Frequency Reconfigurable Microstrip Antenna for Cognitive Radio Applications

Nishant kumar, P. Ananda Raju, Santanu Kumar Behera, *Senior Member IEEE*

***Abstract*— This paper presents a selective frequency reconfigurable antenna, suitable for cognitive radio applications. Reconfigurability is achieved by inserting PIN diode switches in DMS(defected microstrip structure) 'T' slot filter. The proposed antenna is capable of switching between a wide operating band of 3.0 GHz – 10 GHz and six different narrow band operating from 5 GHz to 10 GHz. UWB case is used for sensing the entire band and then adjusting its bandwidth to select the suitable sub-band and pre-filter out the other ones to communicate with wireless devices without interference with others. The proposed antenna patch is a combination of two semi-circular patches. For each case reflection coefficient is calculated, it maintains less than -10 dB throughout the operating frequency. Radiation Patterns for each case also reveal a very low distortion as required. Gain is more than 70% in each case.**

Index Terms— Cognitive radio, frequency-reconfigurable antenna,P-i-n diode switches, wideband-to-sub-bands reconfiguration, defected microstrip structure.

I. Introduction

The increasing demand for higher data rate and connectivity has led to dynamic spectrum access as the licensed and unlicensed spectrum users are very large. Cognitive radio (CR) Technology allows users to use spectrum in a better way by allocating secondary users the unused band of the primary user in an opportunistic way. Smart antenna which is reconfigurable and changes its operating frequency as per the environment is used to implement it. Microstrip antenna is a low profile antenna and also to save space same antenna can be implemented for both sensing and communication.[1].In overlay Cognitive radio technology front end of the system consist of a sensing antenna that is a ultra-wideband antenna and a communication antenna that is narrow-band antenna. In this paper wideband-to-sub-bands reconfiguration has been shown using filter in the feedline. If a primary user is allocated n bands and in this, one is not being used ,then a secondary user can use the free band of the primary user by filtering out n−1 bands to reduce interference between them and for reliable communication.Various antenna scenarios have been reported in the literature [3]-[15].

Nishant kumar is with the National Institute of Technology, Rourkela, India. (Phone: 06612464462: kumar.nishant1278@gmail.com).
P.Ananda Raju is with the National Institute of Technology, Rourkela, India. (Phone: 06612464462: anandraju040@gmail.com).
Santanu Kumar Behera is Associate Professor, Dept. of ECE, National Institute of Technology, Rourkela, India. (e-mail: skbehera@ieee.org).

The current distribution in the patch can be changed and thus resonance frequency by using active switches based on micro electro mechanical systems (MEMS)[4] and p-i-n diodes [3] or using a mechanical movement of different patches by using stepper motors[9] or even using a photo- conductive switches. Researchers are working to minimize the antenna size to be used in mobile devices side by side can work for multiple usages. In this antenna single- port have been used as overlay CR antenna by using switching elements (PIN Diodes)[5] put at the feed line of the microstrip antenna.The filter is based on a symmetrical defected microstrip structure(DMS) implemented in the feed line of the UWB antenna. It has a T-shaped slot, which by itself, has bandstop characteristics. However, when placed between a pair of gaps,which act as capacitors, a band pass structure results [2].For the purpose of achieving frequency reconfigurability, three pairs of gaps are symmetrically placed around the T-slot, and seven electronic switches are placed across the slots ,Six switching cases are considered in this antenna.Suitable choice of switches results different operating bands for communication or sensing.[8]

II. Antenna Geometry

The schematic of the proposed antenna is shown in Fig.1(front view) and fig 2(rear view) .It consists of a radiating element in the form of two semicircular patches of different radius, fed by a microstrip line. The antenna is based on FR4-epoxy substrate with a dielectric constant of 4.3, thickness of 1.6 mm, and loss tangent of 0.0018.Parameters used in the design is given in Table I. For the purpose of achieving frequency reconfigurability, three pairs of gaps are symmetrically placed around the T-slot, using DMS bandpass structure[2] and seven electronic switches are placed across the slots as shown in fig. 3(a)and 3(b) shows the equivalent circuit of the DMS bandpass filter.

