EVOLUTION OF UWB SLOTTED C SHAPED MONOPOLE ANTENNA FOR COGNITIVE RADIO APPLICATIONS

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Abstract: The proposed antenna designed specifically for Cognitive radio applications consists of a circular monopole which is evolved into the C shaped slotted monopole by a systematic process . The evolution of antenna is detailed. The evolved geometry enhances the gain with still good value of bandwidth. This ultra-wideband sensing antenna covers the spectrum from 4.305 GHz -12.73 GHz [8.428GHz] with a gain of 5.47 dBi as against 10.56GHz bandwidth of plane circular monopole with a gain of 2.17 dBi. Simulated results are presented and find in good agreement with the expected results. This antenna with slight modification can also be used as UWB antenna working in the range of 3.1GHz to 10.6GHZ.

Index Terms: Cognitive Radio, Frequency Reconfigurable, C shaped monopole, UWB Antenna

1. INTRODUCTION

The emerging feature-rich and high-data-rate wireless applications have resulted in an increasing demand on radio spectrum. The scarcity of the spectrum and the inefficiency in its usage, as caused by the current radio spectrum regulations, necessitate the development of new dynamic spectrum allocation policies to better exploit the existing spectrum. The current spectrum allocation regulations assign specific bands to particular services, and grant licensed band access to licensed users only. Cognitive Radio (CR) [1] is expected to revolutionize the way spectrum is allocated. In a CR network following the hierarchical access model [2], the intelligent radio part allows unlicensed users (secondary users) to access spectrum bands licensed to primary users, while avoiding interference with them. According to the Federal Communications Commission (FCC), a cognitive radio is "a radio that can change its transmitter parameters based on interaction with the environment in which it operates". Thus, in cognitive radio system, we need the capability to sense the spectrum ("sensing" antenna), and communicate ("reconfigurable communicating" antenna).Thus Cognitive radio is a communications system that can change its parameters based on interaction with the environment in which it operates [3], providing the capability to select and use the best available channel or share the spectrum in an opportunistic manner. One of the most novel features of the transceiver for a cognitive radio system is the ability of sensing and using various bands of interest which requires specific hardware technologies such as antennas, which can work efficiently in different bands. Sensing the environment may involve the measurement of the communications traffic and interference across a large part of the electromagnetic spectrum. The radio will also have knowledge of the intentions of its user, to enable it to match its searches to the needs of the user.

In the future, it is suggested that the spectrum will be deregulated and cognitive radios could operate in any frequency band within the available spectrum. To this end, CRs must sense the spectrum to find a suitable frequency band to operate in, and then use it to transmit and receive data. While there is no agreed scheme for the operation and the sensing modes in cognitive radios yet, one possibility involve having an antenna with its front-end used for continuous sensing and another antenna with its front-end for the operation. To make sensing of the whole spectrum quick, it is suggested that the sensing antenna could be very wideband and the front-end would perform the frequency subdivision, scanning and filtering to achieve a convenient noise level for measuring the interference. It is also suggested that the communicating antenna should be narrowband to help filter out-of-band signals.

The proposed UWB antenna is based on a disc monopole, because this is the radiator shape that is most commonly used for UWB communication systems due to their large bandwidth. Some features of monopole antenna includes a wide bandwidth, omni directional pattern, linear polarization and simple structures easy to manufacture [6].One of the most important parameters in a disc monopole design is the radius of the disc, because it determines the lower cut-off frequency. In the proposed UWB antenna, the disc monopole radiator has been modified, as well as the ground plane in order to obtain the desired results.

The disc monopole is designed for a wide band width but with quite less gain .The same antenna evolves with C shaped gives better band-width with a substantial increase in gain .The performance of the design is further improved by introducing slots into the C shaped monopole.

2. OBJECTIVE

The objective of this paper is to design a sensing antenna for cognitive radio applications which can span over a wide band width from around 4 GHz to 12 GHz and good gain of about 5dB.The antenna for this sensing application should also be omni directional. To evaluate the performance of this compact size antenna several factors need to be considered viz. Input Impedance, VSWR, Return loss, bandwidth, directivity, polarization, gain, radiation pattern etc.

