Reconfigurable Microstrip Patch Antenna with Switchable Polarization

Kyungho Chung, Yongsik Nam, Taeyeoul Yun, and Jaehoon Choi

ABSTRACT—A novel reconfigurable microstrip patch antenna with frequency and polarization diversities is proposed. A U-slot is incorporated into a square patch, and a PIN diode is utilized to switch the slot on and off, which realizes the frequency diversity characteristic. The polarization diversities among linear polarization (LP), right-hand circular polarization (RHCP), and left-hand circular polarization (LHCP) are also obtained by switching three PIN diodes on the slot and the truncating corners of a square patch on and off. The antenna design and experimental results are presented.

Keywords—Microstrip antenna, reconfigurable antenna, diversity antenna.

I. Introduction

Reconfigurable antennas have recently received much attention in wireless and satellite communication systems due to their selectivity for operating frequency and polarization. A microstrip patch antenna is an attractive candidate to provide reconfigurability with low profile, light weight, conformability, and easy fabrication properties [1]. In order to attain frequency or polarization selective functions, several researches for a patch antenna have been studied. The antenna suggested in [2] worked at dual frequencies with a linear polarization (LP) characteristic. The switchable dual-band patch antenna with a circular polarization (CP) characteristic was proposed in [3]. The antenna presented in [4] operated with right-hand circular polarization (RHCP) or left-hand circular polarization (LHCP). In [5], the slot antenna having polarization diversity capability between RHCP and LHCP was introduced. The reconfigurable microstrip antenna in [6] was capable of making polarization diversity among LP, RHCP, and LHCP.

In this letter, we propose a novel reconfigurable microstrip patch antenna having frequency and polarization diversities simultaneously. A U-slot is incorporated into the square patch. The frequency diversity characteristic of the antenna is realized by switching a PIN diode on a U-slot of a microstrip patch on and off. The polarization diversity is also obtained by turning three PIN diodes on the slot and the truncating corners of a square patch on and off. The proposed antenna is designed to operate at 2415 MHz in wireless local area network (WLAN) systems or at 2650 MHz in digital multimedia broadcasting (DMB) systems. The design has been successfully implemented and the experimental results are presented.

II. Antenna Design

The geometry of the proposed reconfigurable microstrip patch antenna with a U-slot and truncated corners is illustrated in Fig. 1. A single-fed square patch with a side dimension of L is fabricated on a substrate of thickness h and of relative permittivity ε_r. A U-slot with parameters of Ls and Ws is inserted into the patch. A corner truncation approach is used to realize a CP characteristic [7]. This corner-truncated square patch has two small parasitic conductors of triangular shape with side lengths of s. To obtain the diversity characteristic of the proposed antenna, four PIN diodes are used. PIN diodes 1, 2 are inserted into the center and side of the U-slot, respectively, and PIN diodes 3, 4 are placed at the gaps between the patch and the triangular conductors. Frequency and polarization diversities of the antenna are controlled by switching the diodes on and off. In this letter, four cases (denoted as antennas 1 through 4) of antenna diversity have been studied.

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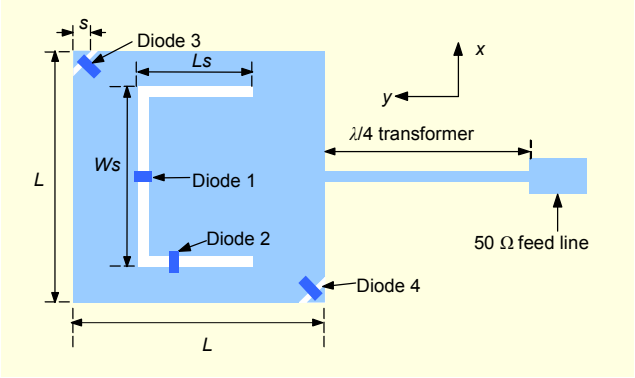

Fig. 1. Geometry of the proposed microstrip patch antenna with a U-slot.

