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Reconfigurable Notch Band Monopole Slot Antenna for WLAN/IEEE-802.11n Applications

Kosuru Murthy[1] Kodidasu Umakantham[2] Korlapati Satyanarayana Murthy[3] Boddapati Taraka Phani Madhav[3]

[1]*Department of Electronics and Communication Engineering, K L University, AP, India*
[2]*Pydah Kaushik College of Engineering, Visakhapatnam, AP, India*
[3]*Department of Electronics and Communication Engineering, K L University, AP, India*
* Corresponding author's Email: btpmadhav@kluniversity.in

Abstract: This article presents a compact dual band antenna for WLAN/IEEE-802.11n applications with frequency reconfigurability nature. The resonant modes are achieved through slots incorporated in the radiating structure and tunability in the band is achieved by PIN diodes switching. The proposed monopole slot antenna with dimensions of 55 X 52 X 1.6 mm placed on Rogers RT-duroid substrate of permittivity 2.2 and loss tangent 0.0009. The changes in first and second resonant frequencies are attained with switching of diodes connected between slot gaps. The switching properties of the diodes are utilized in optimum way to notch certain frequencies and to choose operation frequencies. Low cross polarization with stable radiation pattern and average gain of 2.8 dB are the key elements for this novel antenna. The designed antenna is showing good impedance bandwidth of 68% and peak realized gain of 4.86 dB at 5.6 GHz WLAN band. A good matching between measured results and simulation studies are obtained from the current antenna design.

Keywords: Notch, Monopole, Reconfigurable, Slot antenna, WLAN.

1. Introduction

Advanced microwave devices integrated reconfigurable antennas are gaining their importance in the communication systems [1]. This integration involves so many challenges like low profile, impedance matching and low cost etc [2]. Reconfigurability will provide the advantages like minimization of reinstallation of devices, infrastructure and gives rise to have minimum hardware at low cost [3]. The reconfigurable and tunable devices will open the doors for effective utilization of hardware and management of dynamic spectrum access in optimum way [4]. The time sharing of hardware with reconfigurable nature gives rise to size and mass reduction in communication systems. By limiting number of microwave components and interconnections in the signal routing, the overall size and cost of the antenna can be reduced [5].

Frequency reconfigurable antennas are needed in transmitters and receivers of communication modules to switch between multibands [6]. The patch elements will be connected with MEMS switches to ON and OFF the conduction between elements [7]. By activating these switches connected between radiating patches, the resonant frequency can be shifted. Clearly, the desired frequency is controlled by the switch operation. This technique reduces the size and number of antennas mounted on board in a multi-band communication [8]. Radiation pattern and beam reconfigurable antennas able to alter its radiation pattern during the real time operation and maintain its broad pattern in the absence of interferences, and are capable of narrowing its pattern beam width [9].

A polarization reconfigurable antenna with characteristics of polarization diversity is gaining popularity in wireless communications and radar systems, especially with circular polarization [10]. Left hand and right hand circular polarizations with

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same feeding made these antennas as promising elements in the desired field of operation [11]. An antenna can alter between linear and circular polarizations at fixed operating frequency made flexibility in the applications [12]. Some of the antenna models are capable of both frequency and radiation reconfigurable simultaneously [13]. These Reconfigurable antennas have great potential to add substantial degrees of freedom and functionality in mobile communications and in commercial application modules [14].

Now a day's people are looking for a single communication system with multiple utilization schemes. Different antenna designs with dual, triple, multiband and UWB are developed [15]. To mitigate interference because of the other nearby systems, the UWB is not preferable when compared with multiband antennas [16]. Several designs are available for multiband operations like slots in the radiating element, defected ground structures and fractal geometries with good radiation characteristics and wide bands coverage [17]. The major drawbacks in these antennas are lack of reconfigurability in frequency, bandwidth and polarization [18]. There is a serious demand and necessity of reconfigurable multiband antennas in modern wireless communication systems [19]. These antennas will maintain same properties like other antennas with respect to radiation characteristics, low size, low cost and also maintains dynamically adjust to other parameters [20].

