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Comparative Analysis of Integrated Wideband/Narrow Band Antenna for Cognitive Radio Applications

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Abstract

Cognitive radio is an inventive system to wireless technologies in which radios are designed with an astonishing level of intelligence and agility. This handles the available spectrum in an expedient manner to avoid spectrum scarcity. The cognitive radio antenna consists of integrated wideband and narrow band antenna in same substrate which is taxing task. A UWB antenna is pondered for the wide band operation which has the bandwidth of 7.5 GHz respectively is used for sensing vacant slots in the spectrum. For narrowband antenna the frequency and pattern reconfigurable antenna is usually suggested which is used for transmission of data through the vacant slots from the outcomes of sensing antenna. In this paper the various cognitive radio antennas are investigated in tremendously.

Keywords: *Cognitive radio, ultra wide band, narrowband, antenna, data*

INTRODUCTION

The radio spectrum is naturally available scarce resource. The FCC regulates the available spectrum to users according to the requirement. The wireless communication technology is rapidly evolving in day by day so limited spectrum services become more congested. The wireless world research forum states that 7 trillion wireless devices are serving 7 billion people in 2017

Reports of recent FCC measurements conclude that many licensed frequency bands are unused 90% of the time [1]. To provide future wireless communication technological development the cognitive radio is the way to avoiding bottleneck of shortage of spectrum resources [2]. In cognitive radio the dynamic spectrum sensing is the novel method [3]. In CR paradigm, two users are accessing the spectrum called primary (licensed user) and secondary (unlicensed user). Generally the primary user has more spectrums with very less utilizing but the secondary user has very less spectrum with over utilization. Here the CR serves for both the users with neutralized spectrum access and very negligible amount of interference between them. The conventional regularity of spectrum causes underutilization of available spectrum. The dynamic spectrum access method is doing wide role in CR systems [4–6].

The cognitive radio working intelligently in all modules like modulation, coding and RF front end. In this paper the cognitive radio antenna system is discussed. From literature Microstrip patch antennas are commonly used in cognitive radio due to their benefits in many aspects. The integrated wide and narrow band antenna is operating for CR system as following in Figure 1.

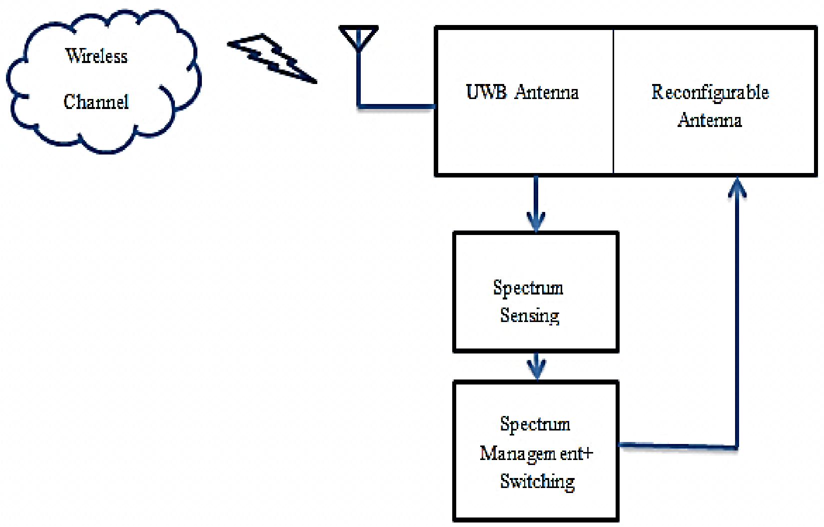

Fig. 1: *Cognitive Radio Antenna.*

In cognitive radio, the RF antenna is operating intelligently according to the environmental condition. The antenna working for two different scenarios one used for spectrum sensing and other for communication. The spectrum sensing is done by the UWB antenna which receives the entire UWB spectrum and the sensing is carried out by the effective spectrum sensing algorithm [7]. Depending upon the sensing outcome the spectrum is managed for communication purpose then the switch control unit taking appropriate action to configure the reconfigurable mode. Still there are so many researches going on to get fully reconfigurable antenna according to the white band available.

SURVIVING DESIGN

Combined Pattern and Frequency Reconfiguration of Single-Element Ultra-Wideband Monopole Antenna for Cognitive Radio Devices [6].

The antenna consists of complex structure as shown in Figure 2. The top view shows that the radiated element is regular patch structure with a substrate material of Taconic TLC-30 with thickness of 0.88 mm, relative permittivity of 3 and a loss tangent of 0.025 and the dimension of $34\times31\times0.88$ mm^3. The bottom view shows the reconfigurable design by the use of three diodes. In reconfigurable design both frequency and pattern reconfigurable is used.

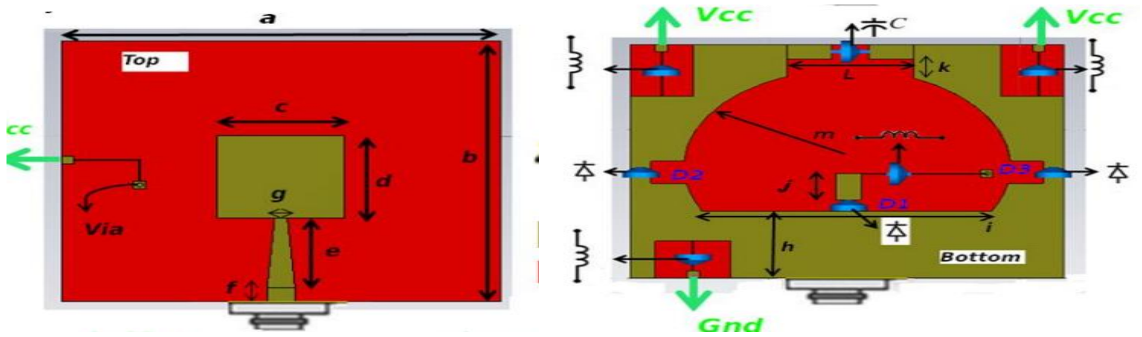

Fig. 2: *Antenna Structure both Top and Bottom View.*

The UWB mode is operatingunder all diodes are in off stage. The following return losses shown in Figure 3 shows the sensing antenna is very wider in bandwidth.

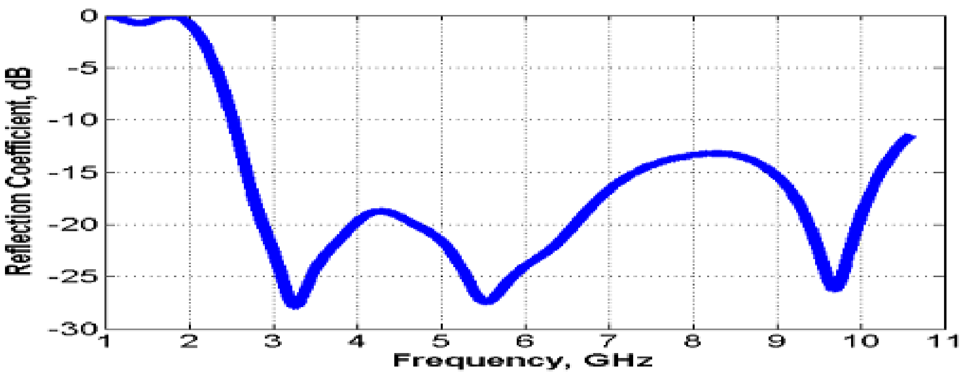

Fig. 3: *Return Loss of UWB Mode.*

When D1is ON and the total length of the stub is 5.6 mm, the antenna will be reconfigured to work in narrowband (3.7–3.9 GHz) which can be used for WIMAX applications. When D1 is on, switches D2 and D3 will control the radiation patterns of the antenna at the reconfigured frequency band.

Reconfigurable Antenna System with a Movable Ground Plane for Cognitive Radio [7]

The antenna reconfigurable is about mechanical movement of ground plane position. The radiated patch consists of regular shape patch antenna with slots on it. The substrate is Rogers Duroid 5880 (RO 5880). It has dimensions of 7 × 7 cm, a height of 0.16 cm and a dielectric constant εr= 2.2. The ground plane is fixed at one end and movable at another end depending up on the distance it moves the frequency will change as shown in Figure 4. The dedicated setup is required to make movable ground plane.

