for practical usage of microstrip antennas are Frequency reconfiguration and polarization diversity. The frequency reconfigurable antennas radiate at different frequencies and with different radiation patterns. By the usage of different RF switching devices like PIN diodes, FETs and varactor diodes reconfigurability is achieved. Based on the switching speeds and the switched power levels, the switch selection will be done. In the design of shaped antenna, we can use pin diodes (s1, s2,s3,s4,…) are configured inside the patch. By turning on and off the pin diodes in various combinations, frequency of the radiation of antenna varies. The equivalent circuit of a PIN diode consists an inductor and a resistor in ON condition whereas it consists of a inductor in parallel with a resistor and capacitor in OFF condition. By using the same concept, a novel microstrip antenna with E shaped patch allowing frequency switching is proposed and attentively examined in this paper.

II. Reconfigurable antennas

An Antenna is a transitional structure between wave guide and free space. The term Reconfigurable is the reusability. A reconfigurable antenna is an antenna capable of modifying its frequency and radiation properties dynamically, in a controlled and reversible manner. In order to provide a dynamic response, reconfigurable antennas integrate an inner mechanism (such as RF switches, varactors, mechanical actuators or tunable materials) that enable the intentional redistribution of the RF currents over the antenna surface and produce reversible modifications of its properties. Reconfigurable antennas differ from smart antennas because the reconfiguration mechanism lies inside the antenna, rather than in an external beamforming network. The reconfiguration capability of reconfigurable antennas is used to maximize the antenna performance in a changing scenario or to satisfy changing operating requirements. The advancement in wireless communications requires the integration of multiple radios into a single platform to maximize connectivity. They are particularly useful in situations where several communications systems converge because the multiple antennas required can be replaced by a single reconfigurable antenna.

Types of antenna reconfigurations

- Frequency reconfiguration
- Radiation pattern reconfiguration
- Polarization reconfiguration
- Compound reconfiguration

Frequency reconfiguration

Frequency reconfigurable antennas can adjust their frequency of operation dynamically. They are particularly useful in situations where several communications systems converge because the multiple antennas required can be replaced by a single reconfigurable antenna. Frequency reconfiguration is generally achieved by physical or electrical modifications to the antenna dimensions using RF-switches, impedance loading or tunable materials.

Radiation pattern reconfiguration

Radiation pattern reconfigurability is based on the intentional modification of the spherical distribution of the radiation pattern. Beam steering is the most extended application and consists of steering the direction of maximum radiation to maximize the antenna gain in a link with mobile devices. Pattern reconfigurable antennas are usually designed using movable/rotatable structures or switchable and reactively-loaded parasitic elements. In the last 10 years, metamaterial-based reconfigurable antennas have gained attention due their small form factor, wide beam steering range and wireless applications. Plasma antennas have also been investigated as alternatives with tunable directivities.

Polarization reconfiguration

Polarization reconfigurable antennas are capable of switching between different polarizations modes. The capability of switching between horizontal, vertical and circular polarizations can be used to reduce polarization mismatch losses in portable devices. Polarization reconfigurability can be provided by changing the balance between the different modes of a multimode structure.

Compound reconfiguration

Compound reconfiguration is the capability of simultaneously tuning several antenna parameters, for instance frequency and radiation pattern. The most common application of compound reconfiguration is the combination of frequency agility and beam-scanning to provide improved spectral efficiencies. Compound reconfigurability is achieved by combining in the same structure different single-parameter reconfiguration techniques or by reshaping dynamically a pixel surface.

III. Design considerations

The S Parameter losses for the designed antenna with all the states of the diodes are shown below .When the diode switches S1,S2 and S3 are OFF the proposed antenna resonates at 4.82 GHz , 4.3 GHz with Reflection Coefficient of -21.94 dB,-21.8 dB and a VSWR of 1.71 and the switches S1,S2 and S3 are ON the antenna resonates at 7.1 GHz with Reflection Coefficient of -18.12 dB VSWR of 1.28.Therefore this antenna achieves frequency reconfiguration.

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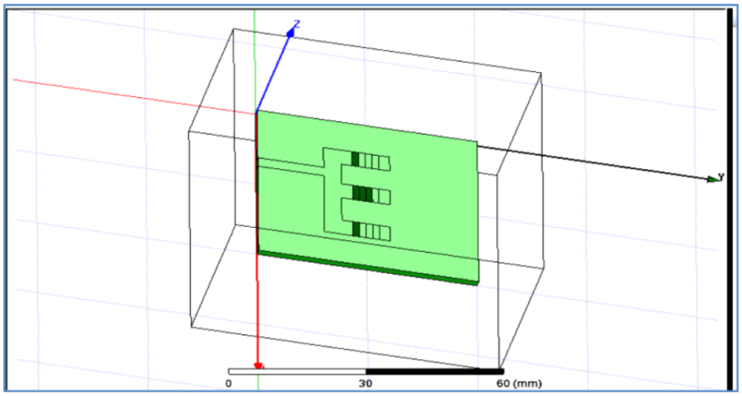

