On Antennas for Cognitive Radios

F. Ghanem[1], *M.H. Rijal*[2], *and P.S. Hall*[2]

[1]Prince Mohammad Bin Fahd University, Al- Khobar, Saudi Arabia. fghanem@pmu.edu.sa

[2]The University of Birmingham, Birmingham, United Kingdom. mxh753@bham.ac.uk. p.s.hall@bham.ac.uk

Abstract

Cognitive Radios (CR) are a concept of radios endowed with an intelligence that allows them to perceive changes in their environment and adapt their parameters to maintain a quality of Service (QoS). While the parameters concerned by the adaptation enclose theoretically all of those of a radio (modulation, coding, ...etc.), it is certainly the change of the operating frequency that is the most characteristic of CR. In light of this new requirement, the present paper analyzes the features that CR antennas can have. Then, examples of frequency reconfigurable antennas developed by our group for CR will be presented.

1. Introduction

Cognitive radios are attracting the interest of an increasing number of researchers. This interest is due to the new possibility these systems give. Indeed, Cognitive Radios (CR) is a concept of radios endowed with an intelligence that allows them to perceive changes in their environment and adapt their parameters to maintain a quality of Service (QoS) [1]. While the parameters concerned by the adaptation enclose theoretically all of those of a radio (modulation, coding ...etc.), it is certainly the change of the operating frequency that is the most characteristic of CR. A cognitive Radio is able to sense the conditions of communications through measurement of interference level or noise level for example; and when these conditions come to deteriorate, then the radio can take the decision to change the operating frequency band.

This concept is attracting as it is seen as one the potential solutions to reduce the spectrum congestion. Indeed, some studies showed that the spectrum occupancy is irregular. While some frequencies are saturated, other frequencies are almost empty. Thus, by allowing to users of the saturated frequencies to go to the empty ones, better global quality of service will result. Ultimately, it is predicted that the spectrum will be deregulated in total or in part so users can easily migrate from one band to another.

On the other side, the implementation is not obvious at least at the management level and lots of specialists are skeptic about the future of CR, at least as it is presented initially. Indeed, frequency bands are owned by operators who make money on them. So, it is not obvious to see these operators open their frequencies easily.

A good news came from Ofcom (British Frequency Regulation Authority) where they announced that they are studying the possibility of opening frequencies used for TV broadcasting around 400 MHz [2]. These frequencies are not owned by communications operators, which make the issue less conflicting given that the use of these frequencies does not perturb the TV reception.

At the system level, challenges are also important at least with the actual vision of the radios. For example, it is difficult to see a GSM user for example going to bands dedicated to CDMA users without adapting its architecture. So, system architecture adaptability is an issue and the radios need to have a flexibility of reconfiguration. In this perspective, Software Defined Radios (SDR) can be the solution. Indeed, these radios digitalize the signal at the Antenna output and all the signal processing is done numerically. The technological advance in integrated circuits will certainly be beneficial to the architecture flexibility.

An important component of CR's is the antenna. The system flexibility alone without the antenna flexibility cannot be sufficient to achieve the performances expected from CR. In this perspective, antenna frequency reconfiguration and/or Signal Processing Antenna are other important key features of CR. Also, the antenna is the first filter (space and frequency filter) of the radio and its filtering performances have a direct impact on the whole system performances. Indeed, it is known that system noise factors are mainly determined by the first stages. So, any noise or interference suppression at the antenna level will considerably release the constraints on the filters inside the radio. This feature takes a special importance in the CR context where it can use a large part of the spectrum. In addition, in the sensing, when measuring the noise or interference levels in a given frequency band, for example, it is important that antenna measures the noise inside this band and minimize the added noise from adjacent bands.

In the next section, features of the antennas suitable for CR will be described and then examples of antennas developed in The University of Birmingham for CR will be presented.

978-1-4244-6051-9/11/$26.00 ©2011 IEEE

2. Features of Antennas for CR

Cognitive radios have two modes: sensing mode and operating modes. In the first one, the radio proceeds to a series of measurements (can be measurement of the noise or interference levels) in order to make a decision on the communications conditions or quality of service. In the second mode, the radio sends and receives information data with distant users. To be able to determine the suitable features for CR's, one needs to know the standards adopted for them. However, since the concept is relatively new and most of the research work has been mainly on the data Link and Network layers, no standard has been adopted for CR's yet. Therefore, the features described here are intended to be taken as a guideline only.