According to [2] the capacitance Cp in pF, the inductance Lp in nH and the resistance Rp in ohm of the equivalent circuit of a bandstop DMS filter as shown in Fig. 3 is given by equation (1)

$$C_p = \frac{fc}{200\pi(f_0^2 - f_c^2)} \tag{1}$$

Once the capacitance value of the equivalent circuit is extracted, the equivalent inductance given by equation (2) ,

$$L_p = \frac{1}{4\pi^2 f_0^2 C} \qquad (2)$$

where f_0 is the resonant frequency and f_c is the 3-dB cutoff frequency.For simplicity we ignore the frequency dependence of Rp and use a constant value for Rp obtained for ω = ω0. Using equation (3)

$$R_p = 2 z_0 \frac{1 - S_{21}(\omega_0)}{S_{21}(\omega_0)}, \qquad (3)$$

Where S_{21} is the transmission coefficient that can be obtained by using port 2 in place of the patch of the antenna.In the case of a bandpass DMS configuration, the equivalent inductance and coupling capacitance form a series resonance circuit.[2]

Six switching cases are considered, as indicated in Table II. Case 0 corresponds to all the switches being ON. In this case, the effect of the filter is canceled, bringing back the UWB response of the antenna.The reflection coefficient curve is shown in fig 5 which shows UWB band covering from 3GHz to 10 GHz. The frequency characteristics of the filter depend on the dimensions of the slots, and on the switching state. The computed reflection coefficient plots for the six switching cases are given in Fig. 6. The operation of the antenna makes it suitable for employment in cognitive radio applications, where Case 0 could be used for sensing the channel (to determine the holes in the spectrum), and the other cases for communicating in the corresponding holes[1]. Further resonances can be obtained by including more gaps around the T-slot and appropriately choosing their locations and widths as shown in the Table1 .By controlling the switches the resonant frequency can be varied from 5.33GHz to 10 GHz, the parameters for designing this antenna are given in table2.It must be noted that the switches used here is simulated in CST by using equivalent circuit model in forward and reverse biased condition as shown in fig4.

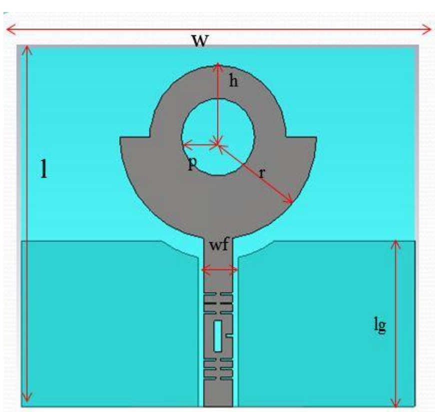


Fig. 1. A reconfigurable UWB/NB antenna, front view

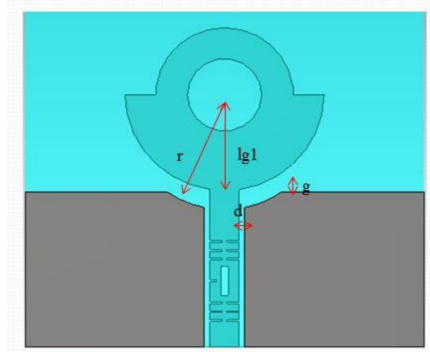
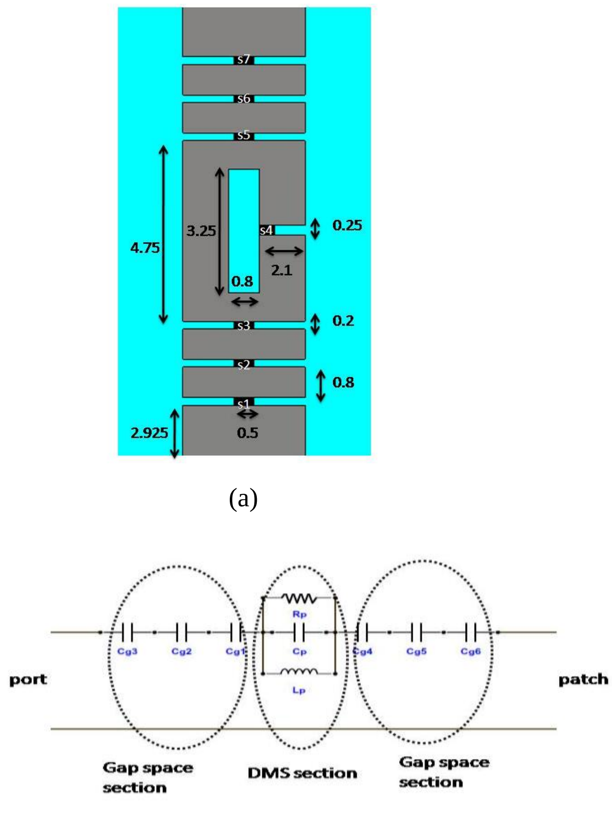