In this paper, monopole slot antenna with defected ground is used and diodes are added at slots for switching between frequency bands. Three PIN diodes are placed at three locations and this antenna model tackles the frequency reconfigurability with switching property of these diodes. The concept proposed in this work leads to a compact tunable and reconfigurable structure that can be applied for various microwave communication systems.

2. Antenna geometry

The design evolutions of the antenna with iterations are presented in Fig 1. The basic monopole slot antenna and placement of each diode at corresponding slot junction is clearly shown in the Fig 1. The ground plane is defected to extract additional resonant bands and a small u-shaped cut is placed for impedance matching. Fig 2 shows the proposed monopole slot antenna with three diodes at three junctions. The overall dimension of the antenna is around 55 X 52 X 1.6 mm on Rogers RT-duroid substrate with dielectric constant 2.2 and loss tangent 0.0009.

For the geometry of Fig 2, the dimensions are presented in Table 1. Ls=Length of the substrate, Ws=Width of the substrate, Lp = Length of the patch, Wp = Width of the patch, Wg = Width of the ground plane slot, Lg = Length of the ground plan slot, Lf1 = Length of the upper part of feed line and Lf2 = Length of lower part of feed line. The ground plane length is 10 mm and the width of the ground plane is similar to width of the substrate.

The methodology that was followed in this work is categorized here in point wise.

1. Dimensional characterization is performed based on operating frequency and structure of the radiating element selected in the antenna model.

2. Design and simulation of antenna model with CST Microwave studio tool

3. Parametric analysis for optimization of the model at desired operating band

4. Prototyping the optimized model and real time testing on VNA for validation.

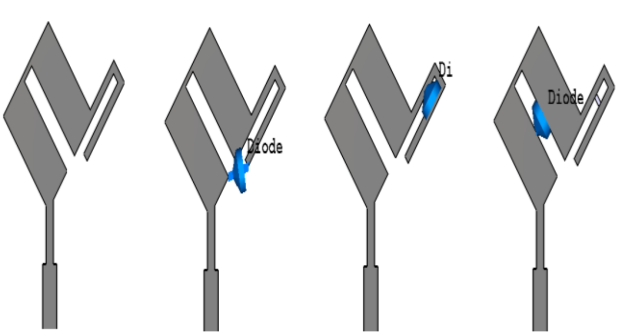
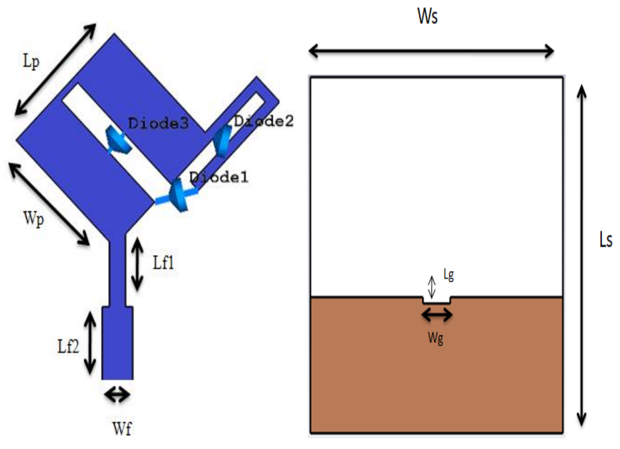


Figure.1 Reconfigurable antenna iterations with diodes



(a) (b)

Figure.2 Proposed reconfigurable monopole slot antenna: (a) top side and (b) bottom side

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Table 1. Antenna dimensions in mm

Parameter	**Ls**	**Ws**	L_p	W_p	L_{f1}
In mm	55	52	16	16	10
Parameter	L_{f2}	W_f	W_g	L_g	
In mm	10	4	6	2	

