

# Frequency Reconfigurable Patch Antenna for Bluetooth, WLAN and Radar Applications

Cheruku Jaya<sup>1</sup>, Tumati Venkateswara Rao<sup>2</sup>P.G. Student, Department of Electronics and Communication Engineering, Sir C.R.Reddy College of Engineering,  
Eluru, Andhra Pradesh, India<sup>1</sup>Head of the Department, Department of Electronics and Communication Engineering, Sir C.R.Reddy College of  
Engineering, Eluru, Andhra Pradesh, India<sup>2</sup>

**ABSTRACT:** This paper describes the design and simulation of a frequency reconfigurable microstrip patch antenna for Bluetooth, WLAN and Radar applications. Bluetooth and WI-FI operates at 2.45GHz frequency, WLAN and WI-MAX operate at 5GHz band, and Marine Radar operating frequency is 7.5GHz. These three antennas are designed and simulated using Ansoft HFSS V.13 software. Rectangular patch antenna with inset feeding is used as radiating element. Rogers RT/duroid 5880 (tm) dielectric substrate with  $\epsilon_r = 2.2$  and thickness 1.6mm is taken. For each antenna Return loss, VSWR, Radiation Pattern was observed. These three antennas are integrated into single structure and RF-switches are used to achieve frequency reconfigurability.

**KEYWORDS:** Microstrip Patch Antenna, HFSS, VSWR, Reconfigurability.

## I. INTRODUCTION

Ultrawideband technology was discovered by Robert A. Scholtz. Federal Communication Commission (FCC) has [1] allocated 7,500MHZ of spectrum from 3.1 to 10.6GHZ for unlicensed use of ultrawideband (UWB) communication in 2002. It is a short range radio technology compliment to existing long range technologies such as Wi-Fi, and cellular communication. It finds applications in various areas where simple hardware, low power consumption and high data rate is required such as medical, vehicular radar systems, surveillance systems, imaging systems etc [2-3].

In wireless communication system antenna is one of the important component. Antenna is an electromagnetic transducer that converts guided waves in the transmission line into free space radiated waves in transmitting mode and reverse in the receiving mode. There are several types of antennas exist, among all microstrip antennas are low profile antennas. These antennas are very useful where low cost, less weight, and high performance are required. Most common type of microstrip antenna (printed antenna) is the microstrip patch antenna or simply patch antenna. The patch can take any shape [4-6] but rectangular, circular and triangular [7-9] are most commonly used. Microstrip antennas have several advantages such as simple, inexpensive to manufacture. They can be fed by various types of feeding techniques [10-12] such as microstrip line feeding, coaxial feeding, aperture coupling, and proximity coupling. Microstrip line feed can be either inset/cut feed, edge feed and it is easy to fabricate and easy to match by controlling the inset position [13-14]. Modified feed structures for bandwidth enhancement were presented in [15-16].

UWB antenna design is a challenging task due to the interference from existing technologies such as WLAN which operates between 5.1-5.8GHZ. But they have the advantage that they can implement notch characteristic on the antenna itself. Numbers of single band notch, dual, triple band notch designs were presented in [17-19]. As the demand for antennas with switchable systems is increasing recently reconfigurable antennas have drawn much attention [20]. Reconfigurable means capable of modifying. That means they have the ability to change their operating frequency, polarization, radiation pattern and phase through the use of GaAs FET, pin diodes, RF MEMS [21-23]. Several single and dual band reconfigurable designs were proposed [24-25].

In this paper, a single feed frequency reconfigurable triple band microstrip antenna with three patches for 2.45/5.5/7.5GHZ was proposed. It uses 3 diodes for switching between frequency bands. Patches and ground plane

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were separated by a thin dielectric substrate Rogers rt/duroid 5880 (tm) of thickness 1.6 mm and dielectric constant 2.2.

Paper is organized as follows. Section II describes Microstrip patch antenna design. Design methodology is given in Section III. Section IV presents simulation results. Finally, Section V presents conclusion.

