Motion-Activated Reconfigurable and Cognitive Radio Antenna Systems

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***Abstract*—In this letter, we present a new technique to control reconfigurable and cognitive radio antenna systems. For both cases, the control is done by sensing a movement in the antenna surroundings. This surrounding awareness ability is achieved by incorporating an infrared (IR) motion detector with the antenna system. Once a movement is detected, the IR sensor generates a voltage that can be used to activate the biasing network of a reconfiguring element on an antenna structure. This concept is first tested on a varactor-based reconfigurable antenna. Then, a modified version of the circuit is used to control a cognitive radio antenna system that consists of a reconfigurable antenna and a wideband sensing antenna.**

***Index Terms*—Cognitive radio, infrared, motion detection, reconfigurable antennas, varactor.**

I. Introduction

THE OPERATION of reconfigurable antennas is based on the appropriate biasing of their reconfiguration networks. The biasing of these networks should be incorporated with the antenna by ensuring a minimal negative effect on the antenna radiation characteristics. The activation of the biasing process is based on supplying the appropriate voltage/current to the integrated switching elements used to reconfigure the antenna's mode of operation. The correct activation of these switching elements is essential to ensure a smooth and fast functioning of the system controlled by the incorporated reconfigurable antenna.

In general, reconfigurable antennas can rely on switching elements such as p-i-n diodes [1], varactors [2], or photoconductive switches [3], as well as on the usage of mechanical tuning tools such as actuators or stepper motors [4].

The rise of a new communication protocol based on cognitive radio has pushed antenna designers to create new antenna systems. These systems should possess the ability to sense the channel for unoccupied parts of the spectrum and tune the communicating mode of operation accordingly. Therefore, a typical cognitive radio antenna system should consist of two sets of antennas. One set is dedicated for sensing and achieved via a wideband sensing antenna, and a second set is dedicated for communication. The second antenna (communicating antenna) should exhibit frequency tuning to be able to operate at identified idle and unused frequencies [5].

In this letter, surrounding awareness is added to both reconfigurable and cognitive radio antenna systems by proposing the integration of an infrared (IR) sensing circuit. This control mechanism is based on a variable dc voltage supply. An IR emitter and another IR sensor detect movement in a specific area and generate a predetermined voltage. The output voltage can be used to bias and control reconfiguring elements on reconfigurable and cognitive radio antenna structures. The whole biasing circuit is *software* controlled by an "arduino" board, portable and powered by batteries. This wireless tuning approach can play a useful role in "first response" situations such as in homeland security, law enforcement, and disaster relief scenarios.

In Section II, the IR motion detection circuit is discussed. Section III presents the control of a varactor-based reconfigurable antenna. Section IV discusses the control of the cognitive radio antenna system. Section V details potential applications for such technique, and Section VI concludes this letter.

II. IR Motion Detection Circuit

The IR motion detection circuit is based on an IR emitter and an IR detector. Once the link between these two devices is broken, a voltage is generated. The object that intercepts the link acts as a reflective object [6].

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. It is essential to note that the area covered by the 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 IR circuit is software controlled and battery powered, which allows portability and ease of installation. It is mainly 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 that is responsible for the software control is programmed to generate a specified output voltage. This output voltage is fed through a 5-V relay to a voltage regulator that is controlled by a 5-kΩ potentiometer.

The variable power supply block generates a variable voltage by changing the value of the 5-kΩ potentiometer through a knob. Once an object comes within a predefined area, the IR circuit responds based on a predefined output voltage specified by the user [6]. This can be changed by altering the value of the

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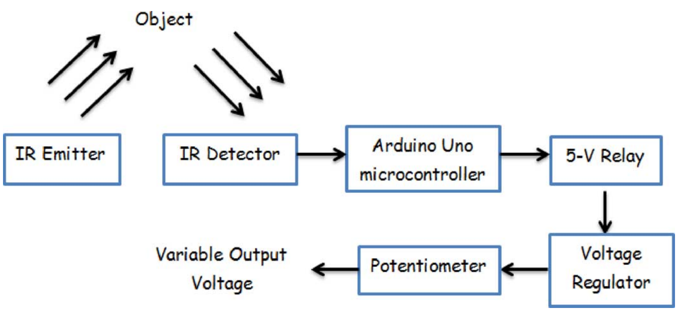

Fig. 1. IR circuit block diagram.

