A reconfigurable Filtenna for Cognitive Radio Application

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Abstract. This paper describes a compact size UWB rectangular planner monopole antenna with impedance band from 7.6-15 GHz, having gain of 5.94 dBi which act like a sensing antenna for CR. After that, a filter structure is implemented at feed line of the monopole antenna with Incorporation of reconfigurable elements(switches) to make the antenna reconfigurable. By operating the switches as ON or OFF, the UWB antenna now operated at different frequencies like 8.7 GHz, 9 GHz and 11.4 GHz with narrowband functionality. This condition is helpful to CR for communication in desired band.

Keywords: CR, UWB, Narrow band, Filtenna, PU, SU

1 Introduction

Cognitive radio is a key supporting technology which offers the capability to distribute the wireless channel along with the licensed(primary) and unlicensed(secondary) clients in an adaptable manner [1]. To share the spectrum with licensed(primary) and unlicensed(secondary) users without interfering with them. To meet the various quality of service applications, each CR secondary user in a CR network must have the capability to sense the spectrum and can able to detect [2,4] those frequency bands which are not used by the primary users[3]. Two methodologies for spectrum allocation between licensed (PU) and unlicensed users (SU) have been adopted for CR: underlay and spectrum overlay [1]. In the underlay method, unlicensed users should operate beneath the noise floor of licensed users, and thus constraints are imposed due to interference between the licensed(primary) and unlicensed(secondary) transmission power [5]. In the spectrum overlay methodology, the unoccupied part of the spectrum is searched by CR and the signal transmitted in that unused spectrum hole without any power constraints. In this system, the unlicensed user (SU) can use that spectrum when the primary user is inactive without any intervention. For this type of CR, there is a requirement of two antennas: one UWB antenna for monitoring the spectrum hole and a reconfigurable narrow band antenna for communication [6, 8, 15,16].

Antenna with filters are important parts of all wireless transceiver communication systems. The filters and antennas in wireless transceivers are distinct circuits which gather up their own individual space. Furthermore, as these are different circuits, the expense of producing them is separate too. Hence, to bring them all together in the shape of a single component (filtenna) has several advantages [7,9]. Hence there is the reduction of overall size of the wireless transceiver [10]. As well as there will be a reduction in the production cost. Number of research paper demonstrate multi-channel multiband system, where each band have its own antenna and filter. But the traditional antenna and filters were bulky and costly.
As a result, filtenna were introduced [13]. Here we replaced the traditional UWB [11,12] antenna system to filtenna which perform all task of the specific antenna and the filter. Configurations of filtenna resonate at multiple frequencies of different narrow bands and broadbands. In this communication, the filter is integrated inside the Ultra-Wideband antenna. The aim is to achieve effective and efficient assimilation of antenna and filters for CR application. The additional objective is to demonstrate that the incorporation of filters and antennas will resolve concerns relating to wideband and narrowband (NB) antennas and thrive to our solutions. Which incorporate the amalgamation of Reconfigurable bandpass filters assimilated with any antenna, for UWB applications. The combination of reconfigurable UWB filters with UWB antennas will establish a new type of reconfigurable filtenna for overlay type CR applications.

2 Design Consideration

We begin with a rectangular UWB monopole antenna (figure 1) for operating frequency of 9.5 GHz. It designed with a low-cost dielectric substrate FR4 ($\varepsilon_r = 4.4$) with 1.6 mm thick. The dimensions of the rectangular monopole antenna are in (table 1).

![Figure 1: Structure of the propose monopole antenna](image)

**Table 1: Dimensions of proposed antenna**

| Parameter | Wm (mm) | Cm (mm) | Lm (mm) | Lf (mm) | Lb (mm) |
|-----------|---------|---------|---------|---------|---------|
| **Value** | 7.4     | 1.2     | 13.5    | 7.6     | 10      |

After design, an UWB monopole antenna (figure 1), we modified the feed line as a bandpass filter. The Defected Monopole Structure (DMS) at feedline gives us band-stop characteristics. By the formation of coupling gap in DMS structure, that can change the operation from band stop to band pass. Band-pass frequency depends in the position and width of coupling gap in DMS. Now the proposed DMS filter is inserted in the feedline of the Antenna (UWB) to get a narrow band operation (figure 2). We
used four switching elements (1,2,3 and 4) at the specified gap (figure 3) to adjust the operation from UWB to reconfigurable narrow band. These element switches in OFF state is behaves as 5 K ohm resistor and in ON state 1-ohm resistor for simulation propose.