## II. RELATED WORK

B. C. C. Chang *et al.* [27], proposed a reconfigurable leaky mode/patch antenna controlled by PIN diode switches. This paper represents, for the first time, a fully electronically controlled reconfigurable aperture using PIN diode switches, to realize the switching between the leaky mode/patch antenna operation. A. W. M. Lee *et al.* [28], proposed a reconfigurable aperture (recap) patch antenna with resonant frequencies of 18 GHz and 28 GHz for use in the wideband gap filler satellite system. Finite-element method (FEM) computations are performed and compared with experimental results. V. K. Kunda *et al.* [29], proposed a stacked microstrip patch antenna that can be reconfigured for operation at 2 GHz and 600 MHz. Reconfiguration is achieved by using PIN diode switches. N. Jin *et al.* [30], proposed a novel reconfigurable antenna with both frequency and polarization diversities. M. A. Alayesh *et al.* [31], proposed a reconfigurable stacked Microstrip Patch Antenna (MSA) of operating frequencies in the range of (2-5) GHz for wireless applications. A. Muscat *et al.* [32], proposed feed antenna that can be tuned to a frequency in the range 450 MHz to 2.2 GHz. Ya-Chi Liu *et al.* [33], proposed a multiband frequency reconfigurable antenna that operates at multiband from 2 GHz to 4.5 GHz. Songnan Yang *et al.* [34], proposed a Frequency-reconfigurable antennas for multiradio wireless platforms. Y. Tawk *et al.* [35], proposed a new antenna design suitable for cognitive radio communication. M. T. Ali. *et al.* [36], proposed a reconfigurable rectangular microstrip slot patch antenna of operating frequencies in the range of (2-6) GHz for Wireless Local Area Network (WLAN) applications. Mansoul, A. *et al.* [37], proposed a simple frequency reconfigurable microstrip patch antenna for wireless communication, operating at either 2.2 GHz or 2.45 GHz depending on the state of the diodes PIN switches. Ramli, N. *et al.* [38], presented a Frequency Reconfigurable Stacked Patch Microstrip Antenna (FRSPMA) using PIN diode switch, operating at either at 2.6 GHz or 3.5 GHz frequency. Majid, H.A. *et al.* [39], presented a Frequency-Reconfigurable Microstrip Patch-Slot Antenna capable of frequency switching at nine different frequency bands between 1.98 and 3.59 GHz. Tayfun Ozdemir *et al.* [40], proposed a A frequency tunable antenna for 4G global roaming devices operating in the 2.3-2.7GHz band.

## III. MICROSTRIP PATCH ANTENNA DESIGN

Patch antenna is a type of microstrip antenna and it consists of a radiating patch on one side of the dielectric substrate and ground plane on other side. Copper is used for patch and ground plane. Rogers rt/duroid 5880 (tm) is used as dielectric substrate. Dielectric constant is 2.2, thickness is 1.6mm and loss tangent is 00009. Microstrip antennas have several advantages like low profile, easy fabrication but they have narrow bandwidth and low gain. In this paper bandwidth enhancement is done by using a thick substrate with low dielectric constant. Number of feeding techniques exists for coupling power to antenna. Microstrip line feeding is simple and easy to fabricate. In this paper microstrip line inset feeding is used. Individual antennas resonating at 2.45GHz, 5.5GHz, and 7.5GHz are designed using 3D EM software- Ansoft HFSS. The integrated structure is designed using RF switches.

Reconfigurability is the capability of an antenna to change or modify its fundamental operating characteristics by means of switching or material changes. Changing the resonant frequency of an antenna is called frequency reconfigurability. This can be achieved by using switches, Variable reactive loading, Structural/ mechanical changes, Material changes. PIN diodes, FETs, Optical switches, RF-MEM switches can be used to switch between different bands. In this paper MSS40155 diodes are used to achieve reconfigurability. The values of  $R_s$ ,  $R_p$ , and  $C_p$  can be obtained from the data sheet of diode.

In order to calculate patch, ground plane, feed line dimensions, number of analysis models exists. In those Transmission line model is simple. Formulas are presented in [4].

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## IV. DESIGN METHODOLOGY

HFSS design models for frequencies 2.45GHz, 5.5GHz, and 7.5GHz. The values are calculated from the formulas mentioned in [4].