As with any system, it is expected to have high performance CR's and lower standard ones. Relatively to the sensing and operating modes, a high performance CR would be one that does a continuous sensing so when the communication conditions come to be deteriorated, the radio would be ready for a change of frequency. On the opposite, a lower quality CR would use the sensing and operating modes by alternation so; the radio will wait until the communications conditions deteriorate in order to perform sensing. In the first case, the CR must have at least two front-ends, while in the second case, only one front-end is enough. For continuous sensing CR's, one can have two separated antennas, one for each mode and alternatively, one can have one integrated antenna having one radiating element and two ports with a minimum of isolation between them. It is worthwhile to highlight the importance of having the two ports that excite the resonator collinear so they operate on the same polarization. Indeed, when it comes to isolate the two ports, the straightforward solution would consist in making the ports perpendicular so they have perpendicular polarizations. However this should be avoided as it is important to sense at the same polarization as the operation.

An important feature that CR antennas must have is the frequency tuneability. Indeed, in order for a CR to be able to change the operating frequency, the antenna resonating frequency must be tuneable. However, this is not enough as when tuning an antenna, the relative bandwidth remains usually constant and this is not necessarily what is needed. Indeed, a CR should be able to pass, for example, from UMTS to UWB or vice-versa and these two standards have different relative bandwidths. So, it is important that CR antennas be able to change their bandwidths.

Finally, the last feature of CR antennas is related to the operating frequency change or frequency migrations. It is important to mention that any frequency migration results in an interruption of the communications, which can be costly especially for high performance radios. Thus, any help from the antenna that could reduce the migrations and prolong the communications periods would give an added value. To do, an antenna can either reshape its radiation diagram to put a null in the direction of the interferer or insert a notch at its frequency.

3. Examples of antennas for CR

In this section, we will present example of antennas developed at The University of Birmingham. The first antenna consists in a two-port one for continuous sensing CR's. It is composed of a disc monopole excited at opposite sides as shown in Fig. 1 [3].

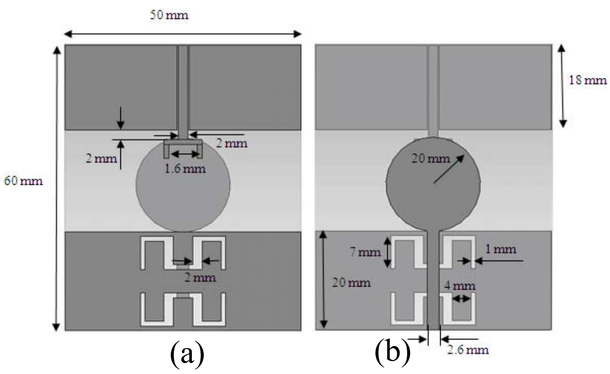


Fig. 1: Schematic of the proposed two-port antenna. a) top view. b) bottom view.

One port excites the disc directly with a microstrip feed line while the other port excites the disc by coupling through a coplanar feed line. The fact of putting them opposite results, first in giving them the same polarization and second in a high decoupling between them as shown in Fig. 2. As it can be seen from the figure, the S_{21} parameter between the two ports is at worst -10 dB. The coplanar port behaves like a regular disc monopole and is Ultrawideband (UWB). The microstrip port has slots printed underneath and disposed at the proximity of each other in order to couple them and obtain a filter as shown in Fig. 3.

