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SINGLE PORT SENSING AND COMMUNICATING ANTENNA FOR COGNITIVE RADIO APPLICATIONS

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Abstract

This paper presents a single antenna structure design to switch between UWB and four narrow band frequencies. The antenna consists of rectangular patch with curved shape on one side and switchable band pass structure on other side. Proposed antenna is very much suitable for cognitive radio applications. Antenna operates in five states. One state of antenna is operates in wide band which is used for channel sensing and remaining four states operates in narrow band frequency which is used to communicate over a desired frequency band. Its performance evaluation is carried out with the help of simulation and physical verification and the results are presented.

Keywords:

UWB, Band Pass, Cognitive, Sensing, Narrowband

1. INTRODUCTION

Cognitive Radio is a wireless transponder that can sense the environment in which it wishes to operate and can adapt itself to optimize its operation [1]. In a CR, the intelligent radio part allows unlicensed users (secondary users) to access spectrum bands licensed to primary users, while avoiding interference with them. One approach to this spectrum sharing between primary and secondary users is spectrum overlay. In spectrum overlay CR, secondary users search for unused frequency bands, called white spaces, and use them to communicate.

Thus RF front end of Cognitive Radio requires a sensing antenna to monitor the spectrum and a communication antenna that can be reconfigured to communicate over a chosen frequency band.

Most of frequency-reconfigurable antennas are only capable of switching between different narrowband modes [2]-[4]. In [2], a switchable quad-band antenna by using MEMS switches has been proposed. By controlling the states of switches, the patch antenna in [3] can operate in four different frequencies. Recently some research has been done related to the design of antennas for cognitive radio applications. In [5], a combination of wideband and narrowband antennas into the same volume with dual port is presented. The wideband antenna is designed using hourglass-shaped monopole that operates from 3 to 11GHz. The narrowband antenna is a microstrip patch printed on the reverse side of the substrate, and connected to the wideband antenna via a shorting pin and designed to operate from 5.15 to 5.35GHz. In [6], a frequency reconfigurable antenna to cover either the 3-5GHz or the 5-8GHz bands is designed.

In [7], [8], the system combines wideband and narrowband antennas into the same volume and printed on Taconic TLY substrate. The antenna is basically UWB, which makes it sensing capable, and has a reconfigurable band pass filter embedded in its feed line [7] and in the ground plane [8].

The main objective of this paper is to design a single antenna structure which can be reconfigured to act as a wideband sensing antenna and narrowband communication antenna for cognitive radio applications. In the proposed antenna band pass filter structure with small notch is printed in ground plane below the feed line. Impedance matching is improved by placing small notch in the ground plane. The proposed antenna has more compact in size, better return loss characteristics and different frequency bands as compared to antennas reported in [7] and [8].

The configuration and the design concept of the antenna are described in section 2. The simulated and measured return loss results and radiation pattern results of the single port sensing and communicating antenna are presented in section 3. Finally, a conclusion is presented in section 4 followed by references.

2. ANTENNA DESIGN

The design of the antenna divided into two parts as wide band and narrowband antenna. Wideband antenna is for sensing application and narrowband is for communicating applications. These two antennas are essential for any cognitive radio applications.

2.1 ANTENNA CONFIGURATION

The configuration of antenna is shown in Fig.1. To obtain the ultra-wide band with good return loss characteristics, rectangular patch with curved shape structure is proposed. Curved shape is introduced between rectangular patch and 50 ohms feed line for good matching. The dimensions of the radiating patch are 20×12.6mm and radius of the curve is 14.7mm. Micro strip feed with the size of 5×15.3mm is used to feed the radiating patch. The proposed antenna is printed on top side of FR4 substrate of dielectric constant 4.2 with dimensions of 30×35mm and thickness 1.6mm which is compact in size as compared to antenna (40×40mm) reported in [7]. The partial ground plane with size 30×14mm is printed on the bottom side of the substrate below the micro strip feed line is shown in Fig.2.