Fig. 2 . Rear view of the antenna



(b)

Fig. 3. Bandpass DMS configuration (a) closer view of the filter (b) related Equivalent circuit [2]

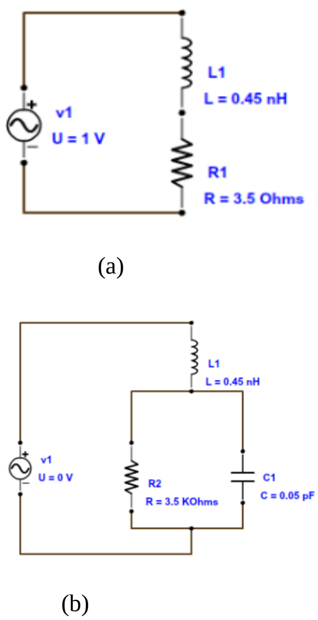


Fig. 4. Equivalent circuit of PIN diode in (a)forward bias and (b) reverse bias

TABLE I VALUES OF DIFFERENT PARAMETERS USED FOR DESIGNING THE ANTENNA

NAMES	VALUES	DESCRIPTION
l	38	Length of the substrate
w	44	Width of the substrate
lg	17.6	Length of the feedline
h	6.83	Radius of smaller patch
g	0.6	Gap between feed and ground
d	0.8	Gap between patch and ground
wf	3.2	Width of feedline
r	10.5	Radius of larger patch
p	3.5	Radius of slot in patch

III. Simulation Results and Discussions

Performance of proposed antenna, was investigated by using the CST Microwave Studio software .The optimized dimension is shown in Table I .Reflection coefficient (dB) shows that when all switches are on it is below -10 dB in frequency range 3.0 GHz to 10GHz ,this condition is used to sense spectrum to identify holes (unused) frequency bands .

The simulated result is shown in fig 5 and 6 which shows the agreement for all cases as in Table II. For case 1 switches 3, 4 and 6 is in off state that gives operating band from 6.33 GHz to 7.07 GHz, likewise other cases gives different operating bands. The radiation pattern for this antenna is shown in fig7 which shows that it is almost omnidirectional that is good for mobile applications. The gain (dBi) and efficiency for reconfigured antenna and UWB antenna is shown in table III and IV respectively, it shows more than 70% efficiency in all cases .Surface current and radiation pattern for three different cases (a)5.2GHz, (b) 6.5 GHz and (c) 7.2 GHz is shown in fig 7.The proposed narrow /ultrawideband antenna is incorporated into the same substrate, which reduces the space requirements and places the two antennas required for cognitive radio communication in the same plane.

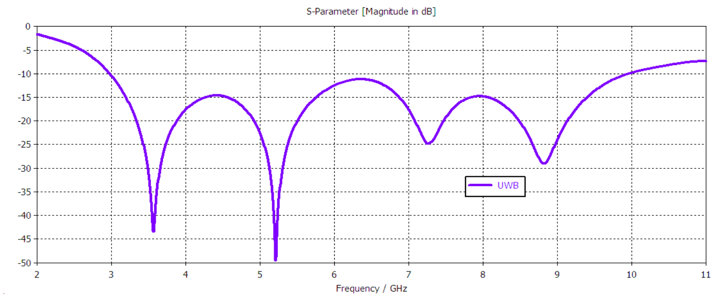


Fig. 5. Simulated reflection coefficient curve when the antenna is in the UWB band