3. Results and discussion

The design and simulation work in this paper was carried with CST microwave studio tool. Fig 3 shows the reflection coefficient of the basic monopole slot antenna and the individual diodes placed antenna iterations. The basic monopole slot antenna providing notch band from 2.8-3.2 GHz with pass bands at 2.4-2.8 GHz and 3.2-7.7 GHz. As per wireless communication standards WLAN/IEEE 802.11n coverage is at 2.4 GHz and 5 GHz with data rate of 600 Mbps. The designed monopole slot antenna operating bands are well suitable for WLAN/IEEE 802.1n applications. The iteration 1 model with diode 1 providing notch band between 2.6-3.3 GHz. The pass bands from 2.1-2.6 GHz and 3.3-7.7 GHz. The iteration 1 covering the bands of LTE and wireless communication service (WCS). The antenna iteration 2 model with diode 2 notching the band between 2.9 to 4.4 GHz and allowing dual bands from 2.4-2.9 GHz and 4.4-6.3 GHz. The antenna iteration of model 4 with diode 3 is blocking 3.1 to 3.7 GHz of Wi-Fi band and allowing bands from 2.6-3.1 GHz and 3.7-7.7 GHz. The individual diodes placement providing different notch bands in the wideband from 2.1 to 8 GHz and this reconfigurable nature is needed in some advanced communication modules. The proposed model significantly designed to improve 802.11 in the amount of bandwidth supported by utilizing multiple wireless signals and better range over earlier standards. The proposed model is providing 4.8 dB gain with impedance bandwidth of more than 68% in the operating band. The current model supporting the distance coverage of almost 65 ft around with the obtained gain. Sufficient gain with considerable bandwidth made this antenna more suitable for wireless distribution system in the communication modules. This is possible due to the improvement in signal intensity and more resistant to signal interference from outside sources.

The simulation examination is continued with placement of all the three diodes at respective slots and switching characteristics are analyzed with respect to reflection coefficient. Fig 4 shows the reflection coefficient of the proposed antenna model with diodes switching.

Case1: Diode 1 is off and the diode 2 and 3 are in on condition. The proposed antenna in this

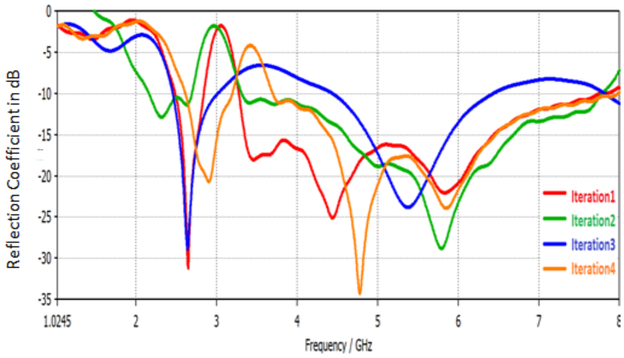

Figure.3 Reflection coefficient of antenna iterations from 1 to 4

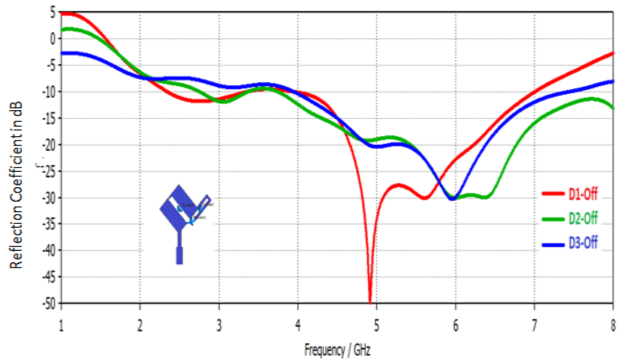

Figure.4 Reflection coefficient of proposed antenna with switching of diodes

condition is providing dual band characteristics with narrow band of 2.3-3.2 GHz at first resonant frequency and wideband of 4.1-6.9 GHz at second resonant frequency. The corresponding radiation characteristics in three dimensions and in polar coordinates are presented in Fig 5. In this condition antenna shows quasi Omni directional pattern and providing peak gain of 3 dB at 5.6 GHz i.e. WLAN band.