The dimensions for 2.45GHz antenna is presented below:

TABLE I. DIMENSIONS FOR 2.45GHZ ANTENNA

S. No	Material and dimensions			
	Material name	Width (mm)	Length (mm)	Height (mm)
1.	Substrate	120.83	82.2	1.6
2.	Ground plane	120.83	82.2	0.05
3.	Patch	40.49	48.4	0.05
4.	Feed line	31.25	4.93	0.05

According to the measured values, antenna is designed in HFSS software. Designing an antenna using HFSS software is presented in [26]. Return loss, VSWR, and radiation pattern plots were presented for each individual antenna and for integrated structure. Return loss should be less than -10dB for an antenna to work efficiently, and VSWR should be less than 2.

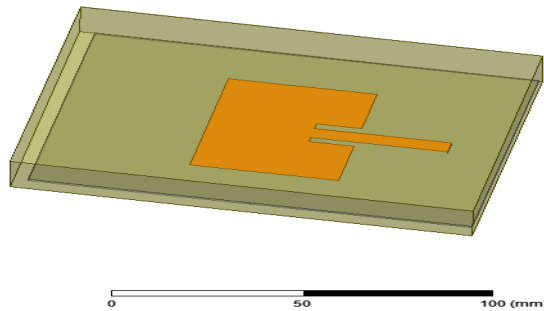


Fig. 1 HFSS model for 2.45GHz patch antenna

Microstrip line inset feeding is used here. The air box or radiation box height must be  $\lambda/4$  of the frequency of interest, in the direction of radiation field.

The dimensions for 5.5GHz antenna is presented below:

TABLE II. DIMENSIONS FOR 5.5GHZ ANTENNA

S. No	Material and dimensions			
	Material name	Width (mm)	Length (mm)	Height (mm)
1.	Substrate	53.21	41.9	1.6
2.	Ground plane	53.21	41.9	0.05
3.	Patch	17.44	21.56	0.05
4.	Feed line	16.614	4.93	0.05

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HFSS design model is:

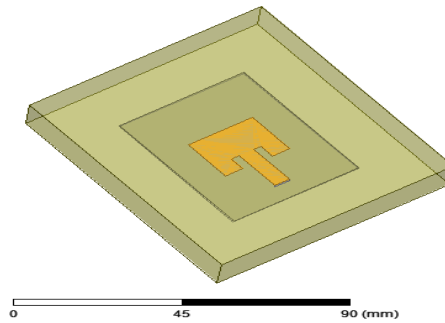


Fig. 2 HFSS model for 5.5GHz patch antenna

From the HFSS model we can see that the patch dimensions or size is decreased when frequency is increased.

The dimensions for 7.5GHz is presented below:

TABLE III. DIMENSIONS FOR 7.5GHZ ANTENNA

S. No	Material and dimensions			
	Material name	Width (mm)	Length (mm)	Height (mm)
1.	Substrate	38.69	33.3	1.6
2.	Ground plane	38.69	33.3	0.05
3.	Patch	12.48	15.81	0.05
4.	Feed line	12.184	4.93	0.05

HFSS model is:

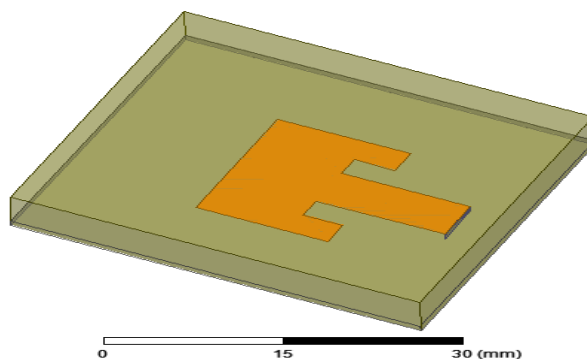


Fig. 3 HFSS model for 7.5GHz patch antenna

The size of radiating patch of 7.5GHz antenna is much smaller compared to 2.45GHz and 5.5GHz antennas. From this we can say that the size of patch is inversely proportional to resonant frequency.

