Circular Monopole Antenna With Dual Reconfigurable Band Stop Characteristics

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Abstract: A simple reconfigurable circular monopole antenna with controllable band stop characteristics is designed and fabricated. In this proposed model to achieve bond notch characteristics, two reversed U-shaped slots one is etched on the patch and another is on feed line. Furthermore, to control band stop characteristics two p-i-n diodes are inserted across the slots. The slot length is controlled by ON/OFF state of the diode, When the diode is in ON state slot is divided as two parts, so there is no band notch characteristics. This antenna is constructed on 38X38X1.6 mm^3 FR4 substrate with dielectric constant 4.4 and loss tangent 0.019. This proposed antenna rejects the interference from Wi-MAX (3300-3700 MHz) and WLAN (5150-5900 MHz) at a return loss -4.8dB and -4.7dB respectively. Simulated and experimental results achieved for this antenna shows good radiation characteristics within the UWB range.

Index Terms: Monopole antenna, UWB, WLAN, Wi-MAX, U-shaped slot, band notching, PIN Diode, Reconfigurability.

1. INTRODUCTION

Ultra-wide band communication systems are the prominent solution to Today's demand for the data high rate because of its wide band (3.1-10.6 GHz), size, Gain, efficiency, simple fabrication, radiation Properties[1], which discriminate them between other systems, there is an indispensable call for adequate communication equipment to work in aforesaid environments. In the antennas designs which are proposed recently, slit antennas are best applicants with great radiation efficiency, low dispersion, and easy to integrate switches. Also, there are interference problem with frequency bands such as WLAN (5150-5350) and (5725-5825) MHz and Wi-MAX (3300-3700) MHz, which are working in UWB range, so many UWB antennas have been proposed to overcome this interference by rejecting frequency band. A small monopole antenna with circular disk-shaped radiating patch is designed in [2]. Dual band stop characteristics is achieved by incorporating C-modeled slot on radiating patch and Two C-modeled strips on two sides of the feed lines. In [3], A Wideband monopole antenna with single and dual band notches by etching parasitical strips on the radiating patch is proposed. Band notching is achieved in [4] by the technique of parasitic patches. An inverted V modeled slot is created on the patch to reject the WLAN band in [1]. The band reject filter Fractal structure, defected ground structure (DGS) and meander lines are other methods used to gain desired band notching function [5-10].

However, all these techniques are permanently rejecting the band, but it is not always necessary mostly when there is no interference, so to utilize the complete spectrum it is desirable to design UWB antenna with reconfigurable band notch properties. A circular monopole UWB antenna with reconfigurable band rejection characteristics is proposed in [11]. reversed U-shaped slot is created on the feed line to reject WLAN band interference and p-i-n diode is etched across the slot to control notching characteristics. The antenna in [12] is a simple elliptical patch fed by 50-ohm microstrip line. Dual bands (Wi-MAX and X-band satellite communication uplink frequency) are rejected by creating two U-modeled slits on the radiating patch and feed line. The band rejection is controlled by the pin diodes which are inserted across slit. In this work a simple disk-shaped patch antenna with microstrip line feeding is proposed. To achieve WLAN and Wi-Max band rejection characteristics two reversed U-modeled slots are embedded, one is on the feed and another one is on radiating patch and these notch bands are controlled by integrating two PIN diodes across the slots. In the rest of paper, the antenna geometry is given first, next its working through simulations and measured results are presented.

2 ANTENNA DESIGN

The proposed circular shaped monopole antenna fed by a 50Ω microstrip line is fabricated on 38X38 mm2 low cost FR4 substrate (ε_r=4.4, tang γ=0.019) with thickness of 1.6mm is shown in figure 1. A 10.2mm radius disk-shaped radiating patch is created on the substrate and rectangular shaped ground plane 38X11.5 mm^2 is on the bottom part of the substrate. The antenna impedance matching is done by controlling the distance between circular radiator and height of the ground plane by using equation