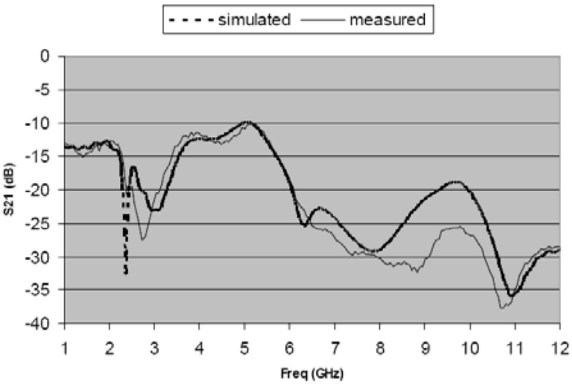
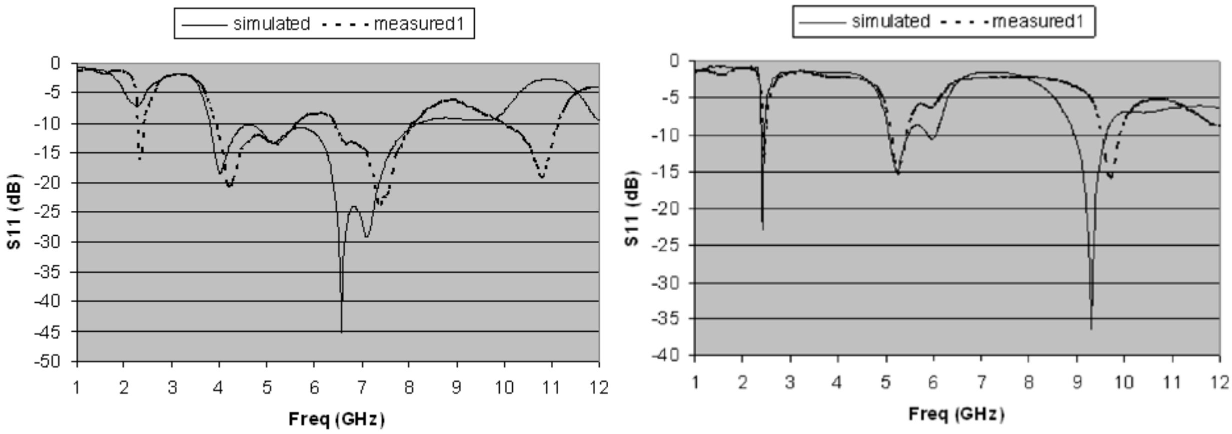


Fig. 2: S_{21} parameter of the antenna of Fig. 1.

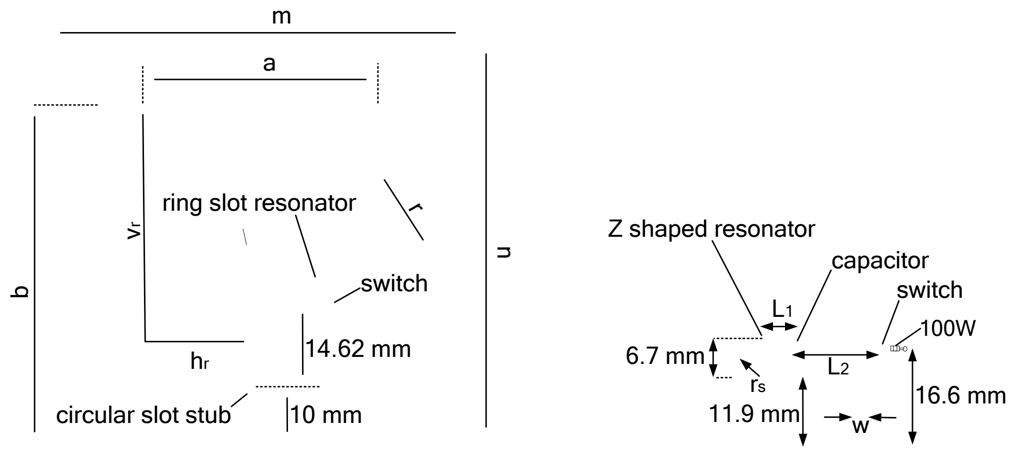
Another interesting feature of this antenna is that effect of the slots can be deactivated by disrupting the slots at the region right under the feed line by using switches [4]. Thus by controlling the switches, the antenna can be switched between UWB mode and narrowband mode. And by controlling the slots dispositions, the antenna frequency response can be tuned in the narrowband mode.



(a) (b)

Fig. 2: S_{11} parameters of the antenna. a) Coplanar port. b) Microstrip port

As an example of antennas for one port CR's is shown in Fig. 4 [5].



(a) (b)

Fig. 4: Schematic of the Vivaldi frequency reconfigurable antenna. a) Top view. b) Bottom view.