Integrated structure for these three frequencies using diodes is presented below:

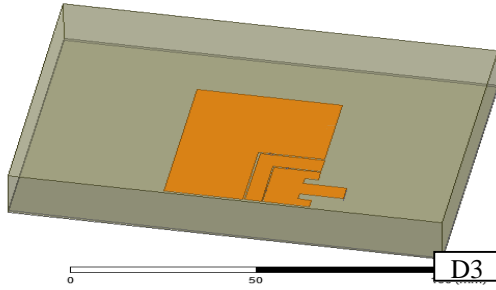


Fig. 4 HFSS model for 2.45/5.5/7.5GHz patch antenna

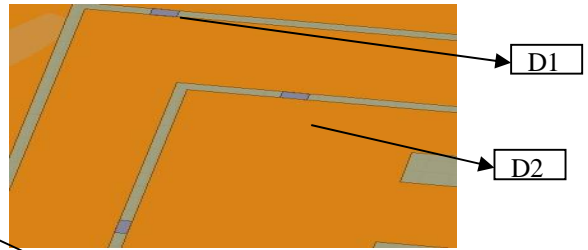


Fig. 5 HFSS model for 2.45/5.5/7.5GHz patch antenna (Zoom)

3 diodes D1, D2, D3 are placed in two L- shaped slots. D1 is placed in y- direction at a distance of 4.78mm. D2 is placed in y-direction at a distance of 10.78mm and D3 is placed in x-direction at a distance of 18.78mm.

**V. SIMULATION RESULTS**

The designed antennas were analyzed using HFSS. Simulated results were given in this section. Return loss values for three antennas and integrated structure are

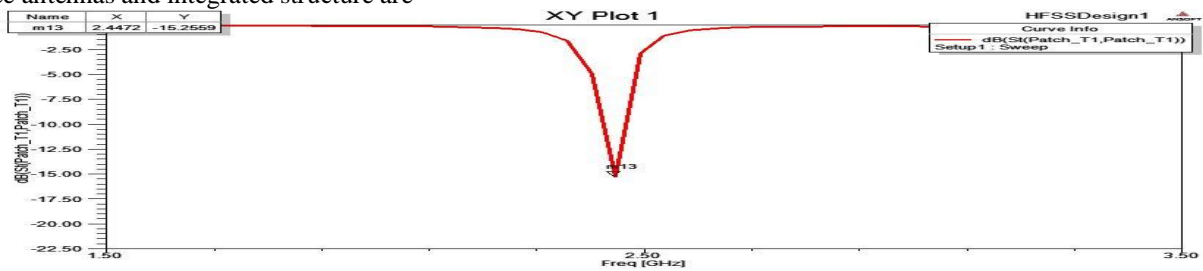


Fig. 6 Return loss plot for 2.45GHz antenna

Return loss obtained for 2.45GHz frequency is -15.2559dB. So this antenna is suitable to Bluetooth and Wi-Fi applications.

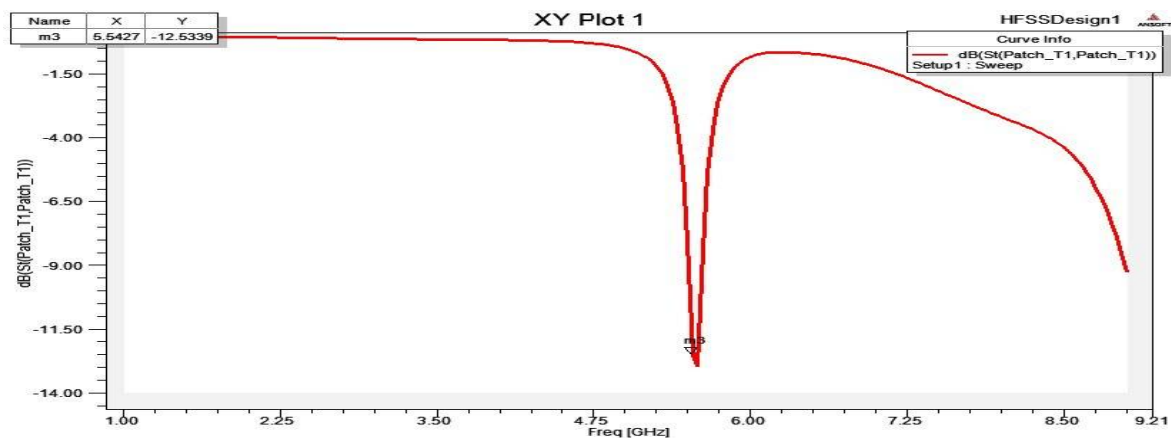


Fig. 7 Return loss plot for 5.5GHz antenna

Return loss obtained for 5.5GHz frequency is -12.5339dB. So this antenna is suitable to WLAN and Wi-Max applications.