$$f_1 = \frac{7.2}{2.25 * R + g} \qquad (1)$$

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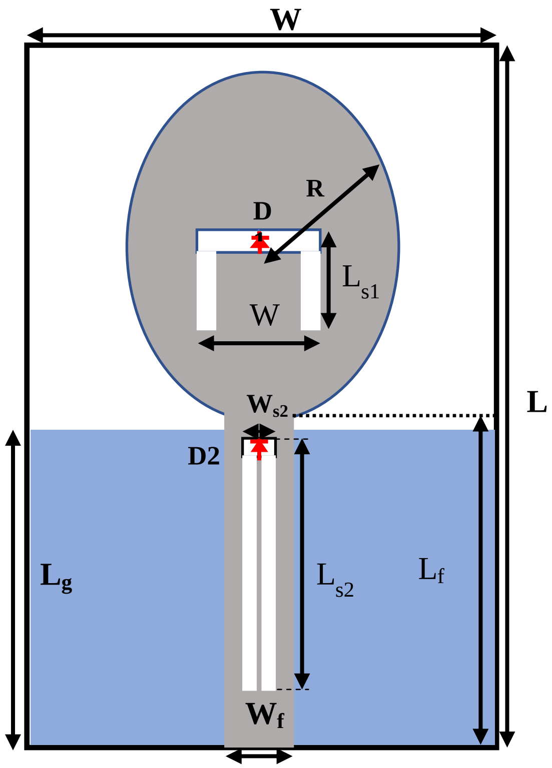


Fig. 1. *Layout of proposed circular monopole antenna with two reversed U-shaped slots.*

Where R is the radius of circular patch and difference(g) between heights of patch and ground plane in centimeters. Where f_1 is the lowest frequency of the broad band antenna. It is 3.07 GHz by choosing R=10.2mm and g=0.5mm. To minimize interference with existing WLAN and Wi-Max narrow band systems two slots are created on the patch and feed line. These slots lengths are calculated by using the relations

$$L_{notch} = \frac{c}{2 f_{notch}\sqrt{\varepsilon_{eff}}} \quad (2)$$

Where f_{notch} is the center frequency of the stop band and ε_{eff} is the effective dielectric constant

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} \quad (3)$$

Where ε_r is the relative dielectric constant. To achieve a band notch function from 5.15-5.85GHz (WLAN) band, slot is created on the feed line which is shown in figure1. Equation 4 is used to estimate length of the slot approximately.

$$L(at\ 5.5GHz) = \frac{\lambda}{2} \approx 2(L_1) + L_2 \quad (4)$$

The estimated length of slot using equation at f_{notch}=5.5GHz and relative dielectric constant ε_r=4.4 is 16.59mm which is almost equal to half wavelength. Similarly, second cut is created on the patch to achieve the Wi-MAX band notch (3300-3700 MHz). The length of the second slot at f_{notch}=3.5GHz is determined by equation (2)

$$L(at\ 3.5GHz) = \frac{\lambda}{2} \approx 2(L_3) + L_4 \quad (5)$$

In both cases simulated and measured slot lengths are approximately equal.

TABLE 1

Design specifications of the circular monopole Antenna

Design Specification	Dimensions(mm)
L	38
W	38
L_f	12
Wf	2
L_g	11.5
R	10.2
L_{s1}	8
W_{s1}	12
L_{s2}	8.2
W_{s2}	1

HFSS is the Electromagnetic simulation software used to enhance and simulate the proposed antenna. At microwave frequencies the most commonly used switching component is PIN diode. In this proposed antenna, BAR 6402V p-i-n diode is used as the switching element to gain the reconfigurable notch bands. We access equivalent circuit of the p-i-n diode from specification sheet to simulate precisely. Figure 2 shows the equivalent circuit model of p-i-n diode for both forward and reverse biased conditions. In the forward biased condition L is 0.45nH and resistance R_{ON} is 1.5Ω are series connected as shown in figure 2(a). In the reverse biased condition intrinsic capacitance (C) in parallel with a resistance (R_{OFF}) while a series L as shown in figure 2(b). The value of Inductance L is 0.45nH and capacitance C=0.25pF and R_{OFF}=2.5KΩ.

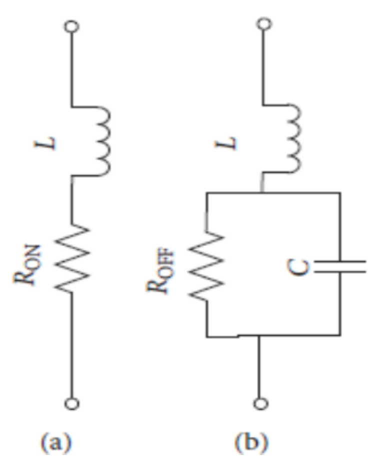


Fig. 2*. Simplified model of PIN diode (a) Forward biasing and (b) Reverse biasing.*

3 RESULTS AND DISCUSSION

In this part a comparison between simulated and experimental results of the suggested antenna is illustrated. The prototype antenna has an impedance bandwidth from 3.1–11 GHz with two notches, one is from 5.15-5.9 and another one is from 3.3–3.7 GHz. These two notch bands coincide to WLAN and Wi-MAX frequencies respectively.