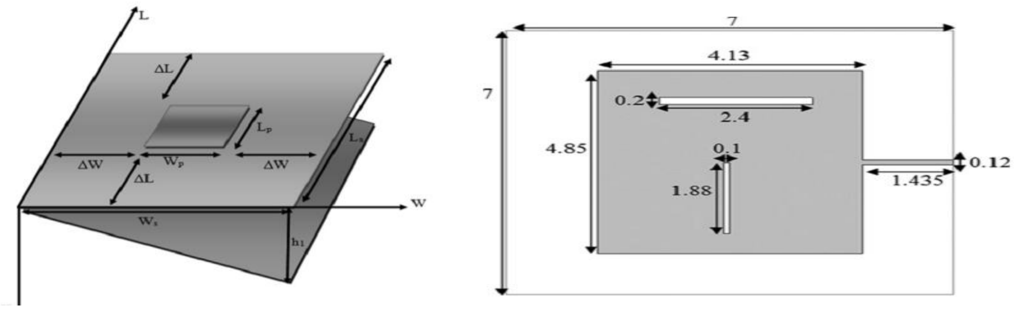

Fig. 4: *Antenna Structure a) Overview b) Radiated Patch.*

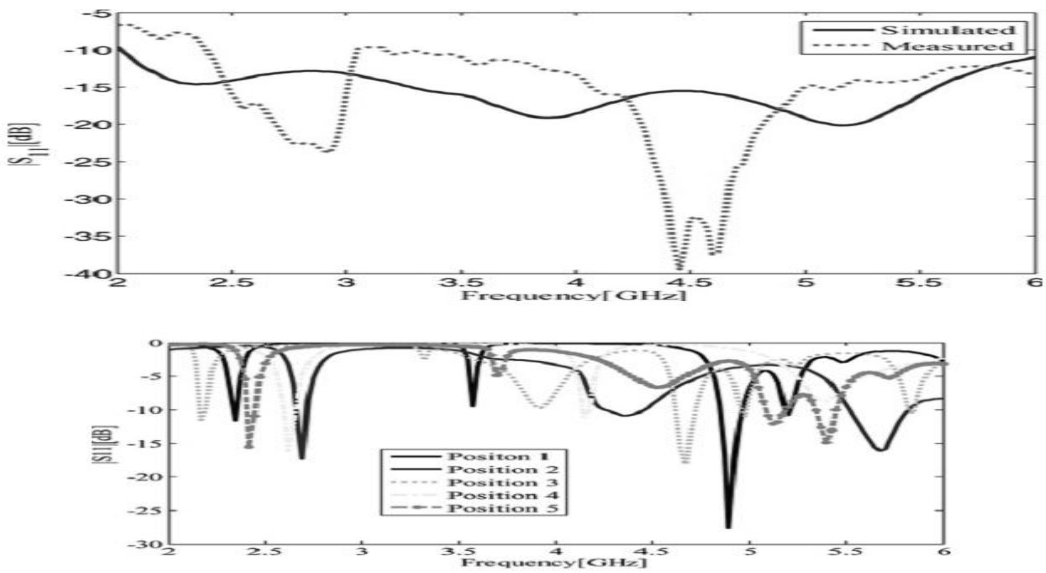

Fig. 5: *Return Loss of UWB and Narrow Band Mode.*

The UWB mode as shown in Figure 5 attain while the ground is initial position. The reconfiguration of the antenna's operation is achieved by moving the ground plane vertically or by tilting its position. The vertical movement or tilt introduces an air gap with a variable height. This changes the substrate's effective dielectric constant and transforms the antenna into a suspended microstrip antenna with variable air gap.

A MIMO Cognitive Radio Antenna System [8].

In this paper, we present an antenna system that is dedicated for a cognitive radio system. The proposed antenna is shown in Figure 6 which is a four port MIMO design. Two ports are frequency reconfigurable antenna structures dedicated to change their operating frequency based on the channel user's demand. The other two ports are a set of two sensing antennas dedicated to monitor the channel activity and provide a tool to achieve the required learning performance. The Rogers Duroid 5880 with a dielectric constant of 2.2, a thickness of 1.6 mm and a dimension of 80 mm x 70 mm is used.

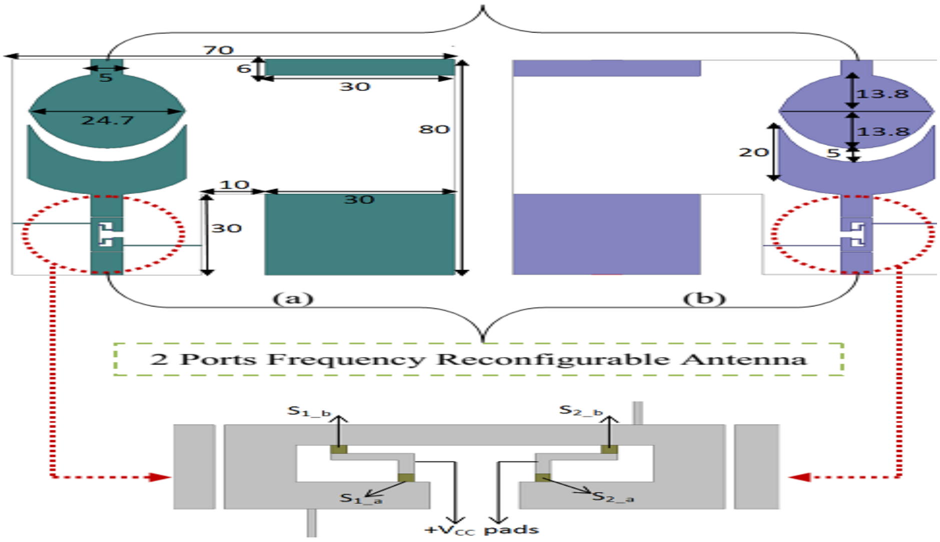

Fig. 6: *Antenna Structure.*

Moreover for each reconfigurable antenna, two sets of biasing lines connect the middle microstrip section of the filter to the antenna ground. These lines are very essential since they provide a DC ground path for the four switches. The reconfigurability is achieved by four switches with two each which is placed in feed line as shown in Figure.

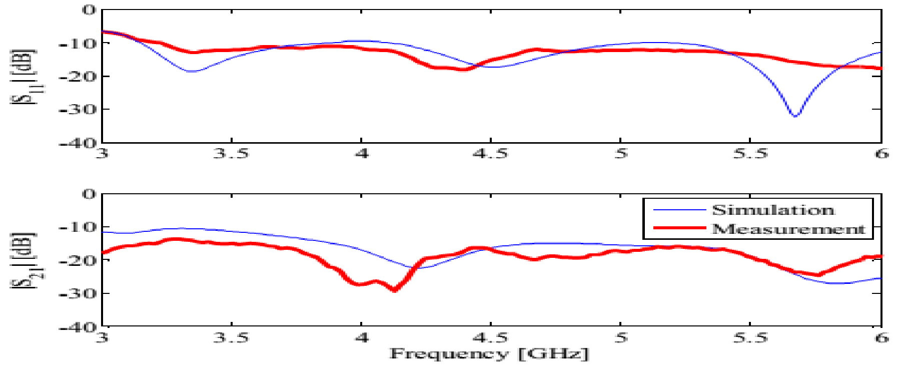

***Fig. 7:** Return Loss of UWB Mode.*

The UWB mode with two various ports can be given in above return loss graph in Figure 7.

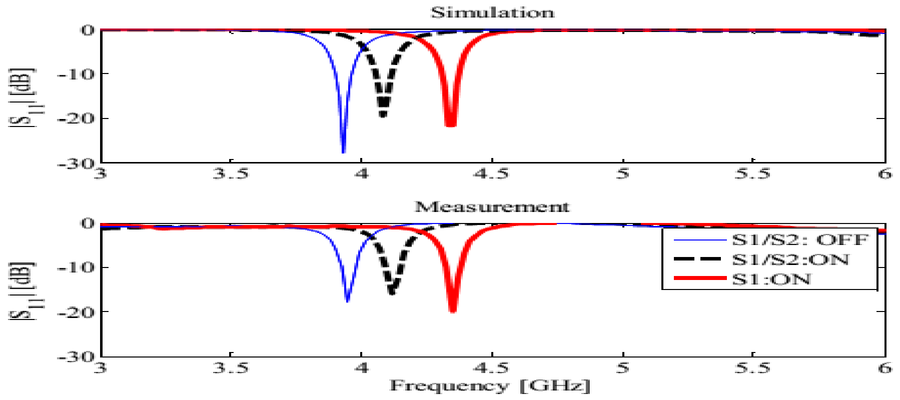

***Fig. 8:** Return Loss of Narrow Band Mode.*

The reconfigurability achieved by adjusting s1 and s2 and the return loss is shown in Figure 8. Only three possible frequency bands alone are used.

