Reconfigurable Trident Antenna for Cognitive Radio Applications

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***Abstract* –This article presents the design and implementation of an 30x30x1.6 mm^3 reconfigurable antenna with multiple operating states. Four PIN diodes as S_1,S_2,S_3 and S_4 are used to reconfigure the transmission frequency to achieve ultra wide band (UWB) of frequency range 3.6GHz-13GHz and multiple narrow band (NB) frequencies are achieved at different conditions of switching. This switching makes the antenna appropriate for cognitive radio applications by preventing interference from the primary user into the secondary user. The proposed antenna consists of a trident shaped UWB antenna compact single port with defected ground structure (DGS) of complimentary ring resonators (CRR). The simulated results indicate that the antenna has good impedance as well as radiation properties.**

***Index Terms* –Trident antenna, cognitive radio, reconfigurable antenna, ultrawide band.**

I. Introduction

The potential of ultra-wideband communication systems to function with very less energy density, high data speeds, and quite less spectral congestions has recently made them the talk of the communication industry. The ultra-wide band (UWB) frequency range certified by the Federal Communication Commission (FCC) spans 3.1 to 10.6 GHz [1]. The advantages of UWB filters over wideband include their compactness, flat group delay, strong selectivity, and good insertion/return loss [2]. For CR applications, we require both the UWB and NB operational states respectively, where the former is for sensing and the second is for communication [3-6].This inspires to build a frequency reconfigurable antenna by fusing a UWB antenna with defected ground structure (DGS) and introducing PIN diode switching for reconfiguring the frequency. The added advantage is the single port resulting in multiple NB frequency bands.

The literatures [7-10] discusses both the wideband and continuously tunable narrowband states, a compact antenna with strong out-of-band rejection but frequency agility issues, no sharp edge band rejections and poor end-fire performance, restricted impedance bandwidth, and frequency selectivity are some of the disadvantages for the above mentioned. There are many more different literatures where varactor diodes and PIN diodes are used for the tuning of different frequencies in the antenna resulting in filtering antenna [11-14]. In some of the literatures [15-18] it is seen that there is compromise with the antenna gain and as well as in some cases it is observed that there are limited operating frequencies achieved after reconfiguring the antenna structure.

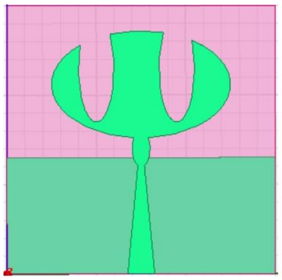
In order to realize this adaptable self-contained component, the proposed literature presents a novel approach of frequency reconfigurable antenna to achieve both narrow band (NB) and ultra-wideband (UWB) by defecting ground structure (DGS) with complimentary split ring resonator (CSRR) and with introducing four PIN diodes as switches. The proposed antenna structure can operate in UWB mode and in different NB mode with the switching on and off of the PIN diodes.

This article is majorly categorized in three sections where section II describes the detailed evolution of the antenna with detail aspect ratio, section III comprises of result discussion and comparative analysis with other recent articles and section IV comprises of the conclusion.

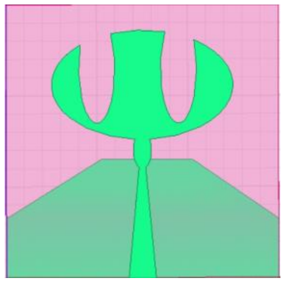
II. ANTENNA DESIGN

The initial stage of antenna was Antenna 1 with a rectangular ground plane and with a trident structure for the antenna resulted in frequency range of (4.5 - 12.8) GHz, then second phase of design was Antenna 2, a bit of modification to the ground plane with no change in the antenna design resulted in frequency range (4.5 - 12.5) GHz. The third phase of the design was Antenna 3, the design involved some changes with the antenna design and rectangular ground plane resulted in frequency range (4.5 - 12) GHz. The fourth stage is the proposed design, Antenna 4 is designed with no change in the modified trident of Antenna 3 but redesigning the ground plane from rectangular to trapezoidal thereby resulting in frequency range of (3.6 - 12.4) GHz. The Fig.1(a),(b),(c) and (d) and (e) depicts the various stages of antenna evolution with the reflection coefficient. The antenna dimensions are 30x30x1.6 mm^3 on FR_4 epoxy with 4.4 and

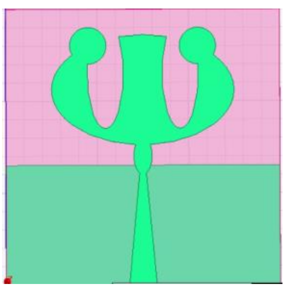
0.019 are dielectric constant and loss tangent respctively. The proposed antenna with the four PIN diodes and DSG is presented in Fig.2(a), (b)and (c) and the detailed antenna dimensions are shown in Table 1. Here L, W and T represent the length, width and thickness of the antenna.