2.2 BAND PASS FILTER DESIGN

In order to achieve the band pass characteristics the slotted structure is placed on the ground plane to eliminate undesired frequency bands and allow the desired frequency bands as shown in Fig.2. On the other hand, the embedded slot below feed line causes stop bands in the UWB range and leaves a pass band between them [9]. The introduction of the slots results in impedance mismatch at the antenna and the decrease of the operating bandwidth as the antenna become more capacitive. Hence the slots in the ground plane act as a band pass filter to the wideband antenna.

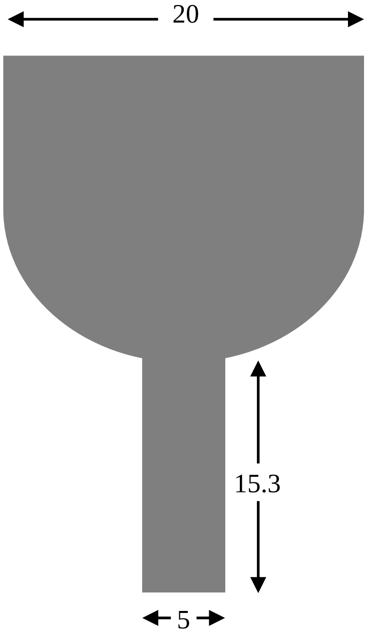

Fig.1. Geometry of single port sensing and communicating antenna (top view) (dimensions are in mm)

Theoretical procedure for design of band pass filter is explained as follows, slot on the microstrip is called defected microstrip structure (DMS). Two *T* shaped slots are connected in cascade as shown in Fig.2 and parametric analysis is done using HFSS simulation software. Defect on the circuit can create resonance characteristics in the frequency response. The resonance effect is due to the abrupt change of the current path. It is observed from parametric analysis that there is a capacitive effect due to width (*G*) of the vertical slots and an inductive effect due to current rotation around T shaped sections. Circuit model is obtained by tracking the path of the current. The equivalent circuit model for two *T* shaped slots shown in Fig.3. The circuit parameters for the derived equivalent circuit can be extracted from the simulation result [10-12]. Filter is tuned by adjusting critical dimensions *A*, *D* and *G* of proposed filter. Inductance of equivalent circuit changes by adjusting the dimensions of *A* and *D*, and by varying the dimension of *G*, capacitance of the circuit is changed.

$$C = \frac{f_c}{200\pi\left(f_0^2 - f_c^2\right)} \tag{1}$$

$$L = \frac{1}{4\pi^2 f_0^2 C} \tag{2}$$

where,

f_0 - Resonance frequency

f_c - Cut-off frequency

By using the above concepts, the final design of proposed band pass structure is shown in Fig.4. By changing the length of the slot the band pass frequencies can be changed. The slot length is varied by electronic switches placed at different positions along the length of the slot.

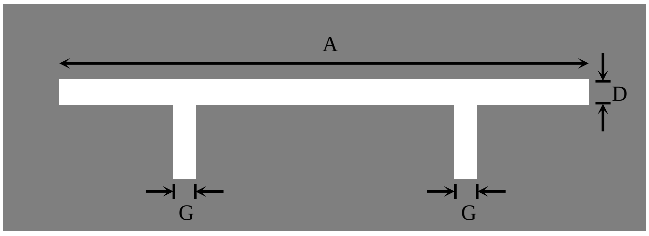

Fig.2. Bandpass filter

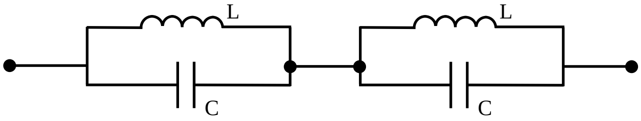

Fig.3. Equivalent circuit model for two T shaped slots

The proposed antenna pass band characteristics completely depend on shape and length of the main slot. Bandwidth of each pass band is controlled by length of the parallel vertical arms. Switches are integrated at proper positions on the main slot and frequency reconfigurability is achieved by controlling those switching states. Location of the switches is fixed after simulation by trial and error method to obtain desired frequency bands.