Thus, theoretically it is expected that the antenna should have

1. VSWR in the range $1 < V < 2$
2. Return loss less than -10dB
3. High gain
4. Omni-directional radiation pattern
5. Large Bandwidth for sensing the spectrum

3. DESIGN OF ANTENNA

The disc monopole is shown in Figure. 1. As mentioned above, the geometry of the proposed UWB antenna is based on a disc monopole antenna, which was designed according to [5], where an antenna of size W = 50mm by L = 60mm is obtained, with a disc of radius r = 12 mm, a microstrip feed of dimensions W_1 = 2.6mm by L_1= 20 mm, and a ground plane of size W_2 = 50mm by L_2 = 20mm as detailed in Table1 is designed. The antenna is designed with a radius of r and a 50 Ω microstrip feed line which is printed on the same side of the FR4 (Flame Resistant 4) substrate with the substrate thickness of h=1.6mm and relative permittivity of 4.4.The ground plane used is a partial ground plane whose dimensions are optimised to a length of 20mm. The simulation is carried out by using an e.m.design tool cad-feko.

The present antenna is mismatched at lower frequencies which are of interest in cognitive radio applications, so to overcome this limitation, elliptical slots are introduced around the rim of the circular disc. This technique 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. And in order to enhance the impedance matching at higher frequencies, and to get the maximum bandwidth, the circular disc monopole antenna is modified into a ring shaped monopole and from ring shaped monopole to C shaped monopole which shows marginal improvement in gain and overall performance.

This evolution of antenna from disc monopole to ring monopole, ring monopole to slotted ring monopole and slotted ring monopole to c shaped slotted monopole has shown improvement in terms of gain and substantial reduction in copper area for the patch with still a good bandwidth. The size of the patch can also be reduced and the antenna can be modified to work in the UWB range.

In the process of designing the disc shaped monopole different dimensions like r, L1 are calculated by standard formulae as described below, while rest of the parameters like L, W, L2, h etc have been optimized after following extensive parametric analysis. In the process of evolution

also a rigorous parametric analysis is followed at every stage of design.

The radius of the circle is obtained from the equation,

$r = 1.8412v_0/2\pi f_r$

where, V_o is the velocity of EM waves

$= 3e10 \ cm/sec \ or \ 3e11 \ mm/sec$

f_r is the resonant (center) frequency(3.49 GHz)

ε_r is the dielectric constant = 4.4

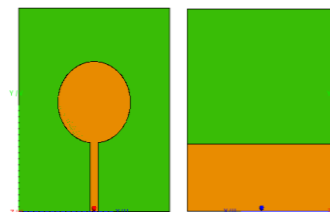Therefore, **$r = 12mm$**

The length of the patch is given by,

$L_1 = \lambda/4$

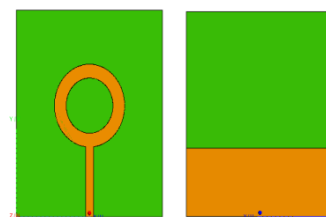where, $\lambda = c/f = 3e8/3.5e9 = 85.89 \ mm$

Therefore, **$L1 = 20.3 \ mm$**

TABLE I
DESIGN PARAMETERS OF PROPOSED ANTENNA

Parameters	Value[mm]
L	60
W	50
W1	2.6
L1	20.3
L2	20
W2	50
r	12
h	0.3

a:front view   b:bottom view
Fig.1:Geometry of Disc Monopole Antenna

a:front view   b:bottom view
Fig.2:Geometry of Ring shaped Monopole Antenna
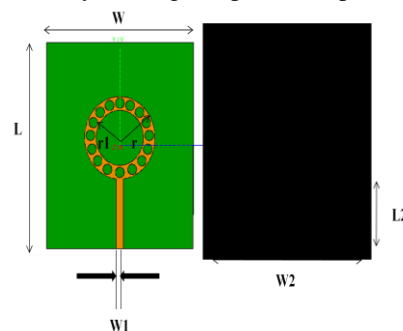

Fig a:front view   b:bottom view
Fig.3:Geometry of Slotted Ring shaped Monopole Antenna
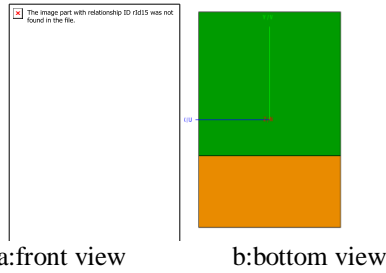
a:front view   b:bottom view
Fig.4:Geometry of C shaped slotted Monopole Antenna

4. RESULTS & DISCUSSION

The simulated results of the proposed UWB antenna are presented in Fig.5 to Fig 21. The proposed C shaped monopole antenna shows a bandwidth from 3.857 to 11.98 GHz in which the return loss is below -10db.This proves to be an excellent antenna for cognitive radio applications because it has a good impedance matching for the whole band of interest.

