INTERNATIONAL JOURNAL OF MICROWAVE AND OPTICAL TECHNOLOGY,
VOL.10, NO.3, MAY 2015

Ultra-Wideband Circular Printed Monopole Antenna for Cognitive Radio Applications

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***Abstract*- Cognitive Radio is a new technology that increases spectrum efficiency by increasing spectrum utilization. In this research paper, a novel ultra-wideband (UWB) printed monopole antenna that is compatible with cognitive radio front end is presented. The submitted antenna is designed to operate in 3.0 GHz to 12 GHz bandwidth. It consists of a half circular disc printed monopole antenna with rectangular slot on the half circular radiator and a ground plane on the reverse side of the substrate. A prototype of the antenna have been fabricated and comparison is performed for impedance matching, radiation pattern between simulated and measured results. Good qualitative agreement between simulated and measured results is observed, which authenticated the proposed antenna design concept for cognitive radio applications.**

***Index Terms*- Cognitive radio, frequency spectrum, printed monopole antenna, radiation pattern, ultra-wideband antenna.**

I. INTRODUCTION

The Cognitive Radio (CR) is the area of interests for researchers around the globe due to radio frequency spectrum scarceness. With increasing demands to utilize the valuable existing radio frequency spectrum, Cognitive Radio technology is developing expeditiously in order to provide optimum and better communication to its users [1]. Cognitive radio is a communication system that can change its parameters based on interaction with the environment in which it operates [2], providing the capability to select and use the best available channel or share the spectrum in an opportunistic manner. Ultra wideband (UWB) and reconfigurable antennas can be used for scanning and communication operation [3-8]. Ultra wideband antenna at the Cognitive Radio front end are used to sense the spectrum in order to find any vacant spectrum holes or white spaces in the frequency spectrum. For high data rate and short range; wireless communication requires wideband operation which imposes the demand for low profile, low cost and miniaturized antennas. The wide impedance bandwidth for wireless personal area networks is provided by monopole antennas. Altered monopole antenna shapes have been taken into consideration and research has been carried out to reduce size and improve bandwidth by changing size of antenna radiator shape [9, 10]. A single antenna is proposed in [11, 12] to be employed in cognitive radio systems that can be tuned or uses multiple antennas which are matched in different bands. However, these options are not the most appropriate when high integration in small terminals is desired and working in several bands with fast response, because the reconfigurable antennas need an external circuit as shown in [13, 14], have additional power consumption. This takes time to adjust the system to a desired band. Also, the complexity and number of components required for the integration into the terminal are increased. The implementation of multiple antennas raises cost, power consumption, and increases space for each additional element [15, 16]. Another option is to use a multiband antenna. This alternative is presented in [17]. However, this type of antennas increases the complexity of designing and manufacturing when the number of bands is large. In this paper, to overcome many of the disadvantages explained above, the proposed antenna is an UWB antenna, which consists of half circular radiator printed on printed circuit board (PCB), since it is easier to design and

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manufacture due to the simplicity of its geometry. However, to achieve matching in all over the frequencies of interest more specifically at 3 GHz or above, the antenna geometry is modified in order to obtain the required impedance in 3 to 11 GHz frequency range.

