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Concentric Circular Ring Loaded Triple Band Antenna for Wireless Applications

Soma Sekhar Rao Kolusu[1]* **Ajay Babu Modala[1]** **Boddapati Taraka Phani Madhav[1]**
Badugu Prudhvi Nadh[1]

[1]*Department of Electronics and Communication Engineering,*
Koneru Lakshmaiah Education Foundation, AP, India
* Corresponding author's Email: btpmadhav@kluniversity.in

Abstract: The article presents the design of the concentric circular ring antenna is designed for wireless application like WLAN, Bluetooth, ISM and WiMAX applications. The antenna provides the triple band characteristics frequencies ranging from2.2-3.6 GHz with impedance bandwidth of 48% at the first band,4.3-4.6 GHz with impedance bandwidth of 9% at second operating frequency and third band ranging from 5.2-5.7 GHz with impedance bandwidth of 10% is observed. The antenna provides the bidirectional and omni directional radiation patterns. The antenna provides the peak gain of 2.05 at 2.9 GHz,3.9dBi at 4.3 GHz and 3.5 dBi at 5.4 GHz at three resonating frequency. The radiation efficiency at the three resonating bands is 96% at 2.05 GHz,93% at 4.3GHz and 86% at 5.4 GHz. The frequency reconfigurable properties are observed.

Keywords: Circular rings, UWB band, CPW feed.

1. Introduction

In the previous few years, UWB (Ultra-Wide Band) technology working with frequency ranging from band 3.1-10.6 GHz has fascinating attention because of its benefits. Example, low power requirement, large channel capacity in this way high information rate, less affectability to the multipath impact resistance to jamming etc. Owing to these preferences the UWB innovation has been received broadly in numerous applications, for example, short range indoor communications, cognitive radio detecting and imaging frameworks, radar target localisation and characterisation, car applications etc. Recently a few UWB antennas with reconfigurable band rejection utilizing dynamic exchanging components, for example, PIN diodes, varactor diodes, radio frequency micro-electromechanical system (MEMS). As field have been accounted for a large portion of these radio wires are equipped for dismissing or tuning a solitary band just (WiMAX or WLAN) respectively [1]. Among these antennas printed monopole antennas plays a critical job because of their attractive highlights of a basic structure, a low profile and sensibly decent execution. Particularly studies on the circular ring monopole antenna have been conducted [2]. Reconfigurable and multiband antennas have gained importance in RF-systems and software defined radio sensing systems. These reconfigurable antennas reduce the bulk hardware components and provide multifunctionality with compact structure. The usage of Pin diodes is commercially available and easy to fabricate the antenna when compared to MEMS switches integration of switches is very complicated when compared to Pin diodes.

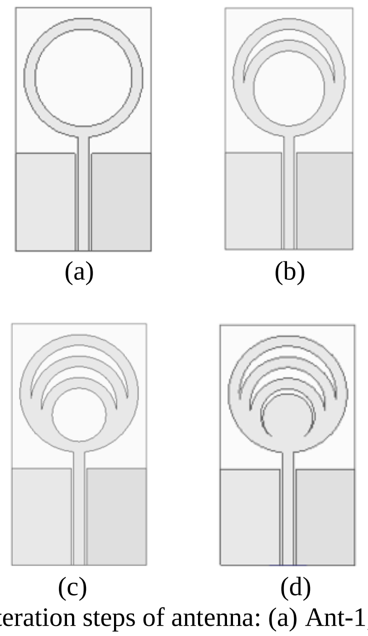
In the previous literature to achieve the multiband operation in microstrip antennas they use several strips and stacked structures for creating different currents paths. In the convectional techniques increases the dimensions of antenna and creating structure complexity. Even though the use of the conventional LC-Loading techniques has also used to achieve the multiband frequencies, but he complexity of design increases. In the proposed article BAR-64-02V Pin diodes are used to multifrequency applications. Because of quick development of wireless communication in everyday life communication system requires micro-strip antenna, which is minimized, adaptable, light weight, ease and simple to coordinate with little size and handheld convenient wireless devices [3]. To stay away from obstruction of UWB systems with these signals a band stop channel is required. A different channel along with UWB antenna will expand general size of antenna. A reduced stop band system that can be embedded with antenna without expanding the size is required. In this setting a few specialists have revealed their work to make the notched-band characteristics [4]. UWB monopole antenna with projected structure have been accounted for these antennas are not suitable for integration with a printed circuit board as a result of non-planar sort configuration [5]. Circular polarization is a standout amongst the most engaging polarization conspires due to having high immunization to multipath impedances, robustness to polarization mismatches between the transmitter and receiver and better transmission qualities in adverse weather conditions. It is subsequently broadly utilized in different applications, for example, RFID, radar, WLAN, worldwide situating and satellite systems [6].