Frequency and Bandwidth Reconfigurable Monopole Antenna for Cognitive Radios [9].

In this paper, a new design of reconfigurable monopole antenna that allows controlling both the frequency and the bandwidth is presented. By incorporating four slots and a ring slot to the ground plane, the antenna can be switched between four different frequency and widths within the ultra-wideband range. To achieve switched band properties, the proposed approach consists in varying the electrical length of the slot resonators by means of switches.

The antenna design is shown in Figure 9 which is based on a 30 mm x 26 mm substrate with the material of FR4 epoxy substrate with a dielectric constant εr of 4.3 and a thickness of 1.6 mm. The four slots are used to control the antenna frequency bandwidth by varying their electrical length by means of switches. It is worthwhile to mention that the on/off states of the switches are modeled by the presence/absence of a perfect conductor.

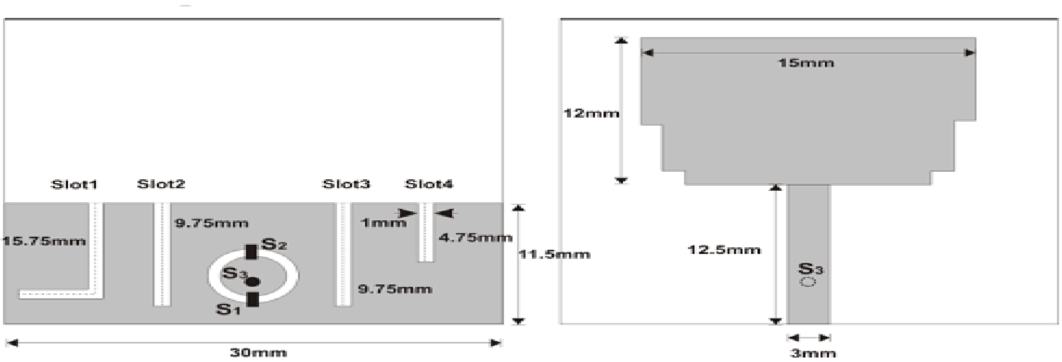

Fig. 9: *Antenna Structure a) Bottom b) Top View.*

The ring slot is used to filter out highFrequencies in the low band mode by activating the switch (S3) which connects the cylinder-shaped surface to the feed line. To disable its effect, S1 and S2 are turned on, and S3 is turned off. Four different frequency bandwidths can be switched within the ultra-wideband range. The complete reconfigurable case is given by following Figure 10.

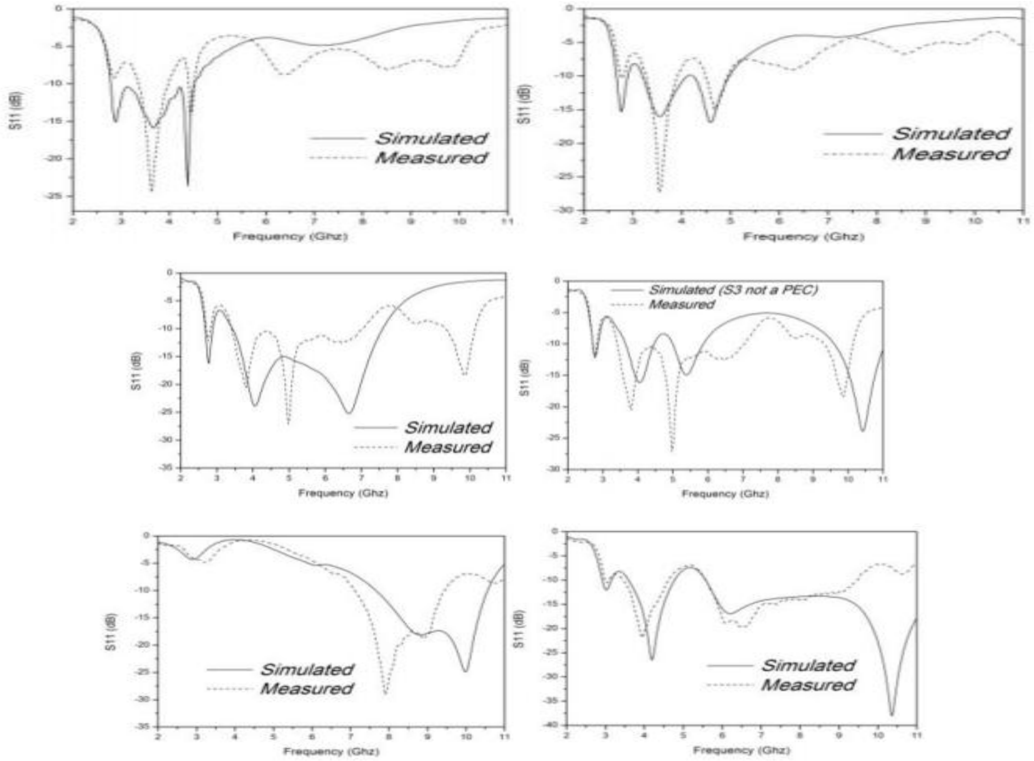

Fig. 10: *Return Loss of UWB and Narrow Band Mode.*

The Figure 10 in above graph shows the UWB mode remaing is reconfigurable mode.

Polarization Reconfigurable Ultra Wideband Antenna for Cognitive Radio Devices [10].

A novel compact planar ultra wideband monopole antenna with reconfigurable polarization capability is shown in Figure 11. By adding two rectangular slots near the edges of the patch, the antenna can be switched from linear polarization (LP) to right hand circular polarization (RHCP) or left hand circular polarization (LHCP). The frequency band at which the antenna is radiating circular polarization (CP) can also be controlled by carefully changing the lengths of the etched slots embedded in the patch using RF switches. Taconic TLC-30 substrate with a thickness of 0.88 mm, εr=3.0, and a loss tangent of 0.003.

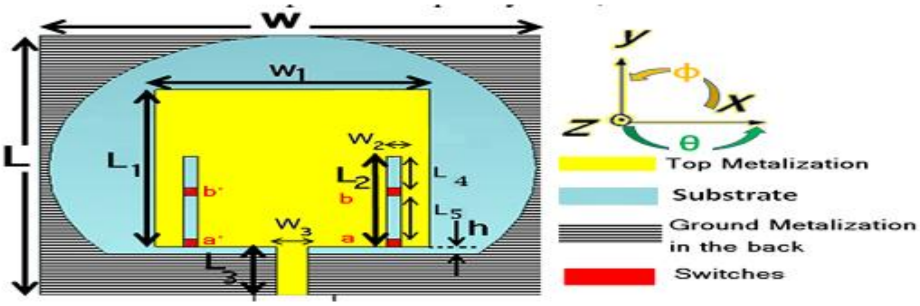

Fig. 11: *Antenna Structure.*

The RF Switches (a, b, a’, b’) used in this prototype are realized as metal pads with dimensions 1 mm × 1 mm. Although this model is ideal, it gives a good approximation for commercial PIN diode switches. When both switches (a, a’) are ON, the 2 slots are shorted and the antenna is linearly polarized and behaves like a conventional ultra-wideband monopole antenna. When switch “a” is OFF and switch “a’ ” is ON, the slot near the right edge of the patch will perturb the current by lengthening the current path in the xdirection without affecting the ydirected surface current leading to excite two near degenerate orthogonal modes with same amplitude and a -90° phase shift and hence LHCP is achieved at a specific frequency band, When switch “a’ ” is OFF and switch “a” is ON, the slot near the left edge of the patch will perturb the current and the near degenerate orthogonal modes will have the same amplitude but with +90° phase shift and hence RHCP is achieved. Switches b, b’are used to change the electrical length of the slots and hence control the frequency band on which the antenna is CP. The return loss of all three models as shown in Figure 12.