The impedance vs frequency plots of different geometries from disc monopole to C shaped slotted monopole shows impedance close to 50 Ω which shows a good impedance match with the 50 Ω impedance of the transmission line. This is clearly visible in the plot from Fig.9 to Fig.12 and from Table2 as well. The return loss plots of the various geometries shows a wide bandwidth which is an essential requirement of the sensing antenna which is very clear from the plot shown in Fig.5 to Fig.8 and Table2.The return loss plot covers an UWB range in the first geometry but slightly shifted from UWB range in other cases which can be modified easily by properly adjusting the parameters. The return loss plot of ring monopole and slotted ring monopole shows clear cut improvement in bandwidth due to due to change in current distribution with the incorporation of slots of appropriate shape and size at appropriate locations. The cut in the slotted ring at appropriate location and of appropriate size is made by observing surface current distribution. VSWR plot shown in Fig.13 to Fig.16 shows the conformity to the results obtained from the return loss because the return loss of 9.5db corresponds to the VSWR of 2 which corresponds to 90% transmission and 10% reflection of power. The radiation pattern plots shown from Fig.17 to Fig.20 shows almost omnidirectional radiation pattern as per the requirement of sensing antenna. The plot also shows a clear cut improvement in gain from disc monopole (2.17dBi) to ring monopole (3.84dBi), ring monopole to slotted ring monopole (4dBi) and slotted ring monopole to 'C' shaped slotted monopole (5.47dBi).
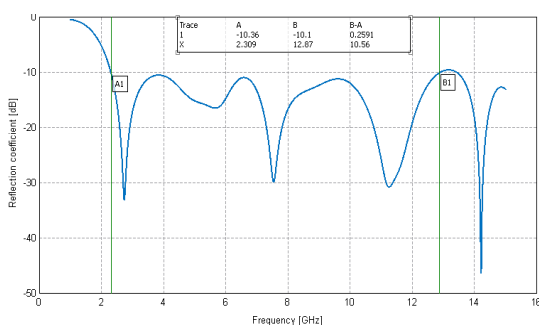
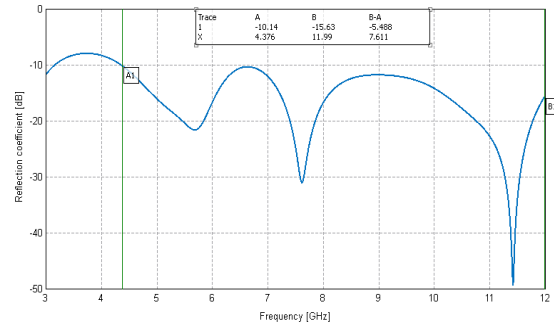Fig.5:Return loss plot of Disc Monopole Antenna

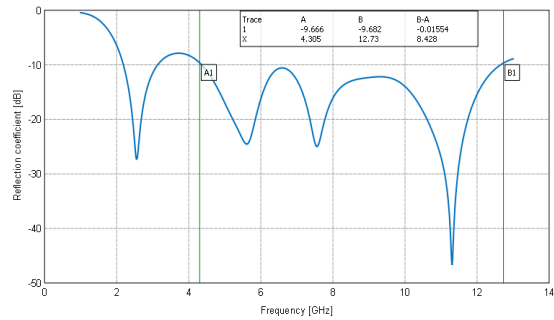Fig.6:Return loss plot of Ring shaped Monopole Antenna

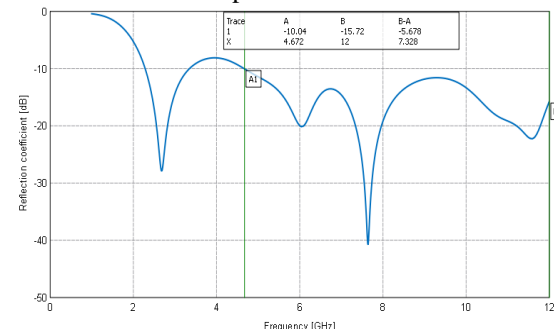Fig 7: Return loss plot of the Slotted Ring shaped Monopole   Antenna.