The main aim of this work is to design the antenna with reconfigurable property and switch to different frequency applications. To attain the reconfigurable property antennas uses the active switching elements such as diodes, RF-MEMS, GaAS-field-effect Transistors and optically tuned switches are used. Out of this BAR-64-02V Pin diodes are used in this paper to check the reconfigurable functionality. As the circular polarization antenna can offer increasingly dependable accepting affectability and has better behaviour during atmospheric propagation. It is exceptionally wanted in mobile wireless communication [8]. In traditional reconfigurable antennas, the bias lines are two overlap and arrival way should be made also to trigger dynamic switch [9, 10]. In this letter we expand the reconfiguration principle of a double band antenna configuration to accomplish independent frequency configurability at both ends [11-13]. The frequency reconfigurable antenna is designed for the multiple band applications [14-18]. The concentric circular ring antenna is designed to shift the ISM band application frequencies given in [19-24]. The u-shaped antenna is designed to shift to get the frequency reconfigurable properties [25-28].

The concentric rings shaped antenna is designed for triple band applications for various wireless application. The arc shaped slots are inserted in the to improve the S11 of the antenna. The antenna operates in the frequency ranges from 2.2-3.6 GHZ 4.2-4.6 GHz and third 5.2-5.7 GHz. In the section 2 provides the antenna design part, in the section 3 provides the result and discussion of the antenna finally section 4 provides the reconfigurability of the antenna.

2. Antenna design

Fig. 1 represents the basic antenna iterations to achieve the proposed antenna design. The basic antenna consists of the circular ring with radius of Rc1 and Rc2.To create the concentric ring inside the antenna structure the ring is inserted with the radius of Rc3 and Rc4. Similarly, to create the third concentric ring inside the second ring the radius of Rc4 and Rc5 is taken. Similarly, to create the fourth smaller circle the circle radius of Rc6 is considered. The FR4 substrate is used for designing the antenna with the dimensions of 45 x 25 x 1.6 mm3. To design the proposed antenna CPW feeding is used. The design of the proposed antenna is done in the commercially available software High Frequency Structural Simulator (HFSS), a full wave EM software capable of simulating a finite element method. the antenna structure was printed on a FR4 substrate with dielectric constant of 4.4 and loss tangent of 0.016. The parametric investigation is done for the proposed antenna designer which can understand antenna characteristics. Fig. 2 represents the dimensions of proposed antenna.



(a) (b) (c) (d)

Figure. 1 Iteration steps of antenna: (a) Ant-1, (b) Ant-2, (c) Ant-3, and (d) Ant-4

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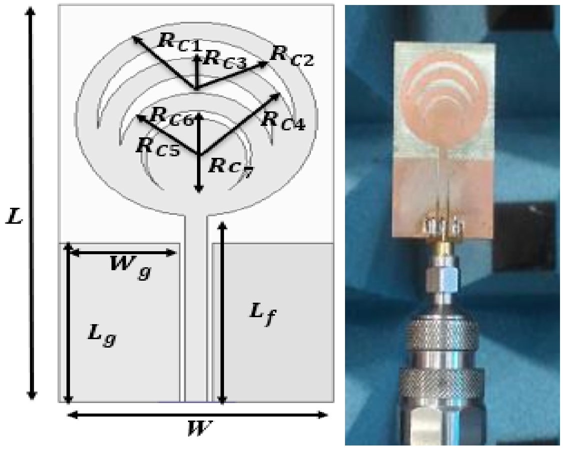

Figure. 2 (a) proposed antenna design and (b) fabricated antenna

Table 1. Dimensions of proposed antenna

Parameter	Value (mm)	Parameter	Value (mm)
L	45	Rc_1	11
W	25	Rc_2	9
L_g	18	Rc_3	8
W_g	11	Rc_4	7.5
L_f	21	Rc_5	7
w_f	2	Rc_6	5
a	0.5	Rc_7	4.6