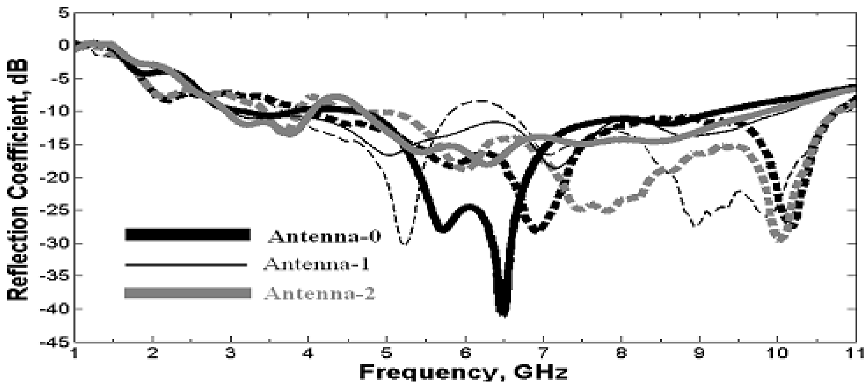

Fig. 12: Return Loss of UWB and Narrow Band Mode.

Evolution of Ultra wide-band Swastik shaped Monopole Antenna for Cognitive Radio Applications [11].

In this Paper, we present a novel Swastika shaped dotted monopole antenna evolved from a simple circular monopole antenna that is used for sensing the radio spectrum. In the same design, stubs can be connected with switches to make the antenna reconfigurable. The plane circular monopole is designed for a wide band width but with quite less gain .The same antenna with swastika slots gives better band-width with a substantial increase in gain .The performance of the design is further improved by introducing dotted slots into the Swastika structure as shown in Figure 13, with FR4 substrate used has a thickness of 1.6 mm. The length and the width of the dielectric substrate are 60x50 mm.Reconfigurability feature can be introduced in the proposed design by connecting different stubs to the monopole feed line using the switches.

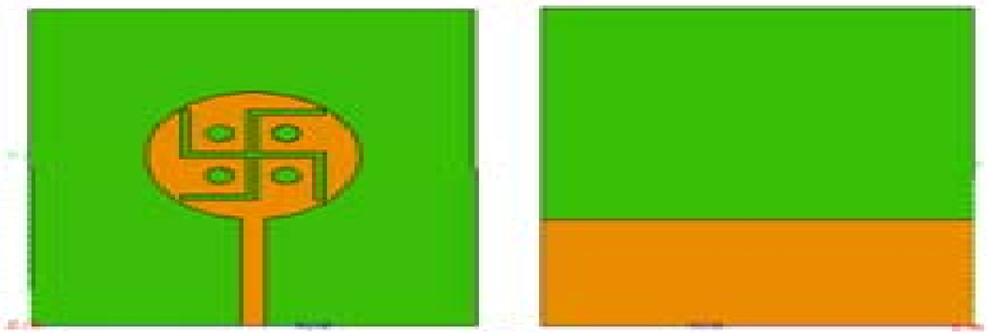

Fig. 13: Antenna Structure Both Top and Bottom View.

The proposed topology is versatile in terms of the availability of different reconfiguration bands. This design will lead to simple integration of the antenna in portable communication systems or future cognitive radio front end.The return loss of sensing antenna is shown in Figure 14.

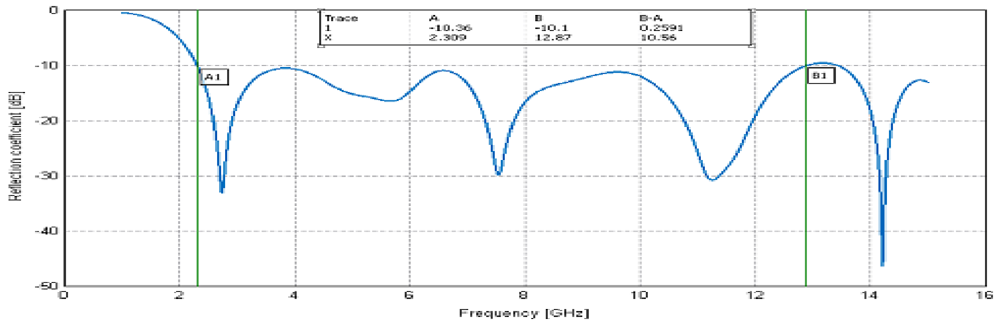

***Fig. 14:** Return Loss of UWB Mode.*

A Selective Frequency-Reconfigurable Antenna for Cognitive Radio Applications [12].

This letter presents a selective frequency-reconfigurable antenna, suitable for cognitive radio applications. The proposed antenna as shown in Figure 15 which is capable of switching between a wide operating band of 2.63–3.7 GHz and four different sub bands, which allows using it for sensing the entire band and then adjusting its bandwidth to select the suitable sub-band and pre-filter out the other ones. The antenna is composed of a radiating element in the form of an inverted U fed by a microstrip line on its upper side. In order to achieve a selective frequency reconfiguration, four horizontal slots with integrated p-i-n diode switches are incorporated in the ground plane to act as reconfigurable filter. Some of the switches are used to alter the antenna bandwidth, while the others are employed to shift the operating band by varying the electrical length of the middle slots.

The FR4-epoxy substrate with a dielectric constant of 4.3, thickness of 1.6 mm, to implement the proposed approach with real switches, some modification must be made on the antenna structure. To be able to bias the p-i-n diodes in order to turn them ON/OFF, 0.4-mm-width slots are introduced in the ground plane to separate the two ports of the switches and be able to have a voltage difference between them.

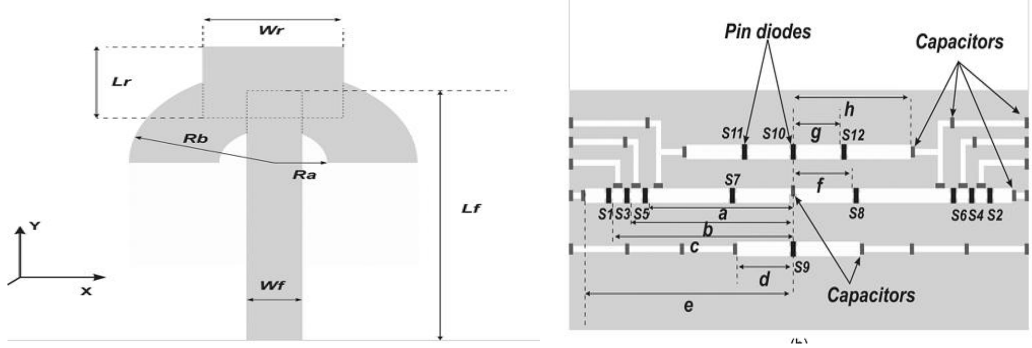

***Fig. 15:** Antenna Structure Both Top and Bottom View.*

However, to maintain a dcseparation and ensure an RF continuity of the ground plane, 100-pF surface-mount RF capacitors are used to bridge the slots, which provide almost a short circuit (less than 0.6) at the operating frequencies.The UWB and NB modes return losses are showm in Figure 16.

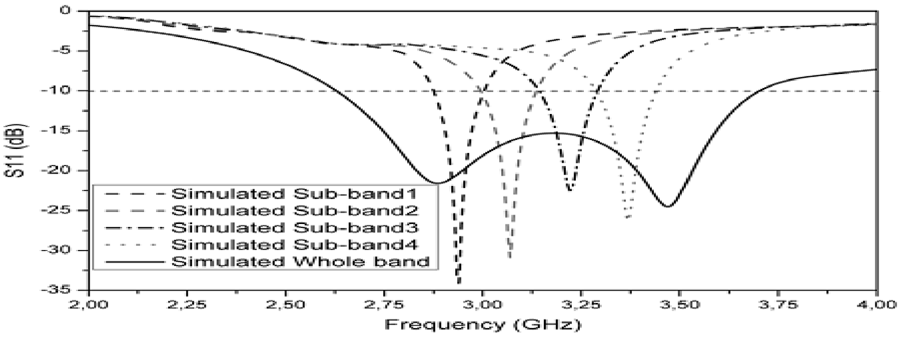

Fig. 16: *Return Loss of UWB and Narrow Band Mode.*

Electronically Reconfigurable Uni-Planar Antenna for Cognitive Radio Applications [13].