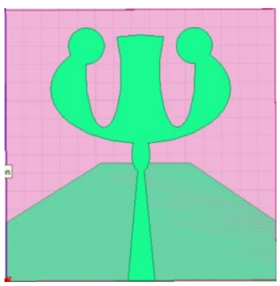
(a) Antenna 1



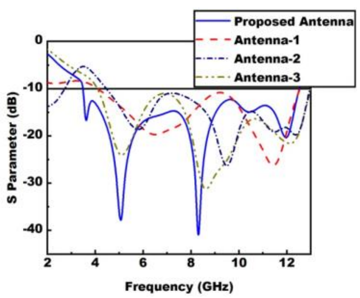
(b) Antenna 2



(c) Antenna 3

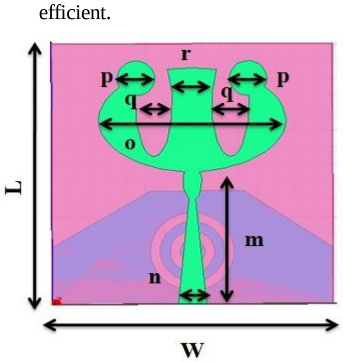


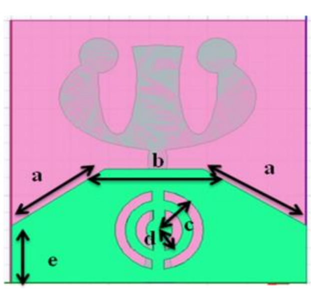
(d) Antenna 4 (Proposed Antenna)



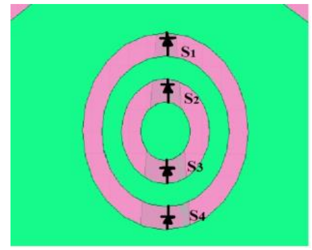
(e) S-Parameter of all Antenna stages

Fig.1 Different evolving stages of the proposed antenna with the reflection co-efficient.





(a)Proposed Antenna Front (b) Four switches on state



(c) Arrangements of four PIN diodes

Fig. 2 Proposed antenna with PIN diodes

In Table I, the proposed design's precise measurements are shown.

TABLE I
DIMENSIONS OF THE ANTENNA.

Sl No.	Parameters	Dimension(mm)
1	L	30
2	W	30
3	T	1.6
4	m	15.2
5	n	3
6	o	20
7	p	4
8	q	3.8
9	r	5
10	a	9.5
11	b	10
12	c	4.5
13	d	2.3
14	e	6.5

III. RESULT ANALYSIS AND DISCUSSION

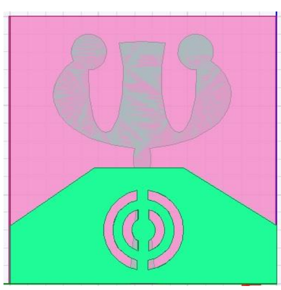
A. *Reflection Coefficient*

The simulated reflection coefficient of all the different switching states of the PIN diodes are discussed in this section The double ring resonator's outer circle radius is represented as c "4.5" mm, while the inner circle radius is represented as d "2.3" mm. The four diodes are switched off and on to illustrate the conditions for an open circuit and a short circuit, respectively. Considering symmetry of DCSRR in the z-direction as a y-axis polarized wave propagates in the z-dzirection the resonance frequency can be obtained with the following formula [19]

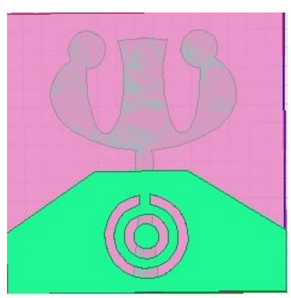
$$\omega'' = \sqrt{\frac{2}{\pi R'' L'' C''}} \ldots\ldots(1)$$

Where, L'' is the inductance between the gaps and C'' represents the capacitance and R'' represents the average radius of the two annular slots. Therefore when the diodes are switched on then the condition achieved is short circuit and when the diodes are switched off then the condition achieved is open circuit as shown in Fig 2(b). Considering only four different possibilities of switching on and off of the four diodes S_1,S_2,S_3 and S_4 are discussed in this work.

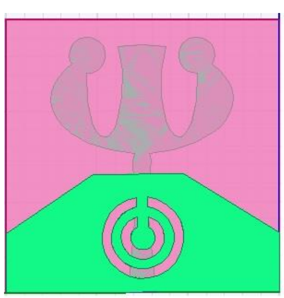
The Fig 3(a),(b),(c) and (d) represents the different conditions when all the switches S_1,S_2,S_3 and S_4 are ON, when only S_1 is ON, when S_1,S_2 are ON and when S_1,S_2,S_3 are ON. From the below Fig 3(e) it is clearly seen that the reflection coefficient of all the conditions represents the UWB sensing when all the PIN diodes are switched ON and different communicating NB frequency bands for other combinations thereby making it a good fit for Cognitive Radio application.



