Progress In Electromagnetics Research, PIER 75, 63–68, 2007

RECONFIGURABLE MICROSTRIP PATCH ANTENNA WITH SWITCHABLE POLARIZATION

W. B. Wei, Q. Z. Liu, Y. Z. Yin, and H. J. Zhou

National Key Laboratory of Antennas and Microwave Technology
Xidian University
Xi'an 710071, Shaanxi, China

Abstract—A new reconfigurable microstrip patch antenna allowing switching between two circular polarizations is proposed. It consists of a square radiating patch and a 3 dB hybrid coupler. Using only a single-polar-double-throw (SPDT) switch, the polarization switching can be achieved. This design of the dc-bias network is extremely simple. From experimental results, the proposed antenna avoids the frequency offset phenomena which often happened to antennas with switchable polarization.

1. INTRODUCTION

In wireless communication systems applications, circular polarization antenna systems play important roles. In satellite communication systems, they are very suitable because of their insensitivity to transmitter and receiver orientations [1]. They are also utilized to realize frequency reuse for doubling the system capability [2]. In polarization diversity, circular polarizations can be used to avoid the detrimental fading loss caused by multi-path effects [3]. In microwave tagging systems, it is used as a modulation scheme such as the circular polarization modulation [4]. Recently, reconfigurable antennas have attracted significant attention [5–9]. Especially, reconfigurable antennas with switchable polarization have become the focus of research. To obtain the switching property between left and right-hand circular polarization (LHCP/RHCP), in most of the related designs, varactor diodes or PIN diodes are used to alternatively short antenna configuration with additional perturbation segments [9–12]. In these designs, two problems are often encountered. One is that excessive diodes will lead to a complex dc-bias network. In order to provide independent bias for each diode, the different biases have to be separated by some special mechanisms, such as using capacitors [3, 9], adding insulating layers [11], and etching thin slits on the patch or ground plane [10, 12, 13]. The other problem is frequency offset caused by polarization switching [12–14]. The phenomenon is usually not accepted for antenna with narrow band operating.

In this paper, a new microstrip patch antenna allowing switching between LHCP and RHCP is proposed. The LHCP/RHCP radiation is generated by simultaneously exciting two orthogonal modes with equal amplitude and a $\pm 90^\circ$ phase difference. The two modes are fed by a 3 dB 90° hybrid coupler. By using a SPDT switch to shift the input port of the coupler, the phase difference between the two outputs of the coupler can be switchable between $\pm 90^\circ$, then the polarization switching between LHCP and RHCP can be achieved.

In this design, only a SPDT switch is employed, thus the dc-bias network is very simple (shown in Fig. 1). Because the circular polarized radiation of the antenna is generated by two orthogonal modes at a same resonant frequency, the frequency offset phenomenon which often happened to antennas with switchable polarization can be avoided.

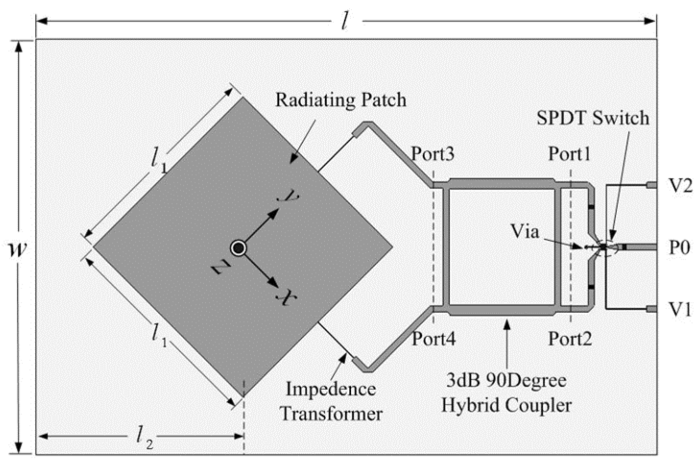

Figure 1. Configuration of the square microstrip patch antenna with switchable polarization and a coordinate system. $l = 180\,\text{mm}$, $w = 120\,\text{mm}$, $l_1 = 61.34\,\text{mm}$, $l_2 = 70\,\text{mm}$.

2. ANTENNA CONFIGURATION

The configuration of the proposed antenna is shown in Fig. 1. It is mainly composed of a radiating patch, a 3 dB 90° hybrid coupler and an

FET SPDT switch. The antenna is built on a 0.76 mm thick Taconic-TLX substrate with relative permittivity of $\varepsilon_r = 2.55$. The side length of the square radiating patch is 61.34 mm, and the resonance frequency related to the length is 1.5175 GHz. In order to match the patch to the 50 Ω lines of the coupler, two narrow 134.2 Ω lines with each length of 14.8 mm have been introduced as impedance transformers. The 3 dB hybrid coupler is operated at 1.5175 GHz. Its four ports are shown in Fig. 1 (denoted as Port1, Port2, Port3, and Port4 respectively). The insert loss of Port3 and Port4 is about −3.17 dB. The phase difference of the two ports is ±90° approximately at 1.5175 GHz. The isolation between Port1 and Port2 is below −41.7 dB.