Case2: Diode 2 is off and the diode 1 and 3 are in on condition. The proposed antenna in this condition is providing dual band characteristics with narrow band of 2.7-3.3 GHz at first resonant frequency and wideband of 3.7-8 GHz at second resonant frequency. The corresponding radiation characteristics in three dimensions and in polar coordinates are presented in Fig 6. In this condition the proposed antenna provides a peak gain of 4.15 dB at 5.6 GHz.

Case3: Diode 3 is off and the diode 1 and 2 are in on condition. The proposed antenna in this condition is providing wideband characteristics from 4-7.3 GHz. The corresponding radiation characteristics in three dimensions and in polar coordinates are presented in Fig 7. In this condition the proposed antennas providing a peak gain of 4.86 dB at 5.6 GHz.

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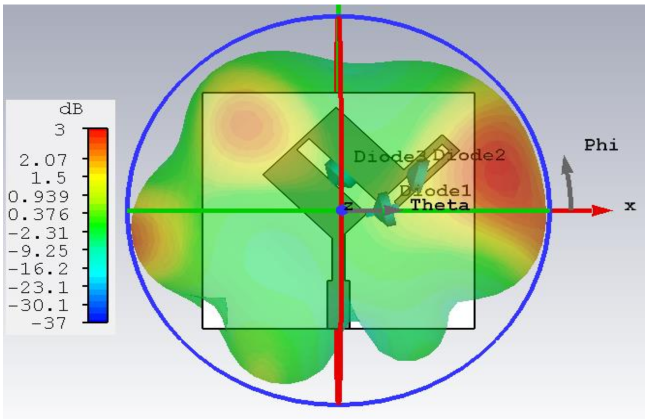

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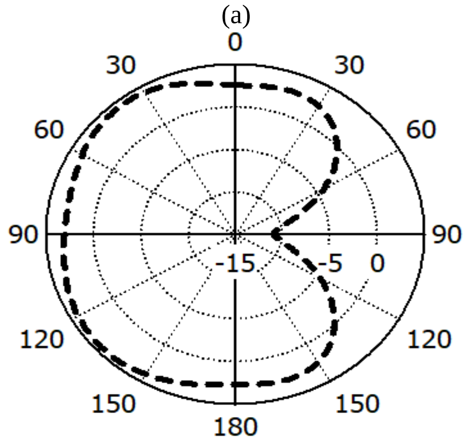

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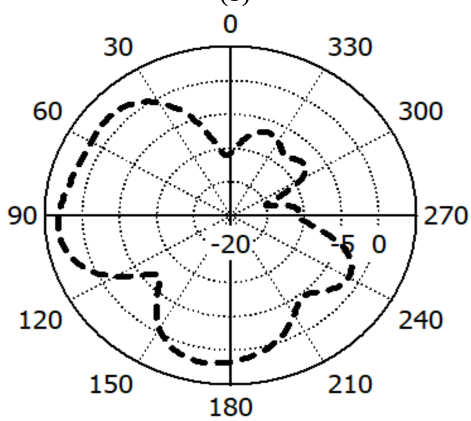
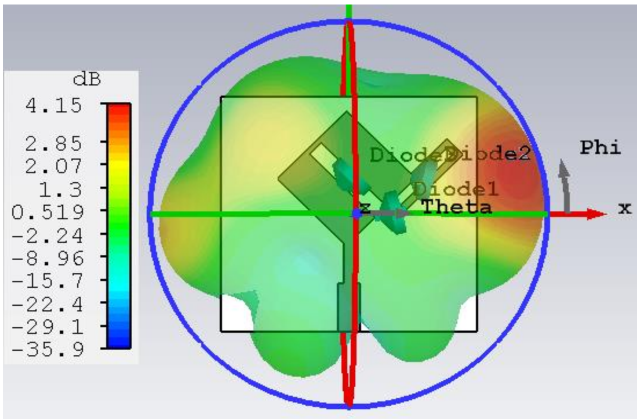


(c)

Figure.5 Radiation pattern in 3D, E-Plane and H-Plane pattern for D1 off and D2, D3 ON at 5.6 GHz