This eliminates the requirement for high degree of inter-port isolation and facilitates identical radiation patterns when operates in wide-/narrow-band mode. Furthermore, an additional tapered slot as shown in Figure 17 will enhances the cross-polar level and therefore better performance. Compared with the recent single port, reconfigurable CR antenna designs, in this work demonstrates advantages of uni-planar design along with pulse reproduction capabilities.Rogers®RO3006 high-frequency laminate with dielectric constant 6.5, loss tangent 0.002 and thickness 1.28 mm

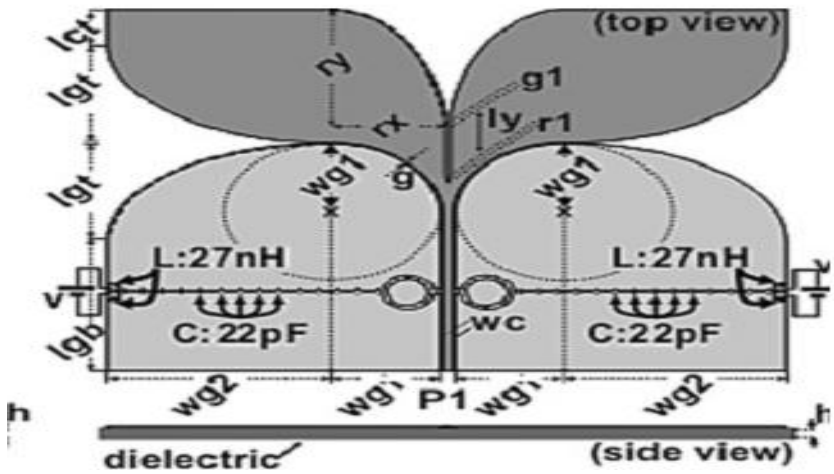

Fig. 17: *Antenna Structure.*

The unique CPW-based design of the slot resonator-based filter facilitates electronic tuning of the operating frequency, when operates in the narrow-band mode. Two interesting designs that facilitate narrow-band tuning are experimentally demonstrated in Figure. First, by activating three RF PIN diode switches placed across the slot and thereby varying the effective length of the larger resonator (l1). As shown in the inset of Figure 9(a), the bias network for this electronic tuning consists of very thin DC isolation lines of width 0.2 mm. The RF continuity across these lines is ensured by integrating 22 pF SMD capacitors across the slots in every 8 mm. The bias linesV1–V6 is isolated from the RF signal using 27 nH chip inductors.The UWB and NB modes return losses are shown in Figure 18.

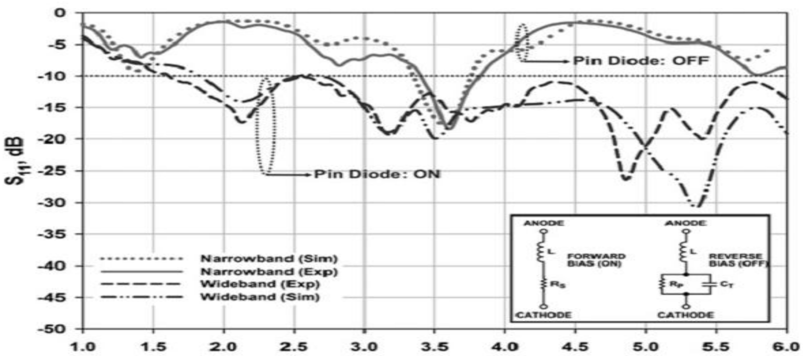

Fig. 18: Return Loss of UWB and Narrow Band Mode.

Integrated CPW -Fed UWB/Dual Narrow Band Antenna for Cognitive Radio Application [14].

This antenna was developed using CPW technique with characteristic impedance 50 ohm. Sensing antenna has three regions namely feed line, feed region and patch. The feed line is specified by parameters wgl, Igs, s, g. The feed region is elliptically tapered, specified by wgl & Iga followed by a tapered slot as shown in Figure 19. The length of elliptically curve is 1I4th of the perimeter of the ellipse specified by wg2 and Iga. The operational dual narrow band antenna has parameters w, p, h is combined to the sensing antenna. There is a resonator inserted to the narrow band antenna for whichthe antenna communicates in dual band. The proposed sensing and communication antenna are developed on a relative permittivity of 3.2 and a thickness of 0.79 mm and loss tangent 0.0025.

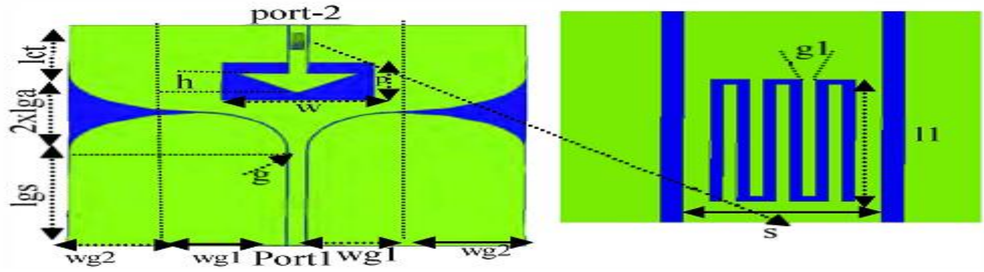

Fig. 19: *Antenna Structure.*

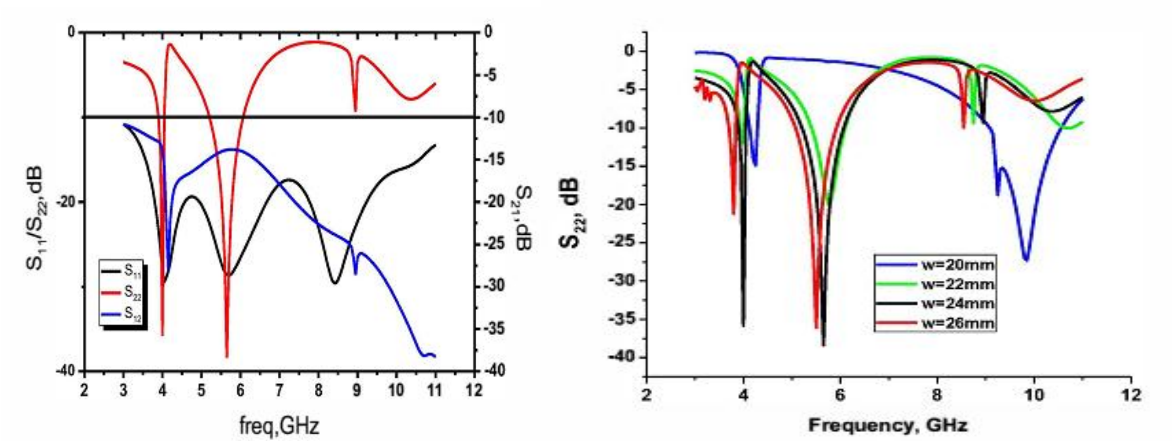

Fig. 20: *Return Loss of UWB and Narrow Band Mode.*

The UWB and various NB modesreturn losses are shown in Figure 20.

Reconfigurable Circular Ring Patch Antenna for UWB and Cognitive Radio Applications [15].

This structure has simple design and easy construction, making it reconfigurable by enabling or disabling the parasitic elements coplanar to the antenna shown in Figure 21. The FR4 epoxy, substrate is used whose relative permittivity is 4.4 and dimension as 40x40 mm^2.

