A New Reconfigurable Antenna Design for Cognitive Radio

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***Abstract*—This letter presents a new antenna design suitable for cognitive radio communication. It consists of two structures incorporated together into the same substrate. The first structure is an ultrawideband (UWB) antenna covering the spectrum from 3.1–11 GHz for channel sensing. The second structure is a frequency reconfigurable triangular-shaped patch for establishing communication with another RF device. The antenna reconfigurability is achieved via a rotational motion. A prototype antenna was fabricated and tested in order to validate the suggested method.**

***Index Terms*—Cognitive radio, frequency reconfigurable, rotating shape, ultrawideband (UWB) antenna.**

I. Introduction

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, a cognitive radio should be able to recognize spectrum availability and reconfigure itself for more efficient communications and spectrum use [1]. The monitoring of the wireless spectrum is the key in cognitive radio since the spectrum can be idle for 90% of the time. Therefore, in such a system, we should differentiate between a primary user that owns the spectrum and a secondary user that wants to access the spectrum whenever it is idle [2].

Some research has been done related to the design of antennas for cognitive radio systems. In [3], a new technique is introduced that uses a tunable narrowband planar inverted-F antenna (PIFA). In [4], two reconfigurable antenna systems, both capable of operating in five cellular radio bands, are presented. Both approaches yield overall improvements in performance and are likely to be used in cognitive radios. In [5], a combination of wideband and narrowband antennas into the same volume is presented. The wideband antenna is a coplanar waveguide (CPW)-fed printed hourglass-shaped monopole that operates from 3–11 GHz. The narrowband antenna is a microstrip patch printed on the reverse side of the substrate and connected to the wideband antenna via a shorting pin and designed to operate from 5.15–5.35 GHz. The authors in [6] discuss some of the possible antenna requirements for cognitive radio applications and outline some design approaches. Results for three antennas, suitable for small and medium-sized terminals, are given.

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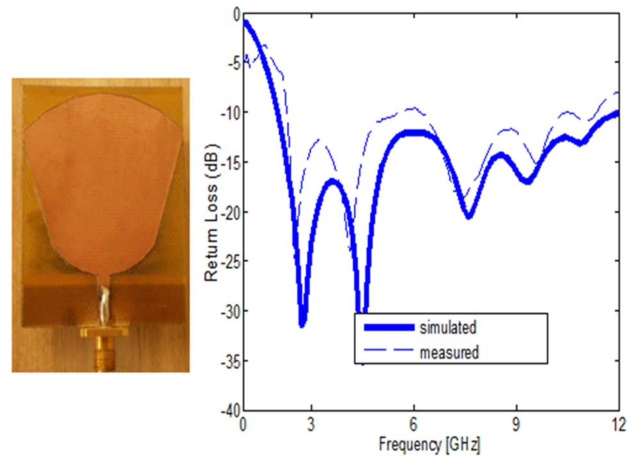

Fig. 1. The antenna structure and its return loss.

In this letter, a new antenna structure for cognitive radio is presented. In Section II, the design of the ultrawideband (UWB) antenna for channel sensing is presented. Section III discusses the reconfigurable triangular-shaped antenna. In Section IV, we show the final cognitive antenna design that is based on the two structures detailed in Sections II and III.

II. "Sensing" Antenna Design

In cognitive radio systems, we need the capability to:

1) sense the spectrum ("sensing" antenna);
2) communicate ("reconfigurable communicating" antenna);
3) resense the spectrum ("sensing" antenna).

A wideband antenna is necessary in order to be able to achieve the channel sensing. This section details the "sensing" wideband antenna structure. The antenna topology is based on the antenna design shown in Fig. 1. Its corresponding return loss is also included.

Our goal is to achieve a "sensing" antenna and a "reconfigurable communicating" antenna in the same substrate. The idea is to remove a slot from the antenna shown in Fig. 1 in order to have space for the "reconfigurable communicating" antenna. The corresponding antenna topology is shown in Fig. 2. It consists of two layers. The top layer is the slotted polygon-shaped patch. The bottom layer is the partial ground. It is fed via a microstrip line to produce radiation above and below the substrate. The chosen substrate is Rogers Duroid with dielectric constant 2.2 and height 1.6 mm. All simulations were done using HFSS ver. 11. The corresponding antenna return loss is shown