This antenna has been highlighted in IET Electronics letter as the first multifunction antenna to combine wideband, notch and narrowband modes. The antenna demonstrated a wideband performance at 2–8 GHz, tunable narrowband rejection between 5.2 and 5.7 GHz, and five narrow passband modes that can be selected at 3.6, 3.9, 4.8, 5.5 and 6.5 GHz. The antenna is composed of a Vivaldi antenna with two ring slot resonators in the tapered slot and a microstrip resonator across it, on the opposite side of the antenna. The narrowband operation is achieved by coupling the slot resonators through gaps in the tapered slot edges. Switched narrowband operations then can be achieved by short circuiting a specific set of pin diode switches in order to control the effective electric lengths of the ring slot resonators. Wideband operation is achieved by decoupling the slot resonators from the tapered slot edges which thus makes the antenna act as a conventional Vivaldi antenna. To reject narrow frequency bands, the microstrip resonator is used in order to insert a notch proportional to its effective electric length. By varying the capacitor, the effective length is varied which results in varying the rejection band. Fig. 5 shows both the simulated and measured S11 parameter of the developed antenna in the wideband mode and in the different narrowband modes

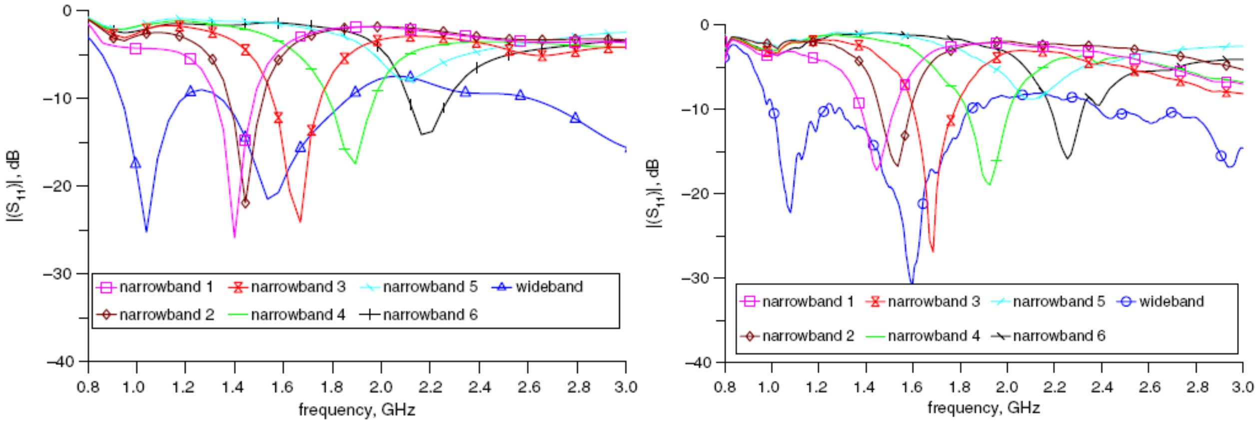


Fig. 5: Simulated and measured S11 in wideband and different narrowband modes. a) Simulated results. b) Measured results.

As indicated in [DD], this antenna has a big potential to be used in CR's with single-port antenna.

4. Conclusion

Antennas for cognitive radios have been treated in this paper. Basic features of the antennas to be used in CR's have been described and two potential antenna candidates developed at The University of Birmingham have been presented and interesting properties have been demonstrated. The area of antennas for CR's is wide open for contributions as very few has been done till now at the hardware level.

7. References

1. J. Mitola III and G.Q. Jr. Maguire, "Cognitive radio: making software radios more personal," IEEE Personal Communications Magazine, vol. 6, nr. 4, pp. 13-18, Aug. 1999

2. W. Webb: "UK Approach to Regulating Cognitive Radio devices", IET Cognitive Radio and Software Defined Radio: Technologies and Techniques Seminar, Sep. 2008, London, UK.

3. F. Ghanem and P.S. Hall, "A two-port frequency reconfigurable antenna for cognitive radios", Electronics Letters, Vol. 45, Issue 11, pp. 534-536, May 2009

4. F. Ghanem and P.S. Hall, "A Bandwidth Reconfigurable Antenna for Cognitive Radios ", Ultra-Wideband, Short Pulse Electromagnetics 9, Springer; 1st Edition, 2010, pp. 397-402.

5. M.R. Hamid, P.S. Hall, P. Gardner, and F. Ghanem, "Multi-Mode Vivaldi Antenna", Electronics Letters Volume 46, Issue 21, Oct 2010

6. IET Magazine, Electronics Letters, features, volume 46, issue 21, "Vivaldi steps up a notch". http://kn.theiet.org/magazine/eletters/4621/vivaldi-steps-up.cfm