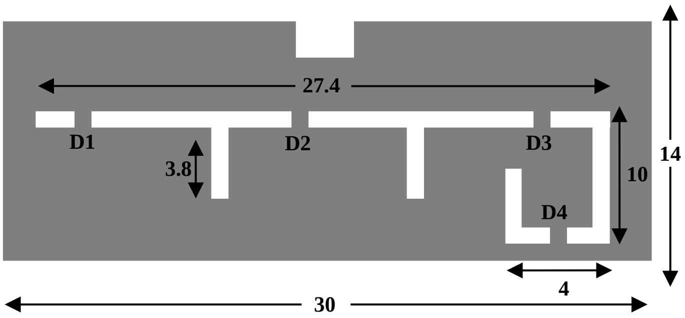

Fig.4. Geometry of single port sensing and communicating antenna (bottom view) (dimensions are in mm)

3. SIMULATED AND EXPERIMENTAL RESULTS

The Single port Sensing and Communicating Antenna is simulated using HFSS [13]. The Simulation involves different cases which depend upon the states of the switches *D*1 to *D*4. In the simulation, the switches are modeled by choosing the capacitance of 0.25pF for OFF state and 1.5 ohm resistances for ON state. The different cases are shown in Table.1.

Since four switches are used here, there are sixteen possible states of the switches. The only five states are reported and the results corresponding to non-useful bands are not presented here.

3.1 RETURN LOSS MEASUREMENT

The return loss characteristics are shown in Fig.5 and it shows that when all the switches are turned on the proposed structure gives a wideband frequency response from 1.99 to 9.89GHz. Return loss characteristics are obtained less than -15dB for entire frequency band and better impedance matching is achieved over the entire frequency band as compared to antenna reported in [7] and [8]. The wideband response is essential for sensing antenna. Hence case 1 gives a sensing antenna.

The return loss characteristics are shown in Fig.7-Fig.10 for cases 2-5 and it is evident that by controlling the switching states, the antenna is tuning at different resonating frequencies and gives narrowband frequency response. The antenna is resonating at single frequency for the switching case 2, 3 and 4 where as for the switching case 5 (all OFF), antenna operate at dual frequency. It is observed that using band pass filter in the ground plane wideband frequency response (sensing antenna) is converted into narrowband frequency response (communicating antenna).

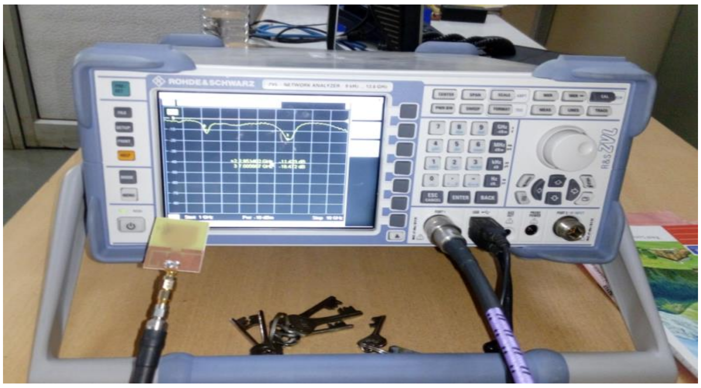

Fig.5. Measurement setup of fabricated antenna.

The simulated antenna is fabricated on FR4 substrate and return loss characteristics are verified using vector network analyzer. The measurement set up of fabricated antenna is shown in Fig.5. In the fabrication, the copper strip has been placed to represent switching device. The presence of the copper strip represents the switch is at ON state, while the absence of the copper strip represents the switch is at OFF state. Return loss characteristics for the case 2 are shown in Fig.7 and shows that when the switches 1 and 3 are ON and 2 and 4 are OFF, the antenna is resonating at 2.45GHz with return loss of -25dB and impedance bandwidth of 430MHz is obtained i.e. 2.3-2.72GHz. The simulated and measured return loss characteristics are very much comparable and shown in Fig.7-Fig.10. They show that good impedance matching with less than -25dB return loss at centre frequency and bandwidth of about 400MHz is obtained for all switching cases reported in Table.1.

