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A Novel UWB Reconfigurable Circular Monopole Antenna for Cognitive Radio Applications

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ABSTRACT: The spectrum scarcity has now become more and more serious with the increasing demand of wireless application but on the contrary, there is still low utility of some licensed spectrum. Cognitive radio makes it possible for unlicensed users to access the spectrum unoccupied by licensed users and thus increase the spectrum utilization. The proposed antenna is a frequency reconfigurable antenna which detect the white spaces in the spectrum ie, the unused frequency bands by the primary user in the designed range which is here the Ultra Wide Band (UWB:3.1 to 10.6 GHz) and allow the secondary users to switch to these frequency bands without causing much interference to the primary user.

KEYWORDS: UWB; Cognitive Radio; monopole antenna; reconfigurable antenna; HFSS

I. INTRODUCTION

Frequency reconfigurable antenna is a novel antenna which can be utilised for very useful wireless applications. One such important application is the Cognitive radio application. According to the Federal Communications Commission (FCC), a cognitive radio is “a radio that can change its transmitter parameters based on interaction with the environment in which it operates”[5]. The cognitive radio network capable of locating the free spaces in the frequency spectrum should have the mechanism to switch to these unused frequency bands. The proposed antenna serves this purpose. The antenna is designed using a monopole antenna which achieves a UWB band and this band is made reconfigurable using PIN diode switches. The antenna is simulated using HFSS software.

The main advantage of the proposed antenna is that there can be different switching cases and out of these different switching conditions, it can switch to any of the frequency bands which is found free during the sensing operation. Also, there is more than one frequency band achieved upon a single switching case hence when the secondary user finds a primary user requesting its frequency band back, without even switching to another switching condition, it can utilize the frequency band in the same switching case if the band is unoccupied by the primary user. This can reduce the energy consumption also.

II. RELATED WORK

In [1] authors designed an antenna which is planar, compact, single substrate, frequency reconfigurable and multiband is presented. Also, the antenna is made to operate as MIMO(Multiple Input Multiple Output). Dual element achieves the MIMO operation both of which utilizes separate switching using PIN diode and varactor diodes for reconfigurability. This antenna has the feature of its planar structure and the unique architecture of its UWB sensing and reconfigurable MIMO antenna sharing the same substrate. The ground plane of the antenna works as a sensing antenna inorder to scan the frequency spectrum and it works as a reference ground plane for the reconfigurable antenna during the communication stage. An antenna is introduced which is uniplanar, polarization diversity with wideband/narrowband switching capability. An open annular slot with orthogonal feeding mechanism is utilized so as to achieve polarization diversity. The antenna provides a wide bandwidth mode from 3.4 to 8.0 GHz. In addition, slot

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resonator based filters are incorporated in the feedline so as to achieve wideband/narrowband switching in [2]. The prototype used Rogers RT /Duroid 6035 HTC substrate In [3] is a selectively reconfigurable antenna capable of switching between a wide operating band of frequency range 2.63–3.7 GHz and four different subbands, which allows using it for sensing the entire band and then adjusting its bandwidth to select the suitable sub-band and prefilter out the other ones. PIN diode switches are incorporated to alter the bandwidth and also shift the frequency range by changing the antenna current distribution. The switches are incorporated in the four horizontal slots as three rows in the ground plane. The upper slot attenuates the lower frequencies in the band, while the bottom one suppresses high frequencies. Once the considered band is suppressed, the introduction of the middle slots in the antenna ground plane creates a high Q operating band whose frequency depends on its length. Thus, by controlling the slot length by means of switches, the antenna operating band can be tuned accordingly. [4] presents an antenna which is reconfigurable with RF-MEMS(Micro Electro Mechanical System) using a nature inspired optimization technique which is particle swarm optimization. The MEMS switches incorporated on the E shaped patch can dynamically alter the slot dimensions and is capable of achieving a wide bandwidth which is almost double that can be achieved with a normal E shaped patch. The optimized antenna works in the frequency range of 2 GHz to 3.2 GHz. This design could be used in large terminals such as laptops or as an array element in highly directive base station antennas.

III. ANTENNA DESIGN

The design is done using a monopole antenna for generating the UWB band (3.1 GHz to 10.6 GHz). The antenna is designed using a circular monopole structure with a microstrip line feed. The monopole antenna is designed on FR4 substrate of thickness 0.87mm. The antenna geometry is as shown in figure 1. The design of the monopole antenna is given by the following equation:

$$\lambda = L + r/0.24$$

$$f = 0.24c/(L+r)$$

where r is the radius, c is the velocity of light and L is taken as r.

