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# Frequency Reconfigurable Split Ring Antenna for LTE And WiMAX Applications

B. T. P. Madhav, B. Prudhvi Nadh, T. Anilkumar, P. Pardhasaradhi, M. C. Rao, and P. Lakshman

***Abstract*—This paper presents frequency reconfigurable dual band antenna for WiMAX and LTE 2500 band applications using four PIN diode switches. The antenna is compact in size with dimensions of 30 x 30 x 0.8 mm3 and designed on FR-4 dielectric substrate with a partial ground plane. The fabricated antenna operates in the frequency range of LTE and WiMAX (2.5-2.69 GHz and 3.4-3.6 GHz) respectively. The frequencies can be controlled by using PIN diodes and antenna attained the gain ranging of 3.34-4.46 dBi. This designed antenna resonating at 2.52 and 3.49 GHz when the PIN diodes are in ON state and resonating at 2.68 and 3.58 GHz when PIN diodes are in OFF state. The proposed antenna has bidirectional radiation at upper frequency bands and unidirectional at lower frequency bands. The proposed split ring structured antenna has the radiation efficiency of 94.12% at 2.52 GHz and 90.34% at 3.49 GHz in ON state. Antenna providing good agreement between the measured (Antenna measurement setup with VNA) and simulated results (Ansys-HFSS).**

***Keywords*—PIN diode, WiMAX, LTE 2500, Split ring antenna, BAR64-02V**

## I. Introduction

ADVANCEMENT of technology change of services now a days is prodigious in Wireless and Satellite Communications with the ample exploration in the field of multiline communications. Wireless, Satellite Communication Systems and IoT (Internet of Things) requires Reconfigurable antennas. Here a compact and easy dual band split ring antenna is used with two pairs of PIN diodes for the application of WiMAX, Wi-Fi and WLAN which has to be compact and systematic [1]. To achieve the multi frequency procedure many investigations done by researchers in printed antennas by using LC resonator loading sets which resonates at two or more frequency lines with also using DGS (Defected Ground Structures). Mechanical switches are used for reconfigurable antenna to get the reliable radiation pattern, frequency and polarization with PIN diodes acting as Mechanical switch where the proposed design is too ponderous and complicated [2-4]. Antennas with competence of tweak characteristics of radiation pattern, polarization and frequencies are said to be reconfigurable antennas. Frequency reconfigurability is accomplished with the use of various RF-MEMS, varactor diodes and RF-PIN diodes (PIN diode) where with the RF-MEMS we get less loss of frequency and quality factor 'Q' is very high. But whereas PIN diodes are economically available with steep power capacity and curbs the electrical dimension of proposed antenna. These diodes are also used for the extraction of excellent isolation with very less Insertion loss and agile ON-OFF modes which is uncomplicated to fabricate [5].

To access the microwave frequencies in WiMAX and WLAN is based on 802.11 e and 802.11b/a respectively. To obtain the WiMAX and Wi-Fi frequencies EM (electromagnetic) metamaterial architectures such as SRR, CSRR referred as Split Ring Resonators and Complementary Split Ring Resonators respectively are used for antenna construction where the split rings are used for making reconfigurability by opening and closing of split disparity [6]. To get the multiline process OCSRR-Open Complimentary Split Ring Resonator structures are proposed to get the reliable values of frequencies, polarization and its radiation where it acts as currents in two ways which is a LC parallel circuit. Current trends in the Universe are highly modified and most reliable and compactness is achieved in every field such as in wireless and satellite technologies largely used for interfacing with many of ground and space human-astronauts to adopt the smart living with the large achievement in the miniaturization of antennas used in those systems. For minimizing the antenna size, make reliable, compactness numerous structures are coming in to use such as by using DGS-Defected Ground Structures, LC's loading, bends (closed loop), snowflake (fractal) like structures [7-8]. Presently antenna essence of its small size, numerous frequency lines, accurate patterns and bandwidth are used for Worldwide Interoperability for Microwave Access-WiMAX and Wireless Fidelity Wi-Fi, Wireless Local Area Networks-WLAN. In this to get the compactness, reliable values a Y-shaped structure with a L-strip loop inside rectangular patch is used to see good radiation pattern [9]. The SSR and CSRR are used because of its important characteristic of exhibiting resonating frequency in Quasi-Static where the wavelengths are larger [10-12]. These split rings are used mainly for to decrease size of an antenna to a very small, also to design a multi-band antenna more compactly, reliable in measured and simulated results which are economical [13-15].