Figure: 1 Design of E shaped Reconfigurable antenna using FR-4 substrate in HFSS

<u>Case i: When all Pin diodes are in OFF condition:</u>

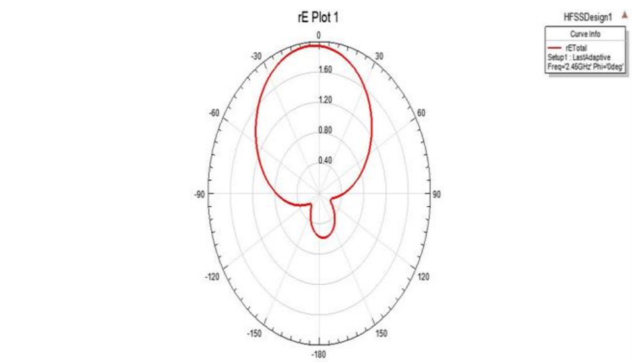

Figure: 2 Radiation Pattern when all Pin Diodes are in OFF condition

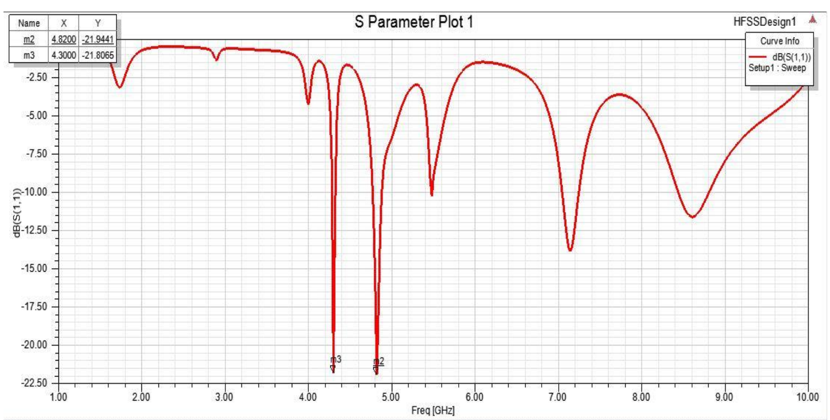

Figure: 3 Reflection Coefficient when all Pin Diodes are in OFF condition

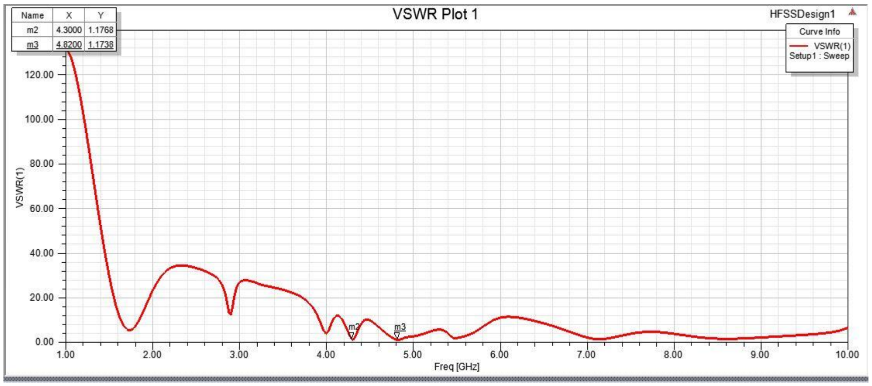

Figure: 4 VSWR when all Pin Diodes are in OFF condition

Table: 1 Results when all Pin Diodes are in OFF condition in E shaped Antenna

S1	S2	S3	Resonant frequency (GHZ)	Reflection Coefficient (dB)	VSWR
off	off	off	4.82	-21.94	1.17
			4.3	-21.8	1.17

These are the results obtained using E shaped antenna .By placing PIN Diode with all the diodes are in OFF condition it will be resonated at 4.82 GHZ and 4.3 GHZ with Reflection coefficient of -21.94 dB and -21.7 dB with a corresponding VSWR of 1.17.

Case ii: when one (s3) Pin Diodes is ON condition:

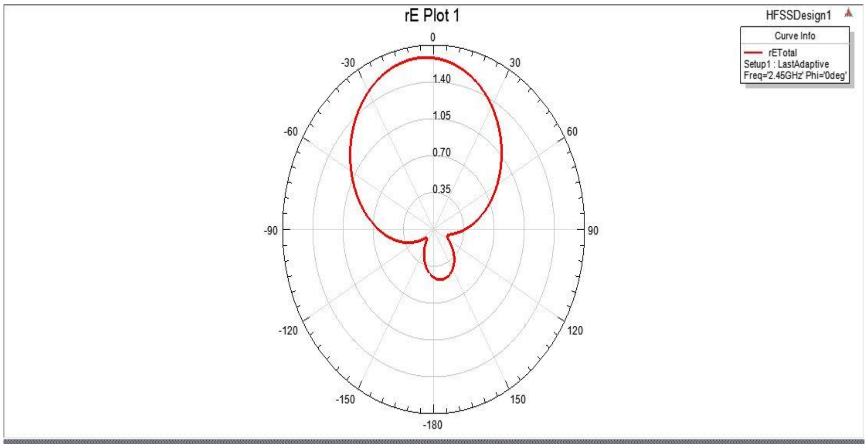

Figure: 5 Radiation Pattern when S3 Pin Diode is ON in E shaped Antenna

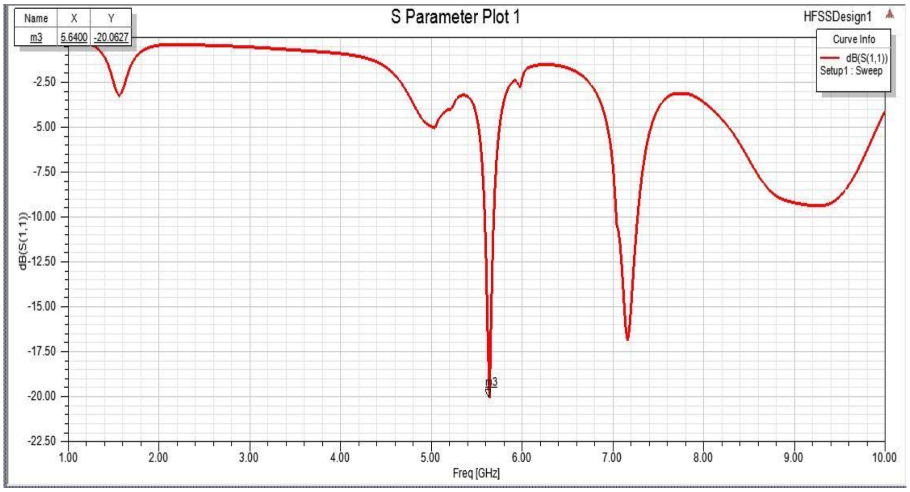

Figure: 6 Reflection Coefficient when S3 Pin Diode is ON in E shaped Antenna

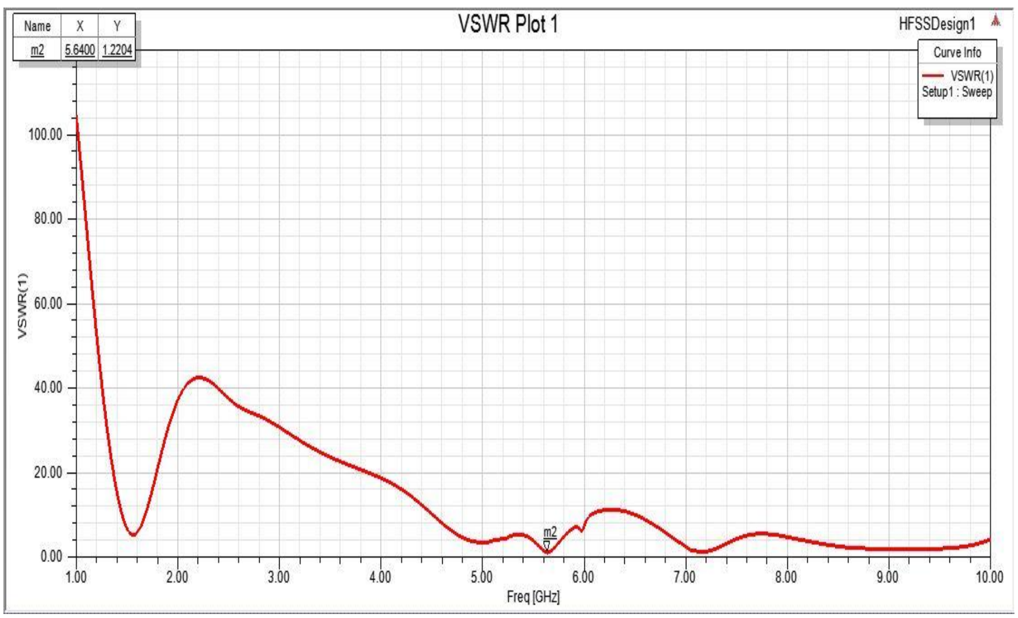

Figure: 7 VSWR when S3 Pin Diode is ON in E shaped Antenna

Table: 2 Results when S3 Pin Diode is ON in E shaped Antenna

S1	S2	S3	Resonant Frequency (GHZ)	Reflection Coefficient (dB)	VSWR
off	off	on	5.64	-20.06	1.22

These are the results obtained using E shaped antenna .By placing PIN Diode with all the diodes are in OFF condition it will be resonated at 5.6 GHZ with Reflection coefficient of -20.06 dB with a VSWR of 1.22.

Case iii: when one (s2) Pin Diodes is ON condition:

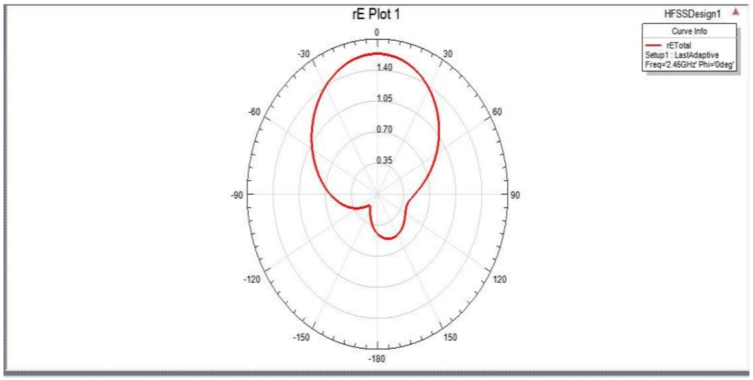

Figure: 8 Radiation Pattern when S2 Pin Diode is ON in E shaped Antenna

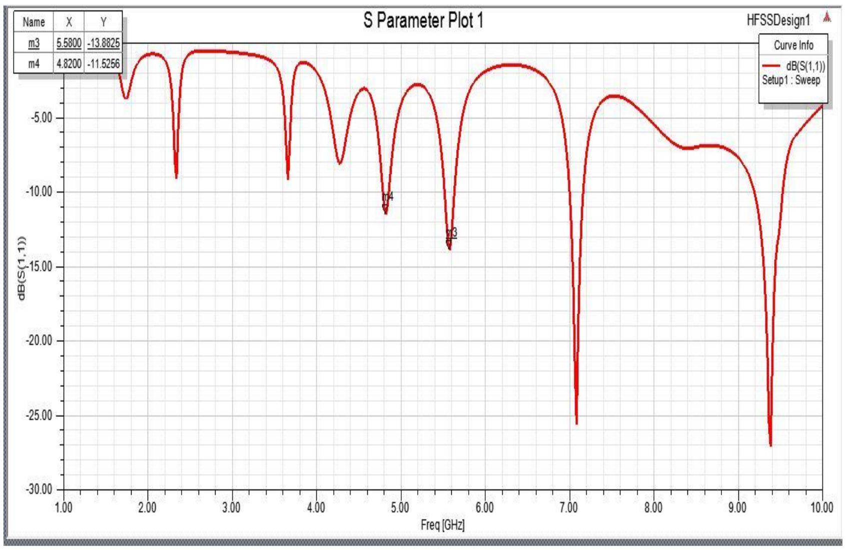

Figure: 9 Reflection Coefficient when S2 Pin Diode is ON in E shaped Antenna

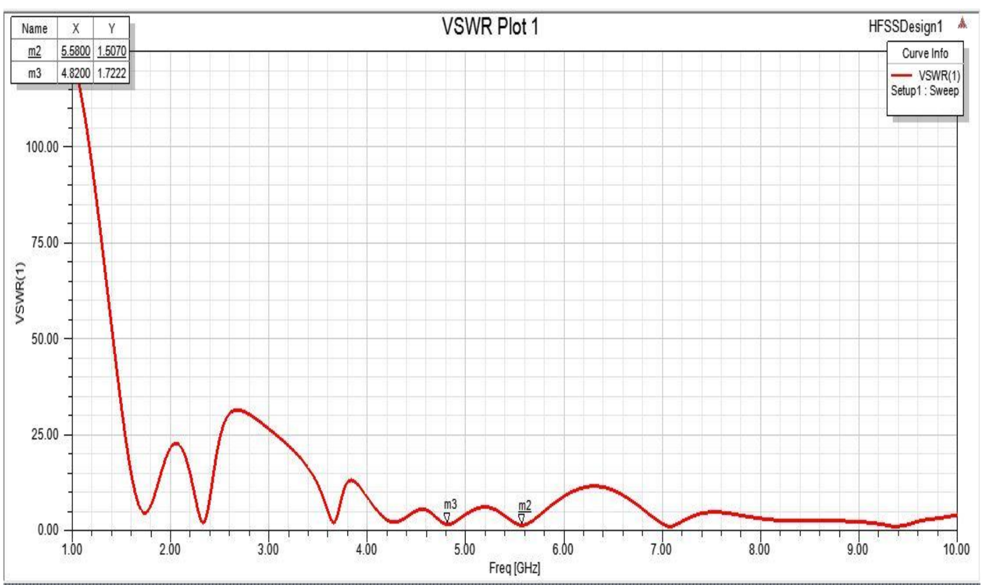

Figure: 10 VSWR when S2 Pin Diode is ON in E shaped Antenna

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Table: 3 Results when S2 Pin Diode is ON in E shaped Antenna

S1	S2	S3	Resonant Frequency (GHZ)	Reflection Coefficient (dB)	VSWR
off	on	off	5.58	-13.88	1.5
			4.82	-11.52	1.72

These are the results obtained using E shaped antenna .By placing PIN Diode with all the diodes are in OFF condition it will be resonated at 5.58 GHZ and 4.82 GHZ with Reflection coefficient of -13.88 dB and -11.52 dB with a VSWR of 1.5 and 1.72.

Case iv: when two (s2, s3) Pin Diodes are ON condition:

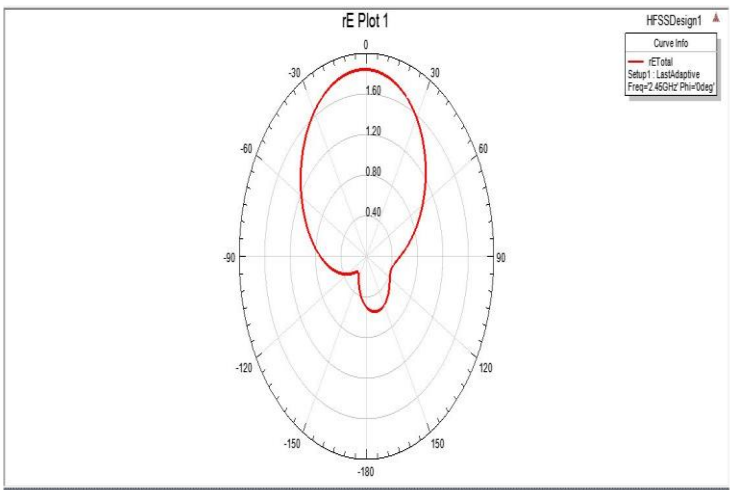

Figure: 11 Radiation Pattern when both S2 and S3 Pin diodes are ON in E shaped Antenna

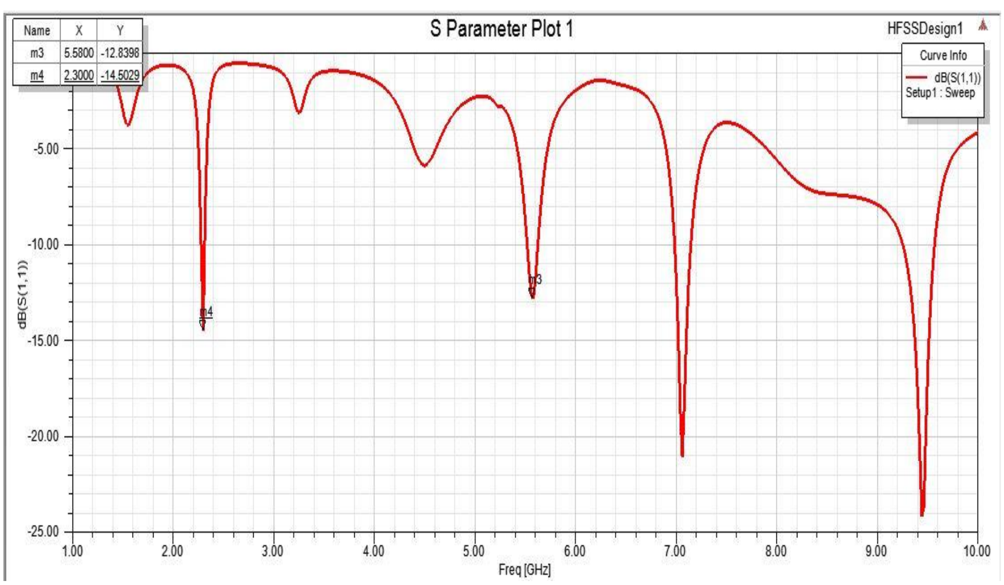

Figure: 12 Reflection Coefficient when both S2 and S3 Pin diodes are ON in E shaped Antenna