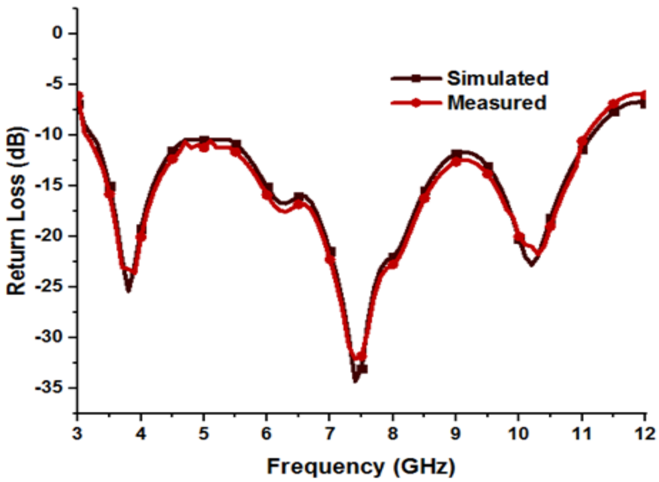


Fig. 3. Comparison between simulated and experimental return loss when both diodes are ON.

Fig. 3 Return loss characteristics of the antenna when both diodes are forward biased. It can be noticed that the suggested antenna shows ultrawideband performance of 3.1-11 GHz. When both diodes are reverse biased, this antenna exhibits UWB performance with two notch bands Wi-MAX (3300-3700 MHz) and WLAN (5150-5900 MHz). We can observe the single notch band performance when D1 is forward and D2 reverse biased and when D1 is reverse and D2 is forward biased. Figure 5 and 6 Shows the simulated and experimental results at these two states. Fig. 4 shows the return loss results for the proposed antenna when both diodes reversed biased.

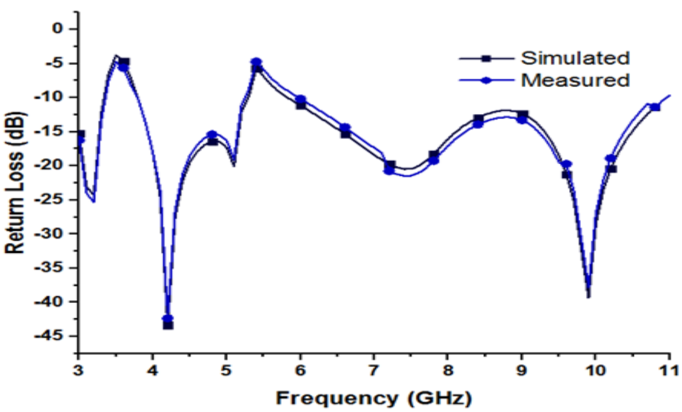


Fig. 4. Comparison between simulated and experimental return loss when both diodes are OFF.

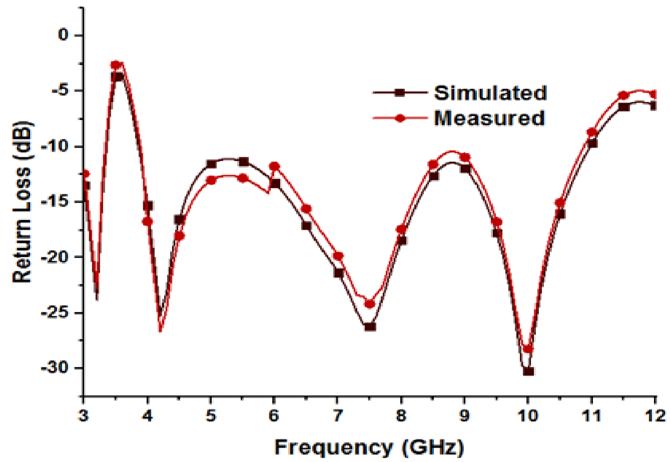


Fig. 5. Comparison between simulated and experimental return loss when D1 is OFF and D2 is ON.

