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A Four-Port Antenna System for Cognitive Radio Applications

Prakash Namdev[1], Om Prakash Meena[2], Madhu Shandilya[3]

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Abstract- The antenna system for Cognitive Radio (CR) that is proposed in this paper is hybrid, compact, low profile, and multi-port. It consists a Funnel shaped UWB monopole (2–11 GHz) and three Slotted Rectangular NB antennas. In this antenna system one ultrawide band (UWB) antenna is used for sensing the frequency spectrum and three narrow band antennas are employed for communication purpose. The ultra-wideband antenna sense 2 GHz - 11 GHz spectrum which cover the ultrawide band frequency range from 3.1 GHz - 10.6 GHz, which is permitted by Federal Communication Commission in year 2002. Over the operational band, this antenna arrangement shows less than −15 dB isolation. CST Microwave Studio is used to simulate the system, and a prototype is built to confirm the outcomes. The observed and simulated results accord rather well. The suggested antenna may be used for public safety wireless communication, marine radio navigation, X-band satellite communication, mid-band 5G, ISM/WLAN/Military applications, and C-band operations.

Keywords *– Cognitive Radio, Ultra wide Band Antenna, Narrowband Antenna, Radio Applications.*

INTRODUCTION

Following the Federal Communication Commission's approval of the 3.1–10.6 GHz spectrum for commercial usage, applications of Cognitive Radio (CR) gained traction. Because of this, there are now a lot of non-commercial uses for CR technology, which shares the spectrum while it's not in use. According to a case study, up to 80% of the allotted spectrums are inactive at some point in time, which supports the technology's applicability. Antenna system performance affects CR performance. A small, low-profile UWB antenna is required for continuous monitoring of unutilized spectrum by a CR antenna system. It establishes communication using an inbuilt narrowband (NB) antenna on any available channel. C-band, ISM, WLAN, and Mid-band 5G are among the UWB specified bands that are categorised for communication. More NB antennas are needed to cover the UWB spectrum in order to use these bands. Packing all of these NB antennas and the UWB antenna into a small antenna system design is a difficult issue. The UWB antenna takes up the majority of the area of a CR antenna. The size of UWB monopole antennas has been decreased by the use of many miniaturisation techniques. Among these is the application of a modified ground plane structure, which enhances impedance matching and reduces the degree of cross-polarization. However, it has an impact on radiation patterns and antenna gain. A planar CPW fed UWB antenna is recommended for modelling the CR antenna system because it makes it simple to integrate NB communicating antennas in a small area.

[1]Research Scholar, Department of Electronics and Communication Engineering, Maulana Azad National Institute of Technology, Bhopal, Madhya Pradesh, India, namdev.prakash88@gmail.com

[2]Assistant Professor, Department of Electronics and Communication Engineering, Maulana Azad National Institute of Technology, Bhopal, Madhya Pradesh, India, opm@manit.ac.in

[3]Professor, Department of Electronics and Communication Engineering, Maulana Azad National Institute of Technology. Bhopal , Madhya Pradesh, India, madhushandilya@manit.ac.in

"Corresponding author: Prakash Namdev

A few prominent integrated CR antenna systems cover the following frequencies: 68×54×0.79 mm3 for the 4 communicating sub-bands and the 3–11 GHz sensing band, 80×65×1.58 mm3 for the 2–5.5 GHz sensing band and the 2.6–2.7 GHz communicating band, 58.35 × 75.7 × 0.762 mm3 for the 3.3–12 GHz sensing band and two communicating sub-bands using 58.35 × 75.7 × 0.762 mm3. Additionally, a 120 × 65 × 1.56 mm3 multiport antenna system described in employs seven sub-bands for communication and two wide bands for spectrum sensing. A sizable detecting antenna in this antenna system serves as the ground plane for additional NB antennas. The CR antenna system has undergone a recent revision, as documented in. The aforementioned integrated CR systems do, however, have several shortcomings, including limited isolation between antennas, large antenna dimensions, low sensing band width, manufacturing complexity, and poor gain and efficiency. Additional components such as microstrip lines, slots, strips, metamaterials, energy bandgap structure, defective ground planes, complementary split-ring resonators, etc. are required to improve isolation without increasing size.