In this research paper reconfigurable dual band split ring resonator (SRR) structured antenna is recommended with a two pairs of PIN diodes to achieve frequency shifting used for LTE2500 and WiMAX applications where the shifting is done between 2.68-2.52 GHz and 3.58-3.49 with BAR64-02V PIN diodes. SRR structured antenna is made reconfigurable by opening and closing of split gaps where the design is very simple and compact with reliable patterns, resonant frequencies by making economical.

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B. T. P. Madhav, B. Prudhvi Nadh, T. Anilkumar, P. Pardhasaradhi, P. Lakshman are with Antennas and Liquid Crystals Research Center, Dept. of ECE, Koneru Lakshmaiah Education Foundation, AP, India (email: btpmadhav@kluniversity.in, prudhvibadugu@kluniversity.in, t.anilkumar@kluniversity.in, pspokkunuri@kluniversity.in, lakshman.pappula@kluniversity.in).

M. C. Rao is with Department of Physics, Andhra Loyola College, Vijayawada 520008, India (email: raomc72@gmail.com).

## II. ANTENNA DESIGN STEPS

To obtain the proposed antenna design it is undergone with few step by step procedure in the starting from the rectangular patch antenna. The rectangular patch antenna is converted to rectangular ring in the step 2 and in the third step antenna is inserted with the rings in the rectangular ring structure. The structure is further modified with by uniting the structure rectangular rings to the outer rectangular ring and further modified with open slit on the rings to insert the diodes in respective positions which is shown in the Fig.1. After placing the diode in the open slits, they attached with the biasing lines and blocking capacitors and inductors shown in the Fig.2.

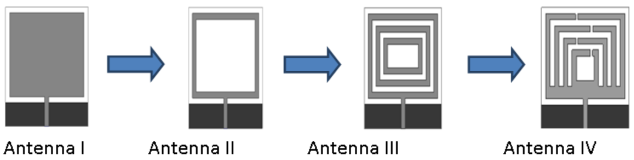



Fig 1. Progression of the proposed antennas

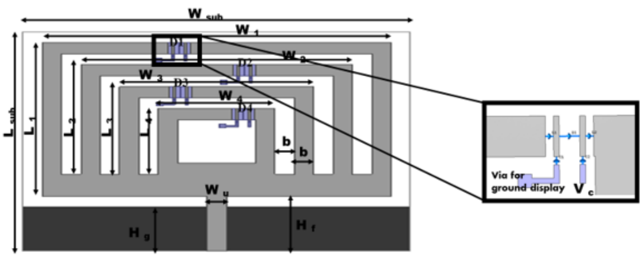



Fig 2. Proposed Reconfigurable Antenna Geometry

TABLE I
RECOMMENDED ANTENNA PARAMETERS

| Parameters | Value (mm) | Parameters | Value (mm) |
|---|---|---|---|
| $L_{sub}$ | 30 | $W_{sub}$ | 30 |
| $L_1$ | 27 | $W_1$ | 27 |
| $L_2$ | 15 | $W_2$ | 21 |
| $L_3$ | 12 | $W_3$ | 15 |
| $L_4$ | 9 | $W_4$ | 9 |
| a | 0.75 | b | 1.5 |
| $H_g$ | 6 | $H_f$ | 7.5 |
| $W_u$ | 1.5 | H | 0.8 |

As shown in above geometry the proposed antenna is fabricated on FR4 substrate with thickness h=0.8mm having dielectric constant4.4 and tangent loss 0.023. The complete size of proposed antenna is 30 x 30 mm2 designed and simulated using HFSS-ANSYS. By employing two pairs of PIN diodes specifically D1, D2, D3, D4 the reconfigurable proposed antenna is built. PIN diode used here is BAR 64-02V series with ON state resistance and inductance 2.1Ω and 0.16μH. The PIN diode with OFF state having 0.17pF and 3kΩ shunt capacitance and reverse resistance respectively. For the operation of PIN diode ON and OFF state a separate biasing network is designed. By employing inductor and capacitor components, the feed lines and bias lines are isolated. Uninterrupted radiation characteristics are observed where the biasing lines are constructed with tiny dimensions having the thickness and length of 0.25mm thickness with 1 mm length respectively. Dimensions of the proposed antenna are presented in the Table I.