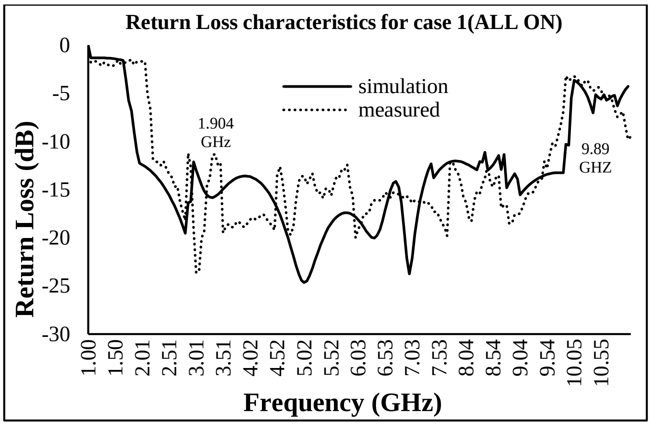

Fig.6. Simulated measured return loss characteristics

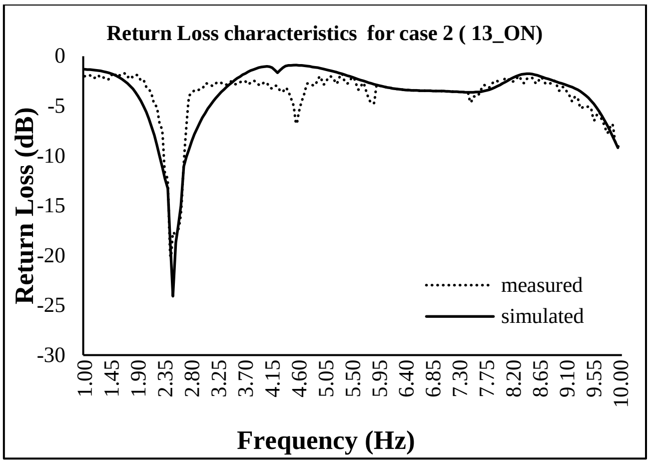

Fig.7. Simulated and measured return loss characteristics for case 2

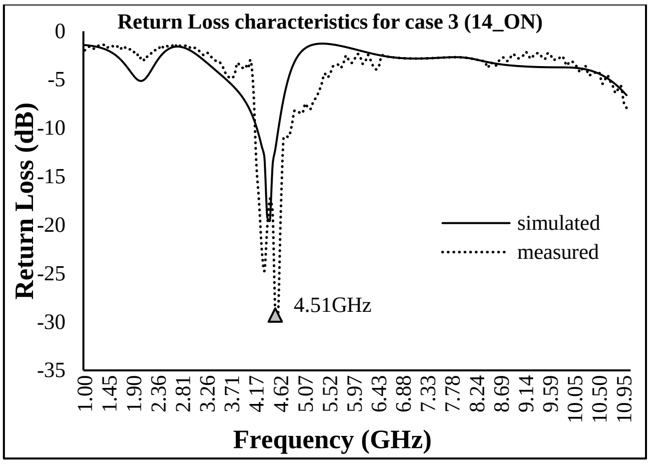

Fig.8. Simulated and measured return loss characteristics for case 3

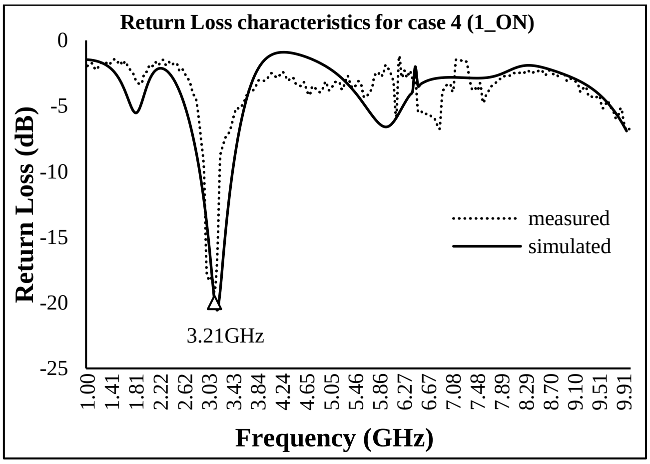

Fig.9. Simulated and measured return loss characteristics for case 4

The detailed frequency band and centre frequency for each state of switches are given in Table.1. The frequency bands achieved for case1, 2 and 5 are very much suitable for applications like UWB (3.1GHz-10.6GHz), Wi MAX (2.3GHz-2.4GHz, 2.5GHz-2.7GHz) and Wi-Fi (3.1GHz-3.3GHz)