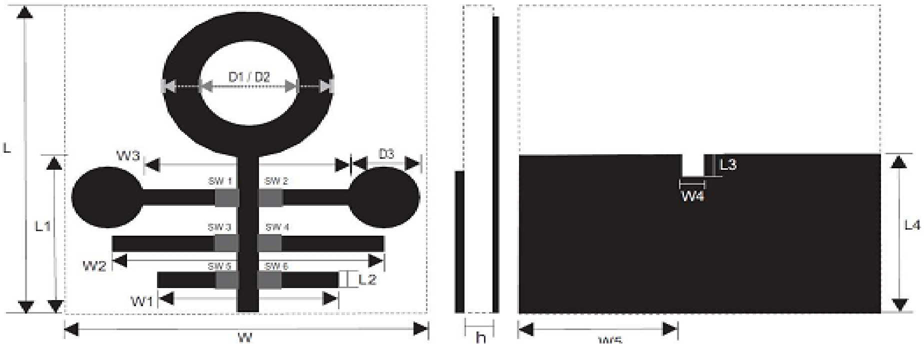

Fig. 21: *Antenna Structure Both Top and Bottom View.*

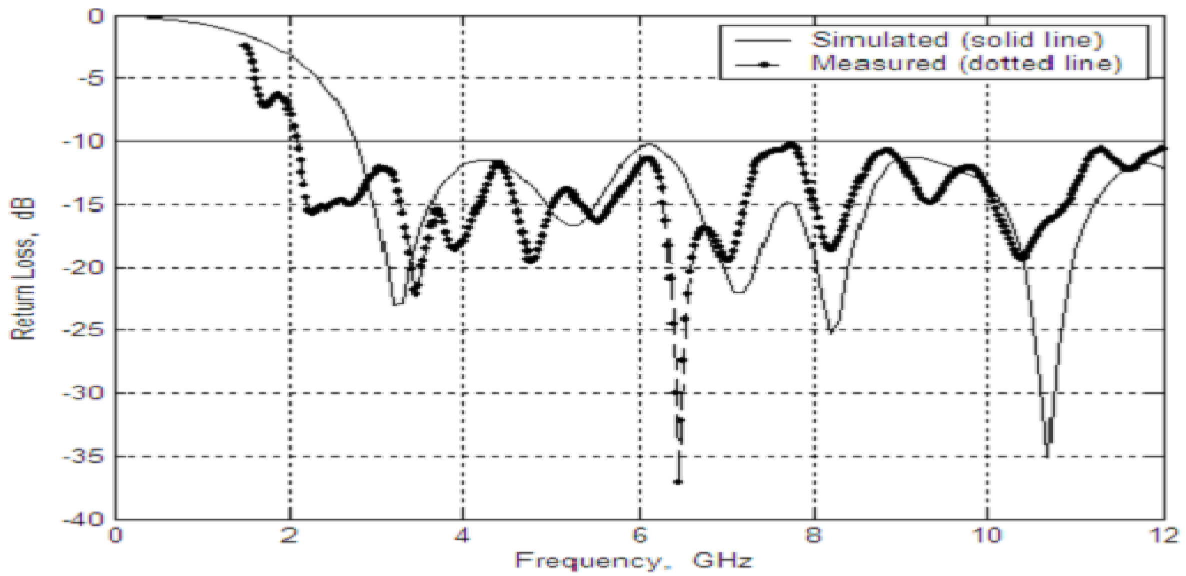

Fig. 22: *Return Loss of UWB Mode.*

The switches SW1 to SW6 have 6.84 mm² of area. Even in the presence of the parasitic elements, if no switch is activated, the antenna has typical UWB response return loss shown in Figure 22, i.e., the device can be used for UWB RF sensing in CRS. The reconfiguration of the structure can be obtained by connecting the parasitic elements arranged coplanar to the feed line of the patch antenna. These connections can be made by various techniques, e.g., active switches like PIN diodes or MEMS. To expand the bandwidth and improve matching condition, it was inserted a slit in the ground plane. The antenna feed line has a width W4 and length L1. Each one of the possible states and various combinations for the switches enable reconfigurable operation over different target frequencies such as 5.8 GHz and 7.5 GHz.

Diversity Antenna with Electronically Switchable Wide / Narrow band for Cognitive Radio Systems [16].

In Figure 23 the two ports, uni-planar design utilizes an open annular slot with orthogonal feeding mechanism to achieve polarization diversity performance across the UWB band from 2.9 GHz to 11GHz is shown. Coplanar wave guide fed electronically reconfigurable slot resonator based filters are deployed for switching between UWB and NB modes. This low profile design facilitates nearly omnidirectional radiation pattern, low envelop correlation coefficient and moderate gain.

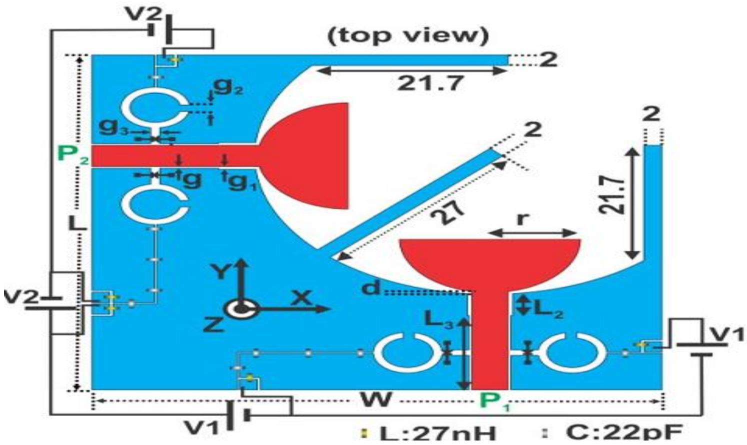

Fig. 23: *Antenna Structure.*

The substrate material used as Rogers RT/Duroid 6035HTC high-frequency laminate with permittivity 3.6, loss tangent 0.0013, and thickness (h) = 1.52 mm.

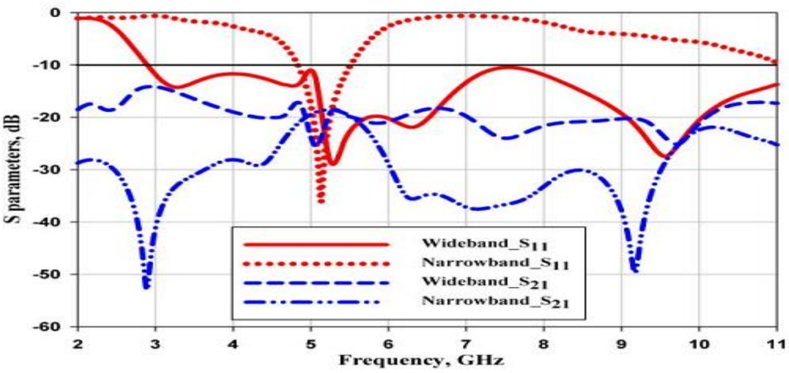

Fig. 24: *Return Loss of UWB and Narrow Band Mode.*

In this design only one wide band and narrow band is obtained as shown in Figure 24.

A Three-Resolution UWB Frequency Reconfigurable Antipodal Vivaldi Antenna for Cognitive Radios [17].

In this paper, a frequency reconfigurable Antipodal Vivaldi antenna is shown in Figure 25 capable of covering a wide frequency band (2.2 to 11 GHz) with three different resolutions is presented. By incorporating four low Q resonators only, the proposed antenna is able to cover the whole band of interest in one (UWB mode), three (3-sub mode) or seven (7-sub mode) sub-bands, giving a multi-resolution UWB antenna. The 3-sub mode is obtained by activating one resonator at a time while the 7-sub mode involves two resonators at a time. The switching between the different bands of a mode is achieved by selecting the proper resonators and controlling their length.

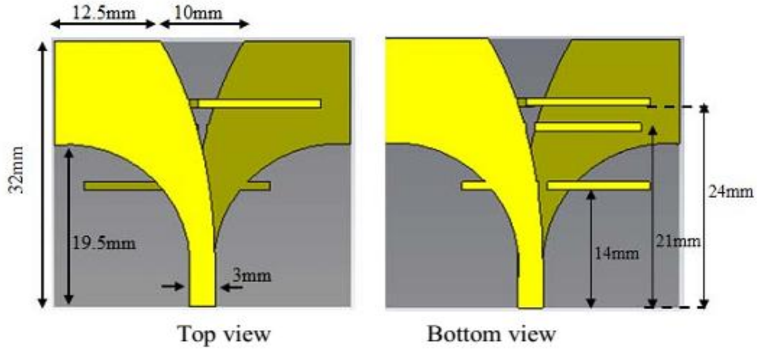

Fig. 25: *Antenna Structure.*

The antenna is printed on a 32x35 mm FR4 substrate with a dielectric constant of 4.3 and a height of 1.6 mm.To increase the frequency selectivity of the antenna and operates it in the 7-sub mode; two resonators are simultaneously activated, this time, which allows covering the considered wide band with seven sub-bands.

