# A Novel Optically Controlled Reconfigurable Antenna for Cognitive Radio Systems

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***Abstract*—An optically controlled compact reconfigurable antenna with integration of wide and narrow bands is investigated for cognitive radio (CR) systems. The proposed antenna consists of two parts, one for spectrum sensing and the other for communication. With an inherent property, four photoconductive silicon switches are used to achieve reconfigurable frequency characteristics. An antenna prototype has been designed, fabricated and measured. The simulated and measured results show that the proposed antenna is a potential candidate for future cognitive radio communications.**

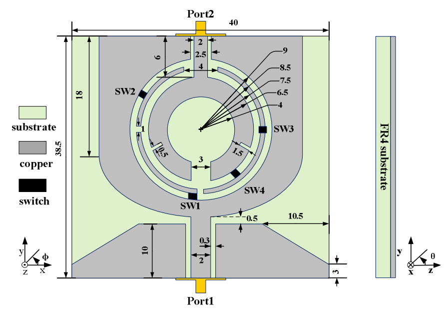
## I. INTRODUCTION

With the increasing demand for wireless communications, the radio frequency spectrum has become a scarce resource. Nevertheless, some frequency bands in the spectrum, especially above 3 GHz, are partially unoccupied at most time [1]. Nowadays, Cognitive radio (CR) is considered as the promising solution to enhance spectrum utilization [2]. In a CR system, the ultra-wideband (UWB) antenna (i.e. "sensing antenna") can scan a broadband for spectrum sensing. When it detects an idle frequency band available, the narrowband reconfigurable antenna (that is "communicating antenna") will switch to the corresponding unused band for communication [3].

Different types of reconfigurable antennas have been proposed. In most cases, electrical devices, such as varactor and PIN diodes, or mechanical switches have been incorporated in the antenna prototypes [4], [5]. In this paper, we present an optically controlled reconfigurable antenna with a compact structure of wide and narrow band integration. Photoconductive silicon chips were employed as the switching elements. This type of optical switch does not need additional biasing lines, with the advantages of less electromagnetic influence on antenna radiation, and high frequency transition speed [6].

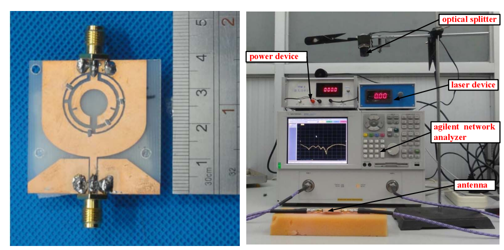
## II. ANTENNA CONFIGURATION

Fig. 1 shows the proposed antenna, which is printed on an FR4 substrate with relative permittivity epsilon_r=4.4, loss tangent tanδ=0.02, thickness h=0.5 mm, and dimension of $40\times38.5$ mm$^2$. The outer coplanar waveguide (CPW) fed U-shaped monopole antenna with tapered ground operates in the wide band from 3 to 11 GHz. The U-shaped patch also works as the ground for inner CPW fed open-annulus narrowband




(a) (b)

Fig. 1. Configuration of the proposed antenna (a) top view (b) side view




(a) (b)

Fig. 2. Photographs of (a) Fabricated Wide-Narrowband antenna and (b) measured devices.

antenna. A coupling slender open ring is divided into four parts and embedded in the space between the UWB and narrowband antennas, enhancing impedance matching of the reconfigurable antenna. To achieve frequency reconfigurable characteristics, four $1\times1\times0.4$ mm$^3$ photoconductive switches (i.e. SW1-SW4), shown with small dark blocks in the figure, are set in the gaps of the proposed antenna. When light illuminates one of switches, it is turned ON and behaves as a short-circuiting conductor. If there is no light beam, the switch is turned OFF and acts as an insulator. The structure or ground of the inner antenna can be changed by combining the different slender ring parts and optically controlled switches states, making different current paths in essence, so as to realize four operating frequencies. When only SW2 and SW4 are ON (case 1), the bandwidth of the narrowband antenna is between 5.8 and 6.8 GHz. Once SW3 and SW4 are ON (case 2), the antenna shifts its operating band to 6.7–7.3 GHz. When only SW1 is activated (case 3), 7.0–8.4 GHz band is covered. In case 4, only SW2 is illuminated, 7.9–9.2 GHz band is achieved.

## III. RESULTS

The proposed antenna was fabricated and measured, as shown in Fig. 2. The reflection coefficient of the UWB antenna is depicted in Fig. 3, validating the expected band from 3 to 11 GHz with $S_{11}$ less than -10 dB. In this experimental measurement, an *n*-type silicon with high resistivity ($\rho=2.5\times10^3$ Ω.cm) was used as the switching element and an 808 nm-wavelength laser with an optical splitter was utilized to activate the silicon switches. Fig. 4 shows the reflection coefficient values of the narrowband antenna for different cases. The four reconfigurable bands are 5.8-6.8 GHz, 6.7-7.3 GHz, 7.0-8.4 GHz, and 7.9-9.2 GHz, which focus on the upper frequency sub-band of UWB. The divergence between measured and simulated S parameters, especially in case 2, is mainly due to laser power and switches manufacture tolerances, e.g. the size of switches that has influence on the resistance. In this design, the two antennas were integrated together to reduce the whole size. To demonstrate the good isolation between the UWB and narrowband antennas in four situations, the transmission coefficients between the spectrum sensing antenna with Port 1 and the communication antenna with Port 2 were simulated and measured. With reference to the figure 5, the $S_{21}$ is below -15 dB in the frequency range from 3 to 11GHz and even reaches -20 dB over the band of 6-10 GHz. Finally, the peak gains of the UWB and narrowband antenna are depicted in Fig. 6. The UWB antenna is changing in range from 2.6 to 4.1 dBi and the narrowband antenna is varying from -0.1 to 4.5 dBi at the four operating bands.

