Tuning A Cognitive Radio Antenna System with Motion Detection

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Abstract— **In this paper we discuss a cognitive radio antenna system that possesses the ability to tune its operation based on sensing movements in its surrounding. The surrounding awareness ability is added by incorporating an Infra Red (IR) motion detector with the antenna system. This concept is tested on a varactor based reconfigurable filter cascaded with a cognitive radio antenna system. Once movement is detected, the IR sensor generates a voltage that can be varied to allow the tuning of the varactor and the tuning of the antenna operating frequency. The cognitive radio system is measured and analyzed for concept validation**

Index Terms— Cognitive Radio, Infra Red, Motion Detection, Reconfigurable Antennas, Varactor.

I. INTRODUCTION

A cognitive radio antenna system is required to be able to dynamically change its operation based on sudden changes in the communication channel. The need for such requirements has pushed antenna designers to develop antennas that are aware of their surroundings, and can change their functionality as a reaction to any changes in their environment and mission.. Reconfigurable antennas used in cognitive radio antenna systems allow tuning on demand with a fast response time. Antenna designers have resorted to various techniques for antenna reconfiguration. Switching components such as p-i-n diodes [1], RF MEMS or varactors [2], photoconductive switches [3] and mechanical tuning tools [4], have been mainly incorporated into different antenna structures for reconfiguration purposes.

In this paper we add a surrounding and environment awareness functionality to cognitive radio antenna designs. The integration of an IR sensing circuit into the biasing network of a varactor based reconfigurable antenna, adds cognition to the antenna system. This IR sensing circuit gets activated as soon as movement is detected in a determined location and generates an output that biases a reconfigurable component such as a varactor. Once the component is biased the antenna is tuned and the function is changed. The idea is to be able to change the antenna operation fast just by waving a hand over the IR sensor.

In this paper, we apply this technique to a varactor based reconfigurable filter [5]. The filter is cascaded with a wideband antenna [6] and is capable of turning the operation of the antenna. This technique can be applied in a cognitive radio or in any application that requires such surrounding awareness. Soldiers in the field, doctors in the operating room or autonomous operation in secured locations benefit from such technique as well.

In the next section the IR motion detection circuit is discussed and detailed. Section III presents the antenna system where this technique is applied. Section IV discusses various potential application of this technique and section V concludes the paper.

II. IR MOTION DETECTION CIRCUIT

The concept of this circuit is summarized in the diagram shown in Figure1. The circuit is composed of two major blocks: The processing block and the variable power supply block. The processing block contains the IR sensor that detects the movement and activates an arduino uno microcontroller [7]. The arduino board is programmed to generate an output voltage once a movement is detected. This output voltage is fed through a 5 V relay to a voltage regulator that is controlled by a 5 KΩ potentiometer. The whole circuit is powered by four, in series, 9V batteries that supply the necessary voltage to operate the circuit. The detailed circuit diagram is shown in Figure 2. The fact that this circuit is battery powered allows portability and ease of installation.

Once an object comes within a predefined area, the IR circuit will respond based on a predefined output voltage specified by the user. The output voltage can be adjusted by changing the value of the “5 KΩ” potentiometer through a knob. This voltage is later used to bias a varactor. The change in voltage tunes the varactor’s capacitance. The effective range of the IR system is adjusted by altering the resistance value attached to the IR emitter which in this circuit is 1 KΩ as shown in Figure 2. The area covered by this circuit is inversely proportional to the value of this resistance, i.e. the lower the value of the resistance, the greater is the active area.

The circuit components are shown in Figure 3 and consist mostly of one arduino uno microcontroller board [7], a Panasonic PNA4601M Series Infrared Receiver [8], a

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Fairchild Semiconductor QEC112/113 Plastic Infrared Light Emitting Diode [9], a 5K ohm potentiometer, and an ST Microelectronics LM 317 Voltage Regulator [10].