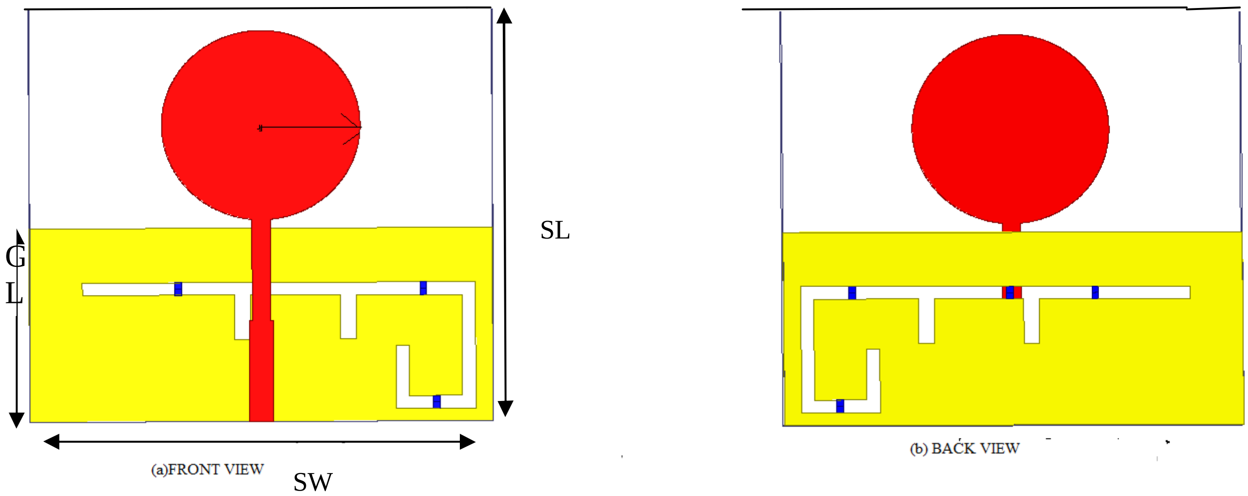

Figure 1: Antenna geometry

Using the design equations, the following dimensions are obtained based upon which the antenna is designed. The antenna is fabricated on an FR4 substrate of dimension (SL×SW) 35mm×35mm dimension. The circular monopole has the radius of 7.5mm. The ground plane has a length (GL) of 15.3mm. The antenna results in UWB band of operation. Inorder to make the antenna reconfigurable, slots are made in the ground plane of length 54.3mm and width of 1mm. PIN diode switches are placed in the slots so as to make the antenna reconfigurable. The ON-OFF condition of the switches control the current distribution and thus the frequency bands. A maximum of four switches are incorporated to obtain different frequency bands.

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IV. SIMULATION RESULTS

The simulation of the antenna is done using Ansoft HFSS software which is an EM simulator based on Finite Element Method(FEM) and the following results were obtained. At first, the return loss graph and the radiation pattern for the UWB band obtained is shown in figure 2 and 3 respectively.

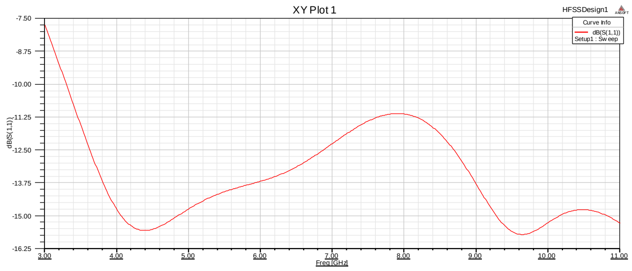

Figure 2: Return loss of UWB band

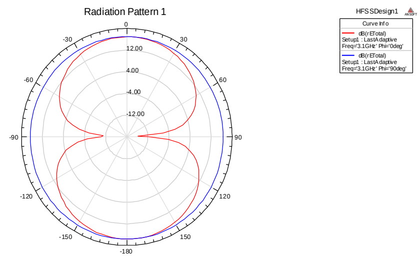

Figure 3: radiation pattern of UWB band

The graph shows that the antenna resonates in the UWB band with the entire band below -10dB and the antenna has a radiation pattern which is omnidirectional.