For the proposed antenna the resonant frequency of this monopole is given as [6]:

$$fr = \frac{c}{2L_1\sqrt{\in_r}} \qquad (1)$$

From the above resonant frequency formula, the terms can be explained as follows:

Where, 'c' is the velocity of light, $L_1$ is the length of the square, $\in_r$ is the dielectric constant of the substrate.

## III. RESULTS AND DISCUSSION

The basic model consisting of rectangular patch 21 x 27mm x 1.6mm as shown in Fig1 which doesn't show any reflection coefficient. Further the antenna is modified to Antenna II which looks like a rectangular ring and operates in the frequency range of 2.68-3.17GHz. In the same way further two iterations are seen by adding external split rings to the second iteration which is seen in Figure:1 Antenna III and Antenna IV respectively. Here we observe the bandwidth of 3.58-3.86GHz for the third iteration and for the final iteration proposed antenna's bandwidth is 2.62-2.72GHz and 3.52-3.62 and provides the bandwidth o.1 GHz and provides dual bands instead of single band at first three iterations respectively.

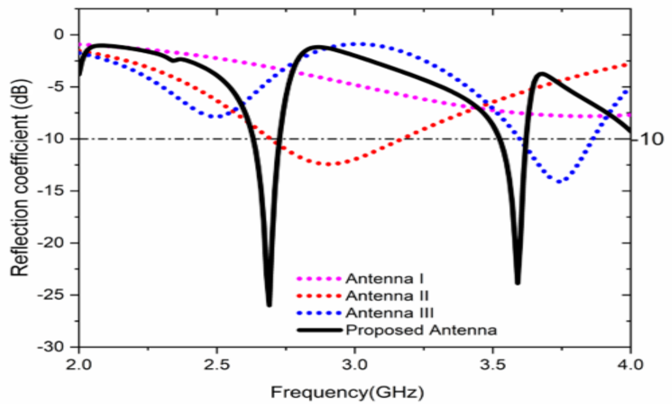



Fig 3. Reflection coefficients of the proposed antenna iterations

### A. *Parametric Analysis*

*(1) Variations of Ground Structure*

The proposed Split ring antenna is attained by variation of length of the ground 'G' from 5mm to 8mm. At G=5mm antenna resonates at 2.57-2.68 GHz, 3.44-3.58 GHz with S11 of -21.60 dB,-21.18 dB respectively, at G=6mm antenna resonates at 2.62-2.72 GHz, 3.51-3.61 GHz with S11of dB -25.88dB, -23.78dB respectively, at G=7mm antenna resonates at 2.66-2.72 GHz, 3.58-3.60 GHz with S11 of -14.55dB, -10.44 dB respectively and at G=8mm antenna doesn't resonates. The parameter 'G' affects at the input of antenna in terms of reflection coefficient in order to get the desired resonant frequencies that are applicable for WiMAX and LTE2500 ranging from 3.58 and 2.68 respectively where the length of the ground 'G' is amend to 6mm as shown in the Fig 4.

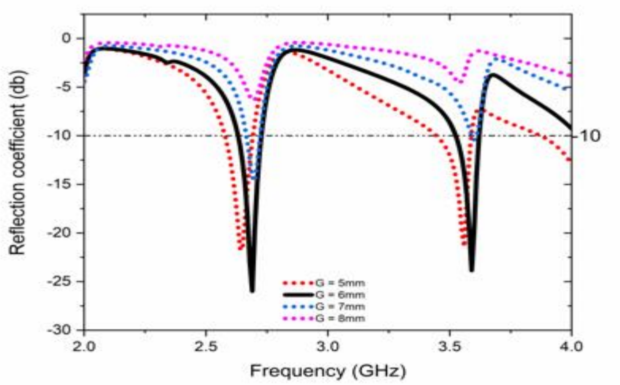



Fig:4. Repercussion of 'G' (ground) parameter on the reflection coefficient

### 2) Variation for feed width

From the Fig 5, we observe the reflection coefficient is better for Wu=1.5mm which is resonating at two bands 2.68 and 3.58 GHz respectively. The proposed split ring structured antenna is attained by variation of width of the feed 'Wu' from 0.5mm to 1.5mm. At Wu=0.5mm antenna resonates at single band ranging from 2.70-2.76 GHz with S11 of -29.16 dB, at Wu=1mm antenna resonates at 2.67-2.75 GHz, 3.56-3.59 GHz with S11of dB -19.08dB, -11.03dB respectively and at Wu=1.5mm antenna resonates at 2.62-2.72 GHz, 3.52-3.61 GHz with S11 of -25.80dB, -23.70 dB respectively. Here Wu is the width of the feed.