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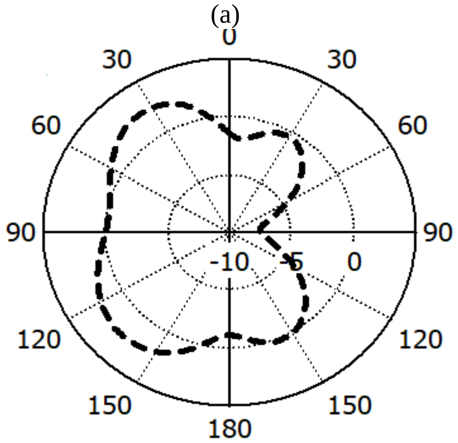

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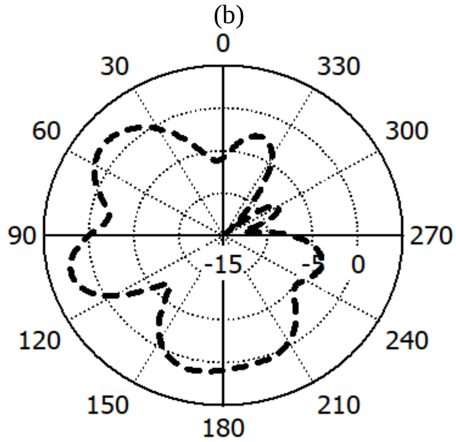

(c)

Figure.6 Radiation pattern in 3D, E-Plane and H-Plane pattern for D2 off and D1, D3 ON at 5.6 GHz

The surface current distribution of the proposed antenna with diodes switching conditions are presented in Fig 8. At 5.6 GHz the distribution of the field over the radiating element was observed. The orientation of current elements on the structure with respect to diodes on and off conditions are analyzed. It is been observed that for diode 3 in off condition isproviding better radiation characteristics when compared with diode 1 in off condition. The peak realized gain also high for the diode 3 off condition case.

The impulse response for the input signal can be observed from Fig 9. The excited signal is the input signal and the corresponding impulse response for diodes switching conditions can be observed in this case. To drive the transmitter, a first order Rayleigh pulse is used. To minimize reflection loss and to avoid pulse distortion, a good impedance matching over the operating band is observed. The distortion in the Fig 9 is just the bandwidth mismatch between source pulse and antenna.

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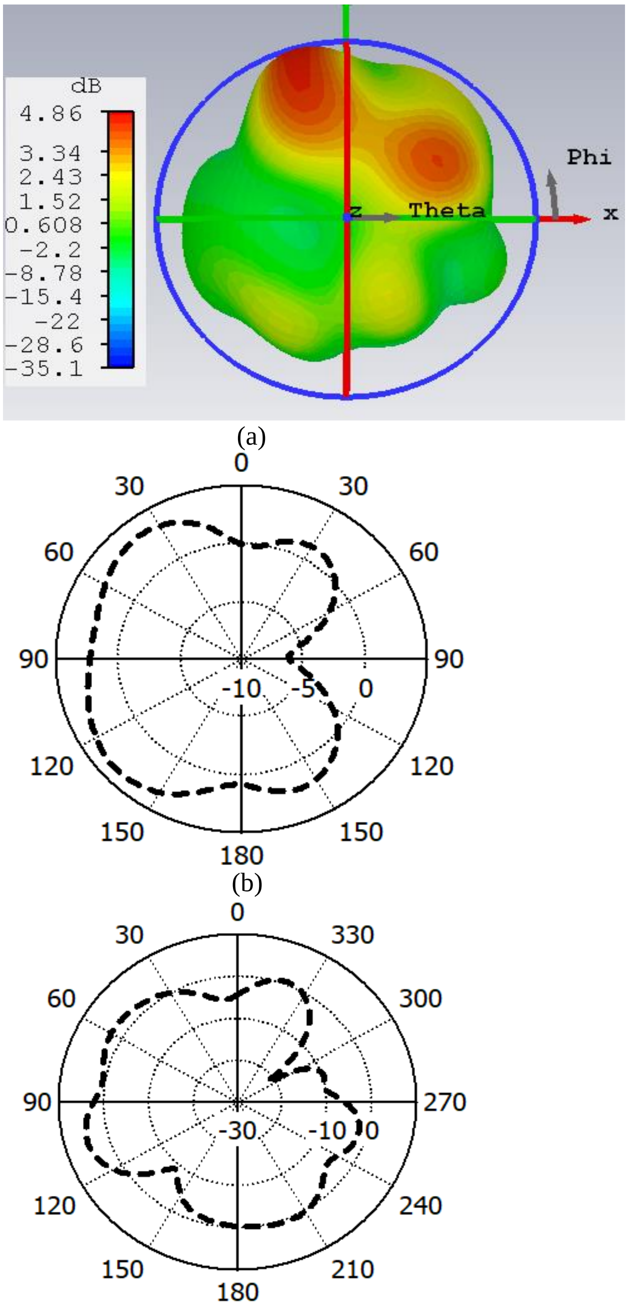