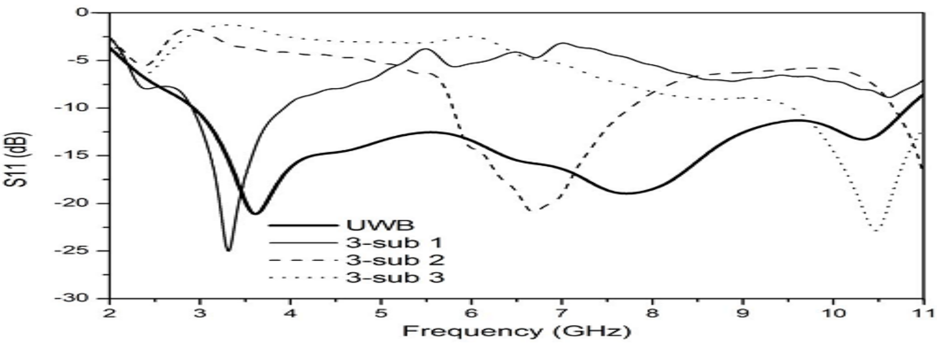

Fig. 26: *Return Loss of UWB and Narrow Band Mode.*

In Figure 26, the return loss graph only three sub bands are shown with UWB mode.

A Novel Optically Controlled Reconfigurable Antenna for Cognitive Radio Systems[18].

In Figure 27, we present an optically controlled reconfigurable antenna with a compact structure of wide and narrow band integration. Photoconductive silicon chips were employed as the switching elements. This type of optical switch does not need additional biasing lines, with the advantages of less electromagnetic influence on antenna radiation, and high frequency transition speed. This design printed on an FR4 substrate with relative permittivity of 4.4, loss tangent tanδ=0.02, thickness h=0.5 mm, and dimension of 40×38.5 mm^2.

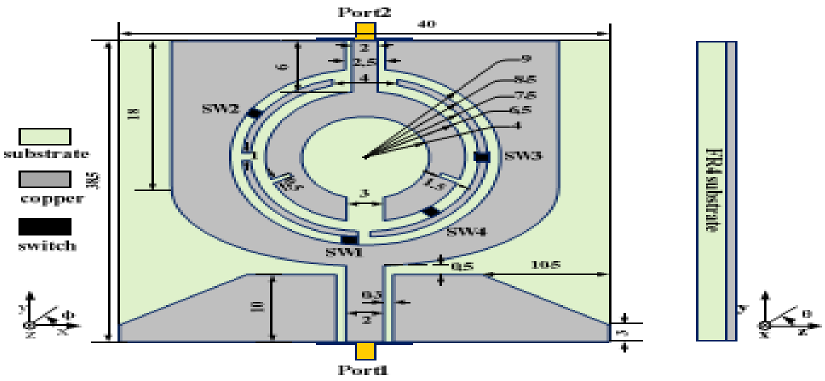

Fig. 27: *Antenna Structure.*

To achieve frequency reconfigurable characteristics, four 1×1×0.4 mm^3photoconductive switches (i.e. SW1-SW4), shown with small dark blocks in the Figure, are set in the gaps of the proposed antenna. When light illuminates one of switches, it is turned ON and behaves as a short-circuiting conductor. If there is no light beam, the switch is turned OFF and acts as an insulator. The structure or ground of the inner antenna can be changed by combining the different slender ring parts and optically controlled switches states, making different current paths in essence, so as to realize four operating frequencies. When only SW2 and SW4 are ON (case 1), the bandwidth of the narrowband antenna is between 5.8 and 6.8 GHz. Once SW3 and SW4 are ON (case 2), the antenna shifts its operating band to 6.7–7.3 GHz. When only SW1 is activated (case 3), 7.0–8.4 GHz band is covered. In case 4, only SW2 is illuminated, 7.9–9.2 GHz band is achieved.

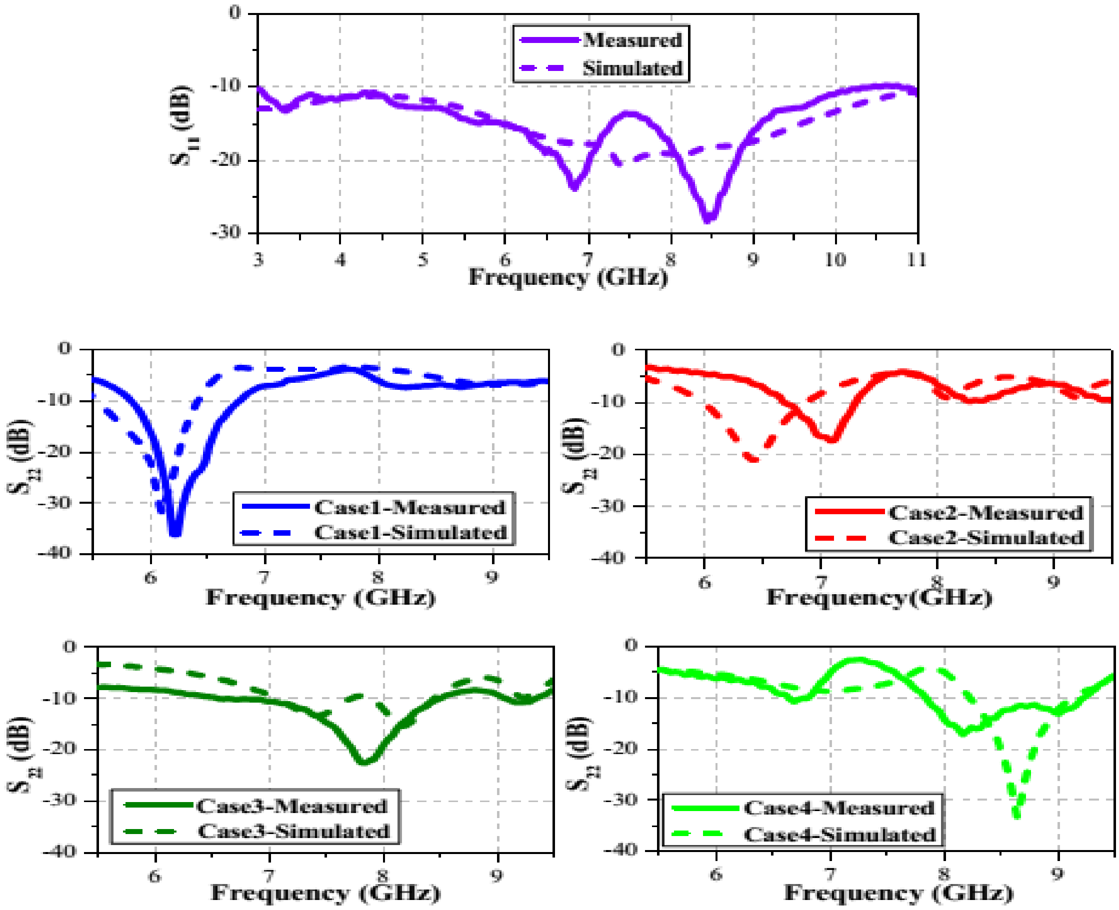

Fig. 28: *Return Loss of UWB and Narrow Band Mode.*

The UWB and various NB modesreturn losses are shown in Figure 28.

Unidirectional Antenna for Cognitive Radio Applications[19].

In this paper, a new band-reconfigurable antenna is proposed by utilizing ME dipole technology. The antenna is composed of a wideband ME dipole and a frequencyreconfigurable narrowband dipole. The Substrate with εr = 2.33 and thickness is 0.787 mm. One wideband mode and four narrowband modes can be achieved by controlling the states of the PIN diode switches. Stable unidirectional radiation patterns can be obtained for all the modes. The antenna structure is shown in Figure 29.

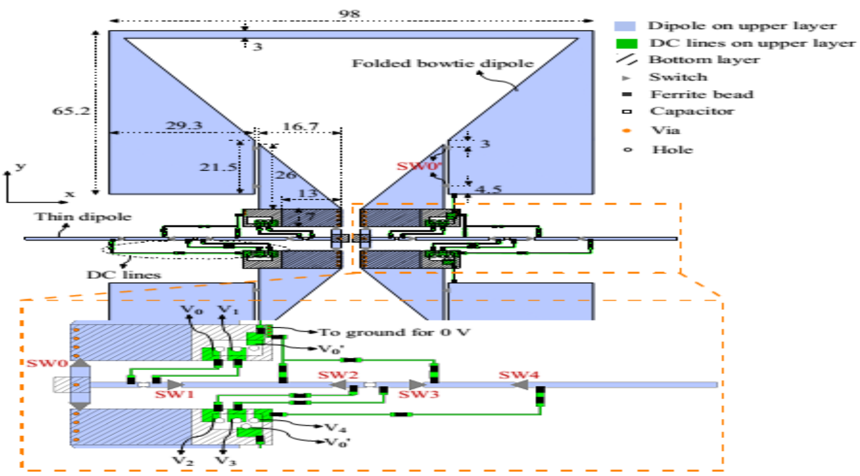

Fig. 29: Antenna Structure.