Frequency diversity is achieved to control the electrical length. When all diodes are off, the currents on the patch have to flow around the slot, and this antenna (denoted as antenna 1) basically operates at a resonant frequency of 2415 MHz. Therefore, the antenna resonates at a low frequency. If diodes 1, 3, and 4 are turned on but diode 2 is off, the current can flow directly through three diodes, and the current path becomes shorter so that the antenna has a higher resonant frequency. As a result, this antenna, denoted as antenna 2, resonates at a higher frequency of 2650 MHz and exhibits an LP characteristic. In the case of the proposed antenna with diode 1 on but diodes 2, 3, and 4 off, RHCP, denoted as antenna 3, can be excited at around 2650 MHz based on the method of corner truncation. When all diodes are on, LHCP, denoted as antenna 4, can be obtained at the same frequency. This is caused by different resonant frequencies of the TM_{10} and TM_{01} modes when the two PIN diodes 1, 2 on the U-slot turn on [4].

III. Experimental Results

The proposed antennas were constructed and experimentally studied. To design the desired antenna, a combination of theoretical analysis performed by Ansoft Corp.'s High Frequency Structure Simulator ver. 9.2 and an empirical study is used. In these experiments, metal tapes are used to replace the on and off states of the diodes. The validity of this simplification has been demonstrated in [2] through [4]. Four square patch antennas are implemented with the following dimensions:

$$L = 25.4\,\text{mm}, \quad h = 1.6\,\text{mm}, \quad \varepsilon_r = 4.4\,\text{mm},$$
$$L_s = 8.8\,\text{mm}, \quad W_s = 17.5\,\text{mm}, \quad s = 1.7\,\text{mm}.$$

Figures 2 and 3 show the simulated and measured return losses for four different antennas in WLAN and DMB service bands. They are similar to each other. The measured data satisfy the

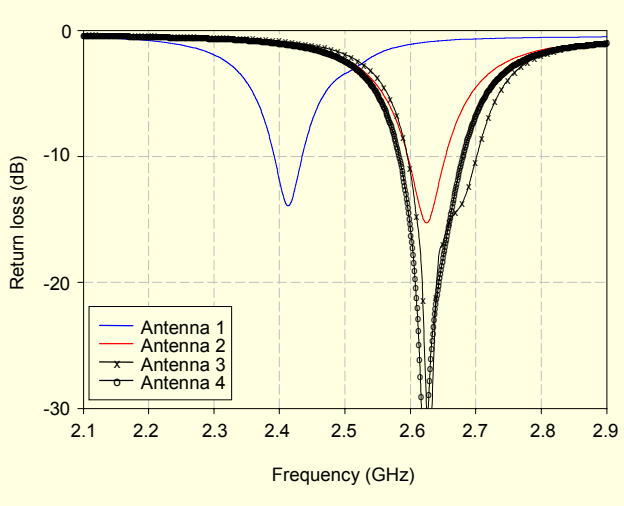

Fig. 2. Simulated return loss characteristics for four different antennas.

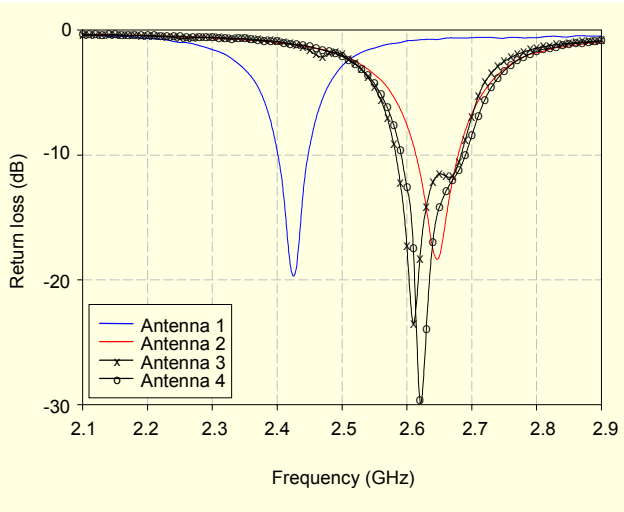

Fig. 3. Measured return loss characteristics for four different antennas.