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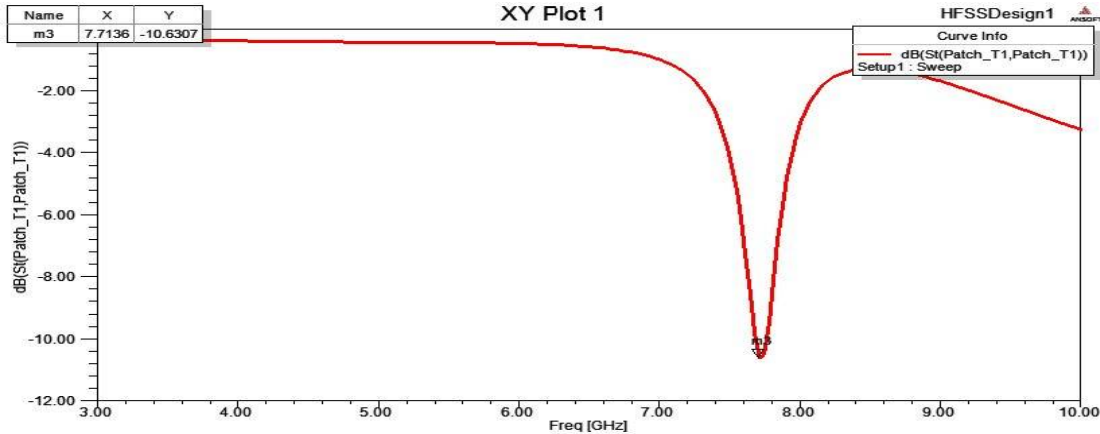


Fig. 8 Return loss plot for 7.5GHz antenna

Return loss obtained for 7.5GHz frequency is -10.6307dB. So this antenna is suitable to Radar applications.

Radiations patterns for three antenna are presented below:

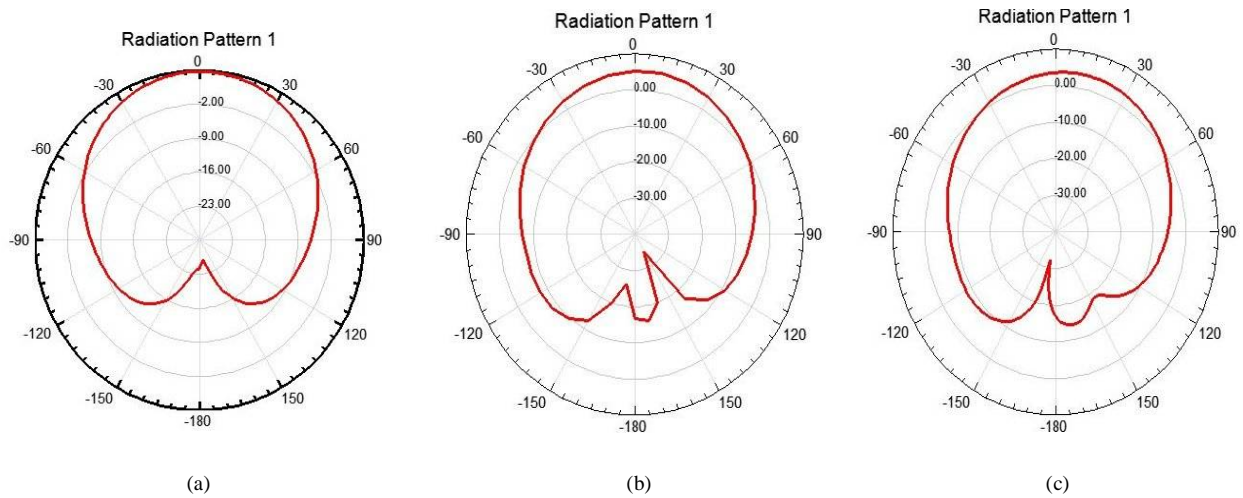


Fig. 9 Radiation pattern (a) for 2.45GHz patch antenna (b) for 5.5GHz patch antenna (c) for 7.5GHz patch antenna

All these patterns shows that each antenna exhibits nearly omni-directional pattern.