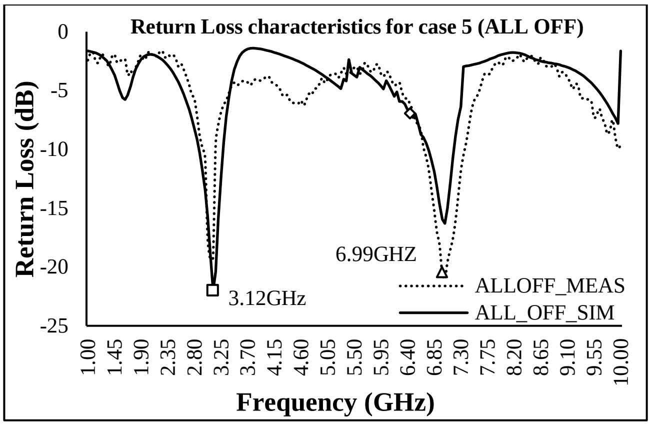

Fig.10. Simulated and measured return loss characteristics for case 5

Table.1. Cases representing States of switches

Case No.	D1	D2	D3	D4	Frequency band/centre frequency (GHz)	Application
1	ON	ON	ON	ON	1.99-9.89	UWB (sensing antenna)
2	ON	OFF	ON	OFF	2.3-2.73 /2.49	Wi MAX (communicating antenna)
3	ON	OFF	OFF	ON	4.21-4.67 /4.4	Narrow band (communicating antenna for cognitive radio)
4	ON	OFF	OFF	OFF	3.11-3.46/3.21	Narrow band (communicating antenna for cognitive radio)
5	OFF	OFF	OFF	OFF	2.9-3.4/3.12 and 6.72-7.34	Wi-Fi (communicating antenna)

3.2 RADIATION PATTERN MEASUREMENT

Radiation pattern measurement was carried out in anechoic chamber is shown in Fig.11. The simulated and measured radiation patterns of the single port sensing and communicating antenna for all switching states are compared and illustrated in Fig.12. Good agreement between simulated and measured results has been observed. The peak gain of 2dBi is obtained at all centre frequencies of switching states. Radiation pattern is stable for each switching state and is essential for any frequency reconfigurable antenna.

The simulated peak gain and the radiation efficiency of the proposed antenna over the UWB frequency band are shown in Fig.13 and Fig.14. The average maximum gain in the entire frequency band is above 3dB and the gain is almost flat with less than 2dB variation over the frequency band. The efficiency is above 75% over entire frequency band and is smoothly decays against frequency due to dielectric losses at high frequencies.

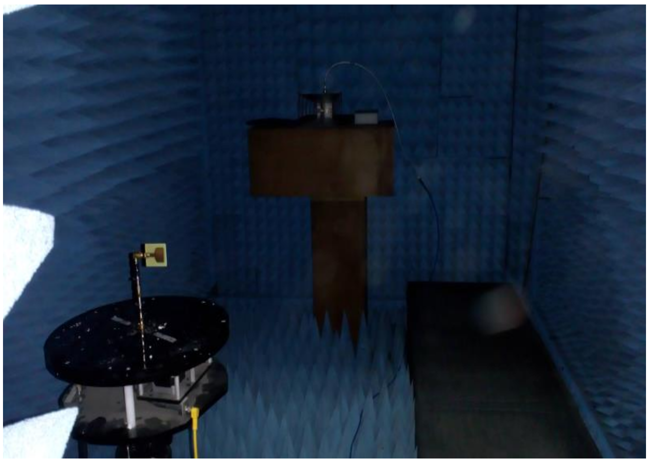

Fig.11. Radiation pattern measurement setup of fabricated antenna (anechoic chamber)