(a)
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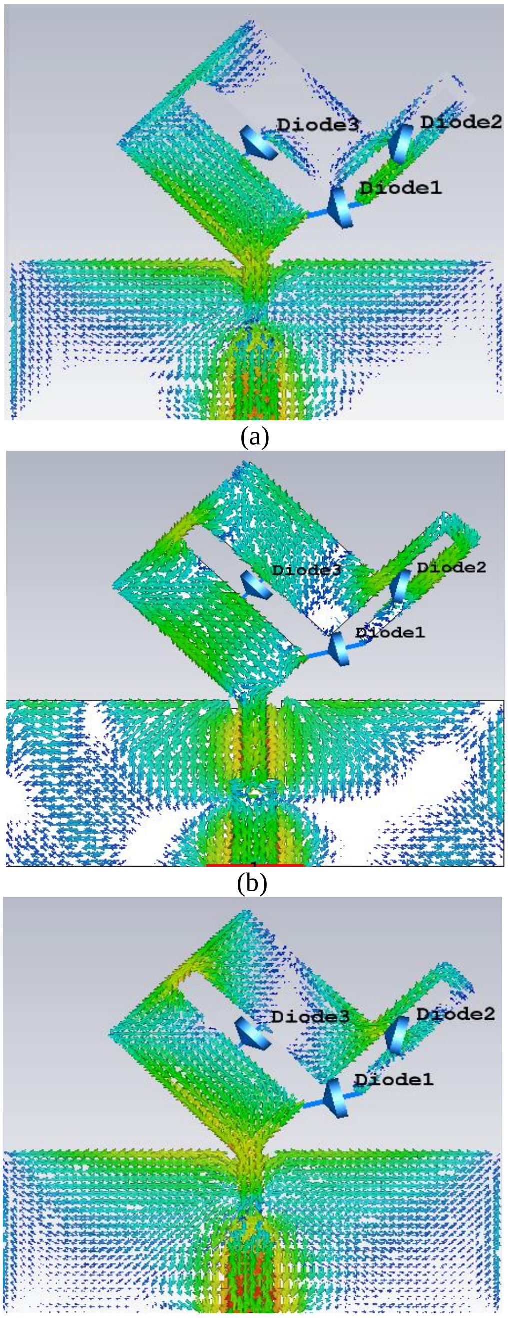
Figure.7 Radiation pattern in 3D, E-Plane and H-Plane pattern for D3 off and D1, D2 ON at 5.6 GHz



(a)
(b)
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Figure. 8 Surface current distribution for diode switching Cases at 5.6 GHz

The proposed antenna was prototyped with placement of PIN diodes, which is shown in Fig 10 and the measured results of reflection coefficient were presented in Fig 11. Almost perfect matching between simulated results and measured results can be observed from this study.