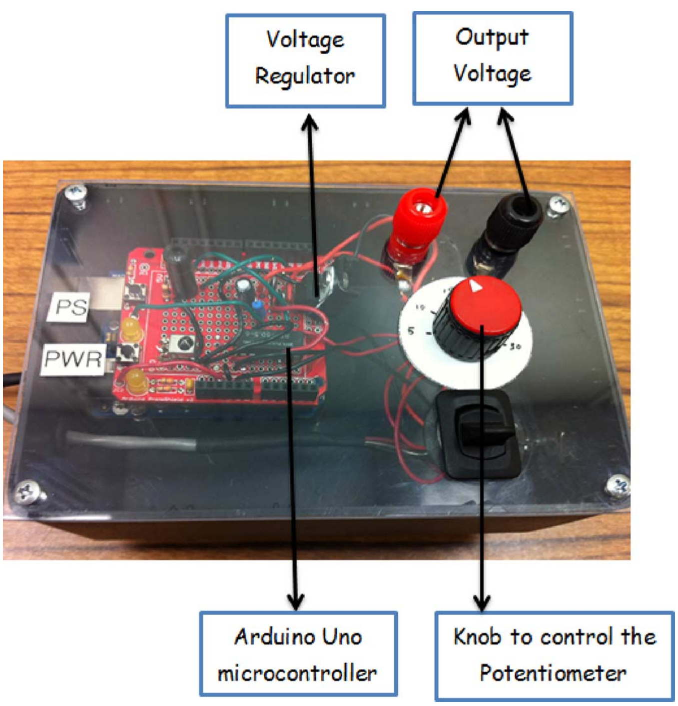

Fig. 2. IR circuit diagram.

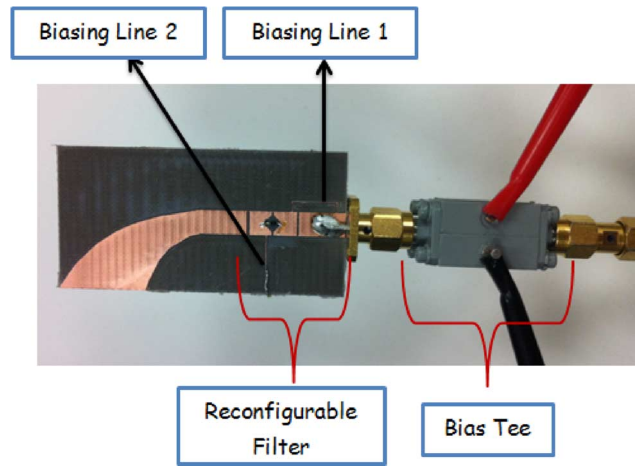

Fig. 3. Fabricated filtenna top layer.

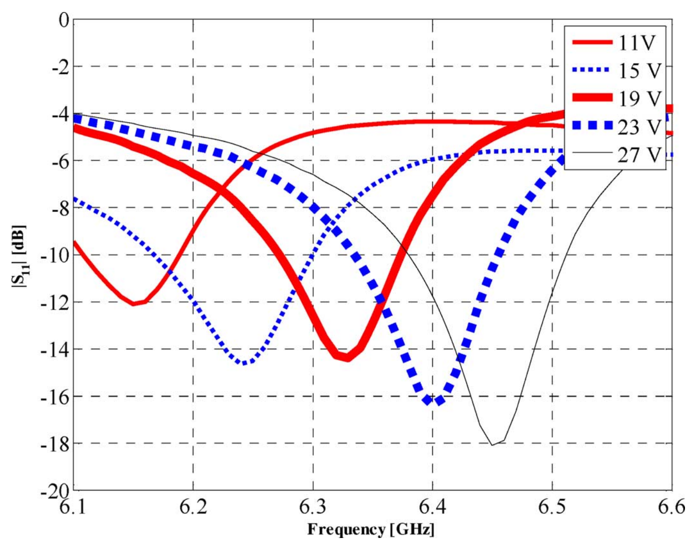

Fig. 4. Change in the reconfigurable antenna reflection coefficient.

potentiometer. A layout of the general operation of the circuit is shown in Fig. 1.