![Figure 2: Structure of proposed Filtenna.](image)

The design parameters are presented in Table 2.

**Table 2: Dimensions of the proposed filtenna**

| Parameter | A (mm) | B (mm) | C (mm) | D (mm) | L (mm) | P (mm) | G (mm) | Gm (mm) | Lm (mm) | Lf (mm) | Wm (mm) | Cm (mm) | Lb (mm) |
|-----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Value     | 0.3    | 1.4    | 0.3    | 0.3    | 3.4    | 0.05   | 8.8    | 1.2    | 13.5   | 7.6    | 7.4    | 1.2    | 10     |

![Figure 3: Structure of proposed filtenna with switches](image)
3 Results and discussion

The proposed filtenna operates at the frequency range of 7.3 to 15 GHz. The system under consideration is of monopole construction, with the rectangular radiating area, and is designed to function at 9.5 GHz. This antenna now combines with a bandpass filter (BPF) to have the same level center frequency, i.e. 9.5 GHz.

In CST return loss calculated by the $S_{11}$ parameter are shown in figure 4 for the proposed filtenna.

![Figure 4: S-parameter for proposed antenna when all switches are open](image)

It is observed (Figure 4) that when the switching element (1, 2, 3, 4) are in open condition then, the bandwidth proposed for filtenna range from 7.6 GHz to 15 GHz. So, the antenna work like sensing antenna for cognitive radio.

![Figure 5: S parameter for filtenna when element 1 is switched OFF](image)

It is observed (Figure 5) that when switches element 2, element 3, and element 4 are put in ON condition and element 1 is switched OFF then 8.7 GHz band can be achieved and the other bands eliminated.
Figure 6: S parameter for filtenna when element 2 and element 3 are switched OFF

It is observed (Figure 6) that when switches element 1, and element 4 are put in ON condition and element 2 and element 3 is switched OFF then filtenna is tuned to 9 GHz and creates band notch characteristics for which the noise interference will be less during communication.

Figure 7: S parameter for filtenna when element 2 switched OFF

It is observed (Figure 7) that when switches element 1, element 3 and element 4 are put in ON condition and element 2 is switched OFF then filtenna is tuned to 11.4 GHz and the other gets eliminated.
Figure 8 shows the E-field radiation patterns of our proposed antenna in which we got the similar radiation patterns for the UWB antenna and when we got different narrowband by changing the switching condition. That is, the pattern consistency occurs for this antenna, so it is suitable for desired CR communication.

4. Conclusion

From the above investigation we found that this proposed filtenna can be implemented for Wi-MAX, satellite and terrestrial communication, military radar, air traffic control, and point-to-point radios etc. at 8.7 GHz, 9 GHz and 11.4 GHz. By Switching the elements ON or OFF as needed, we can switch between notches. And due to the property of wideband to narrowband functionality it can be used for cognitive radio application. when the whole switches are on, the antenna behaves like an UWB antenna which can be utilised for spectrum sensing and reconfigurability narrow bands allow us for communication.
References

