Microstrip Reconfigurable Antenna for Cognitive Radio Systems

Simone Genovesi [1], Agostino Monorchio [2], Giuliano Manara [3]

Dipartimento di Ingegneria dell'Informazione, University of Pisa
Via G. Caruso 16, 56122 in Pisa, Italy

[1] simone.genovesi@iet.unipi.it
[2] agostino.monorchio@iet.unipi.it
[3] giuliano.manara@iet.unipi.it

Abstract—**A compact and low profile microstrip antenna is proposed as a framework to design a frequency-reconfigurable radiating device with four distinct and almost independent resonant frequencies with other single or multiple available resonances that can be usefully exploited by the cognitive radio system. The instant frequency reconfiguration is obtained by using pin diodes as RF switches whereas the biasing network comprises four high-impedance microstrip lines and a bias-tee.**

I. Introduction

The electromagnetic spectrum is a shared but finite resource that is going to be congested by the increasing number of users. Moreover, the exploitation of the available frequencies for new services is more and more difficult due to standard regulation or spectrum fragmentation. Moreover, in the modern device market, a multiple standard operability represents a constraint not only for high-end models. Widespread standards such as the Global System for Mobile Communications (GSM), the Wideband Code Division Multiple Access (WCDMA), the High-Speed Downlink Packet Access (HSDPA), the IEEE 802.11a/b/g/n as well as the forthcoming demands of Long-Term Evolution (LTE) pose additional requirements of interoperability and frequency management.

To face this problem, the employment of unused parts of the spectrum, also considering the contemporary use of multiple fragmented free frequencies slots (band aggregation) may alleviate the RF spectrum congestion. In addition, a temporary shared use of a licensed bandwidth by both primary users and secondary one may offer new resources if supported by a suitable negotiation among them. The Cognitive Radio (CR) paradigm [1] has been proposed as a solution since a CR radio network is able to check the instant occupancy of spectrum and then to decide on this basis how to allocate services on temporarily unoccupied parts of the EM spectrum. By resorting to the CR framework, it is therefore possible to provide a communication with an efficient spectrum usage. However, this increased flexibility and smartness of the system has a cost in terms of complexity, both hardware and software. Since a substantial part of these requirements falls upon critical components of the RF front end, such as filters, matching networks and antennas [2], a great effort in improving the state of art in the field of the reconfigurable systems is ongoing in the last years. In particular the attention is focused on the realization of devices for the implementation of a Software Defined Radio (SDR) [3]. A device based on SDR is an integrated system which must exhibit extreme hardware performance to support the necessary software-based signal processing and guarantee the desired flexibility. The final goal is therefore to implement much of the radio system in software, easy to update or upgrade, without changing the controlled hardware. Therefore a software-radio can be considered the ground base of a CR system which exhibits additional capabilities of sensing the surrounding environment, modifying its behaviour, performing adaptation strategies [4].

Frequency reconfiguration places several constraints on the design of the radiating element which does not exhibit nor a fixed single narrowband nor a multiband frequency response but it has to switch among different instantaneous bandwidths in order to exploit the available portion of EM spectrum and also to minimize the effect of interference or noise. In one of the possible CR implementation a part of the system must perform a spectrum-sensing operation to scout the available frequencies useful for the transmission. Generally this task can be performed by a wideband antenna and the proper electronic circuitry. Once the system is aware of the instantaneous RF spectrum, another antenna has to reconfigure its working frequency to radiate in the chosen instantaneous bandwidth.

The proposed antenna configuration can be considered as a framework in order to provide four distinct and almost independent resonant frequencies with, in addition, other single or multiple resonances that can be advantageously exploited by the CR system.

II. Antenna Framework

The proposed antenna framework exploits the edges of a compact antenna, such as a square microstrip patch, that are selectively connected to achieve a discrete reconfigurable frequency tuning within the range 0.8 GHz-3.0 GHz (Fig. 1). The template comprises a square patch element fed by a coaxial cable and four surrounding elements that can be linked to the central one by forward-biasing the pin diodes to change the current distribution on the microstrip antenna.