ANTENNA DESIGN

The suggested antenna construction is shown in Figure 1. This Funnel shaped UWB monopole antenna is attached to Port-1. Three narrow band slotted rectangular antenna are attached with Port-2 ,Port-3 and Port-4 .

(i) UWB Sensing Antenna- We took into consideration a funnel shaped monopole with consideration for the ground plane reusability. The compact size of this antenna system is $0.18\lambda_L \times 0.30\lambda_L$, where $\lambda_L = C/f_L$ corresponds to the wavelength at lowest frequency f_L of its entire -10 dB operational frequency range.

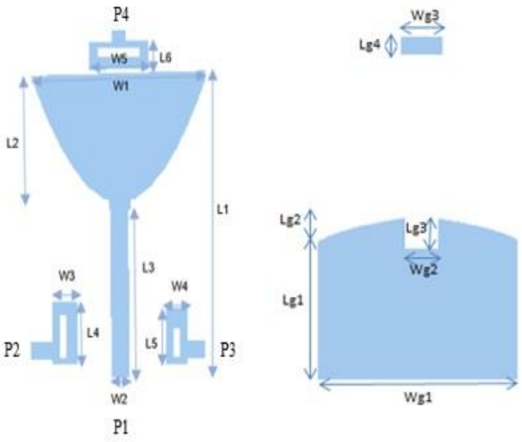


Figure 1. Proposed CR antenna system, (a) front view, (b) bottom view

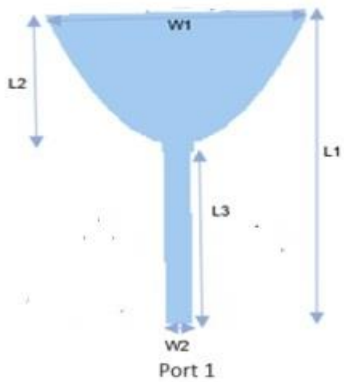


Figure 2. UWB monopole sensing antenna

An UWB monopole's effectiveness is mainly determined by its ground plane width, feed-gap, and effective radius. Beyond a certain length, it is independent of the ground plane's length. Bandwidth and impedance matching are impacted by the CPW ground's breadth. We first set the size of the ground plane to a reasonable amount. Its effect on the impedance values was observed. We added a half-pentagon to the top of the circular monopole, as seen in Fig. 2, to enhance the impedance performance. This supports the finding in that bandwidth (BW) performance is enhanced by vertex reduction in the feed section. The lower circular part is similar to trimming along several vertex points. The bottom circular component increases bandwidth, while the pentagon part enhances impedance performance because of its uniform current distribution. It is well known that a circular monopole has a higher BW than other forms. We were able to accomplish UWB while minimising the size of the ground plane.

The funnel shaped UWB antenna is etched on top of the substrate. The funnel shaped antenna is used for sensing the wide band frequency spectrum from 2 GHz - 11 GHz with VSWR ≤ 2, thus includes complete UWB spectrum from 3.1 GHz - 10.6 GHz which is approved by FCC in 2002. The 50Ω microstrip feed line is connected to the base of the funnel. The shape of the funnel is designed by the equation

$$X = a\ Sin\theta \quad (1)$$

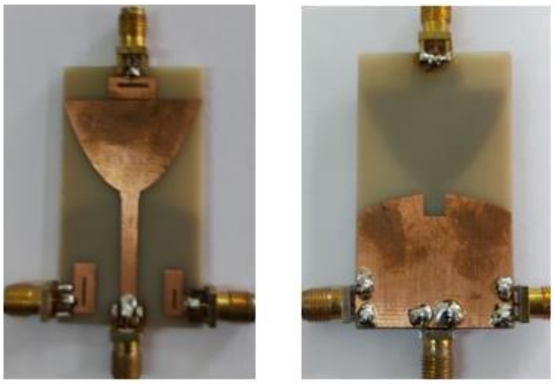
$$Y = b(Cos\theta)^2 \quad (2)$$

Where a is width of the substrate and b is length of the funnel. The metallic ground plane is etched on other side of the substrate; its structure shown in Fig.1. the curved edge of the ground plane is designed with equation (1) and (2), but a = 8.5mm and b = 15mm. A rectangular slot with dimensions W×L = 4.6mm×4.23mm is taken at upper curved edge. This arrangement achieves high impedance matching. The UWB funnel shaped antenna and third NB antenna integrated partial ground obtains ultrahigh impedance bandwidths. This antennas design is simulated in CST Software. The measured results are very closed to the simulated results. However, there are some variations may cause by material impurities, connector losses, faults in fabrication and measurement process.