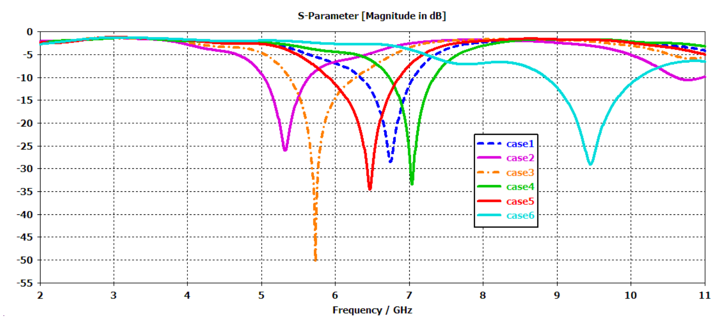


Fig. 6. Simulated reflection coefficient curve when the antenna is reconfigured

TABLE II THE RESONANT FREQUENCIES GENERATED FROM EACH STATES

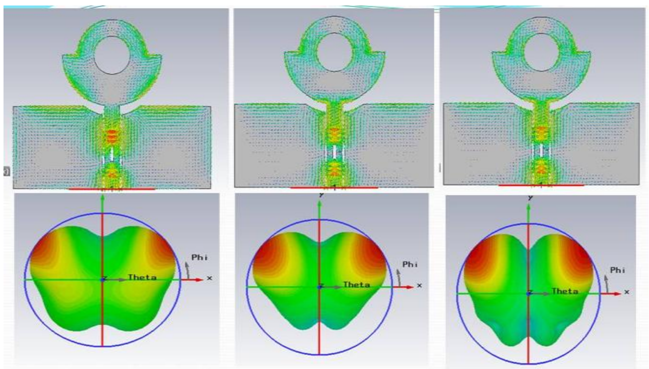
CASE	SWITCHES IN OFF STATE	BANDWIDTH IN GHz(%)
0	None	UWB covering from 3.1 GHz to 10 GHz
1	S3,s4,s7	6.33-7.07(10.7%)
2	S1,s4,s7	5-5.6(12.3%)
3	S2,s4,s7	5.37-6.28(13.9%)
4	S3,s4,s5	5.9-6.86(14.3%)
5	S3,s6	8.83-10.15(12%)

TABLE III SIMULATED REALIZED GAIN AND EFFICIENCY FOR RECOFIGURED ANTENNA

CASE	GAIN(dBi)	EFFICIENCY (%)
1	3.81	70
2	2.02	79
3	2.7	82
4	4.14	70
5	3.76	76
6	3.8	83

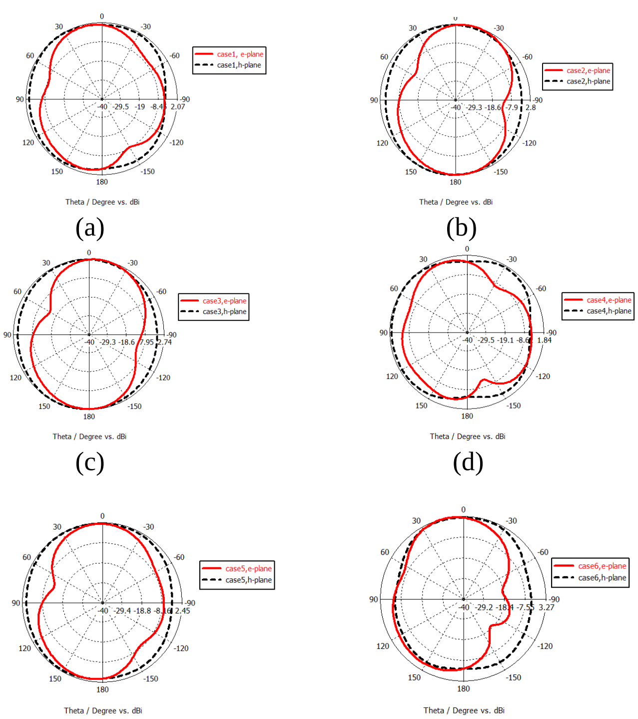
TABLE IV SIMULATED REALIZED GAIN AND EFFICIENCY FOR UWB ANTENNA

CASE	GAIN(dBi)	EFFICIENCY (%)
1	4.75	90
2	3.491	97
3	3.869	90
4	4.687	90
5	4.33	91
6	4.33	82



(a) (b) (c)

Fig. 7. Surface current distribution and 3D radiation pattern at (a)5.2GHz (b)6.5 GHz(c)7.2GHz.