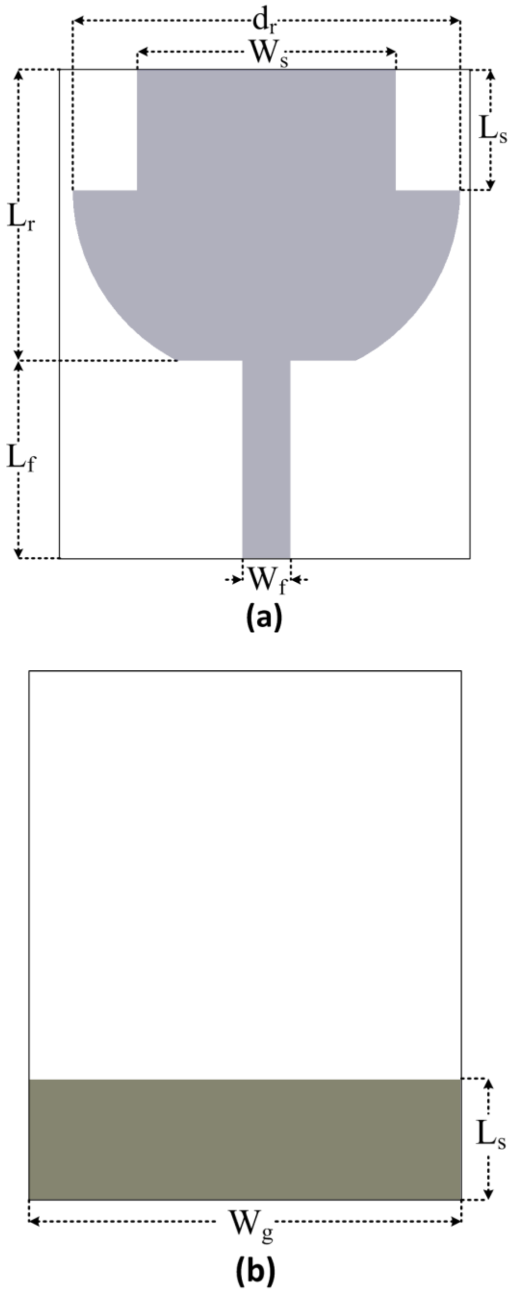

Fig.1. Antenna structure (a) top view (b) bottom view

The UWB antennas for communication systems are designed to operate from 3.1 to 10.6 GHz, since this is the band the Federal Communications Commission has established for ultra-wideband systems. The proposed antenna was designed to work in this frequency range and have operating bandwidth from 3.0 GHz to 12 GHz, so that a cognitive radio can use several bands from 3.0 to 12 GHz bandwidth as do: 2.45/5.2/5.8-GHz ISM, U-NII, DECT, WLAN-2.4, WLAN-5.2, European Hiper Lan I, II, UWB (3.1 GHz -10.6 GHz) or another standard that works in this range.

The proposed UWB antenna is based on a half circular disc printed monopole because printed monopole antenna are widely used for UWB communication systems. The designed antenna has a wide bandwidth, omnidirectional radiation pattern, linear polarization and consists of simple structure which is easy to manufacture. One of the most important parameters in a circular shape monopole is the radius of the radiator, because it determines the lower cutoff frequency. In [18] the numerical analysis is presented in order to obtain the lower edge from the radius of the circular disc. In this paper the proposed UWB antenna's circular disc radiator has been modified, and a rectangular slot is introduced on the half circular radiator to obtain the desired features, as will be shown in the next section.

II. ANTENNA DESIGN

The geometry of the proposed printed monopole is depicted in Fig. 1. The geometry of the proposed UWB antenna is based on a half circular disc printed monopole antenna [19]. With only half modified circular radiator having radius r = 12mm, L_f = mm, W_f = 3mm, and a ground plane size W_g = 44 mm by L_g = 12 mm, antenna resonated from 4 GHz to 12 GHz. However, with half circular disc radiator, antenna was mismatched at lower frequencies which are of interest in cognitive radio applications. To overcome the disadvantage, a rectangular slot of size W_S = 16 mm by L_S = 7.5 mm is introduced.

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This slot was introduced in order to modify the current flow on the patch without abrupt changes, obtaining an improvement in the impedance matching at lower frequencies. The proposed antenna substrate is FR4 with a thickness of 1.6 mm, relative permittivity of 4.7 and a loss tangent of 0.02. The proposed antenna was designed to be printed onto a piece of printed circuit board (PCB) because of its low cost and is easier to manufacture. Another advantage of using printed circuit board is that it can readily be embedded into wireless devices or can be integrated with other RF devices. On the back side of the substrate a metal ground plane is printed. The input microstrip line is connected to 50Ω SMA connector. The width of the microstrip at the start of the main input feedline is 3mm to achieve 50Ω impedance.

Fig.2. Fabricated prototype of the proposed UWB Antenna

Similarly, the dimensions of the rectangular slot, radius of the half circular disc radiator and size of the ground plane are the results of an optimization of the antenna achieved by computer simulations, in order to find the best performance for cognitive radio applications. The simulation procedure is done by using Agilent Advance Design System (ADS) software, which employs the finite integration technique for electromagnetic computation [20]. The prototype of the antenna is shown in Fig. 2.

III. RESULT AND DISSCUSSION

The fabricated antenna is shown in Fig. 2. The measured and simulated port couplings of the proposed UWB antenna are presented in Fig. 3. The discrepancies between simulated and measured curves can be accounted for the fabrication tolerances. Moreover, uncertainties in the relative permittivity of the substrate can change the performance around the center frequency of the ultra-wideband spectrum. In the simulation, the proposed antenna has bandwidth from 3.1 to 12 GHz. However, the measurements results shows the antenna operating from 3.0 to 11.8 GHz, showing a good agreements with the simulated results, thus an excellent device for cognitive radio applications because it has good impedance matching for all the bands of interest. The mismatching in the measured results are due to error in the measuring device.