The UWB antenna is made reconfigurable by putting slot in ground plane and placing diode in the slots. The reconfigurable antenna's operating frequency (f_r), return loss(S_{11}) ,and the peak gain(G_O) is given in the table I. For design purpose, the diode used is HPND 4005. The diode is represented by 5Ω in ON case and 0.017pF in OFF case. Let o denote OFF case and 1 indicate ON case.

case	1	2	3	4	5	6	7	8	9	10
Diode	0000	0001	0010	0011	0100	1000	1001	1011	1110	1111
f_r (GHz)	7.03 & 10.744	3.43, 7.03 & 8.32	7.11 & 7.28	7.09 & 9.57	7.08 & 10.56	3.11 & 10.48	8.34	9.3	4.84, 6.61 & 10.4	4.95 & 9.24
S_{11} (dB)	-19.53 & -24.80	-11.7 ,-11.3 & -11.53	-10.9 & -21.6	-10.7 & -13.0	-30.3 & -27.9	-32.8 & -46.6	-10.8	-13.7	-20.11, -20.03 & -21.75	-18.33 & -11.74
G_O (dB)	4.6	2.79	4.5	4.87	2.54	3.54	1.23	1.31	4.2	5.96

Table I: Operating Characteristics of Antenna

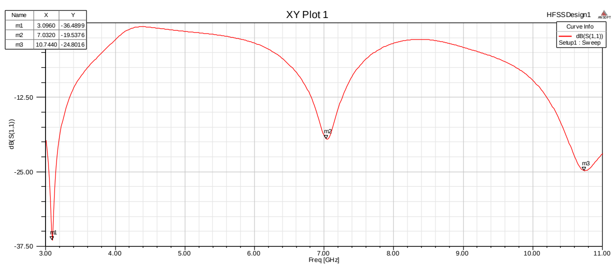

Figure 4: return loss for case 1

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The figure 4 indicates the return loss graph for the antenna where all the switches are off. The antenna resonates at 7.03 and 10.74 GHz with return loss values at -19.53 and -24.8dB respectively.

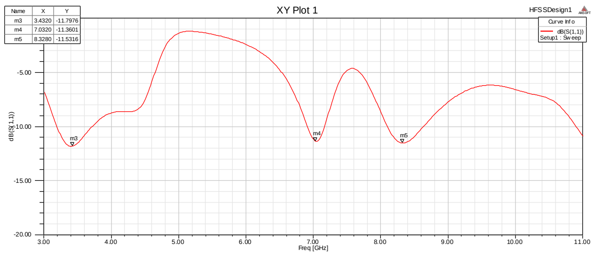

Figure 5:return loss for case 2

The return loss graph in figure 5 indicates that the antenna resonates at triple band frequency of 3.43,7.03 and 8.32GHz with return loss values of -11.7,-11.3 and -11.53dB respectively .

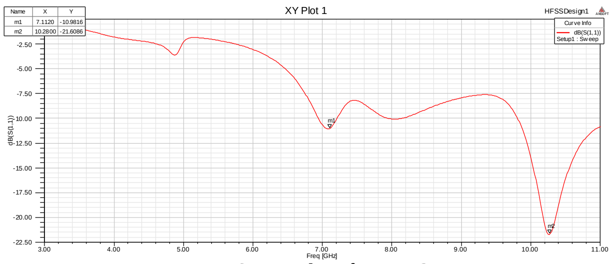

Figure 6:return loss for case 3

For the case 3, the antenna resonates at dual frequency of 7.11 and 7.28GHz with return loss values of -10.1 and -29.6dB respectively.

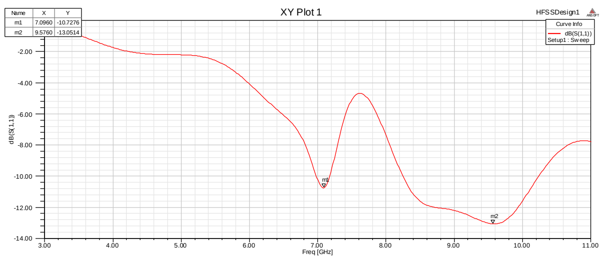

Figure 7:return loss for case 4

The return loss graph in figure 7 indicates that the antenna resonates at frequencies of 7.09 and 9.57GHz.

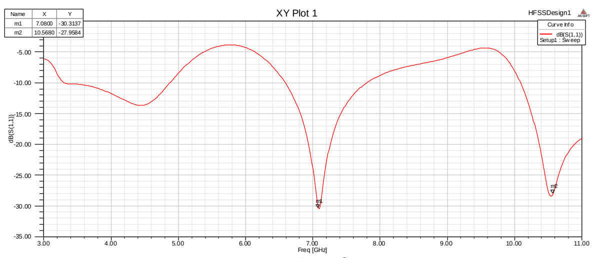

Figure 8:return loss for case 5

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The graph in figure 9 shows the return loss for case 5. It can be seen that the antenna resonates at the dual band frequency of 7.08 and 10.56GHz with return loss values of -30.3 and -27.9dB respectively.