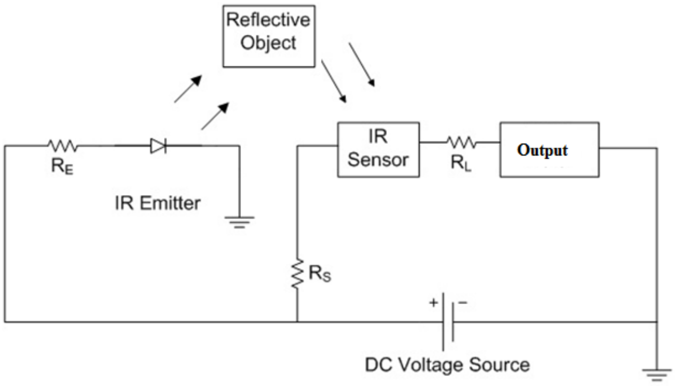

Figure 1 IR circuit Block Diagram

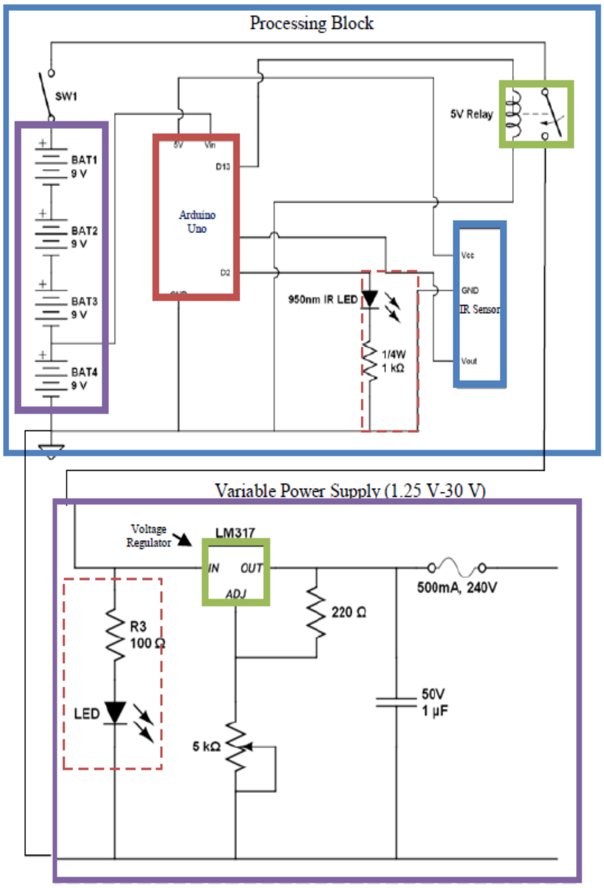

Figure 2 IR Circuit Diagram

III. RECONFIGURABLE FILTER CASCADED WITH A COGNTIIVE RADIO ANTENNA SYSTEM

In this section we cascade a reconfigurable band-pass filter [5] with a wideband antenna [6] to achieve tunable antenna filtering. The wideband antenna originally designed for sensing capabilities *in a spectrum interweave cognitive radio* [11-12], can now be implemented on a more tunable narrowband channel sensing, suitable for *the spectrum underlay cognitive radio* [11-12]. The antenna structure with its dimensions is shown in Figure 4. The reflection coefficient of the wideband antenna is shown in Figure 5 and its radiation pattern for various frequencies is shown in Figure 6 [6].

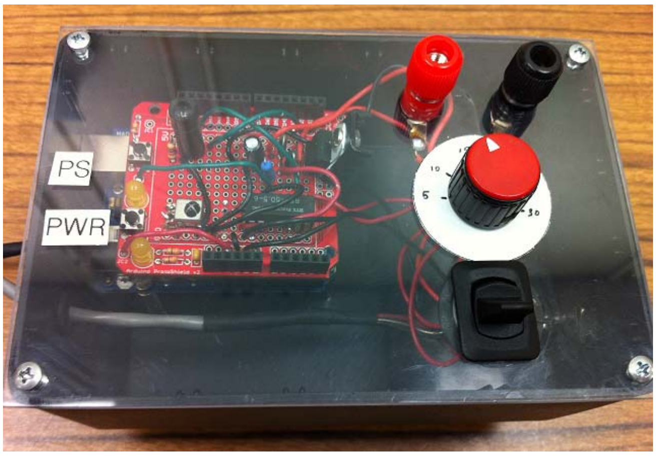

Figure 3 IR Circuit Prototype

The band-pass filter [5] is printed on a Taconic TLY substrate with a dielectric constant of 2.2 and a thickness of 1.6 mm. The total dimensions of the filter are 30 mm x 30 mm. The filter reconfiguration is achieved by incorporating a varactor within its structure. A bias tee is connected to the filter's port. This bias tee allows the RF signal and the DC voltage to feed the filter at the first outer microstrip line section. The biasing of the varactor is achieved by connecting the cathode of the varactor to the outer section (port 1) through a biasing line of width 0.1 mm and length 13.56 mm (line 1) as shown in Figure 7. The second biasing line (line 2) connects the anode of the varactor to the ground of the antenna. This biasing line has a width of 0.1 mm and length of 12.5 mm. The varactor used in this work is the SMV 1405 from Skyworks [13].The DC voltage is supplied from the output of the IR cicuit into the bias tee to activate the integrated varactor. The corresponding filter structure is shown in Figure 7.