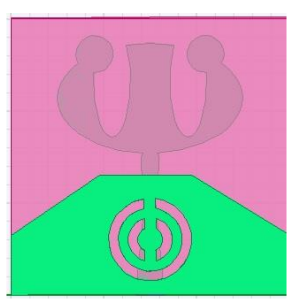
(a) State-1



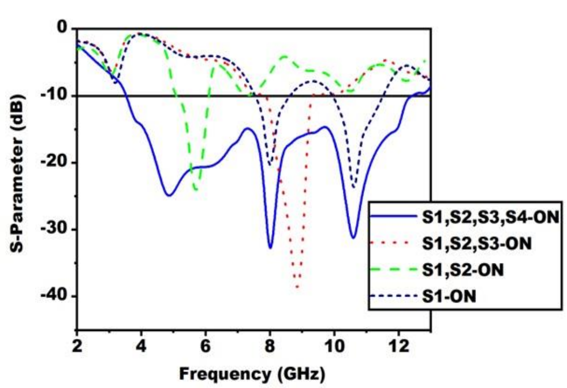
(b) State-2



(c) State - 3



(d) State - 4



(e) Reflection Co-efficient of all Operating States

Fig.3 Antenna states at different conditional switching.

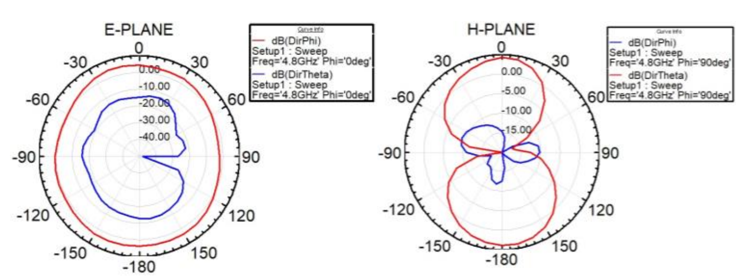
Table II gives the detailed frequency range achieved with various operating states of the diodes. The ON and OFF states of the diodes are combined and stated as different states and with respect to the different operating states the table represents the different operating frequencies achieved and the blocking frequencies. So at the State 2 it is observed that there are dual NB bands at 8GHz and 10.6 GHz, at State 3 only one NB band at 5.6 GHz and at State 4 one NB frequency band at 8.8 GHz is obtained.

TABLE II
DIFFERENT OPERATING STATES OF DIODE

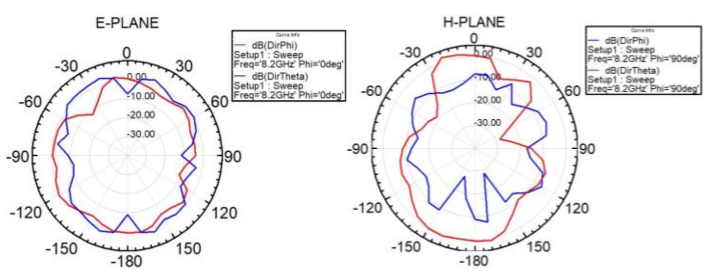
STATE	S_1	S_2	S_3	S_4	OPERATING FREQUENCY(GHz)
1	ON	ON	ON	ON	3.6-12.4
2	ON	OFF	OFF	OFF	8-8.6,10-11.2
3	ON	ON	OFF	OFF	5.4-6
4	ON	ON	ON	OFF	8-9

B. Radiation Patterns and Gain of the antenna at different operating state.

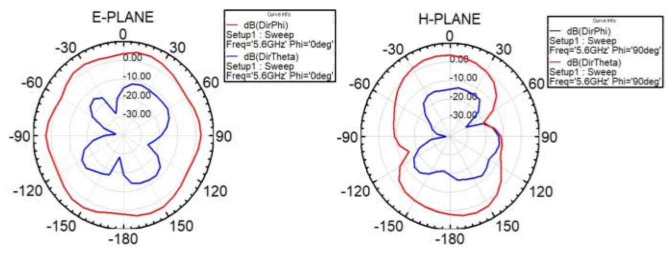
The simulated radiation pattern of the proposed antenna at all the above-mentioned states with selective operating frequencies are discussed in this section. The radiation pattern for state1 is at centre frequency 4.8 GHz, for state 2 it is 8.2 GHz, for state 3 it is 5.6 GHz and for the case of state 4 8.6 GHz is taken in consideration as the centre frequency. Here for all the diagrams the red and blue curve represents the co-polarization and the cross polarization of the antenna respectively in its different operating states. From Fig 4 (a),(b),(c) and (d) it is clear that an omni directional radiation pattern is observed at different frequencies.