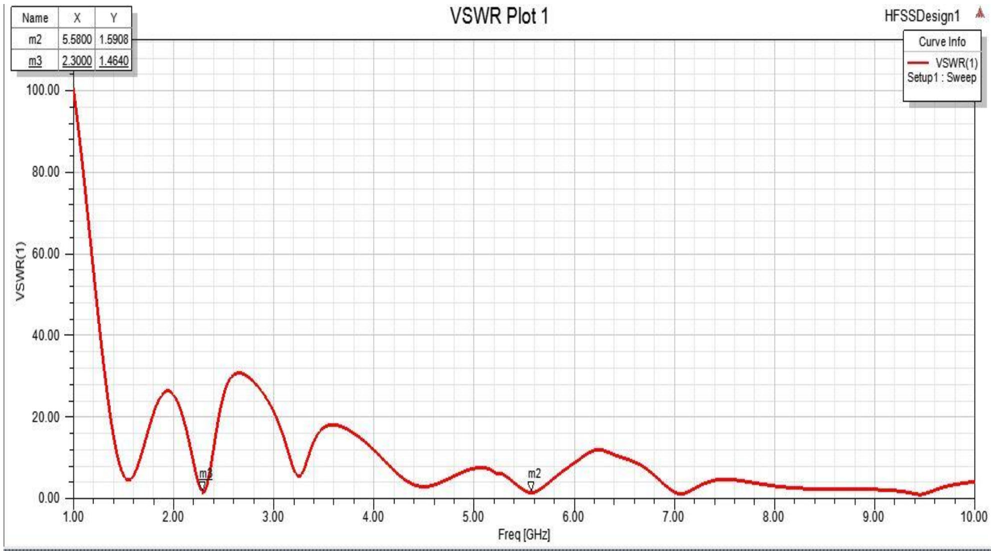

Figure: 13 VSWR when both S2 and S3 Pin diodes are ON in E shaped Antenna

Table: 4 Results when both S2 and S3 Pin diodes are ON in E shaped Antenna

S1	S2	S3	Resonant Frequency(GHZ)	Reflection Coefficient (dB)	VSWR
off	on	on	5.58	-12.83	1.59
			2.3	-14.5	1.46

These are the results obtained using E shaped antenna .By placing PIN Diode with all the diodes are in OFF condition it will be resonated at 5.58 GHZ and 2.3 GHZ with Reflection coefficient of -12.83 dB and -14.5 dB with a VSWR of 1.59 and 1.46.

Case v: when one (s1) Pin Diodes is ON condition:

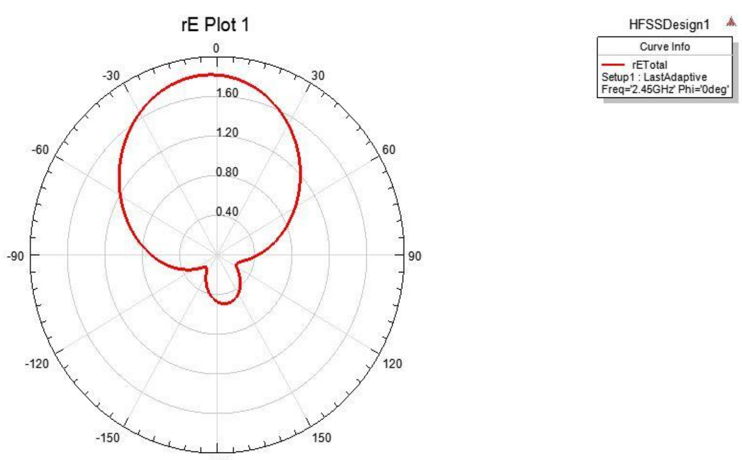

Figure: 14 Radiation Pattern when S1 Pin Diode is ON in E shaped Antenna

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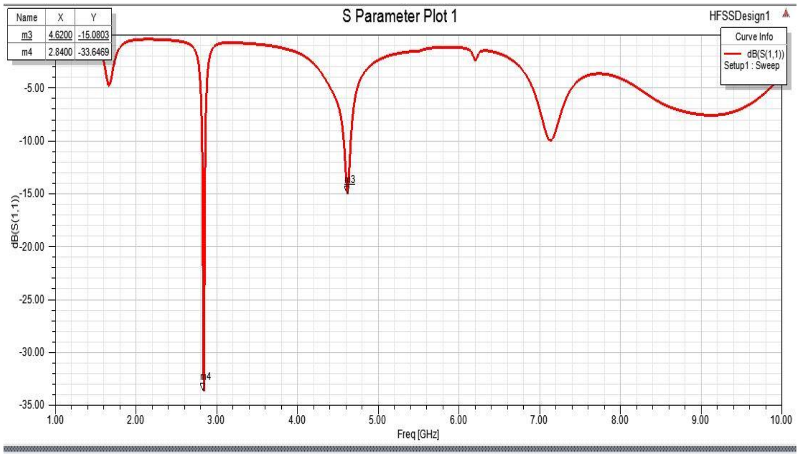

Figure: 15 Reflection Coefficient when S1 Pin Diode is ON in E shaped Antenna

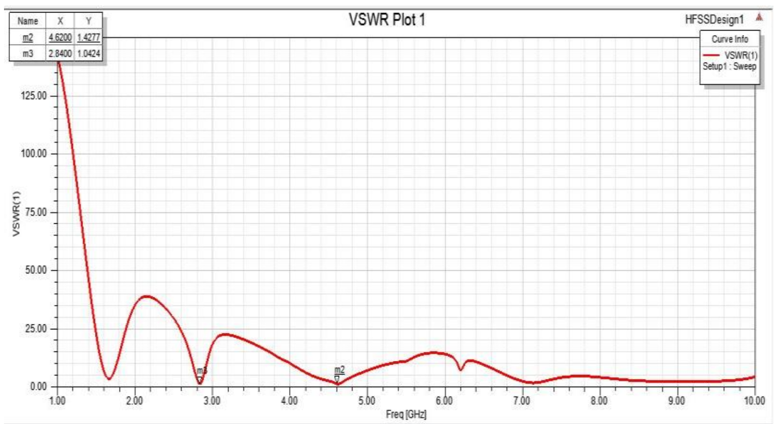

Figure: 16 VSWR when S1 Pin Diode is ON in E shaped Antenna

Table: 5 Results when S1 Pin Diode is ON in E shaped Antenna

S1	S2	S3	Resonant Frequency (GHZ)	Reflection Coefficient (dB)	VSWR
on	off	off	4.62	-15.08	1.42
			2.84	-33.64	1.04