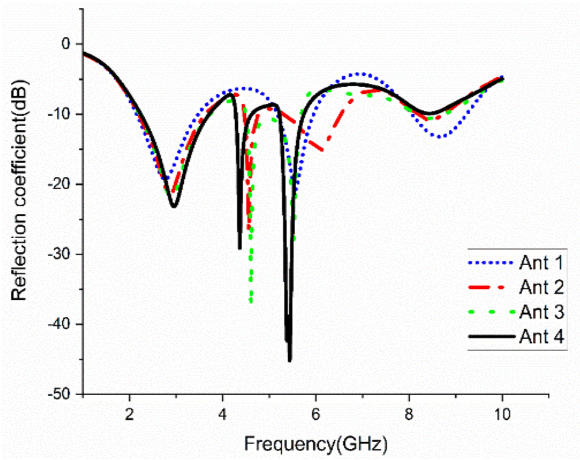

Figure. 3 Reflection coefficients of antenna iterations

3. Results and discussions

Fig. 3 represents the reflection coefficient of antenna iterations. The basic single ring antenna1 resonates at dual frequency ranging from at first band is 2.2-3.45 GHz with S11 of -19dB at 2.7 GHz and second band ranging from 5.2-5.9 GHz with S11 of -20dB at 5.5 GHz. When the second ring is inserted in the first ring the reflection coefficient of antenna changed and operates at 2.2-3.6 GHz with S11 of -21dB at 2.9GHz,second band at 4.5-4.7 GHz with S11 of -26Db at 4.55 GHz and small operating band ranging from 5.36-6.5 GHz with S11 of -14dB at 6.0GHz.Similarly, when the third ring is added in the antenna operates in the frequencies like 2.2-3.7 GHz with S11 of -22dB at 2.9 GHz and 4.5-5.6 GHz with S11 of -36dB at 4.6GHz.Finally the proposed antenna shows triple band.

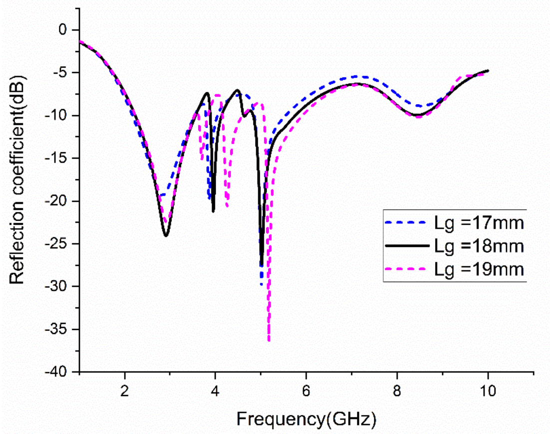

Figure. 4 Parametric analysis for length of the ground

3.1 Parametric study

Fig. 4 illustrates the reflection coefficient for different values of the ground plane (L1). The value of L1 is varied from 17 to 19 mm in all the WLAN/WiMAX bands. It should be noted that the ground plane dimensions can affect the impedance matching and resonant frequency of three operating bands. For the different values of the L1 antenna resonates at the triple band characteristics which covers the frequency ranges 2.2-3.5,3.8-3.7, 4.6-5.5 GHz which cover many wireless application frequency bands WLAN ISM Bluetooth and WiMAX applications. It is observed that the as the value of L1 increases the shift in the frequency is observed in the right side.

Fig. 5 illustrates the reflection coefficient by changing the different values of radius of the circle1.The value of circle 1 is varied from 9mm to 11 mm with the step size of 1mm. The reflection coefficient of the antenna shows the triple band characteristics of the antenna.

To design a good triple band WLAN/WiMAX operation, Rc1 is set at 11mm.similarly, Fig 6 illustrates the return loss for the different values radius of the circle 7(Rc7). It can be seen in figure that the impedance band width and characteristics of the reflection coefficient to be changed if the Rc7 is changed from 2.5 to 4mm. The effect of the finial circle radius is very less when it is compared to the first circle radius. The small variation of the S11 is observed in the plots. For designing of best triple

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band WLAN/WiMAX operation, Rc7 selected to be 3.5mm because it shows the better S11 results compared to other parameters.