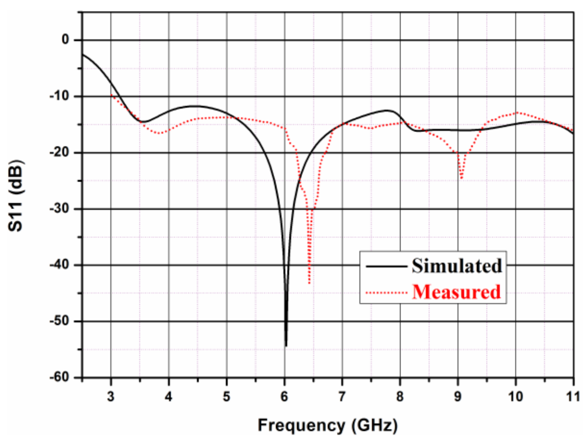

Fig.3. Simulated and measured scattering parameter of the proposed antenna

Since the cognitive radio system is not yet standardized [21]; the idea is to include the largest possible number of frequency bands. With these results, it is observed that the proposed prototype improves the bandwidth offered by other UWB antennas designed for Cognitive Radio such as [22-25], allowing to include greater number of bands in the system. This antenna can be well employed to many communication systems, including cognitive radio applications. Moreover, due to the

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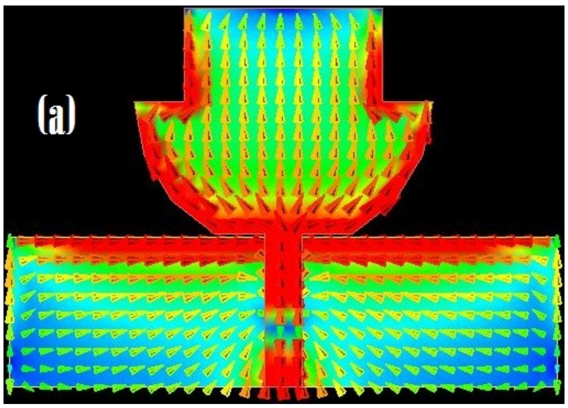
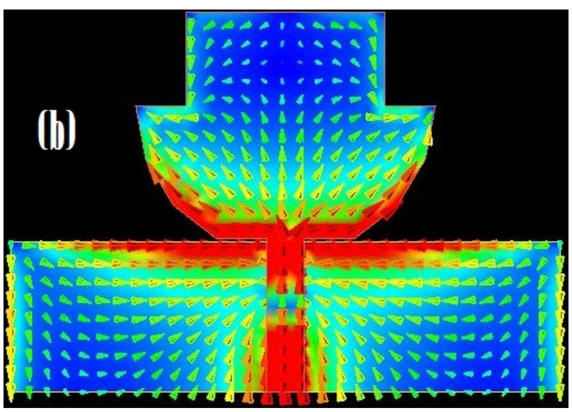
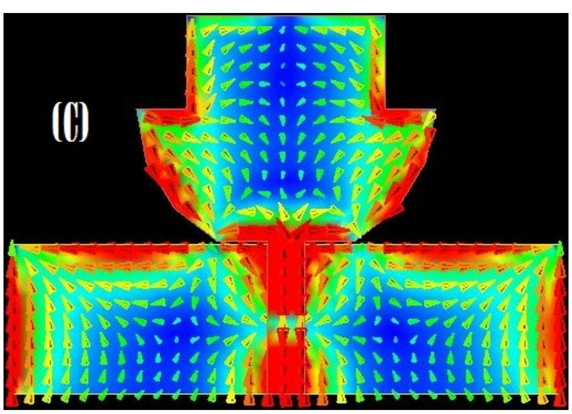
omnidirectional radiation pattern, which is a characteristic in monopole antennas, the proposed prototype can also be employed as an electromagnetic spectrum sensor, giving the advantage of using just one antenna, instead of several devices for different techniques. Fig. 4. shows the current distributions on the radiator at different frequencies. The analysis was performed at 3.1 GHz, 5.0 GHz, 8.0 GHz and