4. Measured results

The proposed antenna model is prototyped on Rogers RT-duroid substrate with permittivity 2.2 and the photograph is presented in Fig 10. Nvis 71 PCB prototype machine was used in the fabrication of the antenna model at ALRC-R&D. Double sided copper coated duroid substrate material is selected in the antenna fabrication and by using Nvis 71 the unnecessary portion was etched. The antenna model is occupying the dimension of 55 X 52 X 1.6 mm with good impedance matching of 50 ohms at the port. Prototyped antenna was connected with SMA connector of female type at port for excitation.

R&S ZNB 20 vector network analyzer is used to measure the reflection coefficient of the antenna models. From Fig 11, it is confirmed that the measured results are in good agreement with the

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simulation results obtained from the CST tool. Fig 12 shows the antenna gain with respect to the frequency. A peak realized gain of 3.6 dB and an average gain of 2.8 dB is attained in the operating band.

The antenna other parameters like power absorbed at ports, power accepted, power radiated and losses in dielectrics are computed and presented in Fig 13. The radiation efficiency of the antenna is around 85% in the operating band. The measured VSWR also shown in fig 14 and in the operating band VSWR of 2:1 ratio can be observed from this plot. A notch band from 2.6 to 3.2 can be observed from the current result.

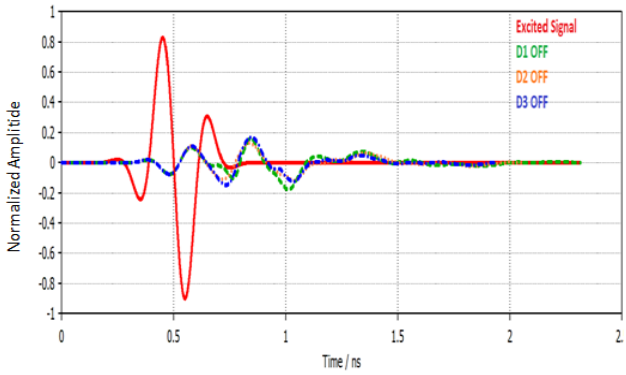

Figure.9 Time domain analysis

Figure.10 Prototyped antenna on RT-duroid

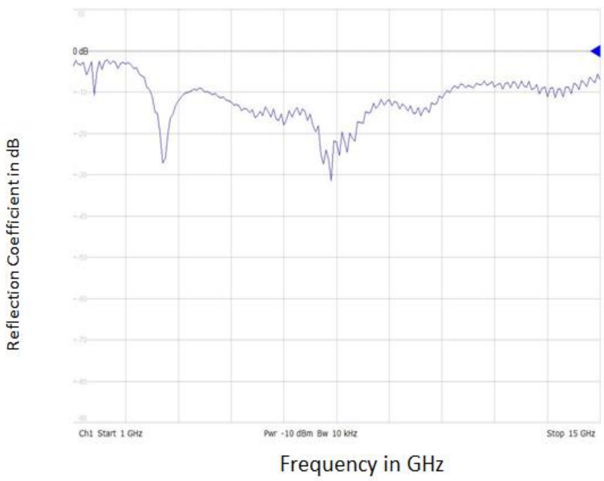

Figure.11 Measured S_{11} on ZNB 20 VNA

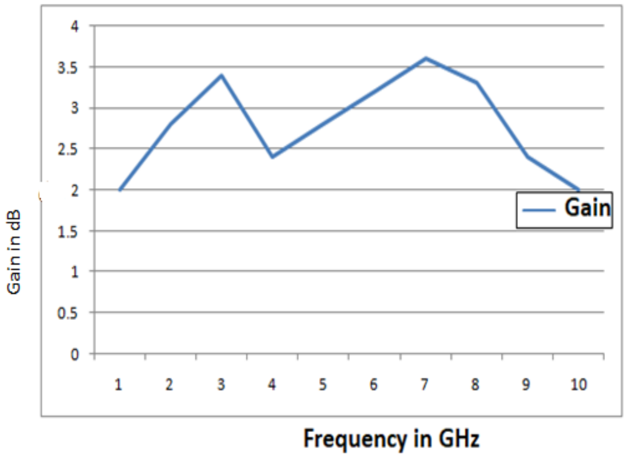

Figure.12 Frequency in GHz Vs Gain in dB

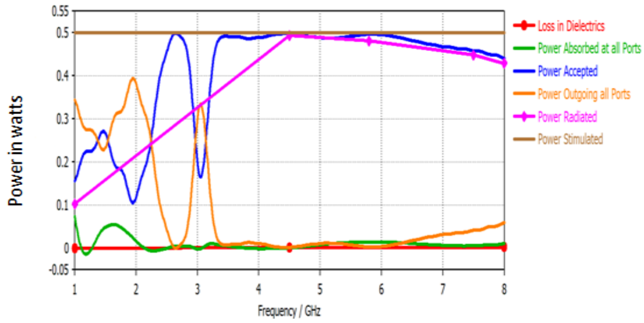

Figure.13 Frequency Vs Power in Watts

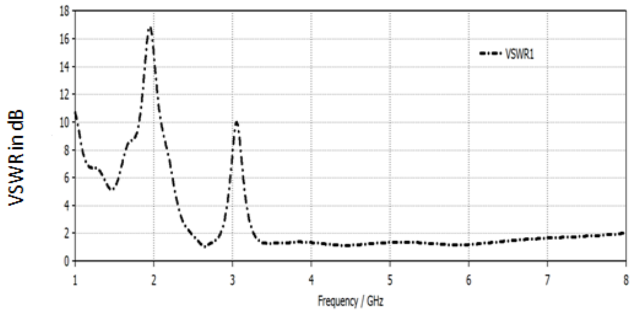

Figure14. Frequency Vs VSWR of proposed antenna

The prototyped antenna is connected with PIN diodes for frequency reconfigurability testing and the following table 2 provides the measured and simulated readings of the resonant frequencies.