3.2 Current distributions

To verify the performance of the proposed antenna reflection and radiation characteristics. To recognize the creation of notch bands the current distributions on the surface of the proposed antenna at 2.8, 4.5, and 5.4 are shown Fig. 5. In Fig. 5(a) it is observed that the surface current are flows around the feed line and ground when the proposed antenna operates at 2.8GHz. the most of the current distributed along the feed line and the edges of the concentric circular rings. Furthermore, the current flows at feed line, ground and some part of the patch, it is shown in fig 5(b). That the current flows are relatively concentrated on the feed line when the proposed antenna operates at 4.5GHz. As shown in fig5(c) the current flows in feed line and some part of patch when the proposed antenna operates at 5.4GHz.

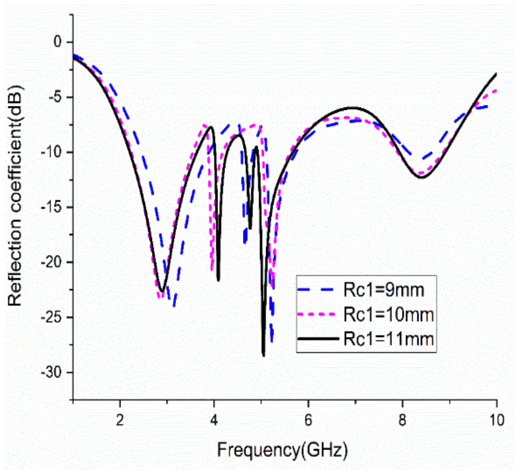


Figure. 5 Parametric for varying first circle radius

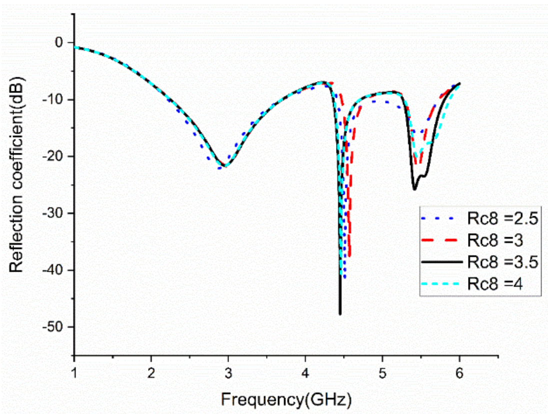
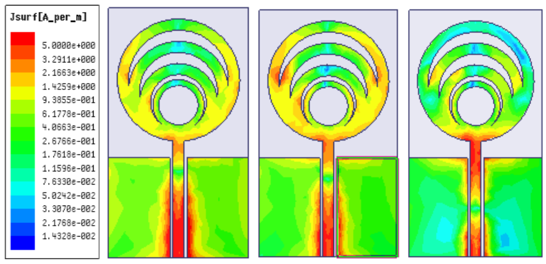


Figure. 6 Parametric analysis for varying the last circle radius

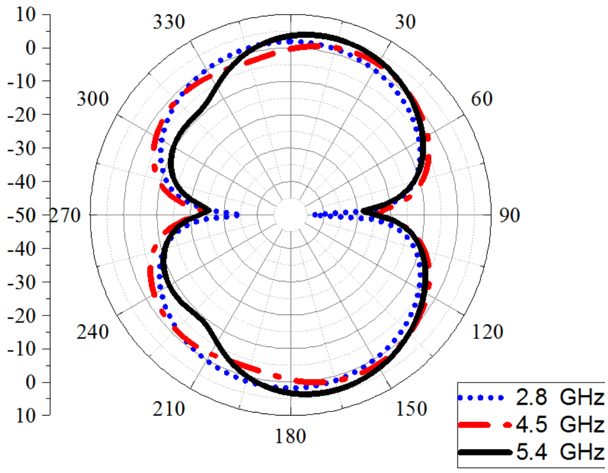


(a) (b) (c)

Figure. 7 simulated current distributions on the radiating patch: (a) 2.8GHz, (b) 4.5GHz, and (c) 5.4GHz

3.3 Radiation pattern

The radiation patterns of the proposed antenna are illustrated in Fig. 8. Among various methods that are available to represent the radiation patterns in this paper uses the XY-plane, YZ-plane and ZX-plane approach. In Fig. 6 (a) the pattern in XY-plane for different frequencies such as 2.8GHz, 4.5GHz, and 5.4GHz are shown. It is seen that the radiation patterns of the designed antenna are bidirectional in XY-plane. In Fig. 6 (b) the pattern in ZX-plane for different frequencies such as 2.8GHz, 4.5GHz, and 5.4GHz are shown. It is seen that the radiation patterns of the designed antenna are omnidirectional in ZX-plane. In Fig. 6 (c) the pattern in YZ-plane for different frequencies such as 2.8GHz, 4.5GHz, and 5.4GHz, are shown.it is seen that the radiation patterns of the designed antenna are bidirectional in this YZ-plane.