The corresponding circuit is shown in Fig. 2. It consists mainly of one arduino Uno microcontroller board [7], Panasonic PNA4601M series infrared receiver [8], 5-kΩ potentiometer, a Fairchild Semiconductor QEC112/113 plastic infrared light emitting diode [9], and an LM 317 voltage regulator [10].

III. Adding Surrounding Awareness to a Reconfigurable Antenna

The reconfigurable antenna consists of dual-sided Vivaldi radiating patches as shown in Fig. 3 [11]. The reconfiguration is achieved by incorporating a reconfigurable bandpass filter within the antenna feeding line. The integration of the filter transforms the wideband behavior of the Vivaldi antenna into narrowband [11]. The combination of the antenna plus the filter is referred to as "filtenna" or "filter-antenna."

The reconfiguration in the Vivaldi antenna operating frequency is achieved by incorporating a varactor [12] in the middle section of the filter structure. The job of the varactor is to change the total capacitance of the radiating structure allowing a change in the Vivaldi antenna reflection coefficient [11].

The corresponding voltage required to change the capacitance of the varactor is supplied from the bias tee to the anode of the varactor via biasing line 1. The job of biasing line 2 is to ground the second end of the varactor. The change in the antenna reflection coefficient is shown in Fig. 4 for different biasing voltages. These measurement data are based on the experimental setup shown in Fig. 5. One can notice that the output voltage from the IR circuit is now connected to the input of the bias tee to be supplied to the varactor. It is essential to note that the bias tee is used to supply the appropriate dc voltage to the varactor as well as the RF signal to the antenna. Once an object is detected by the IR circuit, a voltage is generated that can be changed by controlling the potentiometer value manually via the knob shown in Fig. 2. The potentiometer will be altered via software in a future version of this circuit.

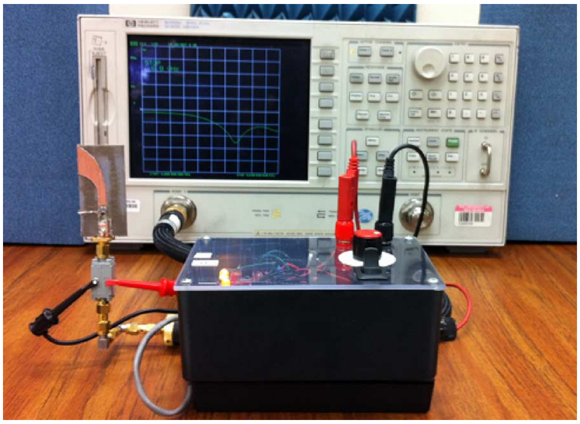

Fig. 5. Measurement setup of the filtenna with surrounding awareness.

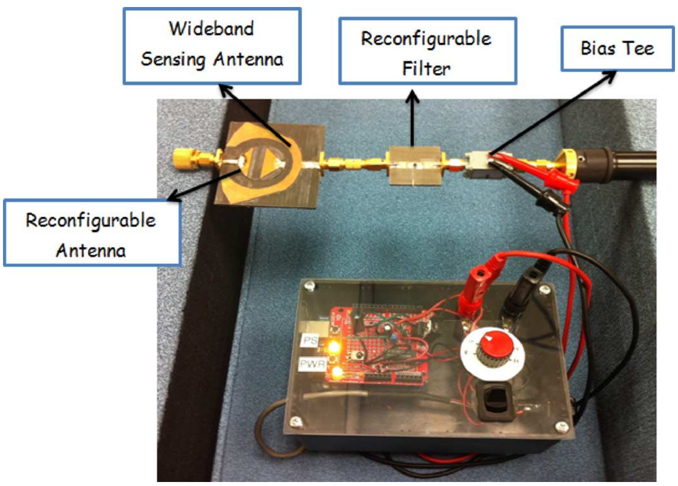

Fig. 6. Cascade of the reconfigurable filter with the wideband antenna.