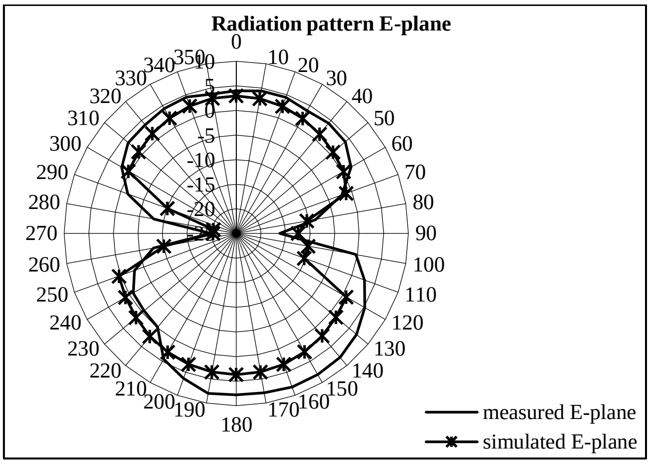

Fig.12(a). Radiation pattern of the single port sensing and communicating antenna for case 1

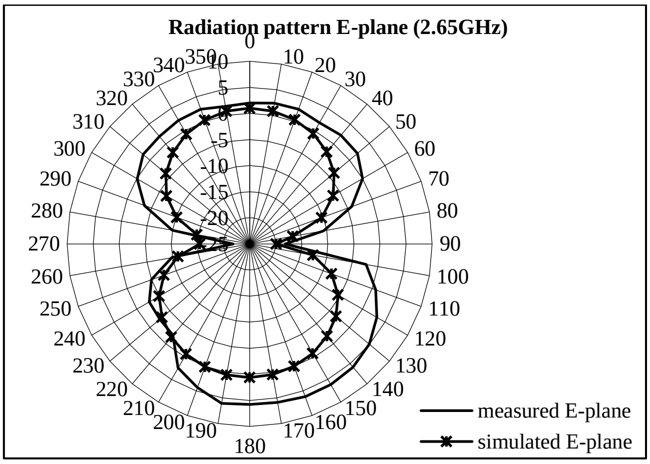

Fig.12(b). Radiation pattern of the single port sensing and communicating antenna for case 2 (2.65GHz)

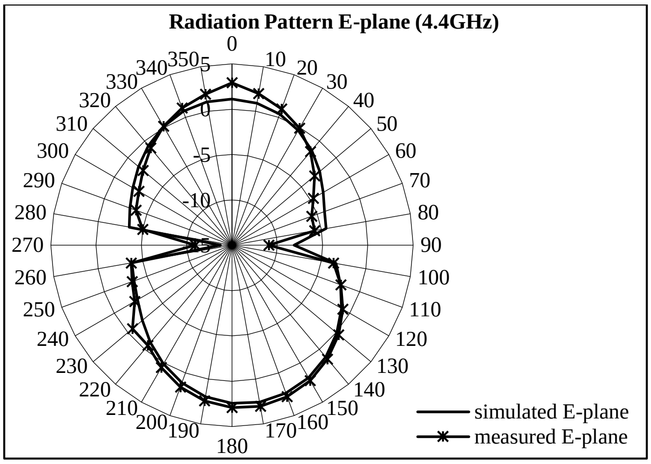

Fig.12(c). Radiation pattern of the single port sensing and communicating antenna for case 3 (4.4GHz)

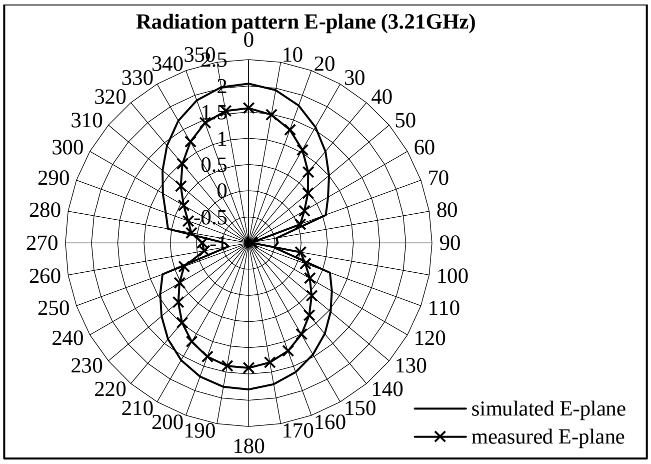

Fig.12(d). Radiation pattern of the single port sensing and communicating antenna for case 4 (3.21GHz)