(a)

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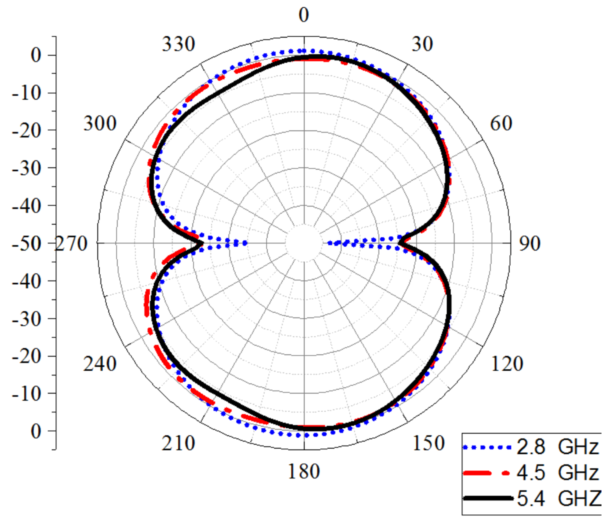
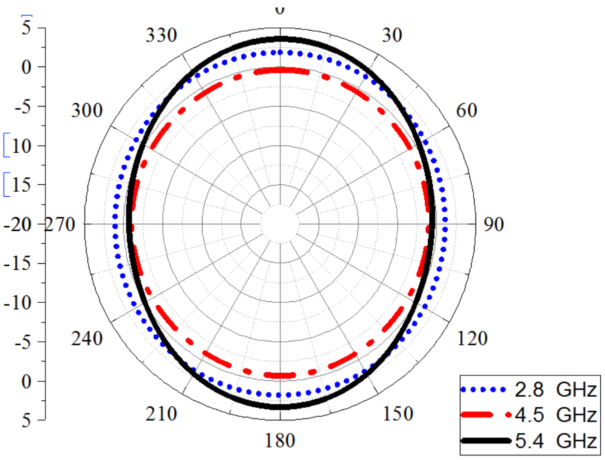


(b)



(c)

Figure. 8 Radiation patterns of the proposed antenna: (a) XY-plane, (b) XZ-plane, and (c) YZ-plane

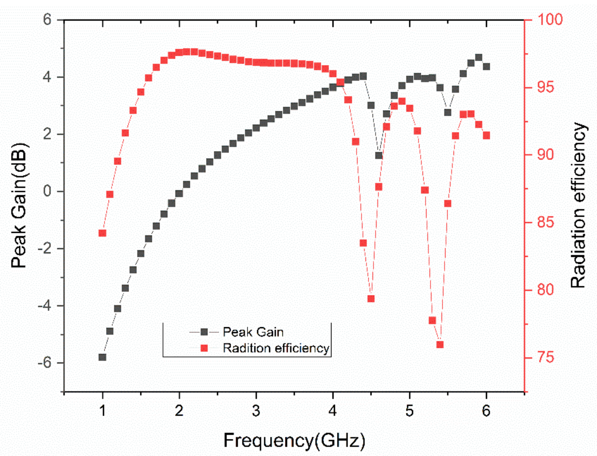


Figure. 9 Peak gain and radiation efficiency of the antenna

3.4 Peak gain and radiation efficiency

The peak gain and the radiation efficiency are observed at the three resonating frequencies. The antenna provides the peak gain of 2.05dBi at 2.9 GHz,3.9dBi at 4.3 GHz and 3.5 dBi at 5.4 GHz at three resonating frequency. The radiation efficiency at the three resonating bands is 96% at 2.05 GHz,93% at 4.3GHz and 86% at 5.4 GHz.