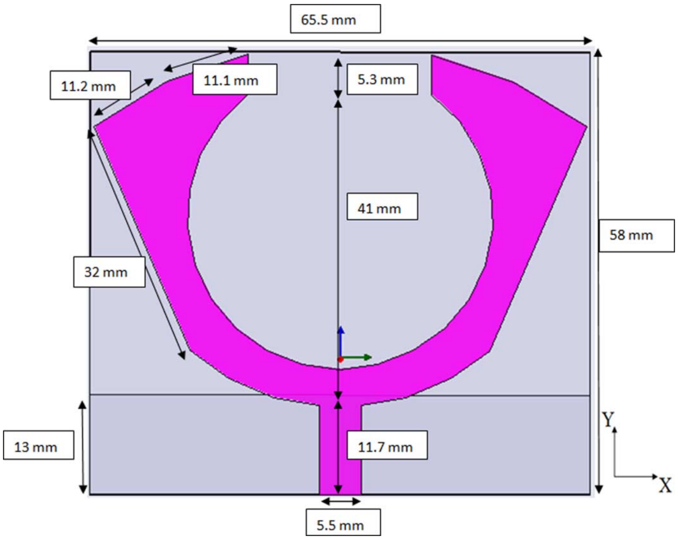

Fig. 2. The "sensing" antenna structure.

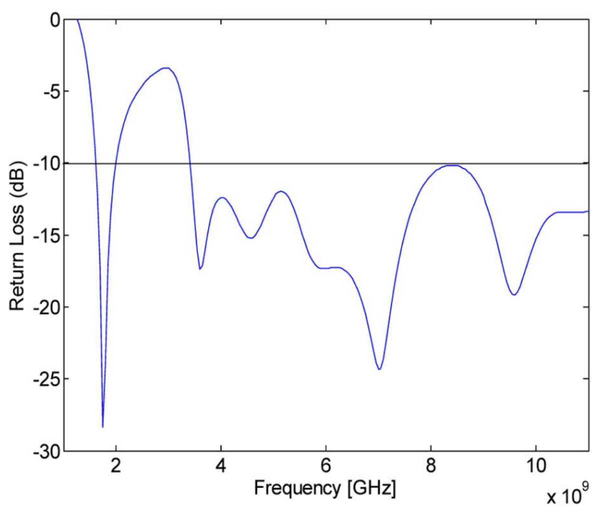

Fig. 3. The return loss for the sensing antenna structure.

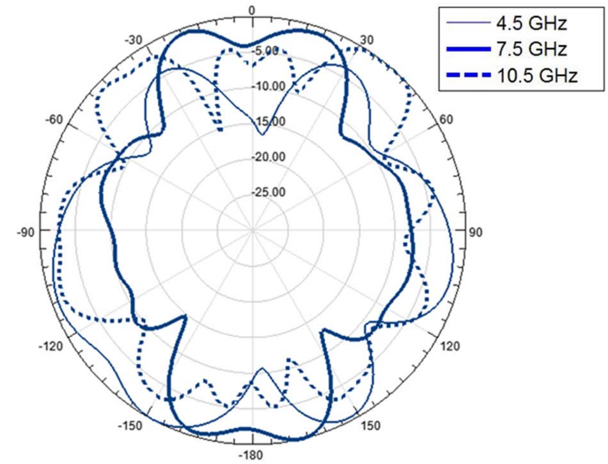

Fig. 4. The normalized antenna radiation pattern for a set of frequencies.

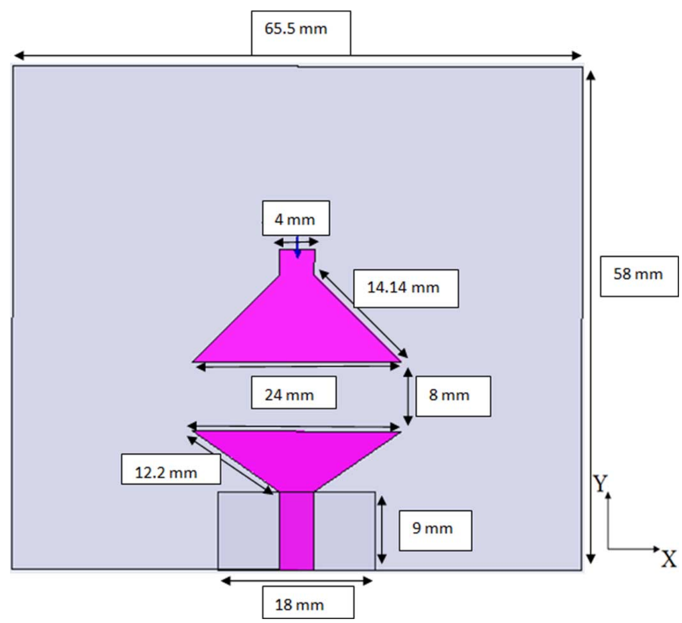

Fig. 5. The "reconfigurable communicating" antenna structure.

in Fig. 3. It shows coverage from 3.3–11 GHz, making it suitable for channel sensing in cognitive radio systems.