(ii) Rectangular Slotted NB Antennas- Slotted rectangular NB antennas associated with port 2, port 3 and port 3 are used for communication. These three NB antennas develop three communication operations. These three NB antennas generate either single band or dual band to cover maximum UWB frequency spectrum which is sensed by Funnel shaped UWB antenna. This technique improves the spectrum utilization efficiency. This four-port antenna system forms three different operation. In first operation, the funnel shaped UWB antenna associated with port 1 (P1) and one narrowband antenna associated with port 2 perform spectrum sensing and direct communication respectively, where other two NB antennas remained off. In second operation, the funnel shaped ultra-wide band antenna allied with port 1 and NB antenna coupled with port 3 are used for spectrum sensing and communication respectively, whereas remaining ports are off. In the third case, the funnel shaped ultra-wide band antenna incorporated with port 1 and narrow band antenna incorporated with port 4 perform continuously spectrum sensing and direct communication respectively, whereas remaining port 2 and port 3 are off. These three operative conditions are discussed in this paper.

RESULTS AND DISCUSSION

Using CST Microwave Studio, the suggested antenna's performance is examined. Furthermore, we created a prototype measuring 30 × 50 × 1.6 mm^3 on a FR-4 substrate (εr = 4.4 and loss tangent = 0.02), as seen in Figure 3. The measuring configuration in an anechoic chamber employing a VNA is shown in Fig. 4.



(a) (b)

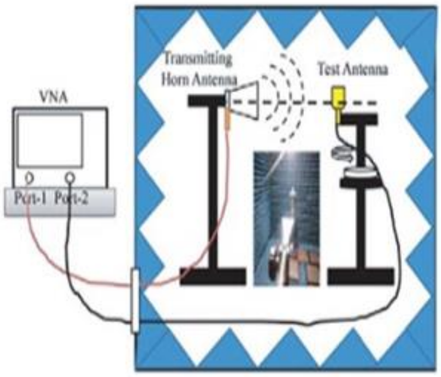


Figure 3. Fabricated antenna prototype, (a) top and (b) bottom view

Figure 4. Setup for radiation pattern measurement inside anechoic chamber

(i) UWB Sensing Antenna- The reflection coefficient (S_{11}) over the frequency range of 2 GHz to 11 GHz, as determined by modelling and experiment, is compared in Figure 5. The close closeness of both plots suggests a strong fit between the simulated and experimental data. The little variations are normal because of intrinsic measuring mistakes. To comprehend this pattern, surface current monitoring is required. The surface current distributions for the freestanding sensing antenna are displayed in Fig. 6 at (a) 2.352 GHz, (b) 4.513 GHz, (c) 8.1 GHz, and (d) 10.533 GHz. The regions of the ground plane with the lowest current amplitudes can be found using these numbers. This is helpful in determining where narrowband antennas should be placed on the different side of the substrate to minimise interaction with the sensing antenna. The area closest to the radiator, or the top part of the ground plane, is where the surface current is primarily found. As a result, once a certain depth is reached over which the surface current is significantly present, the antenna performance is independent of the ground plane length.