Simulation results for the frequency reconfigurable patch antenna for different diode conditions are given below. When diodes D1, D2 are forward biased and D3 is reverse biased, i.e. D1 D2-ON, D3-OFF, antenna operates at 2.4GHz frequency. When all three diodes are forward biased i.e. D1, D2, D3-ON, antenna operates at 5.1GHz frequency. When all three diodes are reverse biased i.e. D1, D2, D3-OFF, antenna resonates at 7.3GHz frequency. Return loss and Radiation pattern plots for 3 conditions are presented.

**D1, D2- ON, D3- OFF**

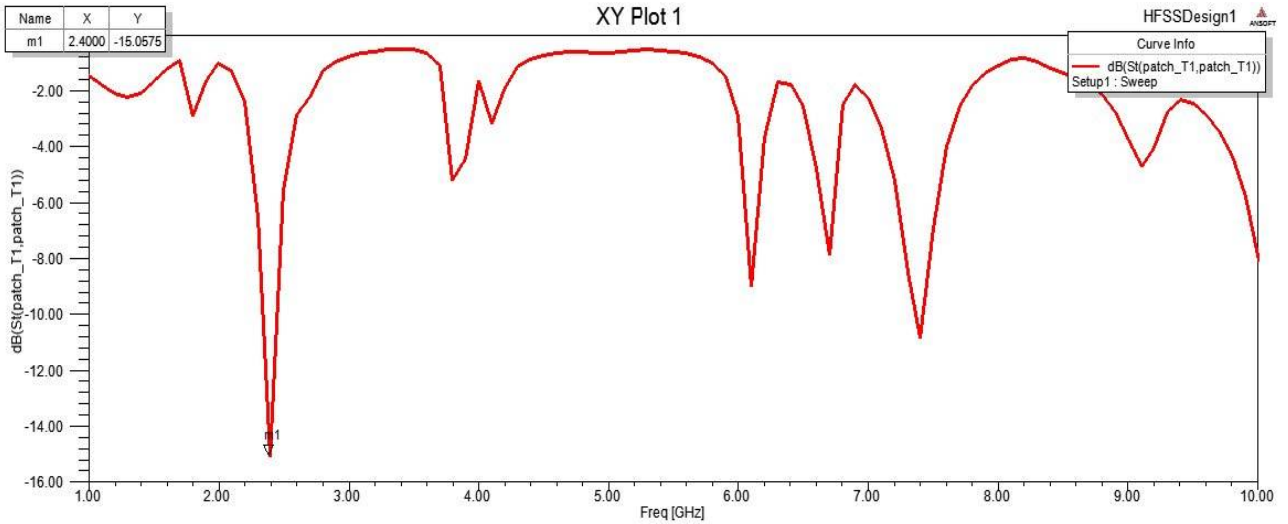


Figure 1. Return loss plot for 2.4GHz frequency

In this condition antenna operates at 2.4GHz with Return loss -15.0575dB.

The radiation pattern for 2.4GHz frequency is shown below:

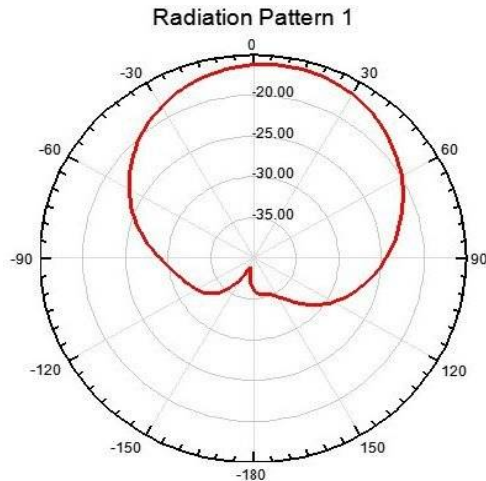


Figure 2. Radiation pattern for 2.4GHz frequency

Antenna in this condition exhibits nearly omni-directional pattern.