By supplying different voltage levels to the varactor, the total capacitance of the structure changes accordingly and hence the filter tunes its operating frequency. The output DC voltage is changed by changing the value of the potentiometer through the rotation of the knob installed in the IR circuit as shown in Figure 2. In a future step the knob will be replaced by software controlled variable resistance to insure the system's self automation.

The filter is then connected through its second port to the wideband antenna shown in Figure 4. The whole cascaded antenna and filter system is shown in Figure 8.The frequency operation of the wideband antenna is now tuned and the antenna has gained surrounding awareness allowing it to tune its pass-band frequency by motion detection. The tuning of the measured reflection coefficient for the whole system is shown in Figure 9 for various voltage outputs.

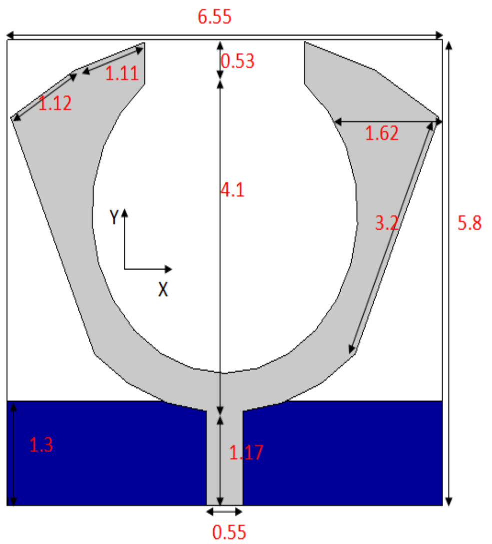

Figure 4 The wideband antenna strucutre with its dimensions [6]

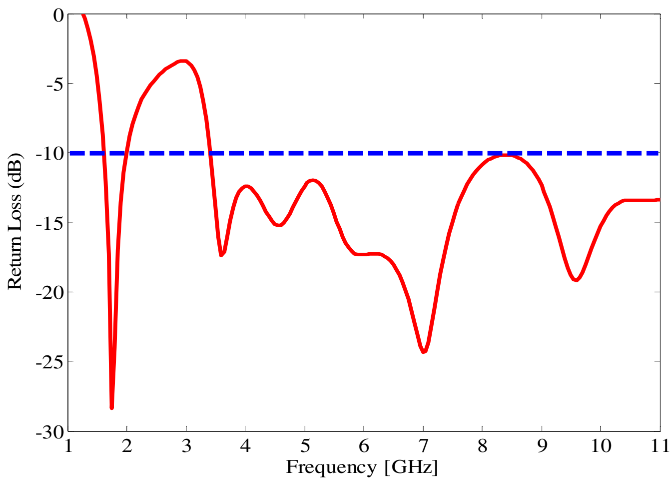

Figure 5 The Wideband Antenna's reflection coefficient

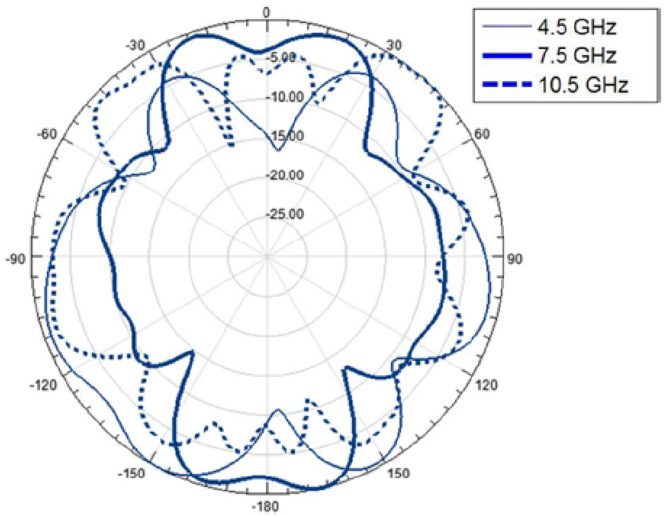

Figure 6 The wideband antenna radiation pattern [6]

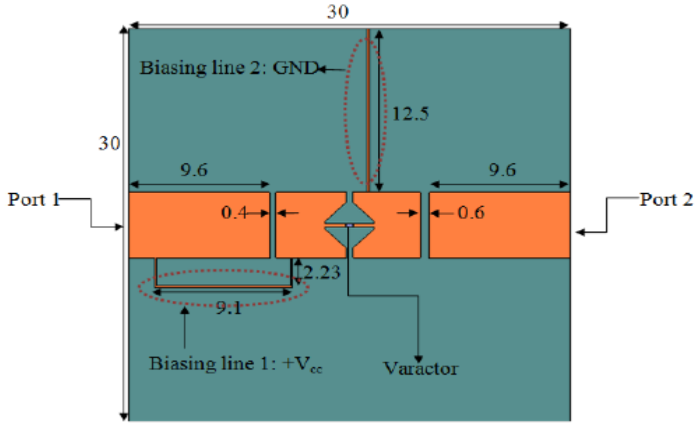

Figure 7 The reconfigurable filter structure [5]