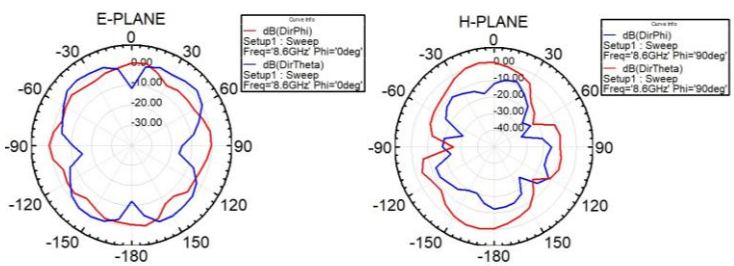
(a) State-1 (4.8 GHz)



(b) State-2 (8.2 GHz)



(c) State-3 (5.6 GHz)



(d) State-4 (8.6 GHz)

Fig.4 Radiation pattern with Co & Cross polarization in both the planes at different operating states (a) State-1 (4.8 GHz) (b) State-2 (8.2 GHz) (c) State-3 (5.6 GHz) (d) State-4 (8.6 GHz)

The Simulated Gain of the various states mentioned are represented in Fig 5. For State 1, when all the PIN diodes are ON the Peak Gain achieved is 4.9 dB in the operating frequency range, for State 2 when S_1 is only on then the Peak Gain is 7 dB, for State 3 when S_1 and S_2 are ON then the Peak Gain is 3.1 dB and when S_1, S_2 and S_3 are ON then the Peak Gain is 2.6 dB in the operating frequency range.

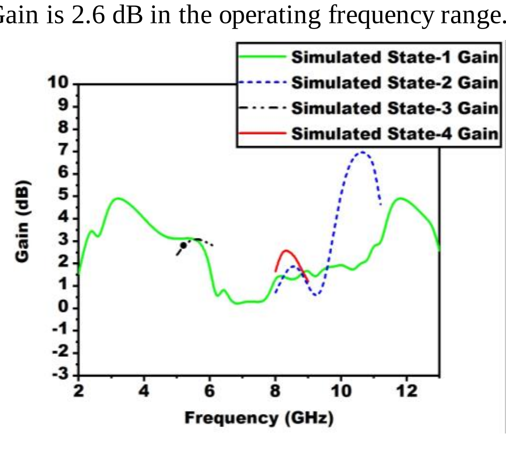


Fig.5 Simulated Gain of Proposed Antenna at different Operating States.

C. Performance Comparison of the Proposed Design to Current Literature.

Table III specifies the proposed antenna's overall performance as compared with current literatures in terms of antenna dimension, Operating Frequency bands and Gain of the antenna.

TABLE III
COMPARATIVE ANALYSIS

Ref. No.	Actuators	Antenna Dimension (mm^3)	Operating Frequency (GHz)	Peak Gain (dBi)
[8]	Varactor diodes	50x30x1.5	2.35-4.98	13.4
[9]	Varactor diodes	29x27x1	2.261-2.447	1.376
[11]	Four PIN diodes	30x60x1.5	1.8, 2.4, 3.5, 5.2	1.1, 2.6, 3, 3.4
[12]	Varactor diode	30x30x1.6	6.2-6.5	5.72, 6.77
[16]	Five PIN diodes	40x45x2	2.2-11, 2.4, 5.8	2.1-2.3
[18]	Two PIN diodes	88x85x1.5	3.1-10.6, 3.1-3.3, 4.1-4.3, 5.9-10.6	5.9
Proposed Antenna	Four PIN Diodes	30x30x1.6	3.6-12.4, 8-8.6,10-11.2, 5.4-6, 8-9	7,4.9,3.1 and 2.6

From the above Table III it is seen that the proposed design is comparatively compact and also resulting in an appreciable gain in the operating bands. The Trident antenna with the reconfigurable characteristics due to the DGS with four PIN diodes results in UWB with multiple narrow bands.

IV. CONCLUSION

The proposed Reconfigurable Trident antenna is a good fit for the cognitive radio application due to its operating frequencies that are in the range of UWB and also the antenna generates multiple NB frequency band with the introduction of reconfigurability due to the integration between CRR and the four diodes. Its compact and simple design makes it more attractive in comparison with other antenna designs discussed in this paper. The peak gain of the trident antenna is also remarkable that varies between 2.6 dB to 7 dB. The Omni-directional radiation pattern of the antenna is observed and also acceptable cross polarization is seen. All the mentioned parameters of this proposed design makes it a good fit for Cognitive Radio Application.

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