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D1, D2, D3- ON

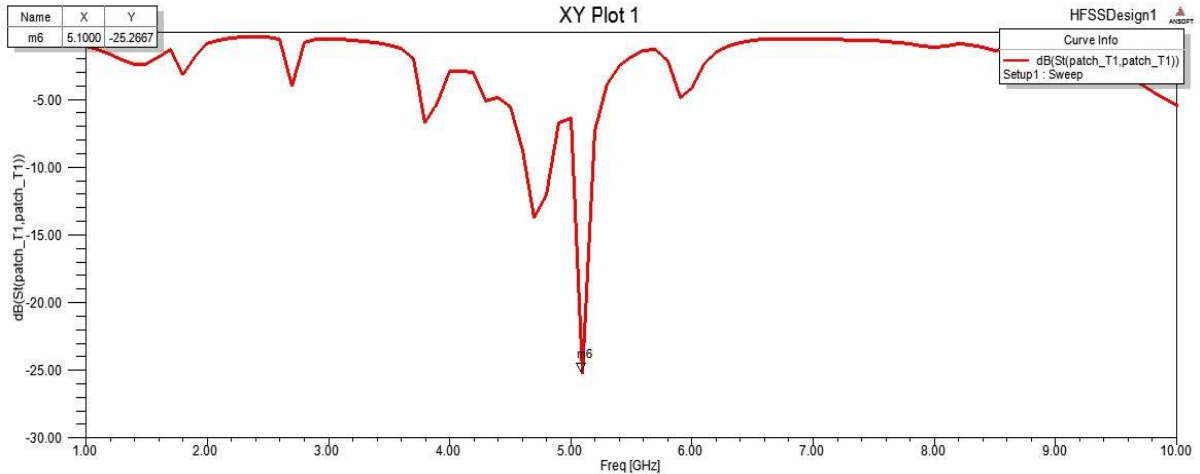


Figure 3. Return loss plot for 5.1GHz frequency

In this condition antenna operates at 5.1GHz with Return loss -25.2667dB.

The radiation pattern for 5.1GHz frequency is shown below:

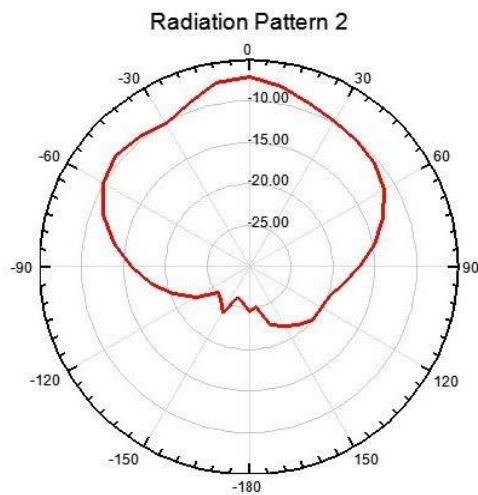


Figure 4. Radiation pattern for 5.1GHz frequency

Antenna in this condition also exhibits nearly omni-directional pattern.