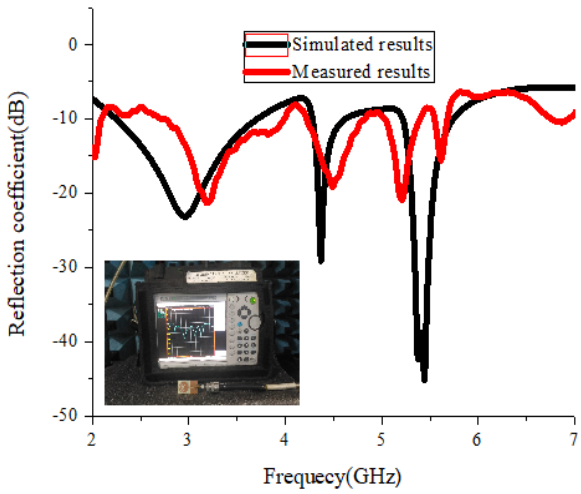


Figure. 10 Simulated and measured reflection coefficient of proposed antenna

The comparison of simulated and measured results of the proposed antenna show in fig.10 and shows triple band frequency application with slight variation in the resonating frequency is observed in Vector Network Analyzer

4. Reconfigurability

To study the reconfigurable nature of the antenna three pin diodes of BAR-64-02V are placed in between the concentric circular and their performance is evaluated. Fig. 11 represents the exact location of the pin diodes on the antenna. By placing the three diodes overall 8 conditions are studied out of this condition only few switches provide the frequency shift in the frequency.

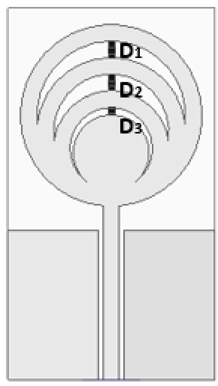


Figure. 11 Diodes placement on the antenna

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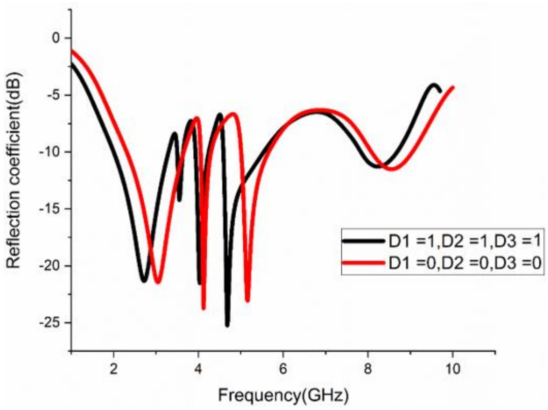

Figure. 12 ON and OFF switching conditions on the antenna

In all switches ON condition antenna resonates at frequency 2.72GHz and operates with frequency range of 2-3.29GHz with $S_{11}$is -21.32dB,and in second resonating frequency of 3.59GHz and operates in the frequency range of 3.5-3.63GHz with S_{11} is -12.59dB,and third resonating frequency of 4.03GHz and covers the frequency range of 3.94-4.24GHz with S_{11} is -21.51dB,and fourth resonant frequency 4.68GHz and covers the frequency range of in 4.59-5.53GHz with S_{11} is -25.22dB. Similarly when all the switches are in OFF condition it first resonant frequency of 3.04GHz and operates in the frequency range of 2.31-3.65GHz with S_{11} is -21.43dB,and second resonant frequency of 4.12GHz and covers the frequency range of 4.06-4.29GHz with S_{11} is -23.72dB,and the third resonant frequency is 5.16GHz and covers the frequencies of 5.01-5.65GHz with S_{11} is -23.06dB,and finally it is having the resonating frequency 8.55GHz at this it is operated in between range of 8.09-9GHz with S_{11} is -11.50dB.

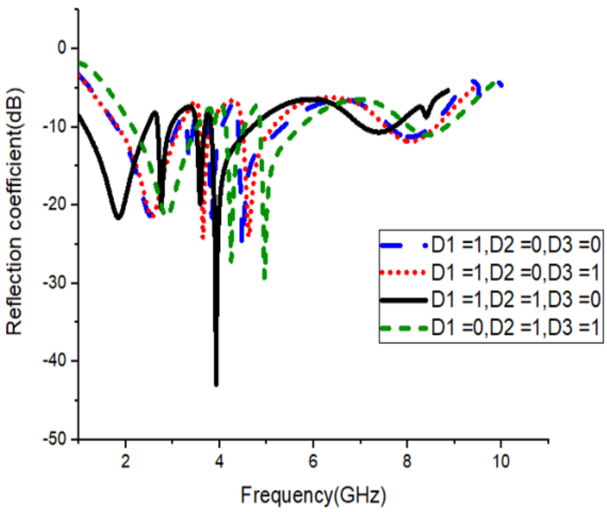

Figure. 13 Antenna performance for different switching condition

Fig. 13 shows the switching conditions of the antenna. When the diodes are (1) ON, OFF, OFF (2) ON, OFF, ON (3) ON, ON, OFF (4) OFF, ON, OFF. Where D1=1 shows the ON and D2=0 shows the OFF modes.