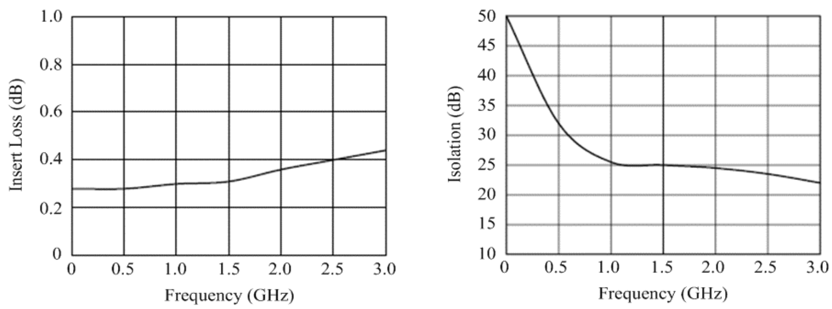

Figure 2. Insert loss and isolation of SPDT switch.

In Fig. 1, an FET SPDT switch is placed between the coupler and the input port of the antenna (denoted as P0). Its insert loss and isolation are plotted in Fig. 2. When dc-bias voltages are V2 = 3.5 V and V1 = 0 V, P0 is connected with Port1. The phase difference between Port3 and Port4 of the coupler is +90°. In this case, the proposed antenna is denoted as antenna 1. Reversely, when dc-bias voltages are V1 = 3.5 V and V2 = 0 V, P0 is connected with Port2. The phase difference between Port3 and Port4 is −90°. In the case, the antenna is denoted as antenna 2. Therefore, the phase difference of two orthogonal modes for circular polarization can be switched between +90° and −90°, and the proposed antenna has the property of polarization switching between LHCP and RHCP.

3. EXPERIMENTAL RESULTS

Figure 3 shows the measured return losses of the proposed antenna. Because antenna 1 and antenna 2 have the same geometry, their return losses are extremely uniform (shown in Fig. 3). Both resonant frequencies of them are 1.5175 GHz. It is clear that the proposed

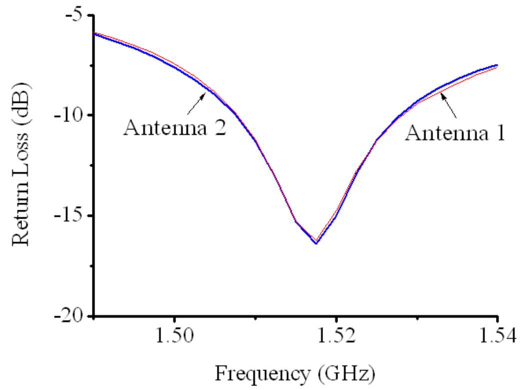

Figure 3. Measured return losses of antenna 1 and antenna 2.

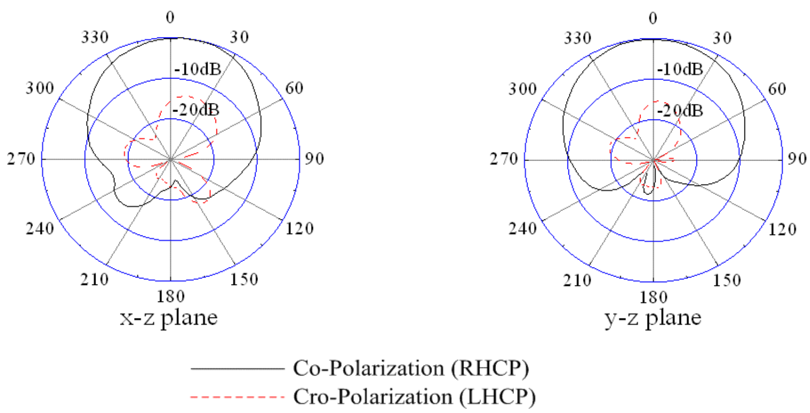

Figure 4. Measured radiation patterns in x-z plane and y-z plane for antenna 1 at 1.5175 GHz.

antenna could eliminate the frequency offset phenomenon.

For these two antennas, the radiation patterns are measured at the resonant frequency 1.5175 GHz. Fig. 4 and Fig. 5 show the measured gain patterns of antenna 1 and antenna 2. The measured gains are 5.12 dB and 5.26 dB respectively. From experimental results, antenna 1 has a RHCP pattern. Its co-polarization and cross polarization patterns at x-z plane and y-z plane are given in Fig. 4. The cross polarization levels for antenna 1 remain below -15.9 dB, and the axial ratio is about 1.38 dB. Compared with antenna 1, antenna 2 exhibits a LHCP whose radiation pattern is similar to the radiation pattern of antenna 1. Its measured radiation patterns are plotted in Fig. 5. The