We also analyzed radiation patterns and current distributions. Due to the limited paper size, they will not be discussed here.

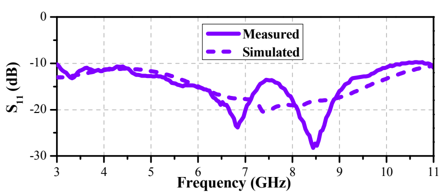



Fig. 3. Measured and simulated reflection coefficients of UWB antenna.

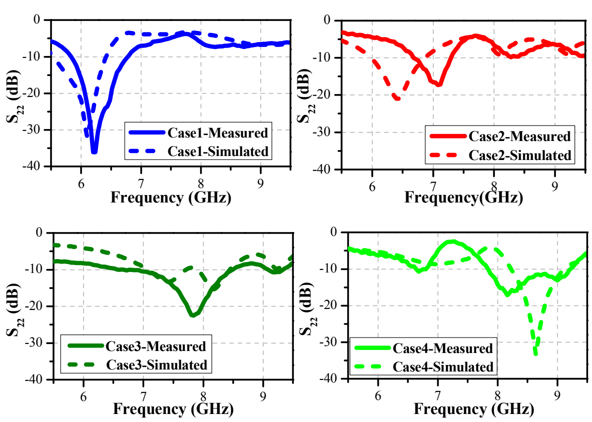



Fig. 4. Measured and simulated reflection coefficients of narrowband antenna in four different cases.

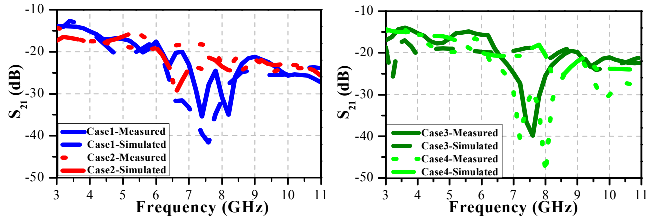



Fig. 5. Measured and simulated transmission coefficients in four different cases.

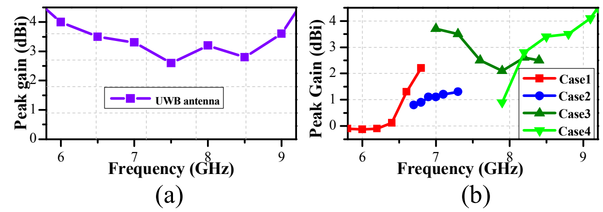



Fig. 6. The peak gains of (a) the UWB antenna and (b) narrowband antenna in four different cases.

## IV. CONCLUSION

A new optically controlled reconfigurable antenna for CR systems has been investigated numerically and experimentally. It consists of two structures. One is a U-shaped monopole UWB antenna for spectrum sensing function and the other is an open-annulus antenna with four photoconductive switches for communicating at four reconfigurable bands, according to different combinations of "ON" and "OFF" states. The antenna performance was simulated, measured and analyzed. The achieved results could find extensive use in future CR communication systems.

## ACKNOWLEDGEMENT

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## REFERENCES

[1] N. K. Hoven, "On the feasibility of cognitive radio," M.S. thesis, University of California at Berkeley, Berkeley, CA, 2005.

[2] J. Mitola and G. Q. Maguire, "Cognitive radiao: making software radios more personal," *IEEE Pers. Commun.*,vol. 6, no. 4, pp. 13-18, Aug. 1999.

[3] G. P. Jin, D. L. Zhang and R.L. Li, "Optically controlled reconfigurable antenna for cognitive radio applications," *Electron. Lett.,* vol. 47, no. 17, pp. 948-958, Aug. 2011.

[4] Y. Tawk, J. Costantine, K. Avery, and C. G. Christodoulou, "Implementation of a Cognitive Radio Front-End Using Rotatable Controlled Reconfigurable Antennas," *IEEE Trans. Antennas Propag.*, vol. 59, no. 5, pp. 1773-1778, May 2012.

[5] E. Erfani, J. Nourinia and C. Ghobadi, "Design and Implementation of an Integrated UWB/Reconfigurable-Slot Antenna for Cognitive Radio Applications," *IEEE Antennas Wireless Propag.* Lett., vol. 11, pp. 77-80, 2012.

[6] Y. Tawk, J. Costantine, and S. Hemmady, "Demonstration of a Cognitive Radio Front End Using an Optically Pumped Reconfigurable Antenna System (OPRAS)," *IEEE Trans. Antennas Propag.*, vol. 60, no. 2, pp. 1075-1083, Feb. 2012.