**D1, D2, D3- OFF**

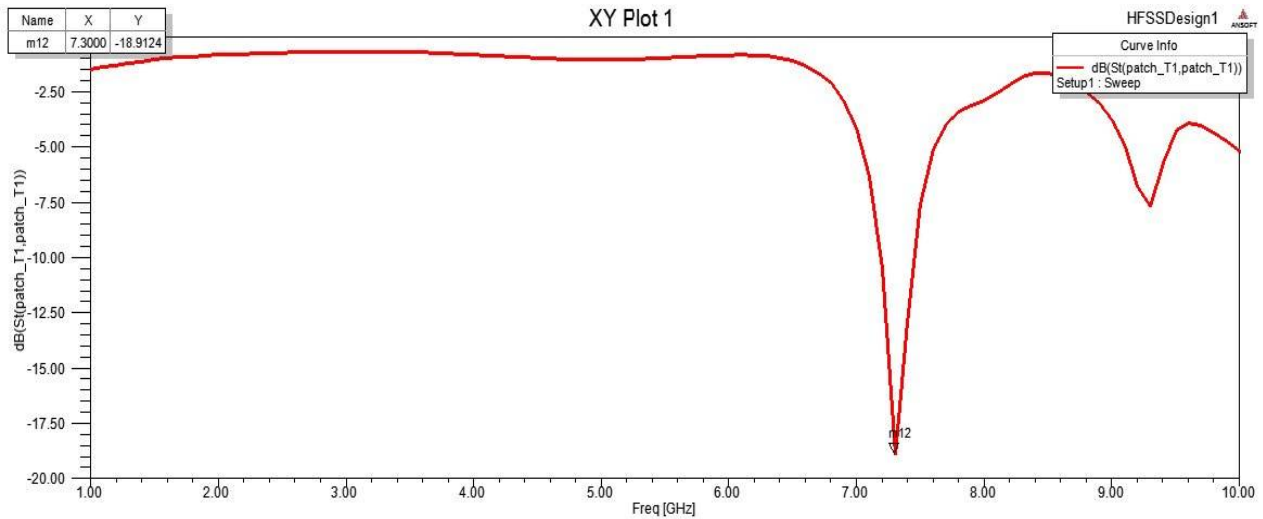


Figure 5. Return loss for 7.3GHz frequency

In this condition antenna operates at 7.3GHz with Return loss -18.9124dB.

The radiation pattern for 7.3GHz frequency is shown below:

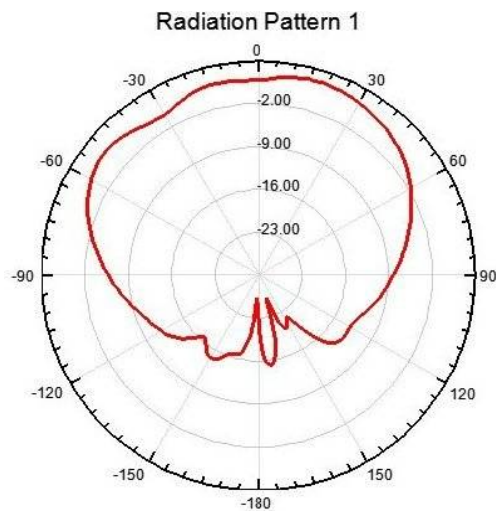


Figure 6. Radiation pattern for 7.3GHz frequency

Antenna in this condition also exhibits nearly omni-directional pattern. This integrated structure is working perfectly by switching between the three bands.

The return loss values for three antennas individually and for integrated structure is placed in atabular form:

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TABLE IV. RETURN LOSS VALUES FOR EACH ANTENNA

Resonant Frequency	Return loss
2.44GHz	-15.2559dB
5.5GHz	-12.5339dB
7.7GHz	-10.6307dB

TABLE V. RETURN LOSS VALUES FOR RECONFIGURABLE ANTENNA

Diode condition	Resonant Frequency	Return loss
D1,D2-ON,D3-OFF	2.4GHz	-15.0675dB
D1,D2,D3-ON	5.1GHz	-25.2667dB
D1,D2,D3-OFF	7.3GHz	-18.9124dB

## VI. CONCLUSION

The simulated results for 2.45, 5.5, 7.5GHz antennas show that return loss obtained is less than -10dB.i.e. 90% of signal gets absorbed and only 10% is reflected back. VSWR obtained is less than 2 for three frequencies. So the antenna works perfectly for Bluetooth, Wireless LAN and Radar applications. These three micro strip patch antennas are integrated together to form a single micro strip patch structure to operate at 3 different frequencies. 3 diodes are used to achieve switching mechanism. In each condition of diode ON or OFF antenna operates at one frequency either 2.45 GHz or 5.5 GHz or 7.5GHz, and in each case it results return loss less than -10dB and VSWR less than 2. As a future work we can implement a frequency reconfigurable MIMO (multi input multi output) antenna to reduce multipath fading.

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