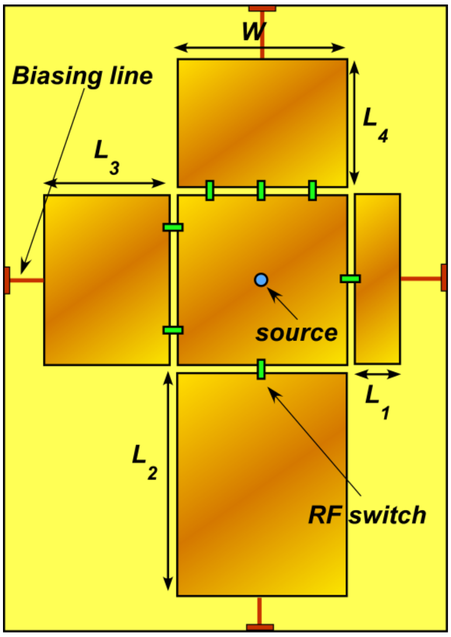

Fig. 1. Antenna template comprising a central square patch element, fed by a coaxial cable (source), connected to the peripheral elements by a series of pin diodes (RF switch). Biasing lines realized with high-impedance microstrips are illustrated as well.

If we consider the state in which only one of the four peripheral elements is connected to the central patch of width W, by properly tuning the length L_i ($i = 1,2,3,4$) of each of the four surrounding units, a single resonance frequency can be independently placed within the desired bandwidth. To accomplish this task a careful analysis of the effects of the number and position of the RF switches, in addition to the shape and dimension of the four patches, has to be carried out. Obviously, all the other possible configurations that allow the flow of the current in more than one peripheral element provide new set of discrete working frequencies.

The biasing lines are placed on the top layer of the antenna substrate thus avoiding any cut in the ground plane which could determined interference with the underneath circuitry (Fig. 1). Their design has to take into account possible undesired degrading effect on the antenna radiation pattern. The RF current flows from the central square patch to a parasitic element depending on the bias state of each pin diode. The DC voltage to the central element can be provided by using a bias tee that avoid the necessity of introducing vias in square patch and limits the number of biasing lines.

A possible set of useful frequencies could comprise 900 MHz (GSM), 1.57 GHz (GPS), 1.84 GHz, and 2.45 GHz which are adopted in GSM, GPS, UMTS and Wi-Fi standards, respectively. An important additional constraint imposed to the antenna design is to obtain a good impedance matching in each instantaneous bandwidth in order to avoid the necessity of an antenna impedance unit which would introduce additional losses in the system.

The antenna framework W and L_i dimensions have been preliminary optimized by using the cavity model of the patch antenna as well as by taking into account the effect of the pin diodes. This analysis allows individuating the best position and number of the RF switches just by observing the flow of the currents on the patch surface. The use of a full wave simulator [5] is important to consider the effect of the pin diode on the resonance frequency both when operating in ON state and in OFF state.

III. Preliminary Results

A preliminary numerical optimization has been carried out for the aforementioned frequencies and the results are shown in Fig. 2. Each curve represents the S_{11} parameter when only one peripheral parasitic element is electrically connected to the central one. It can be seen that each configuration produces a single resonance within the considered bandwidth.

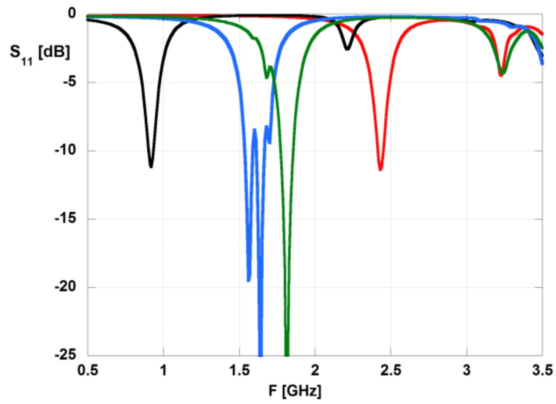

Fig. 2. Simulated S_{11} parameters for each configuration that involves only one peripheral parasitic element at time.

The ongoing activity will evaluate the overall performance of the device in terms of the available resonant frequencies and the radiation pattern realized by the different current paths on the microstrip antenna.

Measurements on a realized prototype will be carried out and compared with simulation in order to assess the reliability of the design process.

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] P. S. Hall, P. Gardner, and A. Faraone, "Antenna Requirements for Software Defined and Cognitive Radios," *Proceedings of the IEEE*, vol. 100, no. 7, pp. 2262 –2270, Jul. 2012.

[3] E. Buracchini, "The software radio concept," *IEEE Communications Magazine*, vol. 38, no. 9, pp. 138–143, Sep. 2000.

[4] Y. Tawk, S. K. Jayaweera, C. G. Christodoulou, and J. Costantine, "A comparison between different cognitive radio antenna systems," in *2011 International Symposium on Intelligent Signal Processing and Communications Systems (ISPACS)*, 2011, pp. 1 –5.

[5] Ansoft HFSS: www.ansoft.com.