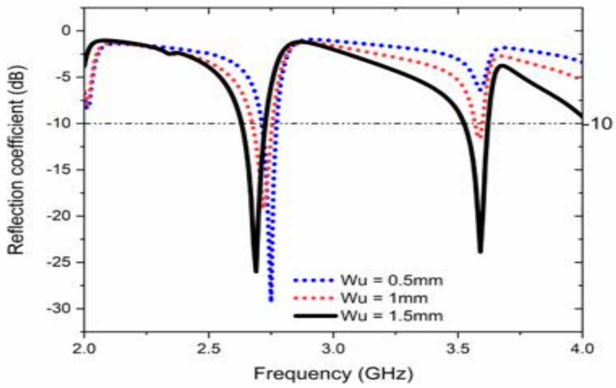



Fig: 5. Repercussion 'Wu' (width of the Feed) parameter on the reflection coefficient

### 3) Variation of width of the 4thSplit Ring

The W4 parameter also affects the antenna at the input in terms of Reflection coefficient shown in the Fig.6 and we get the desired frequencies that are applicable for LTE2500 and WiMAX at W4=6mm where we get the dual band with maximum of S11 -32.5dB at 2.62-2.72 GHz, -32.02dB at 3.5-3.61 GHz respectively. Coming to W4=5mm and W4=7mm reflection coefficient is decayed with S11 of -20.12 dB, -24.45 dB for W4=5mm at 2.62-2.72 GHz, 3.49-3.59 GHz respectively and for W4=733 having S11 of -26.62 dB, -29.23 dB at 2.63-2.73 GHz, 3.513-3.622 GHz frequencies respectively.

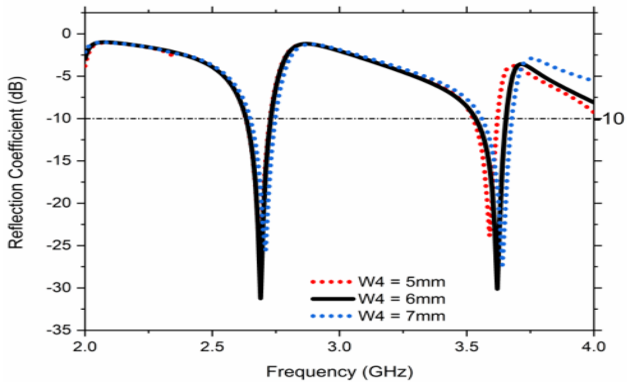



Fig:6. Repercussion of width of the 4th split ring parameter on the reflection coefficient

### B. Surface Current Distributions

At 2.52GHz, 2.68GHz, 3.49GHz, 3.58GHz frequencies of the simulated design, current distributions on the proposed antenna is as shown in Figure: 7. At frequency 2.68GHz antenna is excited because of its current distribution on feed of the antenna and doesn't excited on inner and outer patches Fig:7 (a) for OFF state of PIN diode, at 3.58GHz proposed structure is highly excited because of its current distribution on inner patch of split ring structure as shown in Fig 7 (b) for OFF state of PIN diode. In the same way for the ON state of a PIN diode the current distributions are highly excited on feed and inner, outer patches of Split ring structure at frequencies of 2.52GHz and at 3.49GHz the antenna is excited because of its current distribution on feed and inner, some part of outer patch of the split ring antenna.