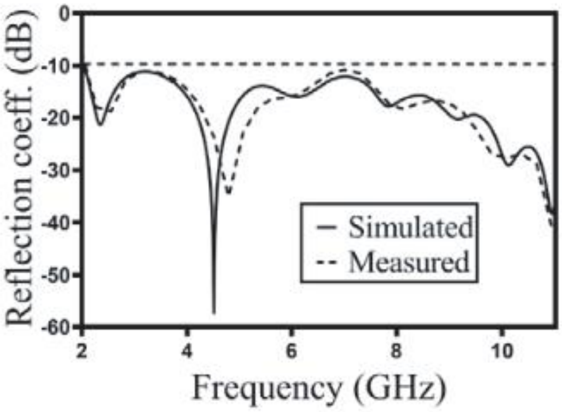


Figure 5. Comparison of simulated and measured reflection coefficients of the UWB monopole

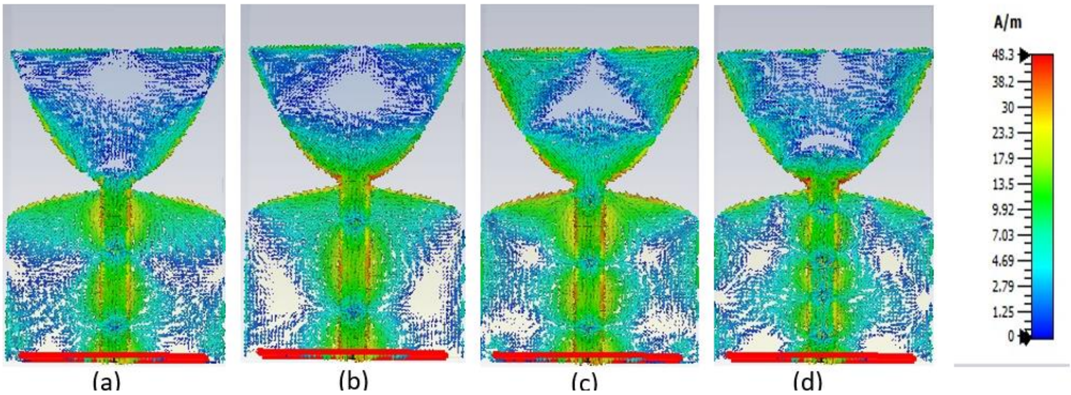


Figure 6. Simulated surface current distribution of Funnel Shaped UWB sensing monopole in standalone configuration at (a) 2.352 GHz, (b) 4.513 GHz, (c) 8.1 GHz, and (d) 10.533 GHz

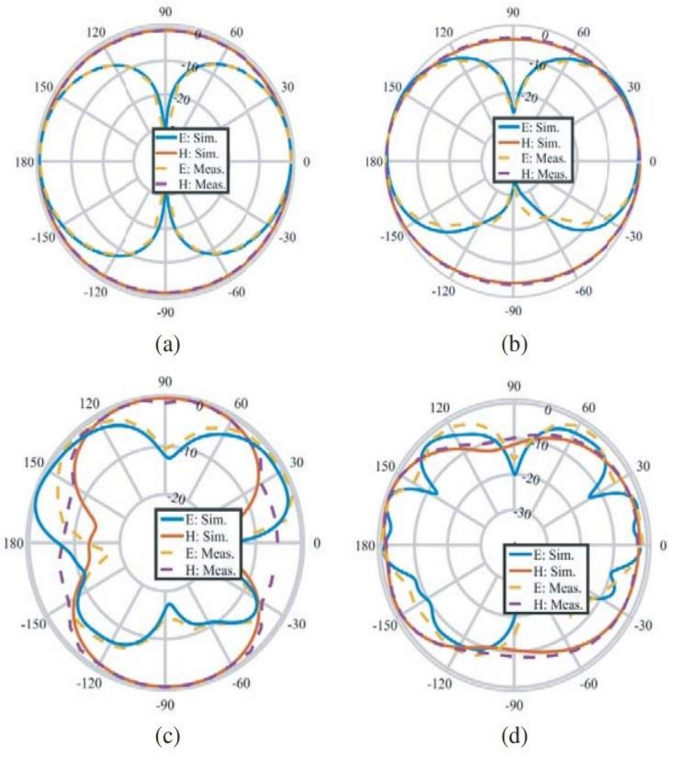
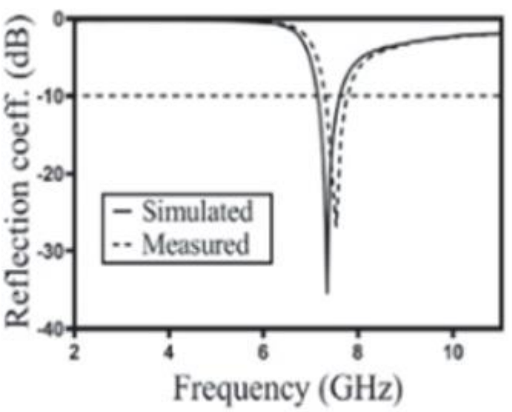