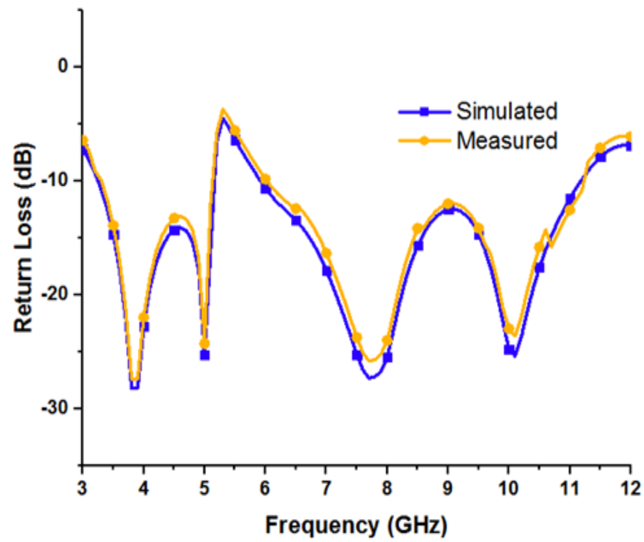


Fig. 6. Comparison between simulated and experimental return loss when D1 is ON and D2 is OFF.

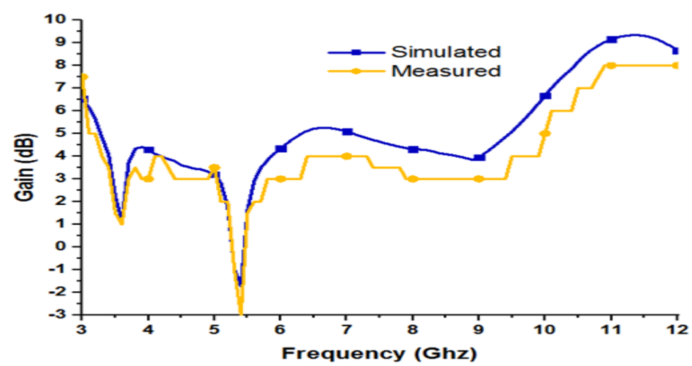


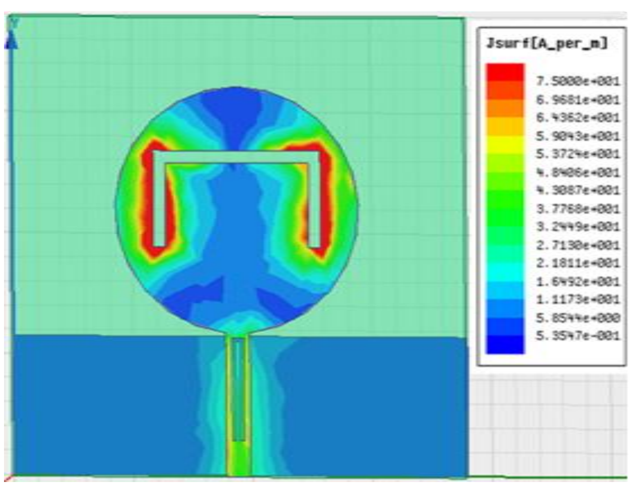
Fig. 7. Comparison between simulated and experimental Gain of the antenna when both diodes are OFF

The simulated and experimental gains with respect to frequency reported in figure 7 when both diodes are reverse biased and observed the -6dB gain reduction at 5.5 GHz and -3dB gain reduction at 3.5 GHz. Where G_{off} =3dB while G_{on}=0.5dB. The average gain of the antenna is 5dB. The simulated electric (E) and magnetic (H) field Patterns are presented in Figure 9. At 3.2 GHz Electric field pattern is toroidal and Magnetic field pattern is omnidirectional as predicted for this antenna. The surface current distribution on the disk-shaped radiating patch is presented in Figure 8 at various frequencies. As presented in Figure 8(a) at center frequency of Worldwide Interoperability for Microwave Access band 3.5 GHz mainly currents are concentrated at the edges of the slot, so there is no radiation. Similarly, at 5.5 GHz (center frequency of wireless LAN Band) current is rich around the slot which is integrated in the feed line. At 3200 MHz surface current is uniformly distributed on the radiating patch, so at this frequency the proposed antenna shows good radiation characteristics.