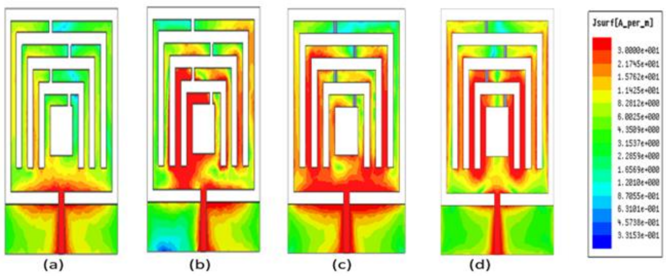



Fig7. Surface Current distribution of recommended antenna at: OFF state: (a) 2.68GHz, (b) 3.58GHz; ON state: (c) 2.52GHz, (d) 3.49GHz

### C. Proportionate circuit of PIN Diode

For the simulation of proposed design, the equivalent circuit of PIN diode is used for switching purposes to discover reconfigurability electronically (PIN diode BAR 64-02V).PIN diode used here is BAR 64-02V series with ON state resistance and inductance Rf =2.1 Ω and L = 0.16μH. The PIN diode with OFF state having CT = 0.17pF and Rp=3kΩ shunt capacitance and reverse resistance respectively with L=0.16μH as shown in the Fig 8.

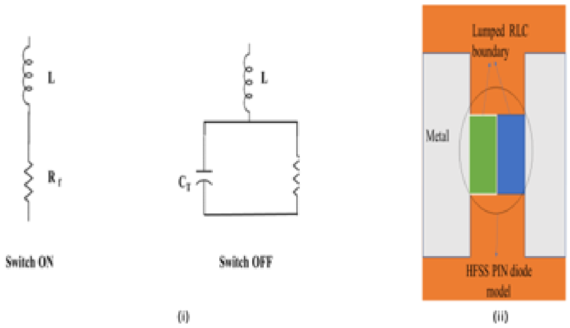



Fig 8. Proportionate circuit of PIN Diode. (i) Equivalent lumped circuit (ii) HFSS Pin Diode model.

### 1) *Measured Outcomes and Analysis*

By using ANSYS-HFSS software dual band finite element antenna is designed and simulated by optimizing the antenna parameters and fabricated to get the reliable outcomes. where the measurements are carried on Vector Network Analyzer. Furthermore, other results of radiation patterns and gains are calibrated in an Anechoic Chamber.

TABLE: II
SWITCHING CONDITIONS OF THE PROPOSED ANTENNA

| Diode State | | | | Bandwidth GHz | Operation mode | Resonant Frequency (GHz) | $S_{11}$ (dB) |
|---|---|---|---|---|---|---|---|
| $D_1$ | $D_2$ | $D_3$ | $D_4$ | | | | |
| 1 | 1 | 1 | 1 | 2.48-2.55<br>3.34-3.57 | Dual Band | 2.52 | -31.73 |
| 0 | 0 | 0 | 0 | 2.62-2.72<br>3.52-3.62 | Dual Band | 2.68 | -25.59 |
| 1 | 1 | 0 | 0 | 2.18-2.25<br>3.04-3.26 | Dual Band | 2.25 | -31.64 |
| 0 | 0 | 1 | 1 | 2.42-2.51<br>3.31-3.41 | Dual Band | 2.48 | -25.88 |

For different switching cases, the simulated antenna results are as shown in Table II. Reflection Coefficients of simulated and measured results are shown in Fig 9. The proposed antenna operates at 2.52GHz can be used for LTE2500 applications with the impedance bandwidth from 2.48-2.55GHz and at 3.49GHz which can be used for WiMAX application with the impedance bandwidth from 3.34-3.57GHz when the PIN Diode is in ON state which is denoted by '1'. In the same manner when the PIN Diode is in OFF state which is denoted by '0' it operates at 2.68GHz and 3.58GHz with the impedance bandwidth from 2.62-2.72GHz and 3.52-3.62GHz respectively. Very tiny errors seen in the simulated and measured results due to fastening of RF-Pin diodes and due to power losses in diode ON state also decays the efficiency of antenna and its performance also, thus proposed antenna amuse the requirements of LTE2500 an WiMAX application.

Fig 10 presents the comparison reflection coefficient of the proposed antenna. The results are obtained when the all diodes are in the off condition. The measured operates in the frequency range of 2.63-2.83 GHz in the first frequency band and in the second frequency band antenna operates in the frequency of 3.3-3.84 GHz. When compared to the simulated results the measured reflection coefficient are higher bandwidth of 0.2 GHz and 0.54 GHz respectively whereas, simulated results it is observed bandwidth of 0.1 and 0.1 GHz at two frequency bands.