Figure 7. Simulated and measured radiation patterns of Funnel shaped UWB sensing antenna at (a) 2.351 GHz, (b) 4.511 GHz, (c) 7.517 GHz, and (d) 10.127 GHz

(ii) NB Communicating Antennas- three NB antennas generate either single band or dual band to cover maximum UWB frequency spectrum which is sensed by Funnel shaped UWB antenna. This technique improves the spectrum utilization efficiency. This four-port antenna system forms three different operation. In first operation, the funnel shaped UWB antenna associated with port 1 (P1) and one narrowband antenna associated with port 2 perform spectrum sensing and direct communication respectively, where other two NB antennas remained off. In second operation, the funnel shaped ultra-wide band antenna allied with port 1 and NB antenna coupled with port 3 are used for spectrum sensing and communication respectively, whereas remaining ports are off. In the third case, the funnel shaped ultra-wide band antenna incorporated with port 1 and narrow band antenna incorporated with port 4 perform continuously spectrum sensing and direct communication respectively, whereas remaining port 2 and port 3 are off. These three operative conditions are discussed in this paper

I. THE FIRST OPERATION OF PROPOSED SYSTEM

In first case, the funnel shaped ultra-wide band antenna incorporated with port 1 perform the spectrum sensing and the narrow band antenna incorporated with port 2 performs communication and remaining port 3 and port 4 are match terminated. In this case funnel shaped antenna is covered the frequency spectrum from 2 GHz to 11 GHz, which includes the unlicensed spectrum 3.1 to 10.6 GHz approved by FCC. The narrow band antenna associated with port 2 generates frequency band from 7.1 GHz to 7.7 GHz with resonant at 7.355 GHz as shown in Fig. 8. 2-D radiation pattern of first NB antenna at resonant frequency is shown in Fig.9.



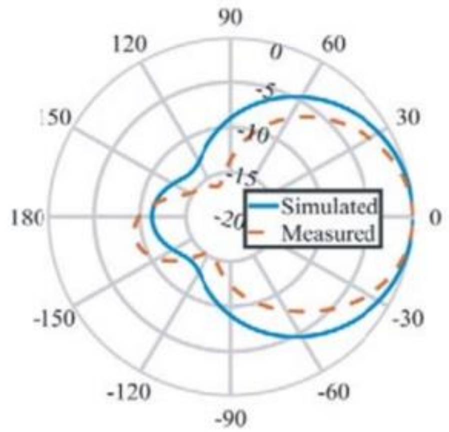
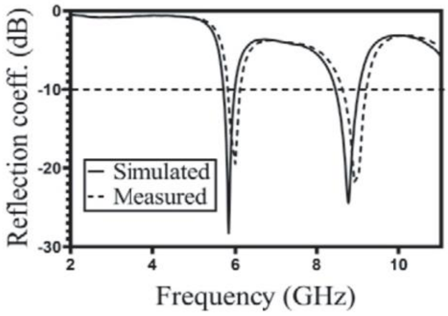


Figure 8. Comparison between simulated and measured reflection coefficients of First NB antenna

Figure 9. Radiation pattern of First NB antenna at 7.355 GHz

II. THE SECOND OPERATION OF PROPOSED SYSTEM

In second case, the funnel shaped antenna incorporated with port 1 perform the spectrum sensing and the narrow band antenna incorporated with port 3 performs communication and remaining port 2 and port 4 are match terminated. In this case funnel shaped antenna is covered the frequency spectrum from 2 GHz to 11 GHz, which includes the unlicensed spectrum 3.1 to 10.6 GHz approved by FCC. The narrow band antenna associated with port 3 generates dual frequency band from 5.7 GHz to 6 GHz with resonant at 5.834 GHz and 8.44 GHz to 9.02 GHz with resonant at 8.786 GHz as shown in Fig.10. 2-D radiation pattern of second NB antenna at resonant frequency is shown in Fig.11.