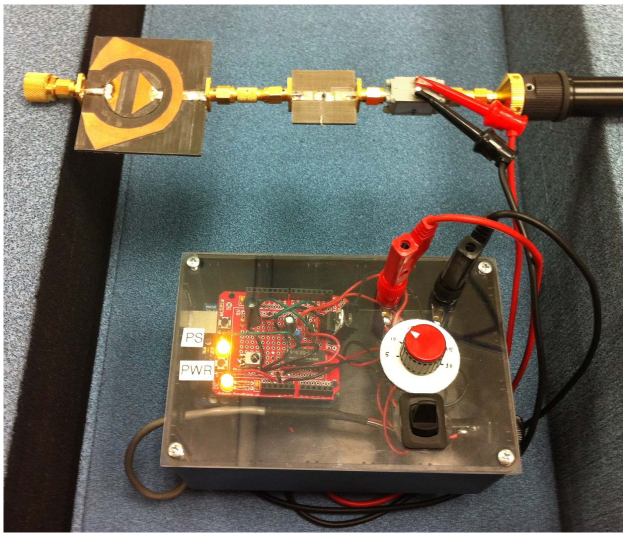

Figure 8 The measurement setup for the whole antenna filter system

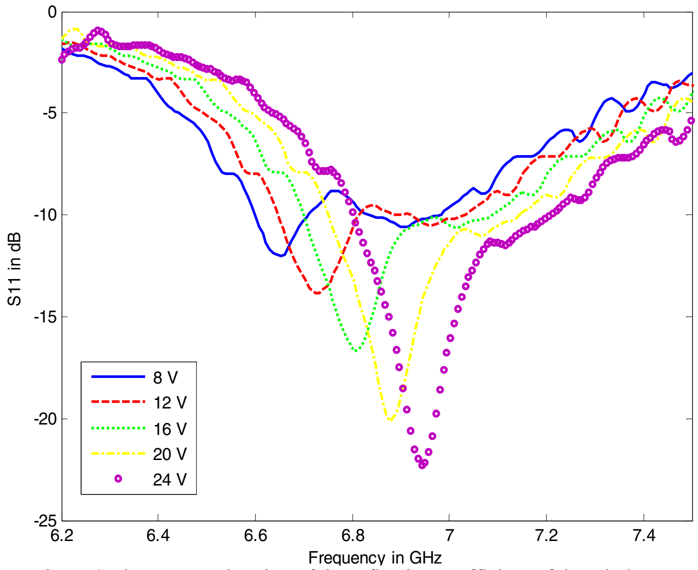

Figure 9 The measured tuning of the reflection coefficient of the whole antenna system showing tunable filtering.

IV. Potential Applications of Antenna Surrounding Awarness Ability

This technique proposes the wireless tuning of a reconfigurable antenna. This tuning is achieved by activating and biasing a varactor through the detection of movement in a predefined area. As a result the antenna tunes its frequency response and reconfigures its operation. Such a technique is proposed for cognitive radio applications where a swift change in frequency response is required. A cognitive radio channel can be achieved on numerous platforms that constitute potential application areas for such technique.

The integration of this surrounding awareness on antennas for implementation with soldier gears, or astronaut equipments constitute a possible venue of applications. Just by a wave of hand, a soldier in the field or an astronaut can tune their communication tools and reconfigure their antenna operation. It will add cognition to the antenna element as well as allow fast tuning and ability to promptly address evolving situations.

This technique is also useful in secured areas where a movement triggers certain communication protocols as a response to intruding activities. In such situations the area of coverage of this system must be adjusted to cover a large landscape. Another venue for such system would be in medical establishments as well as in a hospital's operation rooms where wireless tuning of communications is required for fast communication requirements as well as to preserve sterilization.

Finally it is important to note that many applications can benefit from this technique that adds a lot of cognition and human interaction to the antenna system. It definitely constitutes advancement in reconfigurable antenna control methodologies.

V. Conclusion

In this paper we present a new motion-activated biasing technique. The technique is used to activate a varactor incorporated into a reconfigurable filter cascaded with a cognitive radio antenna by movement detection. The tuning of the varactor capacitance is then achieved by changing the output voltage of the biasing circuit which results in the antenna tuning its operating frequency. This new biasing technique increases the speed of reconfiguration, insures swift antenna tuning and allows wireless control of reconfigurable antennas.

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