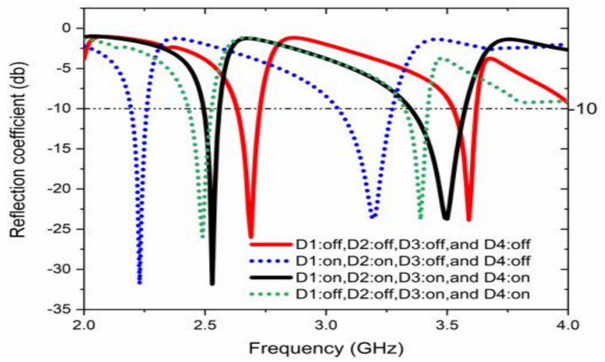



Fig 9. Simulated Return losses of the proposed antenna at different switching conditions

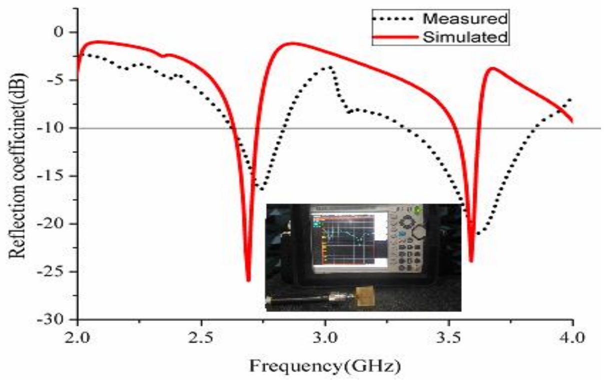
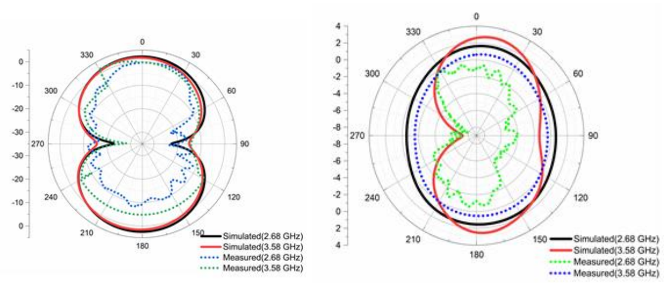


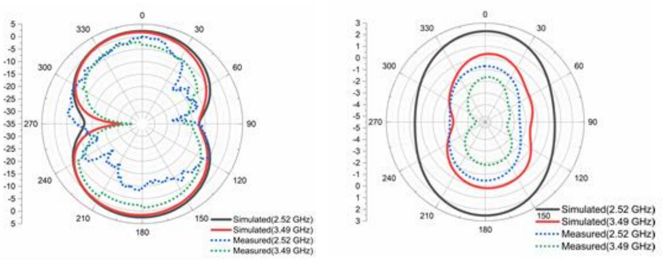

Fig10. Measured Return Losses of the proposed antenna in off state

### 2) *Radiation Patterns*

Radiation Pattern Characteristics of E-plane and H-plane at the frequencies (a) 2.68GHz, 3.58GHz in OFF state of diode and (b) 2.52GHz, 3.49GHz in ON state of simulated and measured values as sketched in Fig11. In E plane we observe the bidirectional patterns. The radiation pattern attained for frequencies 2.68 GHz and 3.58 GHz is almost same.




(a)




(b)

Fig 11. Radiation Patterns of E- and H- plane at the frequencies (a) 2.68GHz and 3.58GHz (OFF State) (b) 2.52GHz and 3.49GHz (ON State)

In H plane radiation pattern achieved for the above-specified frequencies an omni directional pattern. Dissimilar E plane for H plane the pattern attained is distinct for distinct range of frequencies. Figure.13(b) shows E plane and H plane patterns for ON state frequencies. The patterns obtained for two frequencies 2.52 GHz; 3.49 GHz is almost similar with very tiny variations which explains the antenna radiation is same for all frequencies in ON state for E plane. Whereas for H plane, the patterns vary for different frequencies just as in OFF state. The simulated results and measured results of co-polarization are eventually equal.