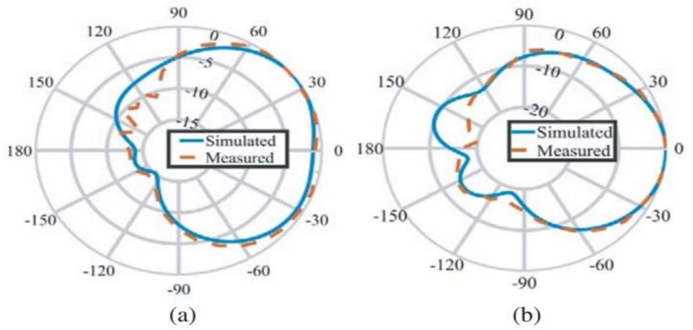
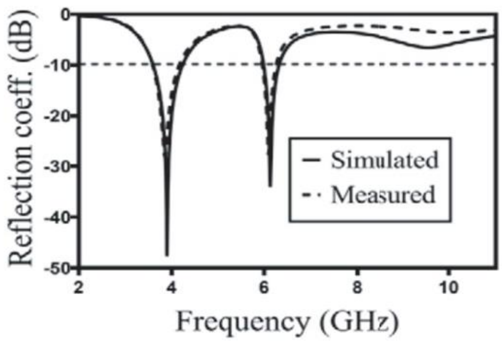


Figure 10. Comparison between simulated and measured reflection coefficients of Second NB antenna

Figure 11. Radiation pattern of Second NB antenna at (a) 5.834 GHz (b) 8.786 GHz

III. THE THIRD OPERATION OF PROPOSED SYSTEM

In Third case, the funnel shaped antenna incorporated with port 1 perform the spectrum sensing and the narrow band antenna incorporated with port 4 performs communication and remaining port 2 and port 3 are match terminated. The narrow band antenna associated with port 4 generates dual frequency band from 3.56 GHz to 4.25 GHz with resonant frequency 3.863 GHz and from 5.96 GHz to 6.36 GHz with resonant at 6.13 GHz and as shown in Fig. 12. 2-D radiation pattern of third NB antennas at resonant frequencies are shown in Fig. 13.



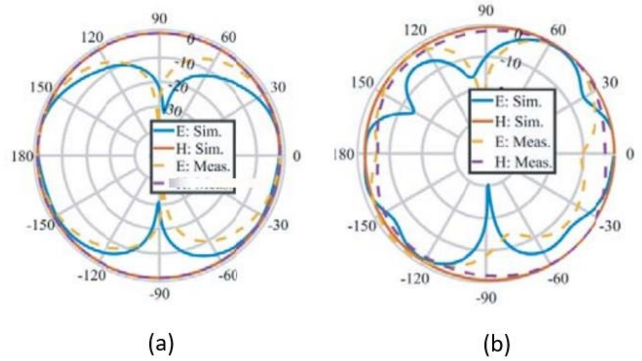


Figure 12. Comparison between simulated and measured reflection coefficients of Third NB antenna

Figure 13. Radiation pattern of Second NB antenna at (a) 3.863 GHz (b) 6.13 GHz

Conclusion

A small, low-profile multi-port CR antenna system was reported in this study. In this paper, a four-port antenna system composed with one funnel shaped UWB antenna and three narrowband antennas are integrated on the same substrate, designed for cognitive radio application, has been presented. The reconfigurable antenna has some drawback and limitation during switching operations, so this antenna system is designed to overcome the drawback of reconfigurable antenna. the three narrow band antennas are able to generate one or more than one frequency bands to cover ultrawide band spectrum for direct communication purpose. This antenna system is able to perform sensing as well as communication task simultaneously and improve the spectrum utilization, which is the main objective of cognitive radio technology. The suggested antenna system satisfies the radiation characteristics—such as pattern, efficiency, gain, etc.—needed for the CR system. The suggested antenna system is suitable for C-band, ISM/WLAN/Military application, mid-band 5G, X-band satellite communication, marine radio navigation, and public safety wireless communication, with isolation of less than −15 dB.

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