IV. Adding Surrounding Awareness to a Cognitive Radio Antenna System

A cognitive radio antenna system consists of a wideband antenna for spectrum sensing and a reconfigurable antenna for communication purposes [5]. In this letter, the antenna discussed in [5] is taken as an example to be controlled via the IR circuit detailed previously.

One of the main limitations of wideband sensing in a cognitive radio environment is the bandwidth of the signal that needs to be processed by the analog-to-digital converters (ADCs). This requires high processing power as well as expensive ADCs. One solution is to convert the wideband sensing into narrowband sensing where the channel is divided into subbands that are sensed consecutively.

To control the wideband antenna, the filter that is integrated in the feeding line of the Vivaldi antenna shown in Fig. 3 is now cascaded with the wideband antenna of the cognitive radio system discussed in [5] as shown in Fig. 6. This cascaded system is now responsible to change the wideband response of the antenna shown in Fig. 7 into a narrowband response. This narrowband response is a result of cascading the reconfigurable bandpass filter with the wideband antenna.

Different voltage levels can be generated by the IR circuit. These voltages are changed by adjusting the potentiometer

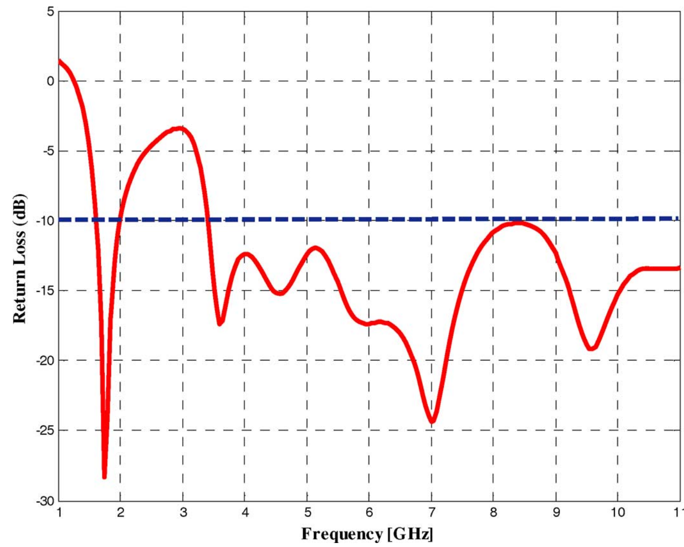

Fig. 7. Reflection coefficient of the wideband antenna.

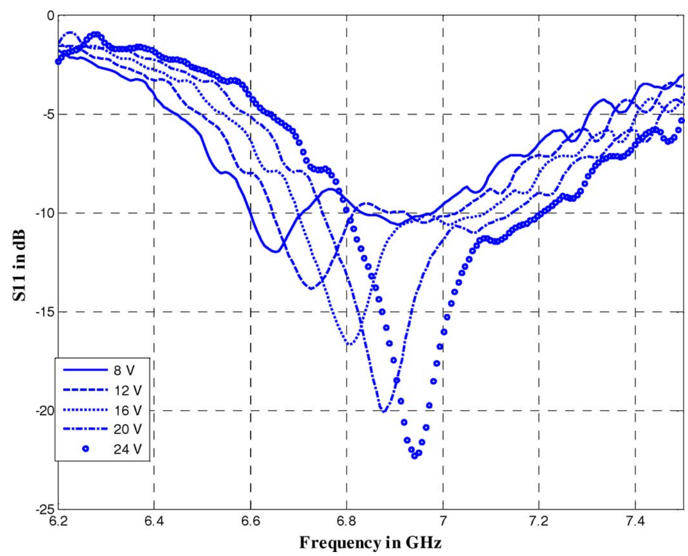

Fig. 8. Measured tuning of the reflection coefficient of the whole antenna system showing tunable filtering.

through the knob connected to it as shown in Fig. 6. By supplying different voltage levels to the varactor through the bias tee, the total capacitance of the structure changes accordingly, and hence the filter tunes its operating frequency.