For an antenna to be suitable for channel sensing, it should possess an omnidirectional radiation pattern. The antenna structure investigated in this section satisfies this requirement. The computed radiation pattern in the X-Z plane at 4.5 (thin line), 7.5 (thick line), and 10.5 GHz (dotted line) is shown in Fig. 4.

It is essential to note that the addition of the rounded shape just after the stripline feed-line is responsible for producing the required wide bandwidth for the antenna. This rounded shape has the effect of making the antenna input impedance close to 50 Ω for the band from 3.3–11 GHz. This antenna structure also shows a resonance at 1.9 GHz.

III. "Reconfigurable Communicating" Antenna Design

In this section, the structure for the "reconfigurable communicating" antenna is detailed. Reconfigurable antennas have drawn considerable attention, especially for broadband wireless communication, space-time adaptive processing, multiple-input–multiple-output (MIMO) systems, and cognitive radio. The reconfigurability is achieved by using active switches. These switches or tuning elements can be fabricated from several technologies (microelectromechanical systems (MEMS)-based, a combination of MEMS and electronic band-gaps materials, piezoelectric transducers, p-i-n diodes, lumped elements, and photoconductive). In this work, we suggest a new way to implement frequency reconfigurable antenna design. A rotating part of the antenna is responsible to produce the required frequency tuning [7]. The advantage of this method is that no biasing circuits for switch activation are needed, which might affect the antenna performance.

The "reconfigurable communicating" antenna structure is summarized in Fig. 5. By rotating the antenna patch by 180°, a different structure is being fed by the microstrip line. This rotation will produce different resonances, making the antenna suitable to communicate at the frequency specified by the "sensing" antenna. The antenna top layer consists of

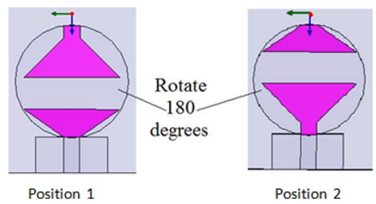

Fig. 6. The process of rotation.

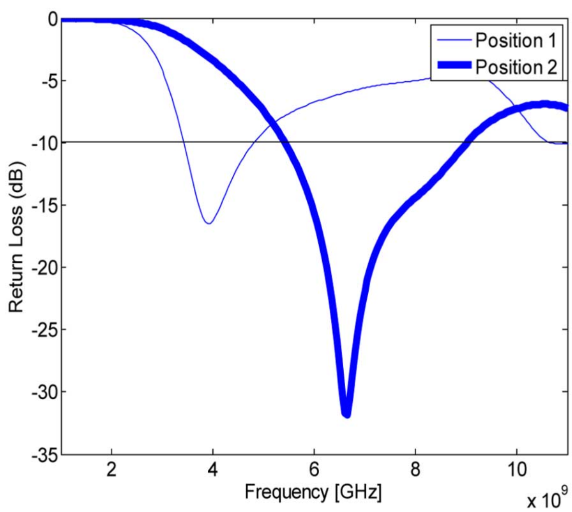

Fig. 7. Frequency tuning for the "reconfigurable communicating" antenna.

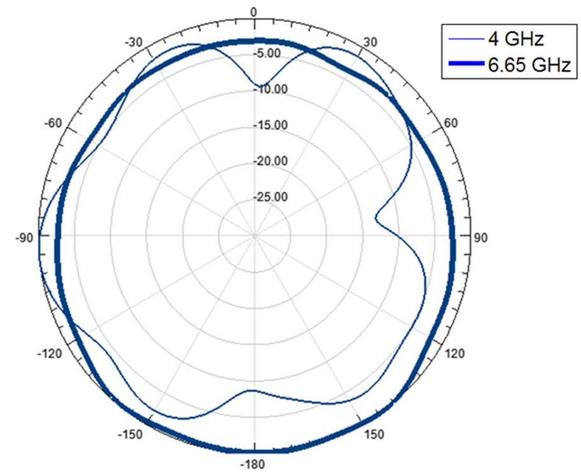

Fig. 8. The normalized radiation pattern for positions 1 and 2.