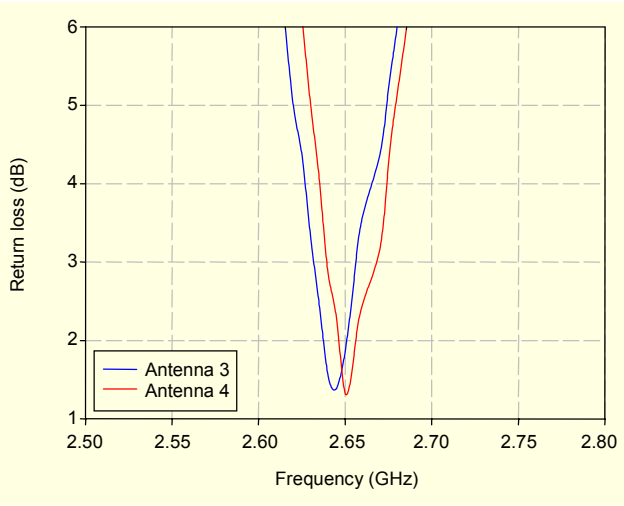

Fig. 4. Measured axial ratio characteristics for antennas 3 and 4.

10 dB return loss requirement for two service bands. The measured axial ratio of the antenna for CP operation in a broadside direction is illustrated in Fig. 4. Observe that the obtained 3 dB CP bandwidths are about 35 MHz and 40 MHz for antennas 3 and 4, respectively. The measured radiation patterns in the yz-plane at 2415 MHz and 2650 MHz are plotted in Fig. 5. As revealed in Figs. 5(a) and 5(b), low cross-polarization levels are observed. Good RHCP and LHCP radiation patterns for antennas 3 and 4 are achieved as shown in Figs. 6(a) and 6(b), respectively.

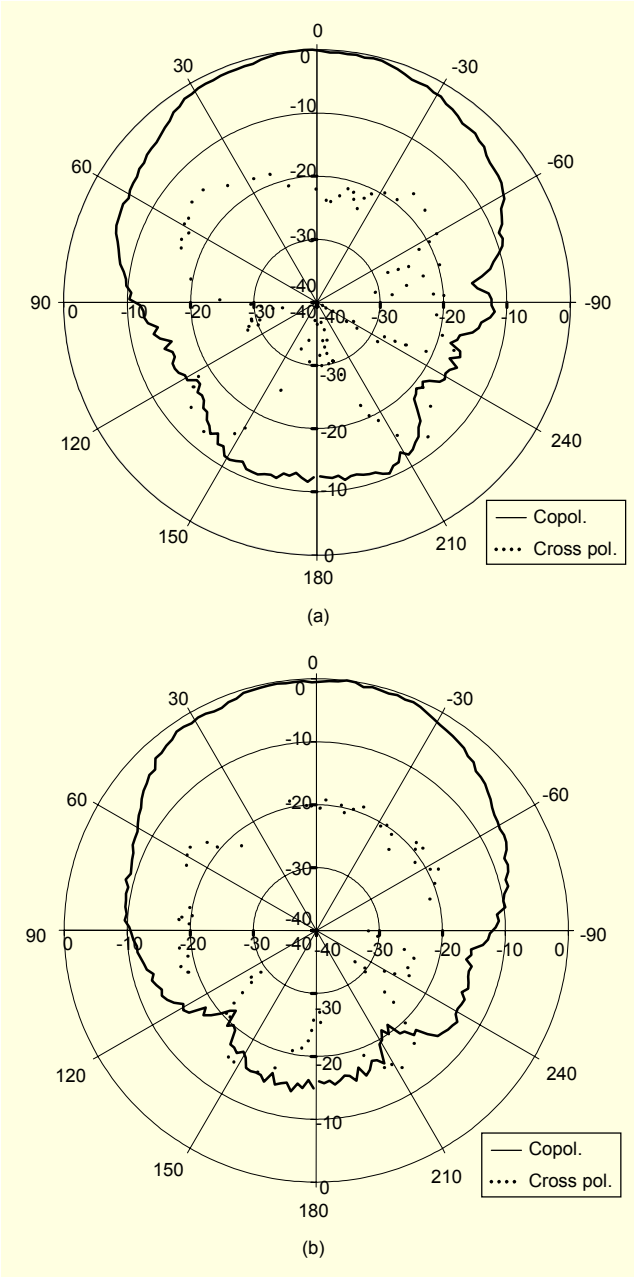

Fig. 5. Measured radiation pattern in y-z plane for the proposed antennas 1 and 2 at (a) 2415 MHz and (b) 2650 MHz.