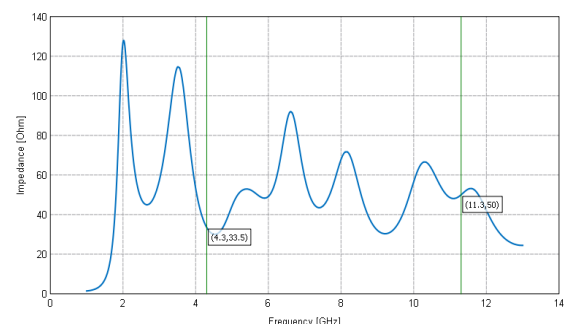Fig 8: Return loss plot of C shaped Monopole Antenna.

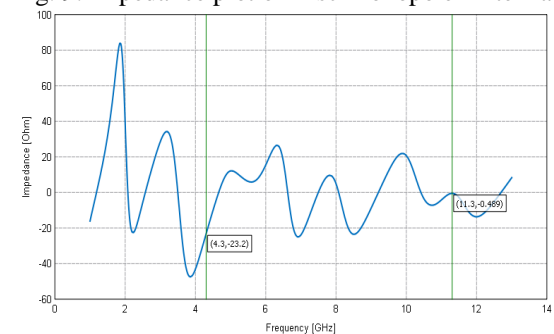Fig. 9: Impedance plot of Disc Monopole Antenna

Fig 10: Impedance plot of Ring monopole Antenna

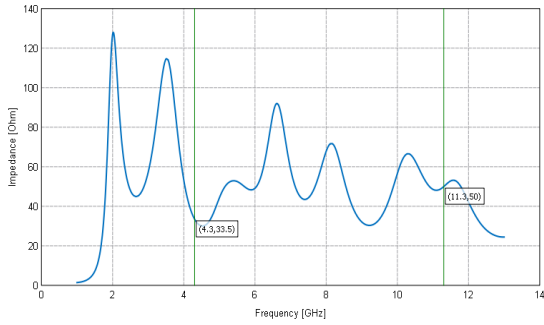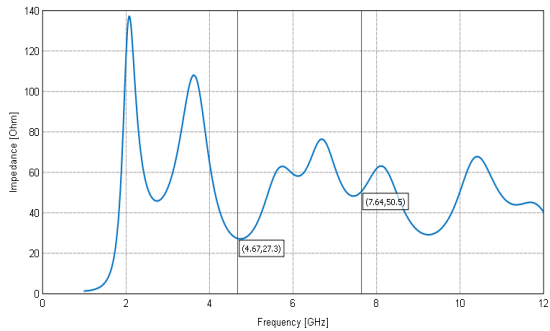Fig. 11: Impedance plot of slotted Ring monopole Antenna

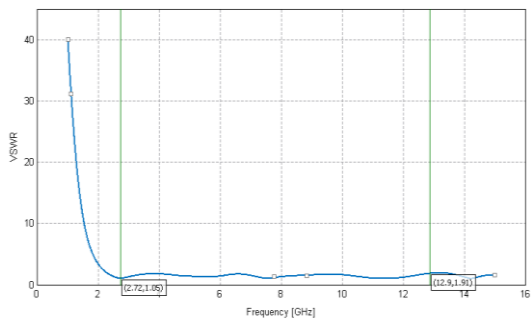Fig.12: Impedance plot of C shaped slotted monopole Antenna
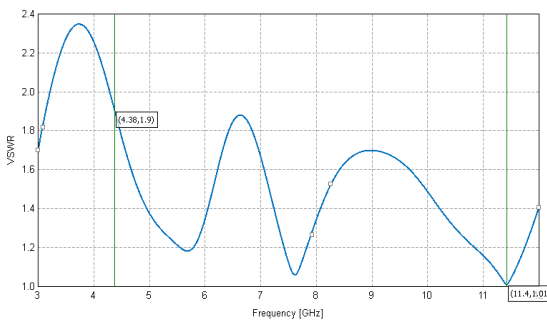

Fig.13:VSWR plot of Disc Monopole Antenna

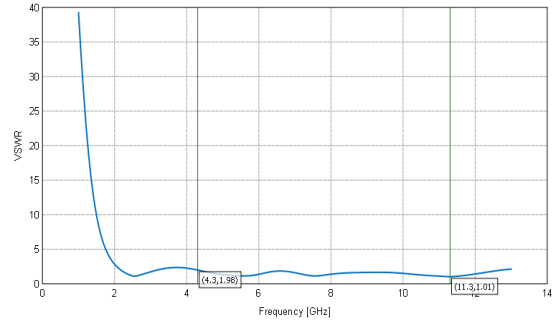Fig.14:VSWR plot of Ring Monopole Antenna