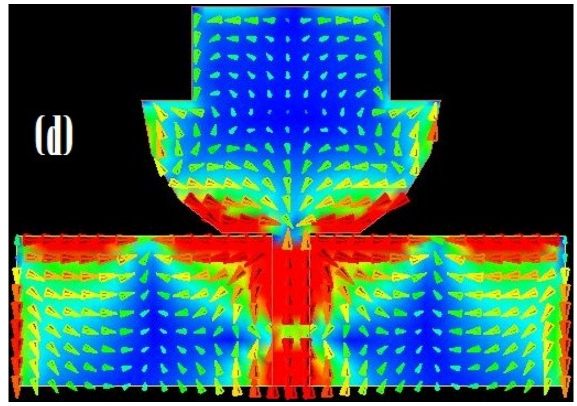
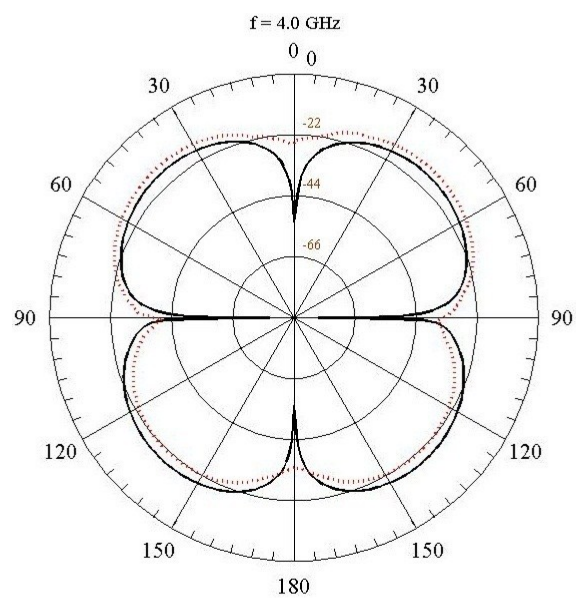


Fig.4. Current distributions at (a) 3.1 GHz (b) 5.0 GHz (c) 8.0 GHz and (d) 10 GHz

10 GHz frequencies. Fig. 4(a) shows current pattern near the first resonance at 3.1 GHz.The current pattern near the second resonance at around 5.0 GHz is given in the fig. 4(b), indicating a second harmonic. Similarly, fig. 4(c) and 4(d) corresponds to nearly third and fourth harmonics at higher frequencies 8.0 and 10 GHz. From the figure, it is seen that the current distributions remains stable at different frequencies, keeping the biggest level on the edges of the radiator, and a small intensity at the center of the patch. Current path lengths corresponds to respective resonance frequencies.



(a)

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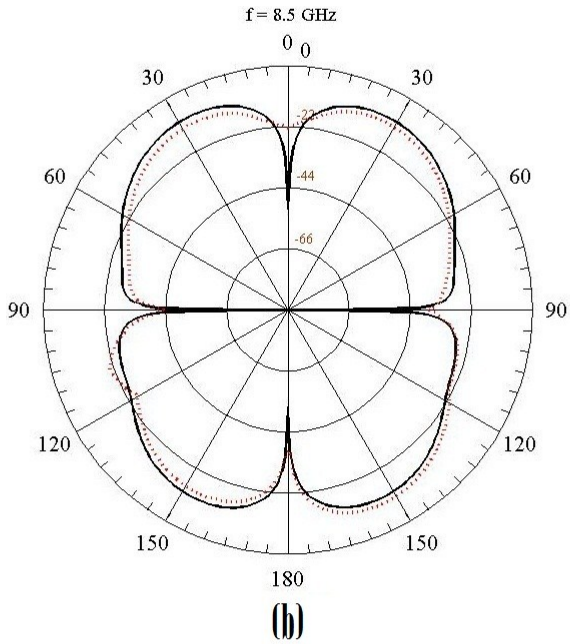

Fig.5. Simulated (thick line) and measured (dotted line) radiation pattern of the antenna in the xz-pane at (a) 4 GHz and (b) 8.5 GHz

With increase in frequency, the current distributions has more half-cycle variations but with reduced amplitude and confines to the outer boundary. On the ground plane, the current is mainly distributed along the edges and the feed line. This explains the importance of an optimized dimension of the ground plane. In this kind of UWB antennas, the current distribution is arc-like and flows along the edge of the antenna [21]. The changes in the current distribution make changes in the radiation pattern especially at higher frequencies. The radiation pattern of the prototype have been simulated and measured at 4 GHz and 8.5 GHz in the xz-plane and are depicted in Fig. 5. From the figure clearly a reasonable omnidirectional radiation pattern is achieved.

IV. CONCLUSION

In this research paper a new UWB printed monopole antenna compatible with cognitive radio applications is presented. The antenna is simple to manufacture and requires no adjustments or extra circuits to operate. It is based on a modified half circular disc monopole radiator with rectangular slot on the radiator in order to improve coupling in the lower frequencies getting an omni-directional UWB antenna which operates from 3.0 GHz to 12 GHz The proposed antenna design was fabricated and the measurements showed that there is a good impedance matching for all the bands of interests and nearly an omnidirectional radiation pattern all over the bandwidth, improving results presented by other antennas designs for the same applications. From the above results it may be concluded that the proposed prototype has a performance suitable for cognitive radio applications.

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