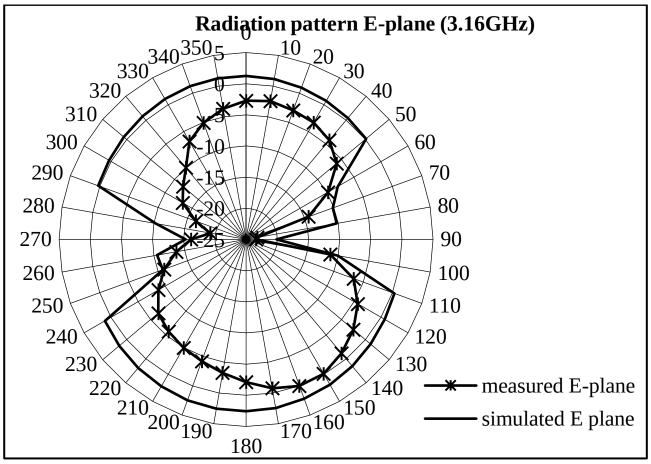

Fig.12(e). Radiation pattern of the single port sensing and communicating antenna for case 5 (3.26GHz)

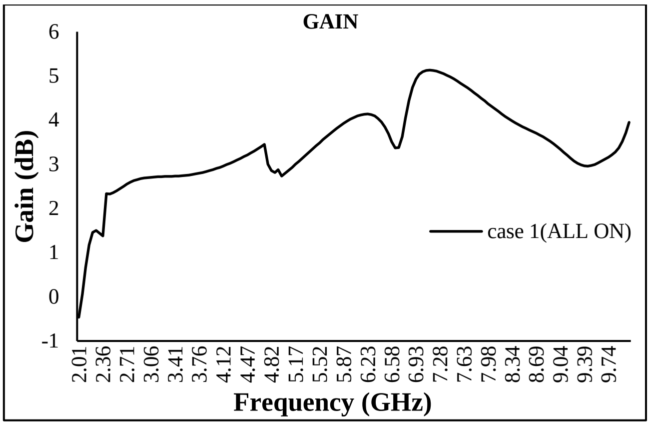

Fig.13. Peak gain of the single port sensing and communicating antenna for case 1 (UWB)

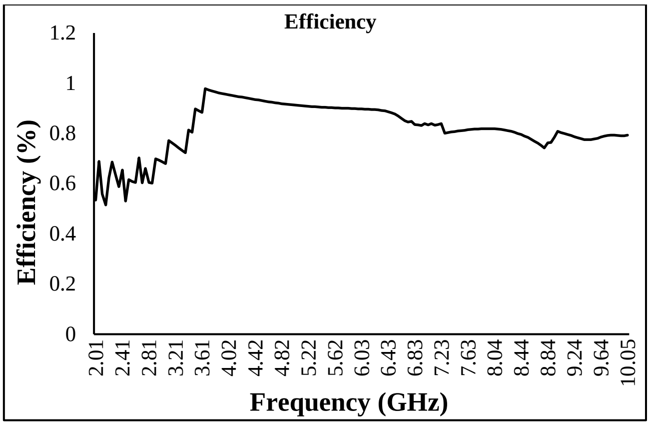

Fig.14. Radiation efficiency of the single port sensing and communicating antenna for case 1 (UWB)

4. CONCLUSION

Single antenna structure to switch between wideband (sensing) and narrow band (communicating) for cognitive radio applications was presented. The slotted structured with switches is introduced on the ground plane to obtain frequency reconfigurability. A good return loss value (<-25dB) and gain 2dB is obtained in all switching states of the antenna. Efficiency of the antenna is more than 80% obtained for entire frequency range in UWB case. The proposed antenna is suitable for the Wi-Fi and Wi MAX wireless applications. Very good agreement is achieved between measured and simulation results.

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