PIN diodes of BAR 64-02 were used in this study. Diodes are placed at respective positions with soldering of connecting wires. Biasing voltage is applied for switching operation of diodes. Based on S11 parameter, the operating bands are measured for that particular case. Table 2 provides the resonant frequencies of three cases with diodes switching condition. The operating bands obtained in the simulation studies are nearly matching with the measured frequency bands from vector network analyzer.

Table 2. Simulated and measured frequency bands

S. No	Resonant Frequencies in GHz when D1-OFF		Resonant Frequencies in GHz when D2-OFF		Resonant Frequencies in GHz when D3-OFF	
	Simulated	Measured	Simulated	Measured	Simulated	Measured
1	2.3-3.2	2.3-3.1	2.7-3.3	2.6-3.2	-	-
2	4.1-6.9	4-6.7	3.7-8	3.8-7.7	4-7.3	4-7

Table. 3 Performance comparison of current antenna with literature

Model as per ref number	Size	Impedance Bandwidth	Gain in dB	Notching
[2]	60X58	52%	3	Single
[4]	56X58	54%	3.2	Dual
[8]	58X60	50%	3.4	Single
[12]	55X50	52%	3	Dual
[14]	62X60	56%	3.6	Single
[20]	58X54	60%	3.8	Single
Proposed Model	55X52	68%	4.86	Dual

5. Conclusion

In this letter, a novel compact reconfigurable antenna was proposed for WLAN/IEEE 802.11n applications. In this design, band notch characteristics are obtained to suppress unwanted frequencies in the WLAN band by placing diodes at slots. The switching properties of the diodes are utilized in optimum way to notch certain frequencies and to choose operation frequencies. For the cases of diode 1 and diode 2 off conditions, the antenna model is providing dual band characteristics and for diode 3 off condition, the proposed antenna providing wideband from 4-7.3 GHz. The designed model is significantly compact in comparison with literature, but by placing shorting vias we can reduce the size further at operating band. Split ring resonators with proper placement with respect to impedance matching will improve the gain and directivity. The designed antenna is showing good impedance bandwidth of 68% and peak realized gain of 4.86 dB at 5.6 GHz WLAN band. The designed antenna is compact in nature and with good correlation in simulation and measurement this model could be a reliable candidate for WLAN/IEEE 802.11n applications.

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