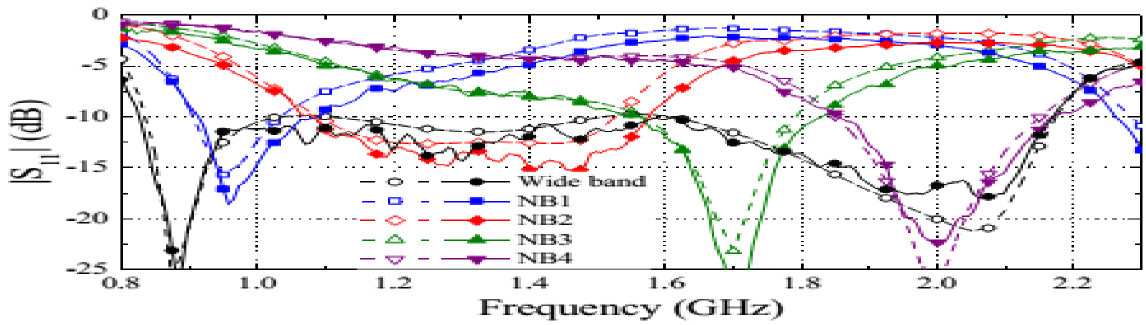

Fig. 30: Return Loss of UWB and Narrow Band Mode.

The UWB and various NB modesreturn losses are shown in Figure 30.

PROPOSED DESIGN

In this paper, a cognitive radio antenna integrated with DMS BSFhas been investigated.The reconfigurable functions are obtained usingthree ideal switchesonDMS-BSF is used. The substrate is made of Fr-4 with the dimension of 32x30 mm^2.The design is very simple as shown in Figure 31. The existing system contains various antennas with different switching modes with less efficient. The prosed antenna prototype is given below.

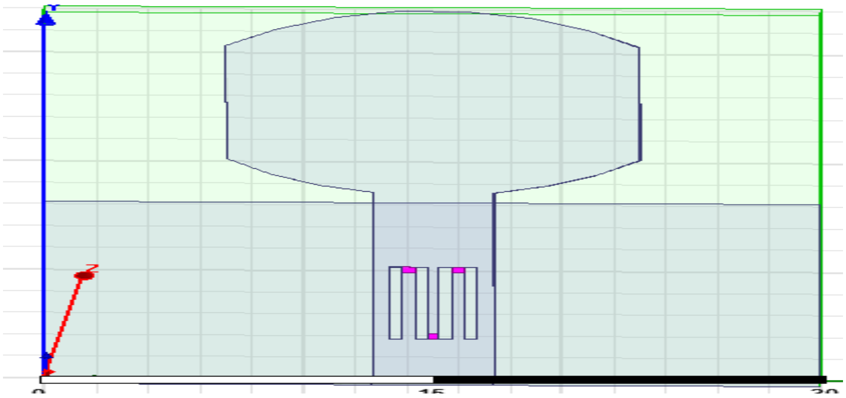

Fig. 31: *Antenna Structure.*

The design is based on DMS with BSF. In reconfigurable mode only three switches are used. By adjusting the switch ON/OFF then eight narrowband notches are obtained with higher bandwidth. In previous design the EMI problems are not addressed but in current design the EMI emission is avoided by defected microstrip design. The wideband antenna has a bandwidth of 8GHz and narrow band is achieved very easily by ideal switches.The return loss of UWB (sensing antenna) is shown in Figure 32.

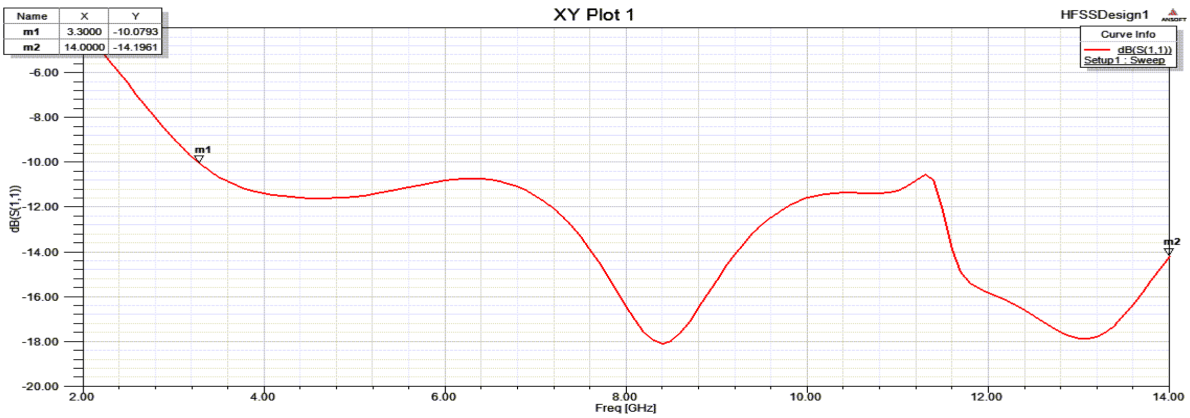

Fig. 32: *Return Loss of UWB Mode.*

Table 1: *Comparison with Existing Designs.*

Paper	Dimension(mm^3)	Material Used(ε_r)	UWB	NB	Switches	Complexity	Remark
	34×31×0.88	Taconic TLC-30$^\#$(3)	2.5-10	-	Diode	High	Material not available commercially , very complex design
	70 × 70x1.6	Rogers Duroid 5880 (2.2)	2-6	5	Ground Plane Move	Very High	Mechanical movement is required
	80 x 70 x1.6	Rogers Duroid 5880(2.2)	3-6	3	Ideal	Moderate	Two ports
	30 x 26 x1.6	FR4 epoxy(4.3)	3-10	5	Ideal	Low	EMI problem
	34x35x0.88	Taconic TLC-30$^\#$ (3)	-	-	RF switches	Low	Material not available commercially
	60x50x1.6	FR4 epoxy(4.4)	2.3-12.8	-	-	High	Feeding line changes
	51x68x1.6	FR4 epoxy(4.3)	2.6-3.7	4	PIN Diode	Very High	Many switches so high biasing voltage required
	128x128x1.28	Rogers®RO3006$^\#$ (6.5)	2-6	1	RF PIN Diode	Very High	Biasing voltage required
	60x75x0.79	Rogers 6010$^\#$ (3.2)	3-11	1	Length Change	High	Two ports
	40x40x1.6	FR4 epoxy(4.4)	2-12	2	Ideal	Very High	More switches required
	63x63x1.52	Rogers RT/Duroid 6035HTC$^\#$ (3.6)	2-11	1	Ideal	Very High	Complex design
	32x35x1.6	FR4 epoxy(4.3)	3-11	3	PIN Diode	High	Complex design
	40×38.5x0.5	FR4 epoxy(4.4)	3-11	4	Ideal	Moderate	Two ports
	65.2x98x0.787	RT/duroid 5870$^\#$	0.9-2	4	Ideal	Very High	Very

		(2.33)					Complex design
Proposed	32x30x1.6	FR4 epoxy(4.4)	3-14	7	Ideal	Very Low	EMI immunity considered

CONCLUSION

In this comparison various recently published (2014) IEEE and IET journal papers are analyzed completely with proposed design. The comparative result given in the following table with the parameter of antenna dimension, material used, UWB and narrow band characteristics, switching type and complexity analysis. The complexity analysis is investigated by considering simulation, fabrication and design issues. In session II the various antenna designs with corresponding output are given. In session III the proposed design are given. According to the existing design the proposed design has very small, simple structure, a compact and very easy switchable case which is obtained from Table 1. It achieved more switchable cases by using only three ideal switches without any external biasing voltage. In this design one port is used so isolation between ports not creating any issues. Mainly all other design not considering DMS so EMI immunity is poor but in proposed design EMI immunity is very small.

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