The frequency operation of the wideband antenna is now tuned, and the antenna has gained surrounding awareness allowing it to tune its passband frequency by motion detection. The tuning of the measured reflection coefficient for the whole system is shown in Fig. 8 for various voltage outputs.

The communicating narrowband antenna discussed in [5] achieves frequency tuning by resorting to a stepper motor that allows the antenna to rotate, thus activating different patches at separate times. This results in frequency tuning of the communicating antenna. The stepper motor can also be controlled at the same time with a modified version of the IR circuit. The modified IR circuit diagram shown in Fig. 9 has two outputs. The first output (Output 1) supplies a variable voltage that

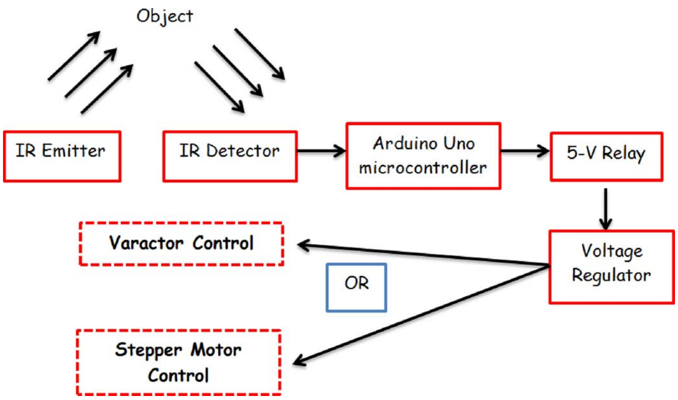

Fig. 9. Modified IR circuit diagram with two outputs.

biases the varactor reconfigurable filter and converts wideband sensing into narrowband sensing. The second voltage output feeds the stepper motor; thus allowing the tuning of the communicating antenna. As a result, the whole cognitive radio antenna system is controlled by the IR detection circuit.

The modified version of the current IR circuit is still a work in progress. We have not completed this experiment yet since we are in the midst of improving the whole antenna system package and diversifying its control. The idea is to be able to control various reconfiguration techniques simultaneously with an added portability function.

V. Potential Applications of Antenna Surrounding Awarness Ability

This technique proposes the wireless tuning of reconfigurable and cognitive radio antenna systems. This tuning is achieved by activating and biasing various reconfiguring elements on antenna structures through the detection of movement in a predefined area. As a result, the antenna tunes its frequency response and reconfigures its operation. Such technique is beneficial in applications where a swift change in frequency response is required, especially in situations such as homeland security, law enforcement, and disaster relief scenarios.

The integration of this surrounding awareness on antennas for implementation with soldier gear or astronaut equipment constitutes a possible venue of applications. Just by the wave of a 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 a system would be in medical establishments as well as in 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.

VI. Conclusion

In this letter, we present a new technique to wirelessly tune reconfigurable and cognitive radio antenna systems. The tuning is based on generating various controlled output to reconfiguring elements on antenna structures. The interception of the link between an IR emitter and IR detector generates an output voltage that can be changed as described in this letter. The technique is tested on a reconfigurable antenna and a cognitive radio antenna system and has proven its validity. In the cognitive radio antenna system, the technique transforms the sensing process from wideband to narrowband and controls the communicating antenna simultaneously.

This motion-activated biasing technique introduces a new method of antenna reconfiguration under stressful and highly demanding environments. By a simple hand wave, a communication protocol is tuned and antenna reconfiguration is achieved.

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