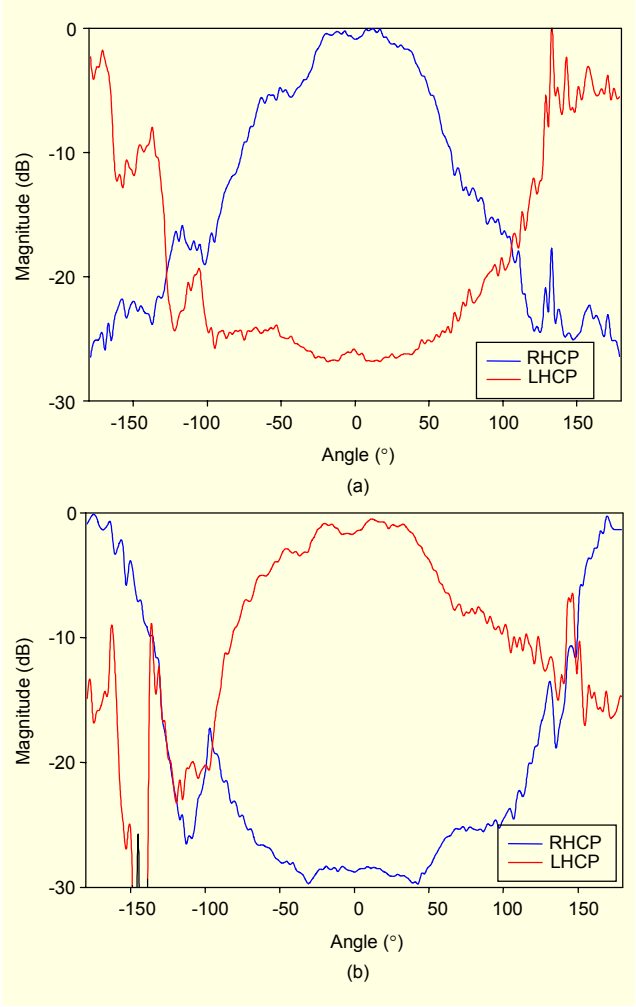

Fig. 6. Measured RHCP and LHCP radiation patterns at 2650 MHz for the proposed (a) antenna 3 and (b) antenna 4.

IV. Conclusion

A novel reconfigurable microstrip patch antenna with frequency and polarization diversities has been designed and fabricated. The frequency diversity characteristic of this antenna is realized by turning a PIN diode located in the middle of a U-slot inserted into a microstrip patch on and off. The polarization diversity is also obtained by switching three PIN diodes on the U-slot and the truncating corners of a square patch on and off. The designed antenna satisfies the 10 dB return loss requirement in WLAN and DMB service bands and also shows a good axial ratio characteristic at the DMB service band. The proposed antenna can be suitable for WLAN/DMB applications.

References

[1] S. Xiao, B. Z. Wang, and X. S. Yang, "A Novel Frequency

Reconfigurable Patch Antenna," *Microwave Opt. and Technol. Lett.,* 36, Feb. 2003, pp. 295-297.

[2] F. Yang and Y. Rahmat-Samii, "Patch Antenna with Switchable Slot (PASS): Dual-Frequency Operation," *Microwave Opt. and Technol. Lett.,* 31, Nov. 2001, pp. 165-168.

[3] F. Yang and Y. Rahmat-Samii, "Switchable Dual-Band Circularly Polarized Patch Antenna with Single Feed," *Electron. Lett.*, vol. 37, no. 16, Aug. 2001, pp. 1002-1003.

[4] F. Yang and Y. Rahmat-Samii, "A Reconfigurable Patch Antenna Using Switchable Slots for Circular Polarization Diversity," *IEEE Microwave Wireless Compon. Lett*., vol. 12, no. 3, Mar. 2002, pp.96-98.

[5] M. K. Fries, M. Grani, and R. Vahldieck, "A Reconfigurable Slot Antenna with Switchable Polarization," *IEEE Microwave Wireless Compon. Lett*., vol. 13, no. 11, Nov. 2003, pp.490-492.

[6] Y. J. Sung, T. U. Jang, and Y. S. Kim, "A Reconfigurable Microstrip Antenna for Switchable Polarization," *IEEE Microwave Wireless Compon. Lett*., vol. 14, no. 11, Nov. 2004, pp.534-536.

[7] W. S. Chen, C. K. Wu, and K. L. Wong, "Novel Compact Circularly Polarized Square Microstrip Antenna," *IEEE Trans. Antennas Propagat.,* vol. 49, Mar. 2001, pp. 340-342.