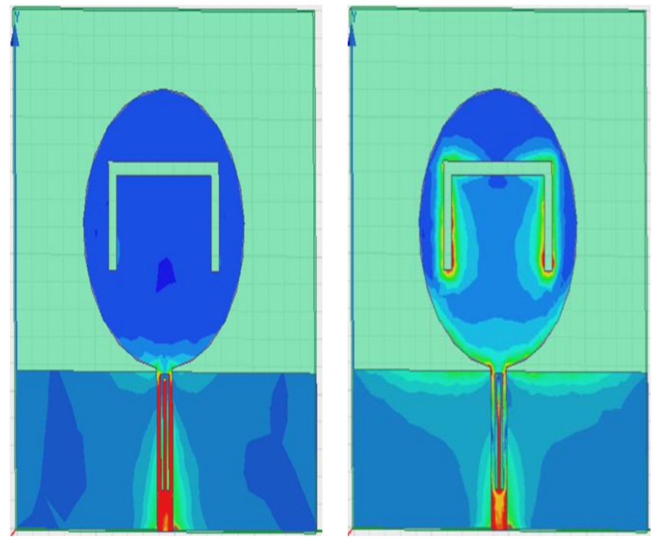
TABLE 2

Various states of the Proposed Antenna

States	State of the Diode		Stop Bands
	D1	D2	
1	OFF	OFF	Wi-Max and WLAN
2	OFF	ON	Wi-Max
3	ON	OFF	WLAN
4	ON	ON	No Band Rejection

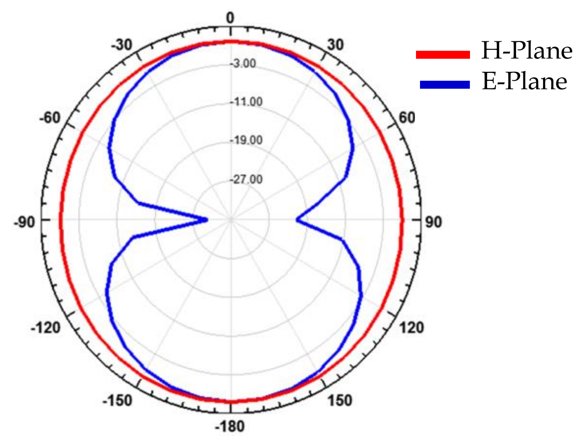


(a)

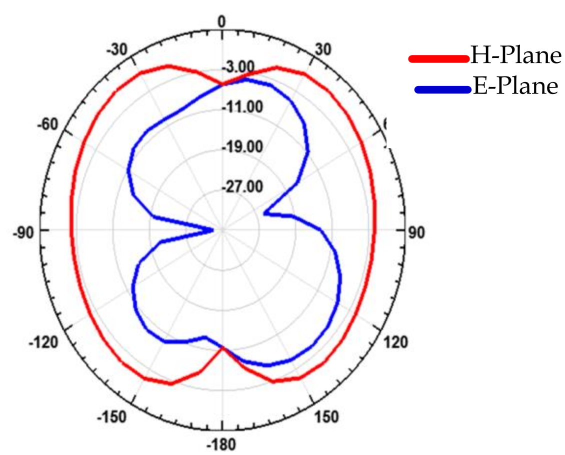


(b) (c)

Fig. 8. *At different frequencies surface current diffusion on the antenna (a) 3.5 GHz (b) 5.5 GHz (c) 3.2 GHz*



(a)



(b)

Fig. 9. *At (a) 4.2 GHz (b) 7.5 GHz, Simulated Electric and Magnetic field radiation patterns of the Circular shaped monopole antenna.*

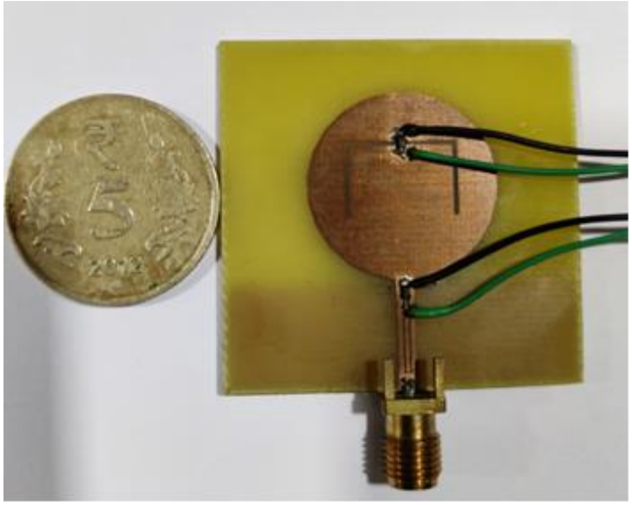


Fig. 10. *Photograph of the prototyped antenna.*

4. CONCLUSION

An UWB circular monopole antenna with two reversed U-shaped slots which are integrated with PIN diodes has been designed and presented. The two PIN diodes reconfigure the band notch characteristics of the proposed antenna. Total UWB is achieved when both diodes are in ON state and two narrow bands are rejected when two diodes are in OFF state. This antenna also rejects single notch band either Wi-MAX or WLAN by controlling state of the diode. We recognized that there is a good compromise between simulated and measured results.

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