These are the results obtained using E shaped antenna .By placing PIN Diode with all the diodes are in OFF condition it will be resonated at 4.62 GHZ and 2.84 GHZ with Reflection coefficient of -15.08 dB and -33.64 dB with a VSWR of 1.42 and 1.04

Case vi: when two (s1,s3) Pin Diodes are ON condition:

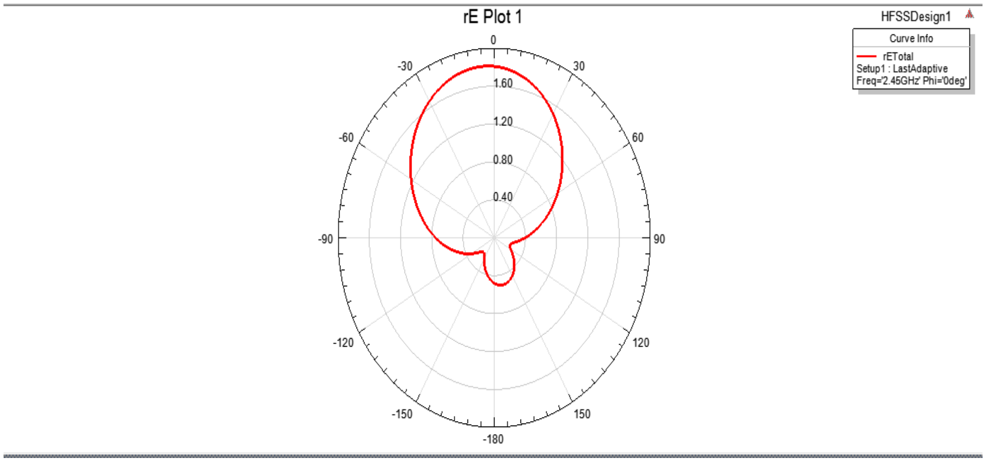

Figure: 17 Radiation Pattern when both S1 and S3 Pin Diodes are ON in E shaped Antenna

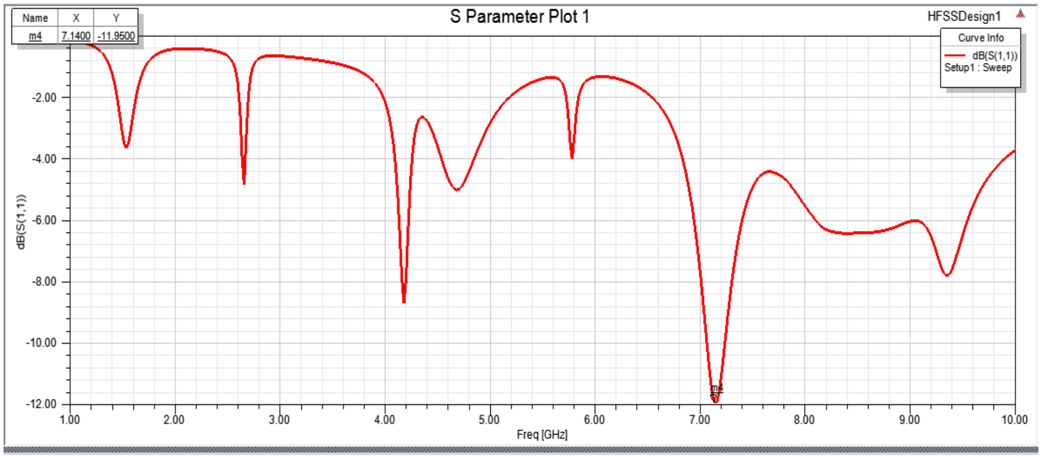

Figure: 18 Reflection Coefficient when both S1 and S3 Pin Diodes are ON in E shaped Antenna

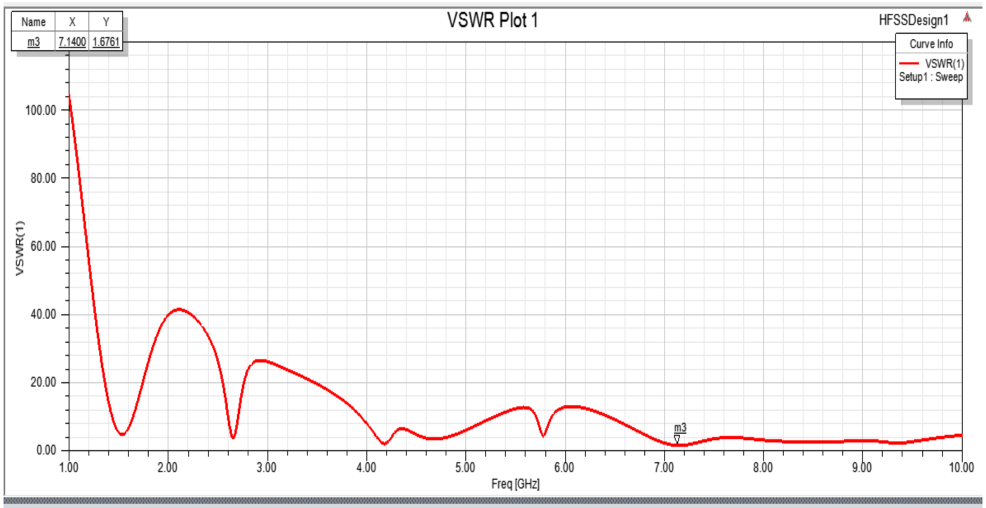

Figure: 19 VSWR when both S1 and S3 Pin Diodes are ON in E shaped Antenna

Table: 6 Results when both S1 and S3 Pin Diodes are ON in E shaped Antenna

S1	S2	S3	Resonant Frequency(GHZ)	Reflection Coefficient (dB)	VSWR
on	off	on	7.14	-11.95	1.67

These are the results obtained using E shaped antenna .By placing PIN Diode with all the diodes are in OFF condition it will be resonated at 7.14 GHZ with Reflection coefficient of -11.95 dB with a VSWR of 1.67.