(a) (b) (c) (d) (e) (f)

Fig. 8. Normalized E-plane and H-plane radiation Pattern at frequencies (a) 6.7 GHz (b)5.32GHz (c)5.7GHz (d)7.04GHz (e)6.46GHz (f) 9.4 GHz

IV. Conclusion

A planar reconfigurable UWB circular-disk monopole antenna using PIN switches has been studied. The reconfigurability is introduced by using filters in feedline .Filter used in this antenna can be reconfigured by using DC bias that can be easily implemented .Communication bands obtained by appropriately choosing switching conditions from 5 GHz to 10GHz .The proposed antenna shows a good omnidirectional radiation pattern ,which remain almost unchanged in different cases. Radiation efficiency is more than 70% in each case. It is simulated in CST Microwave Studio software and validates the purpose of this antenna to be used in cognitive radio applications

References

[1] Hamid,F. Ghanem, F. J.Herraiz-Martinez, and D .Segovia Vargas, “Reconfigurable antenna challenges for future radio systems”,*3rd Eur. Conf. Antennas Propa.,Berlin,Germany, 2009.*

[2] *M. Kazero oni;A. Cheldavi1; and M. Kamarei,” A Novel Bandpass Defected Microstrip Structure (DMS) Filter for Planar Circuits” Progress In Electromagnetics Research Symposium Proceedings, Moscow, Russia, August 18–21, 2009*

[3] R. Jothi Chitra , V. Nagarajan “Frequency reconfigurable microstrip antenna using PIN diode” *, IEEE Twentieth National Conference on communications (NCC) ,2014 ,page(s): 1-4*

[4] M. R. Hamid, P. Gardner, P. S. Hall, and F. Ghanem,”Vivaldi antenna with integrated switchable bandpass resonator”,*IEEE Trans. Antennas Propag.,vol. 59, no11, pp.40084015,Nov.2011.*

[5] Ramli ; Ali, M.T. ; Tan, M.N.M. ; Yusof, A.L, “A Frequency Reconfigurable Stacked Patch Microstrip Antenna (FRSPMA) using PIN diode switch” *ECTI-CON, 2013 10th International ConferencePage(s): 1 - 5.*

[6] Hamza, H. ;Biao Hou,“Simple systematic frequency reconfigurable microstrip patch antenna”*Radar Conference 2013, IET InternationaPage(s): 1 - 4.*

[7] Rodrigues, E.J.B. ; Lins, H.W.C. ; D'Assuncao, A.G. ,“Reconfigurable circular ring patch antenna for UWB and cognitive radio applications”*Antennas and Propagation(EuCAP), 2014 8th European Conference , Page(s): 2744 -2748*

[8] Pei-Yuan Qin ; Guo, Y.J. ; Feng Wei, “Frequency agile monopole antenna using a reconfigurable bandpass filter”*Antennas and Propagation Society International Symposium (APSURSI), 2014 IEEE Page(s): 1250 - 1251.*

[9] Elham Ebrahimi, James R. Kelly and Peter S. Hall,” Integrated Wide-Narrowband Antenna for Multi-Standard Radio” *IEEE transaction on antennas and propagation, vol. 59, no. 7, july 2011.*

[10] H. W. Hsieh, Y. C. Lee, K. K. Tiong, and J. S. Sun, “Design of a multiband antenna for mobile handset operations,” *IEEE Antennas Wireless Propag. Lett., vol. 8, pp. 200–203, 2009.*

[11] Y.Tawk, J.Costantine, K.Avery ,and C.G.Christodoulou, “Implementation of a cognitive radio front-end using rotatablecontrolled reconfigurable antennas,” *IEEE Transactions on Antennas and Propagation, vol.59, no.5, pp.1773- 1778, May 2011.*

[12] K. R. Boyle and P. G. Steeneken, "A five-band reconfigurable PIFA for mobile phones," *IEEE Transactions on Antennas and Propagation*, vol. 55, pp. 3300-3309, Nov 2007.

[13] R. Janaswamy and D. H. Schaubert, "Analysis of the Tapered Slot Antenna," *IEEE Transactions on Antennas and Propagation,* vol. 35, pp. 1058-1065, Sep 1987.

[14] T. Wu, R. L. Li, S. Y. Eom, S. S. Myoung, K. Lim, J. Laskar, S. I. Jeon, and M. M. Tentzeris, “Switchable quad-band antennas for cognitive radio base station applications,” *IEEE Trans. Antennas Propagat.*, vol. 58, no. 5, pp. 1468–1476, May 2010.

[15] T. Y. Han and C. T. Huang, "Reconfigurable monopolar patch antenna," *Electronics Letters*, vol. 46, pp. 199-U22, Feb 4 2010.