*3) Radiation efficiency and Peak*

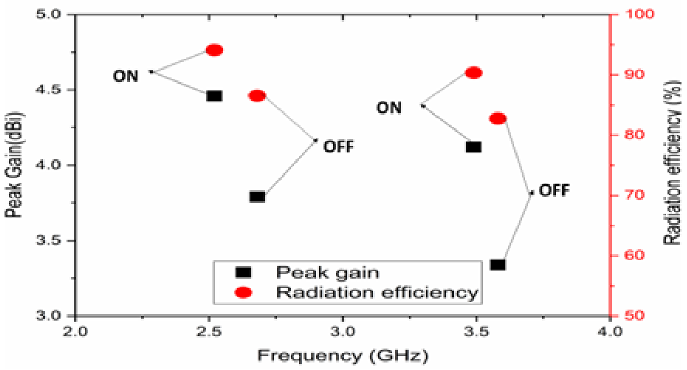



Fig 12. Simulated gain and radiation efficiency of antenna at two frequencies (ON and OFF)

Radiation efficiency and gain of simulated antenna in ON sate and OFF state of a diode is as shown in Fig 12. The Change of gain and radiation efficiency is observed for proposed antenna by its reconfigurability. At ON state of PIN diode gain of the antenna is 4.46 dB with radiation efficiency 94.12 % at 2.52 GHz of frequency, at frequency 3.49 GHz its gain is 4.12 dB with the radiation efficiency of 90.34 %. For OFF state of PIN diode at 2.68 GHz frequency having gain 3.79 dB with the radiation efficiency of 86.54 % and at 3.58 GHz frequency with gain of 3.34 dB having the radiation efficiency 82.75 %. We attain maximum gain (dB) and radiation efficiency at ON state mode of PIN diode at 2.52 GHz whereas for OFF state of PIN diode minimum gain is observed which is shown in the Table III.

TABLE: III
GAIN AND EFFICIENCY OF ANTENNA AT ON AND OFF STATES

| Diode mode | Frequency GHz | Simulated Radiation Efficiency | Simulated Gain, dBi |
|---|---|---|---|
| OFF | 2.68 | 86.53 | 3.79 |
| | 3.58 | 82.74 | 3.34 |
| ON | 2.52 | 94.12 | 4.46 |
| | 3.49 | 90.34 | 4.12 |

The comparison of previous literature is done in table.IV. In this proposed work 4 pin diodes are used in the design and antenna provides the maximum gain of 4.46 in the ON state of pin diode. The antenna is compact in structure when compared previous literature.

TABLE: IV
COMPARISON OF PREVIOUS LITERATURE WITH PROPOSED WORK

| References | Antenna size | Frequency (GHz) | Diode type | Diode quantity | Peak Gain (dB) |
|---|---|---|---|---|---|
| [3] | 60 x 50 x 1.6 | 5.2/5.8 | BAR64-0W | 4 | 3/3.5 |
| [5] | 50 x 45 x 1.6 | 2.4/3.2/5.5 | SMP1320-079 | 2 | ¾ |
| [7] | 35 x 30 x 1.6 | 1.45/2.2 /3.3/5.4 | BAR64-03WE6327 | 1 | 4.6/4.4 /2.8/2 |
| [8] | 38 x 26 x1.5 | 3.5/5.5 | NA | 3 | 4.4/4.05 |
| [9] | 36.5 x 25 x 0.8 | 2.4/3.5 | NA | NA | 2.2/3.8 |
| This Paper | 30 x 30 x 0.8 | 2.52/3.49 | BAR64-02V | 4 | 4.46/4.12 |

## CONCLUSION

In this research paper, compact dual band reconfigurable antenna is described by using Split ring structure and a PIN diode is embedded to get the applicable frequencies used for LTE2500 (2.5 to 2.69 GHz) and WiMAX (3.4 to 3.6 GHz) are attained well. In this two pairs of PIN diodes are used for controlling the resonant frequencies of the dual bands. Here the simulated results and measured results highly matched with each other without any reflections. Reasonably the antenna exhibits bidirectional and omnidirectional radiation patterns observed at E-planes and H-planes respectively with the gain of 3.34-4.46 dBi and radiation efficiency of 82.75-94.12 % in ON and OFF states. The proposed antenna is used for the wireless and communication systems.

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