Case vii: When two (s1,s2) Pin Diodes are ON condition:

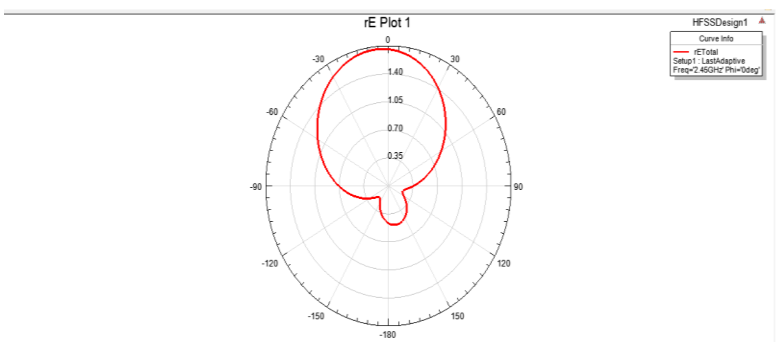

Figure: 20 Radiation Pattern when both S1 and S2 Pin Diodes are ON in E shaped Antenna

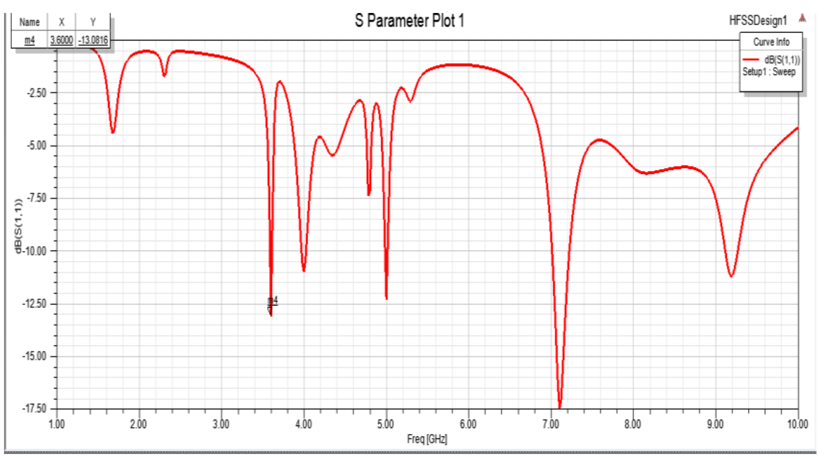

Figure: 21 Reflection Coefficient when both S1 and S2 Pin Diodes are ON in E shaped Antenna

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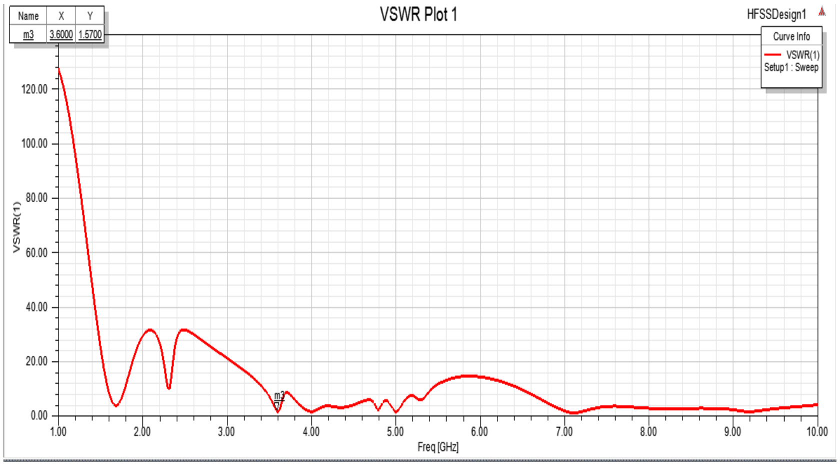

Fig: 4.22 VSWR when both S1 and S2 Pin Diodes are ON in E shaped Antenna

Table: 7 Results when both S1 and S2 Pin Diodes are ON in E shaped Antenna

S1	S2	S3	Resonant Frequency (GHZ)	Reflection Coefficient (dB)	VSWR
on	on	off	3.6	-13.08	1.57

These are the results obtained using E shaped antenna .By placing PIN Diode with all the diodes are in OFF condition it will be resonated at 3.6 GHZ with Reflection coefficient of -13.08 dB with a VSWR of 1.57.

Case viii: when two (s2,s3) Pin Diodes are ON condition:

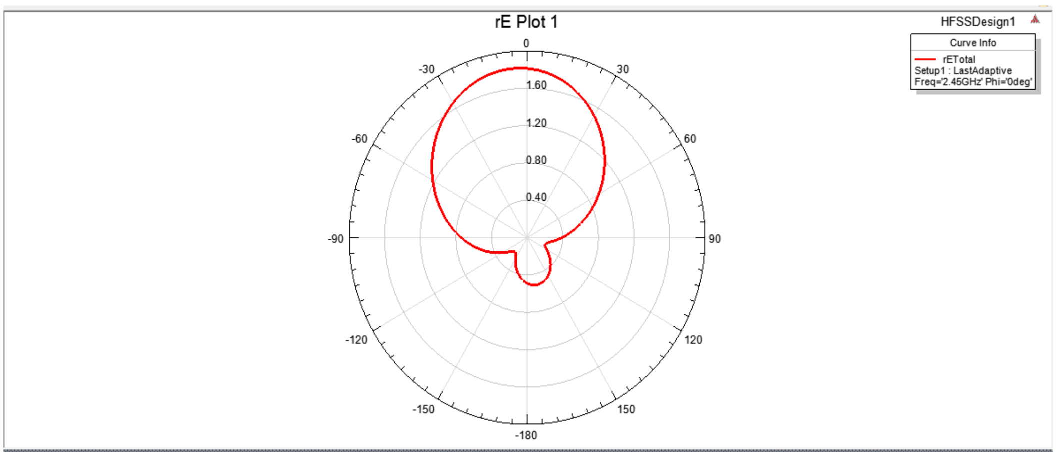

Figure: 23 Radiation Pattern when All the Pin diodes are ON in E shaped Antenna

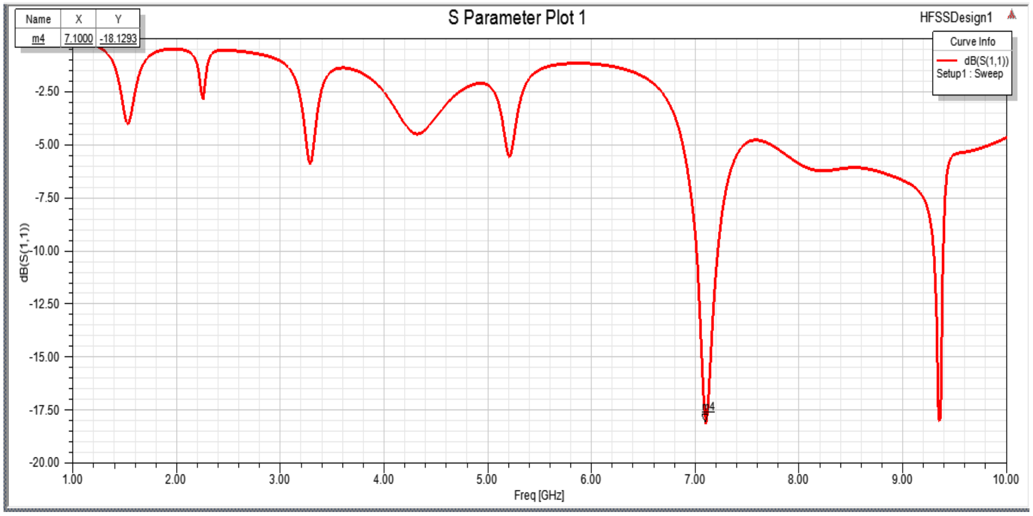

Figure: 24 Reflection Coefficient when All the Pin diodes are ON in E shaped Antenna

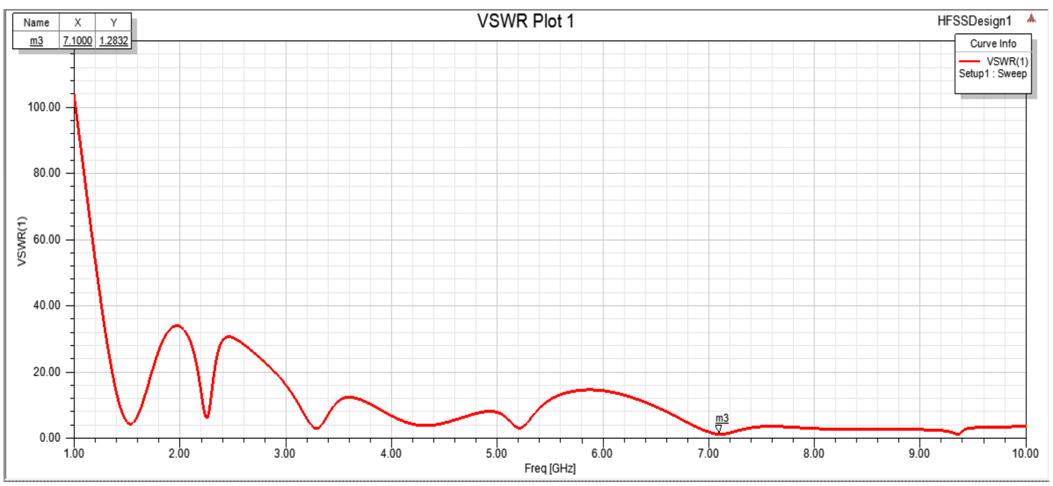

Figure: 25 VSWR when All the Pin diodes are ON in E shaped Antenna

Table: 8 Results when All the Pin diodes are ON in E shaped Antenna

S1	S2	S3	Resonant Frequency (GHZ)	Reflection Coefficient (dB)	VSWR
on	on	on	7.1	-18.12	1.28

These are the results obtained using E shaped antenna .By placing PIN Diode with all the diodes are in OFF condition it will be resonated at 7.1 GHZ with Reflection coefficient of -18.12 dB with a VSWR of 1.28.

Table: 9 Results for Pin Diode

S. No	S1	S2	S3	Resonant Frequency (GHZ)	Reflection Coefficient (dB)	VSWR
1	off	off	off	4.82	-21.94	1.17
				4.3	-21.8	1.17
2	off	off	on	5.64	-20.06	1.22
3	off	on	off	5.58	-13.88	1.5
				4.82	-11.52	1.72
4	off	on	on	5.58	-12.83	1.59
				2.3	-14.5	1.46
5	on	off	off	4.62	-15.08	1.42
				2.84	-33.64	1.04
6	on	off	on	7.14	-11.95	1.67
7	on	on	off	3.6	-13.08	1.57
8	on	on	on	7.1	-18.12	1.28

V . Conclusion

For Frequency diversity applications, this high capability of an adaptable patch antenna has been proposed. The proposed antenna and the simulated results show that a frequency Reconfiguration is achieved using PIN diodes. The HFSS simulation results of E SHAPED patch antenna satisfy the fundamental requirements and can be fabricated. The results show that such an antenna is useful for many applications.

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