D_1=ON, D_2= OFF, D_3=OFF.

In this condition it is having the resonant frequency 2.52GHz at this frequency it is operated between the 1.8-3.09GHz with S_{11} is -21.32dB, at 3.35GHz it is operated 3.3-3.47GHz with [S11]is -14.22dB,and in the frequency range 3.83GHz it is having operating frequency 3.74-4.04GHz with S_{11} is -21.51dB,and resonant frequency is 4.48GHz it is operated at 4.39-5.33GHz with S_{11} of -25.22dB,and finally at the range of 8.04GHz it is operated at 7.64-8.48GHz with S_{11} is -11.28dB.

D_1=ON, D_2=OFF, D_3=ON.

In this condition it is having the resonant frequency 2.56GHz it is operated at 1.83-3.14GHz with the S_{11} is -21.48 dB, and at 3.64GHz it having operating frequency 3.58-3.8 with S_{11} is -24.23dB, next it is having resonant frequency of 4.62GHz with frequency range of 4.48-5.12 with S_{11} is -24.04dB, and finally it is having the 8.06GHz resonant frequency it is operated at 7.55-8.59GHz with S_{11} is -11.82dB.

D_1=ON, D_2=ON, D3=OFF.

In this condition it is having the resonant frequency 1.84GHz with frequency range of 1.13-2.45GHz with S_{11} is -21.59dB, second resonating frequency of 2.75GHz it is operated at 2.68-2.94GHz with S_{11} is -20.48dB, and third resonating frequency of 3.58GHz with frequency range of 3.5-3.68GHz with S_{11} is -19.83dB, and finally at the 3.92GHz with operating frequency range of 3.82-4.69GHz with S_{11} is -42.90dB.

D_1=OFF, D_2=ON, D_3=ON.

In this condition it is having resonant frequency 2.87GHz at this frequency it is operated in the range of 2.15-3.51GHz with S_{11} is -21.49dB, and next it is having the 4.24GHz resonant frequency at this it is operated in 4.14-4.51GHZ with S_{11} is -27.10dB,and in next cycle it is having frequency 4.95GHz at this frequency it is operated in 4.87-5.71GHz with S_{11} is -29.22dB,and finally it is having the frequency 8.41GHz at this frequency it is operated in 8.04-8.8GHz with S_{11} is -11.03dB.

Table 2. Comparison of previous literature

Reference	Antenna Size(mm^3)	Operating bands (GHz)	Impedance Bandwidth (%)	Gain (dBi)	Diodes	Reconfigurable Technique
[1]	40 x 20 x 1	1.9-3.1 3.4-4.1 5.1-6	48.3 19.8 15.2	3.5 1.5 0.8	-	-
[2]	38 x 32 x 1.6	3.05-13	123	5.4	2	Stubs and slots
[8]	40 x 40 x 1.6	2.25-4.04	57	1.56	2	U-shaped slot
[13]	52 x 52 x 1.6	2.4-2.8 3.2-7.7	15 81	4.68	3	Stubs
[14]	50 x 45 x 1.6	2-5.8	97	5.14	2	Stubs
Proposed Work	45 x 25 x 1.6	2.2-3.6 4.3-4.6 5.2-5.7	48 9 10	2.9 3.9 3.4	3	Added Rings

The comparison of previous literature is done in the Tabl.2. the size of the antenna is compact and provides triple band frequency applications and uses the 3-BAR-64-02v Pin diodes to switch 8 different states.

5. Conclusion

In these a modified concentric circular ring antenna which is having the three circular rings with CPW fed antenna was proposed for WLAN/WiMAX applications. The antenna provides the triple band nature and resonates at the frequencies like2.9 GHz,4.3 GHz and 5.4 GHz. The radiation patterns are in omnidirectional and bi-directional at their operating bands. In addition, the proposed antenna is having the good characteristics in operating bands it is very useful for wireless communication systems in multi band applications. In all the three switches are in ON condition the antenna resonates at 2.72 GHz when the switches are in OFF it shifted to 3.04 GHz with shift frequency of 0.32GHz. Similarly the second and third frequencies frequency shift of 0.53GHz and 0.48GHz shift of frequency is observed.

Acknowledgments

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