[1] J. Mitola and G. Q. Maguire, “Cognitive radio: Making software radios more personal,” IEEE Personal Communications, vol. 6, no.4, pp. 13-18, Aug. 1999.
[2] Suneetha Ch., Srinivasa Rao S., Ramesh K.S. (2019), ‘QoS based secondary user selection using swarm optimization techniques in cognitive radio network’, Journal of Critical Reviews, 6(6), PP.472-478. 2019
[3] Preetham C.S., Srikanth G., Kumar J.A., Harper S.S., Ashiq S., Sriram C., ‘Geometric water filling algorithm for resource allocation in cognitive radio networks’, International Journal of Recent Technology and Engineering, 7(6), PP.1697-1701, 2019
[4] Immdadi G., Venkata Narayana M., Anuradha S.Y., Rani M.A., Lokesh K., Meghana B., ‘Dynamic frequency selection in wireless access systems including the band reallocation and allocation by using cognitive radios’, Journal of Advanced Research in Dynamical and Control Systems, 10 (2), PP. 516- 522, 2018
[5] Ramesh D., Venkatram N., ‘Current state of benchmarking spectrum sensing and routing strategies in cognitive radio ad hoc networks’, Journal of Theoretical and Applied Information Technology, 96 (11), PP. 3491- 3510, 2018
[6] Arjuna Moduli, R K Mishra,“ Modified UWB Microstrip Monopole Antenna for Cognitive Radio Application” IEEE AEMC-2015 conference, IIT Guwahati, 18 – 21 Dec 2015, Guwahati, India.
[7] A. H. Ramadan, K. Y. Kabalan, J. Costantin1, Y. Tawk, and C. G. Christodoulou,”A Tunable Filtenna for Cognitive Radio Applications,” 6th European Conference on Antennas and Propagation (EUCAP).IEEE, 2015.
[8] E. Ebrahimi and P. S. Hall, “A dual port wide-narrowband antenna for cognitive radio,” 2009 3rd European Conference on Antennas and Propagation, Berlin pp. 809-812, 2009.
[9] Shaw M., Madhav B.T.P., Kumar P., Mantri M.R., Rakesh Kumar P., ‘Analytical study on lowpass filter with I-shaped defected ground structures for medical ISM band applications’,International Journal of Pharmaceutical Research, 10 (3),PP. 565- 573, 2018.
[10] Lakshmi M.V., Pardhasaradhi P., Madhav B.T.P., ‘Circular monopole reconfigurable antenna with notch band filter characteristics’.Journal of Engineering Science and Technology Review, 11 (5),PP. 139- 143, 2018.
[11] Tilak G.B.G., Kotamraju S.K., Madhav B.T.P., Sri Kavya C., Venkateswara Rao M. (2019), ‘Broken heart shaped monopole for WiMAX applications’, International Journal of Recent Technology and Engineering, 8(2), PP.2333-2337.
[12] Preetham Reddy C.S., Sai Krishna K., Parvathi K., Eswar Pavan Kumar M., Sai Raja P.M.S., Rajesh Kumar K., ‘Design and simulation of ultra-wide band mimo antenna with band notched function’, International Journal of Engineering and Advanced Technology, 8(5), PP.304-307, 2019.
[13] Vishwanath M., Habibullakhan (2018) , ‘Design and simulation of compact band-pass filter using stub loaded plasmonic MIM waveguide’,International Journal of Engineering and Technology(UAE), 7(3),PP. 41- 43, 2018.
[14] Yathiraju R., Pardhasaradhi P., Madhav B.T.P., ‘Experimental investigations on DGS monopole antenna for LTE applications by few iterative techniques for achieving stable gain’, International Journal of Innovative Technology and Exploring Engineering, 8(8), PP.1946-1950, 2019
[15] B B Shankar, D Anantha Sai Kumar, G Venkata Kowndinya, Arjuna Moduli, Deepak Kumar Nayak, “An Ultra-Wide Band Octagonal Antenna with Reconfigurable Narrowband Antenna for Cognitive Radio Applications”International Journal of Scientific & Technology Research, ISSN 2277-8616, Vol. 9, pp: 1573–1576, Issue 1 January 2020.
[16] R. K. Parida, R. K. Mishra, N. K. Sahoo, A. Muduli, D. C. Panda, and R. K. Mishra, “A Hybrid Multi-Port Antenna System for Cognitive Radio” Progress In Electromagnetics Research C, Vol. 106, 1-16, 2020.