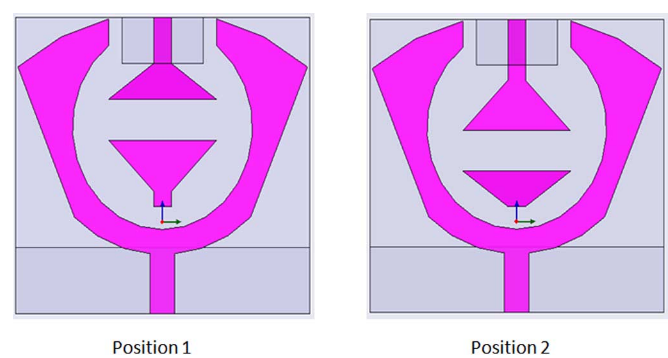

Fig. 9. The cognitive antenna structure.

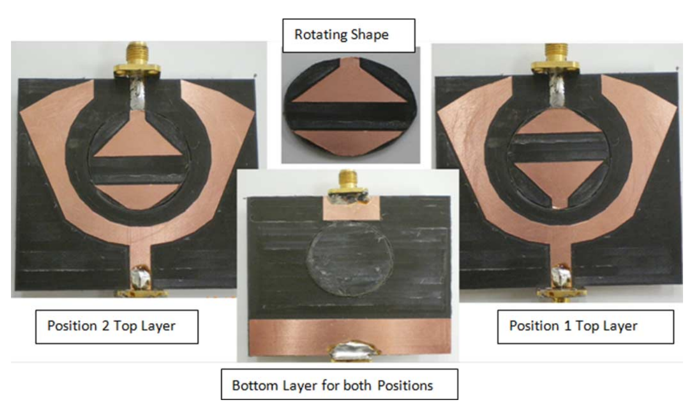

Fig. 10. The fabricated antenna prototype.

two triangular-shaped patches that are separated by a given distance. Similar to the "sensing" antenna, this structure is fed via a microstrip line and has a partial ground. Since this antenna is going to be incorporated with the "sensing" antenna, its substrate size was taken to be the same as the "sensing" antenna. Its ground dimension is taken to be 18 mm $\times$ 9 mm so that it will not affect the radiation from the patch of the "sensing" antenna. The process of rotation is shown in Fig. 6; the structure shown in the left corresponds to position 1, and the structure shown in the right corresponds to position 2.

The frequency reconfigurability of this antenna can be noticed by comparing the return loss plot presented in Fig. 7. This antenna has the property to tune from 5.3–9.15 GHz (position 1) to 3.4–4.85 GHz (position 2). The computed radiation pattern in the X-Z plane at 6.65 GHz for position 1 (thick line) and at 4 GHz for position 2 (thin line) is shown in Fig. 8. For both positions, the antenna satisfies the omnidirectional property.

IV. Cognitive Antenna Design

In the previous two sections, we have separately discussed the design of the "sensing" and the "reconfigurable communicating" antenna. In this section, we incorporate both designs into the same antenna susbtrate. This has the advantage of reducing space requirements and making the two antennas required for cognitive radio communication lie in the same plane.

The suggested antenna structure is provided in Fig. 9. The dimensions of the different parts of the antenna are the same as those mentioned in the previous two sections. The fabricated prototype is shown in Fig. 10.

The comparison between the simulated and the measured return loss for the "sensing" antenna is shown in Fig. 11. This data is for the antenna at position 1. The same return loss is produced for the "sensing" antenna if the entire antenna structure is at position 2.

Fig. 12 shows the measured and the simulated return loss of the "reconfigurable communicating" antenna for both positions. The required frequency reconfigurability is achieved. The first plot corresponds to position 2 and covers the band from

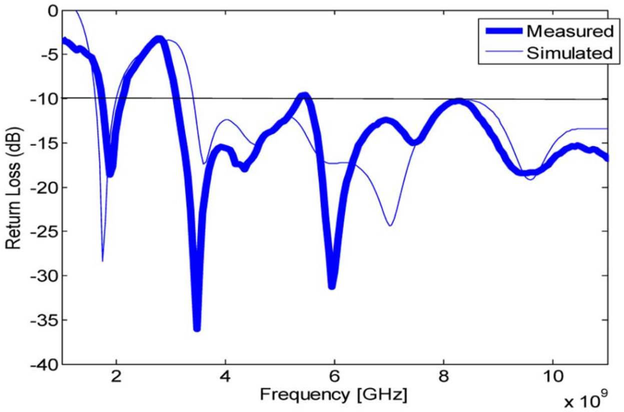

Fig. 11. The "sensing" antenna return loss.