Fig.15: VSWR plot of Slotted Ring Monopole Antenna
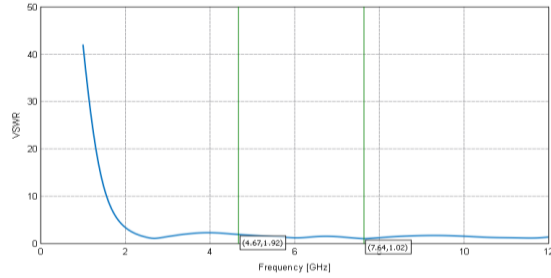

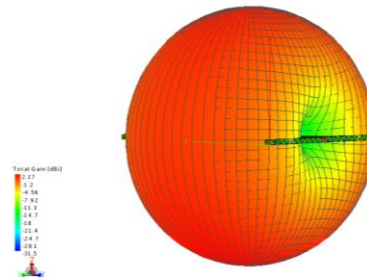Fig.16: VSWR plot of C shaped slotted monopole Antenna

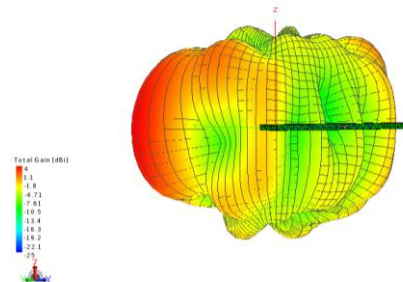Fig.17: Radiation pattern of Disc Monopole Antenna

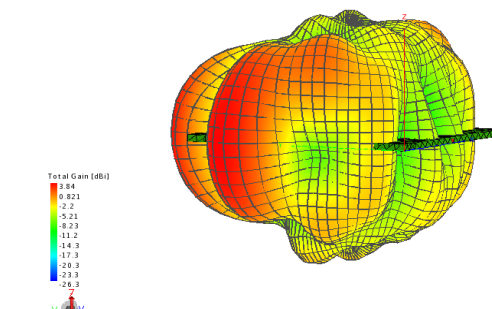Fig.18: Radiation pattern of Ring Monopole Antenna

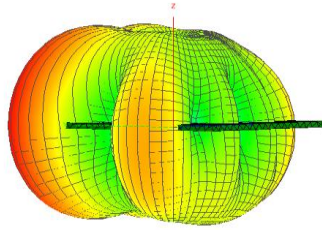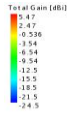Fig.19: Radiation pattern of Slotted Ring Monopole Antenna

Fig.20: The radiation pattern of C shaped Slotted Monopole
Antenna

TABLE2
COMPARISON OF VARIOUS ANTENNAS IN THE PROCESS OF EVOLUTION

SNo	Type of Antenna	Input Impedance at fr	Impedance Bandwidth	Gain [dBi]
1.	Disc Monopole	52.3	10.56GHz	2.17
2.	Ring Monopole	50	8.691GHz	3.84
3.	slotted ring Monopole	50	8.468GHz	4.00
4.	C shaped slotted Monopole	50.5	7.238GHz	5.47

6. CONCLUSION & FUTURE SCOPE

The Disc Monopole Antenna is evolved into C shaped slotted monopole antenna by inserting elliptical slots in the rim, which improves the performance of the antenna. The antenna is simulated using the simulation tool CADFEKO®. The observed results are tabulated above and are found to be in close agreement with the theoretically expected values. This antenna can be used as a sensing antenna in Cognitive Radio applications due to its large bandwidth, good gain and omni directional radiation pattern.

Its usability in Cognitive Radio systems can be enhanced by incorporating a narrowband reconfigurable antenna in the same antenna structure which can make the communication of secondary users possible. This antenna which is the combination of sensing and reconfigurable antenna will make it a complete antenna that can be used in cognitive radio applications. This can be achieved in several ways, but the care is required to be taken that coupling between the two antenna ports must be within acceptable limits.

The antenna with slight modifications in the design can be operated in UWB i.e from 3.1to 10.6 GHz. This antenna can be used for UWB applications as well as in cognitive radio application with Underlay approach i.e. working in the presence of primary user.

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