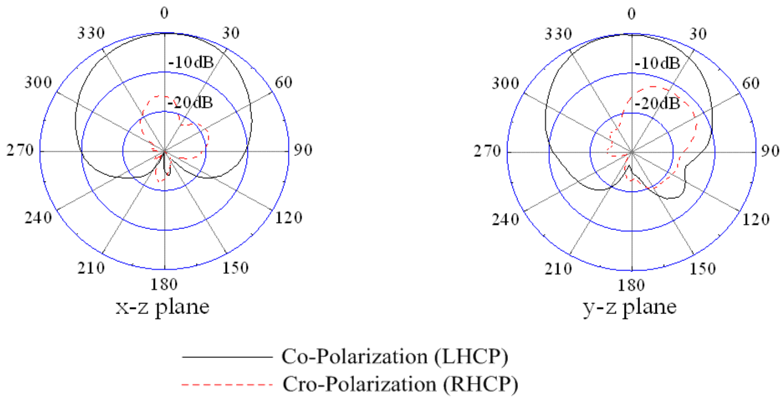

Figure 5. Measured radiation patterns in x-z plane and y-z plane for antenna 2 at 1.5175 GHz.

cross polarization levels for antenna 2 remain below −14.2 dB, and the axial ratio is about 1.59 dB. Obviously, the proposed antenna is able to switch between LHCP and RHCP. In addition, the performances of the proposed antenna in two cases are almost same, such as return losses and radiation patterns.

4. CONCLUSION

A switchable microstrip patch antenna with high potentiality is proposed. The idea of this design is very simple. By using only a SPDT switch, the proposed antenna can be operated in left or right-hand circular polarization according to dc-bias voltages. The dc-bias network is relatively simple. From the experimental results, the performances of the proposed antenna agree well in the LHCP case and the RHCP case. It is very suitable for wireless communication systems applications.

REFERENCES

1. Chang, F.-S., K.-L. Wong, and T.-W. Chiou, "Low-cost broadband circularly polarized patch antenna," *IEEE Transactions on Antennas and Propagation*, Vol. 51, 3006–3009, October 2003.
2. Yang, X.-X. and S.-S. Zhong, "Analysis of two dual-polarization square-patch antennas," *Microwave and Optical Technology Letters*, Vol. 26, No. 3, 153–156, August 2000.
3. Yang, F. and Y. Rahmat-Samii, "A reconfigurable patch antenna

using switchable slots for circular polarization diversity," *IEEE Microwave and Wireless Components Letters*, Vol. 12, 96–98, March 2002.

4. Kossel, M. A., R. Kung, H. Benedickter, and W. Biichtokd, "An active tagging system using circular-polarization modulation," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 47, No. 12, 2242–2248, December 1999.
5. Alkanhal, M. and A. F. Sheta, "A novel dual-band reconfigurable square-ring microstrip antenna," *Progress In Electromagnetics Research*, PIER 70, 337–349, 2007.
6. Shynu, S. V., G. Augustin, C. K. Aanandan, P. Mohanan, and K. Vasudevan, "Design of compact reconfigurable dual frequency microstrip antenna using varactor diodes," *Progress In Electromagnetics Research*, PIER 60, 197–205, 2006.
7. Wu, W. and Y.-H. Bi, "Switched-beam planar fractal antenna," *Journal of Electromagnetic Waves and Applications*, Vol. 20, No. 3, 409–415, 2006.
8. Wu, W., B.-Z. Wang, and S. Sun, "Pattern reconfigurable microstrip patch antenna," *Journal of Electromagnetic Waves and Applications*, Vol. 19, No. 1, 107–113, 2005.
9. Chen, Y. B., T. B. Chen, Y. C. Jiao, and F. S. Zhang, "A Reconfigurable microstrip antenna with switchable polarization," *Journal of Electromagnetic Waves and Applications*, Vol. 20, No. 10, 2006.
10. Fries, M. K., M. Grani, and R. Vahldieck, "A reconfigurable slot antenna with switchable polarization," *IEEE Microwave and Wireless Components Letters*, Vol. 13, No. 11, 490–492, November 2003.
11. Haskins, P. M. and J. S. Dahele, "Varactor-diode loaded passive polarisation-agile patch antenna," *Electronics Letters*, Vol. 30, 1074–1075, June 1994.
12. Ho, M. H., M. T. Wu, C. G. Hsu, and J. Y. Sze, "An RHCP/LHCP switchable slotline-fed slot-ring antenna," *Microwave and Optical Technology Letters*, Vol. 46, 30–33, 2005.
13. Boti, M., L. Dussopt, and J.-M. Laheurte, "Circularly polarised antenna with switchable polarisation sense," *Electronics Letters*, Vol. 36, 1518–1519, August 2000.
14. Nanbo, J., Y. Fan, and Y. Rahmat-Samii, "A novel reconfigurable patch antenna with both frequency and polarization diversities for wireless communications," *2004 IEEE Antennas and Propagation Society International Symposium*, Vol. 2, 1796–1799, June 2004.