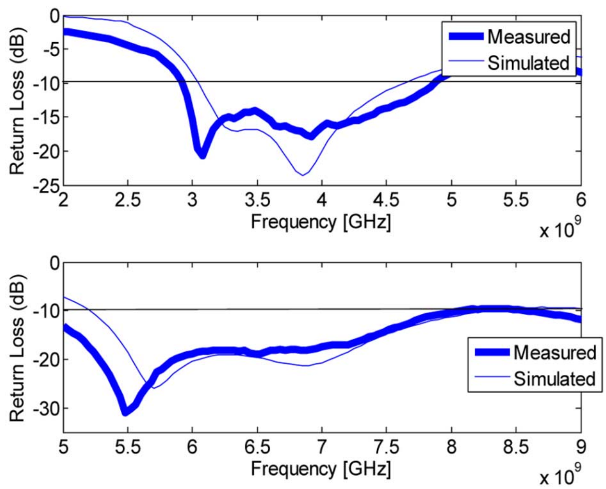

Fig. 12. The "reconfigurable communicating" return loss for both positions.

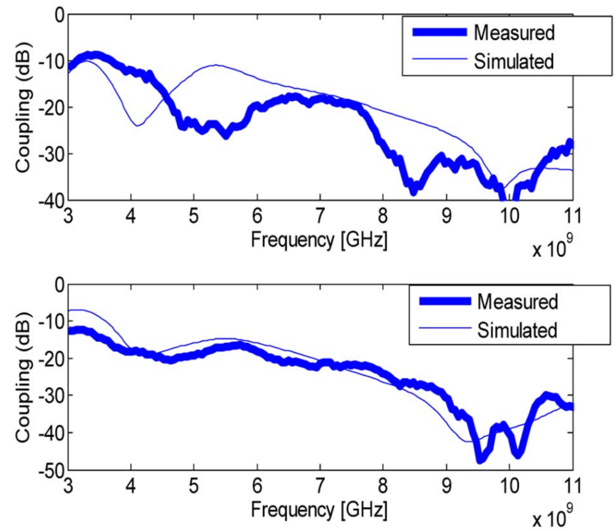

Fig. 13. The antenna coupling for both positions.

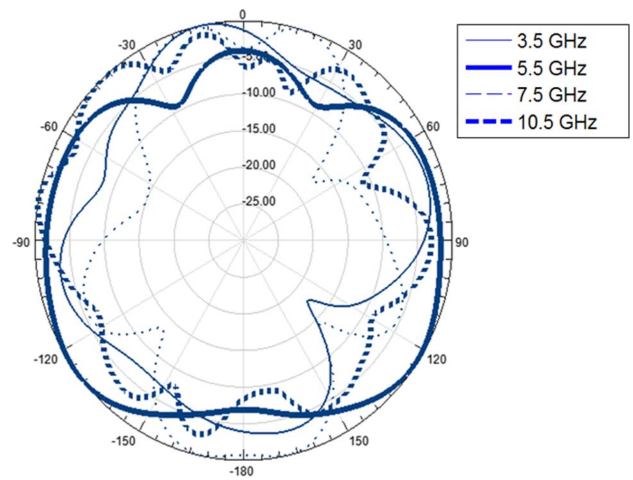

Fig. 14. The normalized antenna radiation pattern.

3–5 GHz. The second plot corresponds to position 1 and covers the band from 5– 9 GHz.

Since the "sensing" and the "reconfigurable communicating" antennas are both incorporated into the same substrate, it is crucial to look at the coupling between them. For both positions, the transmission between the two antennas is below -10 dB for the whole band of interest. Fig. 13 shows the simulated and the measured coupling for position 1 in the first plot and for position 2 in the second plot. The antenna radiation pattern at 3.5 (position 2, thin line), 5.5 (position 2, thick line), 7.5 (position 1, dotted thin), and 10.5 GHz (position 1, dotted thick) is shown in Fig. 14.

V. Conclusion

In this letter, a new antenna design for cognitive radio is discussed. It consists of two structures. The first one is a wideband antenna for channel sensing. The second structure is a reconfigurable triangular-shaped patch. Both structures are embedded into the same susbtrate. A prototype antenna was fabricated to prove the suggested method. A coupling of less than -10 dB is shown for the entire frequency band. This antenna is a best candidate for future cognitive radio communication. For future work, one can control the rotation in the "reconfigurable communicating" antenna via a field programmable gate array (FPGA). Also, the design of the "sensing antenna" can be done to cover a higher bandwidth (700 MHz–11 GHz).

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