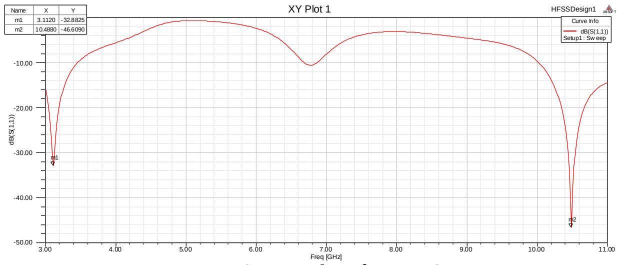

Figure 10: return loss for case 6

The figure 10 shows the return loss graph for antenna resonating at 8.34GHz with a value of -10.8dB.

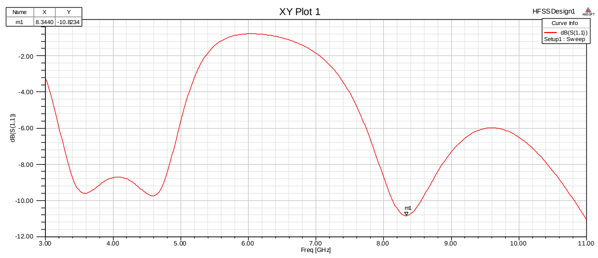

Figure 11: return loss for case 7

The return loss graph as indicated in figure 11 shows that the antenna resonates at frequency of 9.3GHz with the return loss value of -13.7dB.

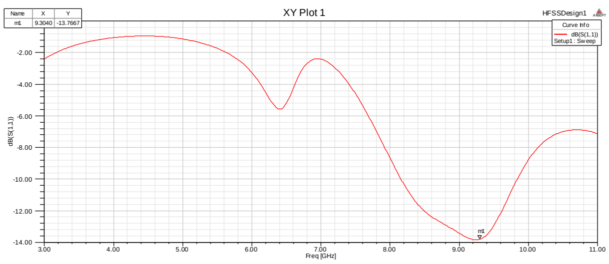

Figure 12: return loss for case 8

The figure 12 depicting the return loss graph for case 8 clearly shows that the antenna resonates at a frequency of 9.3GHz with a return loss value of -13.7dB.

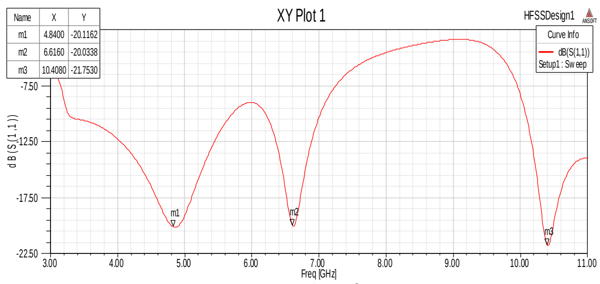

Figure 13: return loss for case 9

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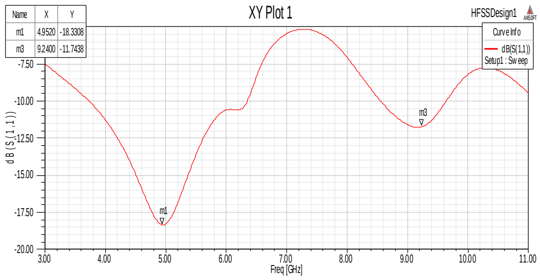
It can be seen from the return loss graph of figure 9 that the antenna resonates at triple band frequency of 4.84, 6.61 and 10.4GHz with the return loss values of -20.11, -20.03 and -21.75dB respectively.



The antenna resonates at dualband frequency of 4.95 and 9.24GHz with return loss values -18.33 and -11.74dB respectively. All the operating characteristics shows that the antenna is best suited for switching between different frequency bands in the UWB band. The radiation pattern remains the same in all the cases as in the UWB case given in figure 3.

V. CONCLUSION AND FUTURE WORK

The simulation results showed that the proposed antenna is a best suited antenna for the desired application, that is, for the cognitive radio application. The antenna is capable of switching to different frequency bands in each switching condition and provides good gain in each switching case also. Another distinct feature is that multiple bands are also obtained for a single switching condition making it a multiple band reconfigurable antenna. The antenna is of short range and techniques can be employed to increase the range without hindering the advantage of high data rate.

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