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Polarization Agile Slot-Ring Array Antenna using Magic-T Circuit

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1. Introduction

Recently, along with the rapid development of wireless communication technology, reconfigurable antennas such as polarization agile antennas have attracted a special interest. These antennas effectively increase the system capacity of wireless systems using polarization diversity and frequency reuse [1]. They can be also used in multiple-input multiple-output (MIMO) systems [2]. In the last few years, many types of polarization agile antennas using reconfigurable slot antennas and microstrip antennas have been reported [1]-[6]. These antennas can radiate circular and linear polarizations. However, they require some RF switching devices such as diodes in order to achieve reconfigurability. It is difficult to extend to antenna arrays.

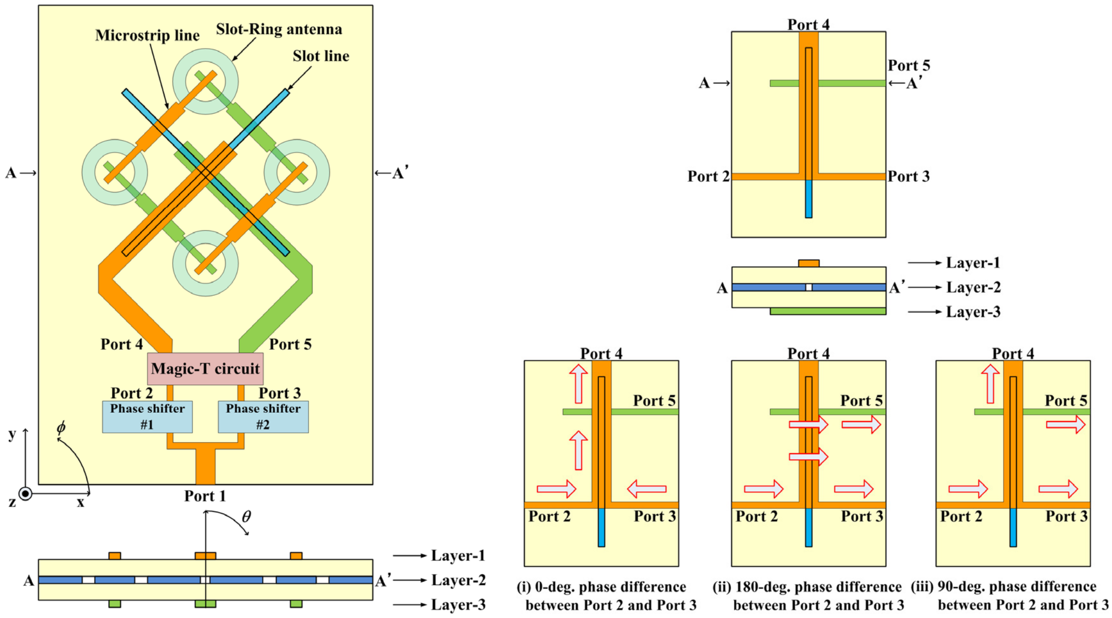
Herein, a novel polarization agile slot-ring array antenna is presented. The proposed slot-ring array antenna is composed of three parts as follows: (I) four slot-ring antennas [6], (II) a Magic-T circuit and (III) two phase shifters. Since the output ports of the Magic-T can be switched by the phase differences, the slot-ring array antenna can radiate and switch four polarizations, the ±45-deg. linear polarizations (LPs), right- and left-hand circular polarizations (RHCP, LHCP). There are no longer needed any switching devices, that is, the slot-ring array antenna is a very simple and compact configuration. Therefore, it is very promising in wide areas of wireless application, such as communications systems and various kinds of RF sensors. In this paper, the basic behavior of the 7.5 GHz slot-ring array antenna is investigated by simulation.

2. Slot-ring array antenna configuration

Figure 1 (a) shows the configuration of the proposed slot-ring array antenna. The slot-ring array antenna [6], which actively uses both-sided microwave integrated circuit (MIC) technology on a multi-layer substrate [7] [8], can radiate the orthogonal linear polarizations. It has the good cross-polarization suppression performances in principle due to the good isolation of the antenna feed circuits [6]. It provides the design flexibility to extend to array sizes such as 4×4 and 8×8 arrays etc. The most important part of this configuration is the Magic-T shown in Fig. 1 (b). It is a kind of directional couplers and effectively used in the feed circuit [7]. The Magic-T enables us to remove any switching devices for polarization switching, and is easily integrated with the array antenna employing Both-Sided MIC technology. Moreover, two phase shifters can be integrated with the Magic-T. Controlling the phase difference of these phase shifters, the output ports of the Magic-T can be switched.

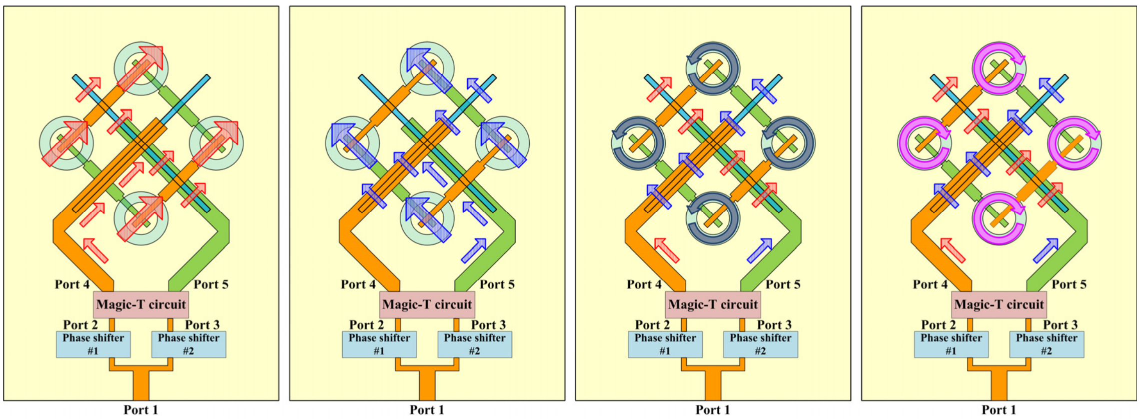
2. Magic-T circuit

Figure 1(b) shows configuration and basic behaviours of the Magic-T. The Magic-T which consists of microstrip lines and a slot line is a directional coupler with two-input and two-output. Summational and differential signals from Port 2 and Port 3 transmits to Port 4 and Port 5, respectively. Therefore, the Magic-T operates as a switching or a 90-deg. hybrid circuits according to phase difference condition of two input signals. When the phase difference of input signals from Port 2 and Port 3 is 0-deg. (Fig 1(b)-(i)), the combined signal transmits through Port 4 ,and Port 5 is isolated. When the phase difference is 180-deg. (Fig 1(b)-(ii)), the signal transmits through Port 5. In the case of the ±90-deg. phase difference, the Magic-T works as a 90-deg. hybrid circuit (Fig 1(b)-(iii)), two signals transmit through Port 4 or Port 5 with ±90-deg. phase difference.



(a) (b)

Figure 1: Polarization reconfigurable slot-ring array antenna using a Magic-T circuit (a) The slot-ring array antenna configuration (b) The structure and basic behavior of the Magic-T

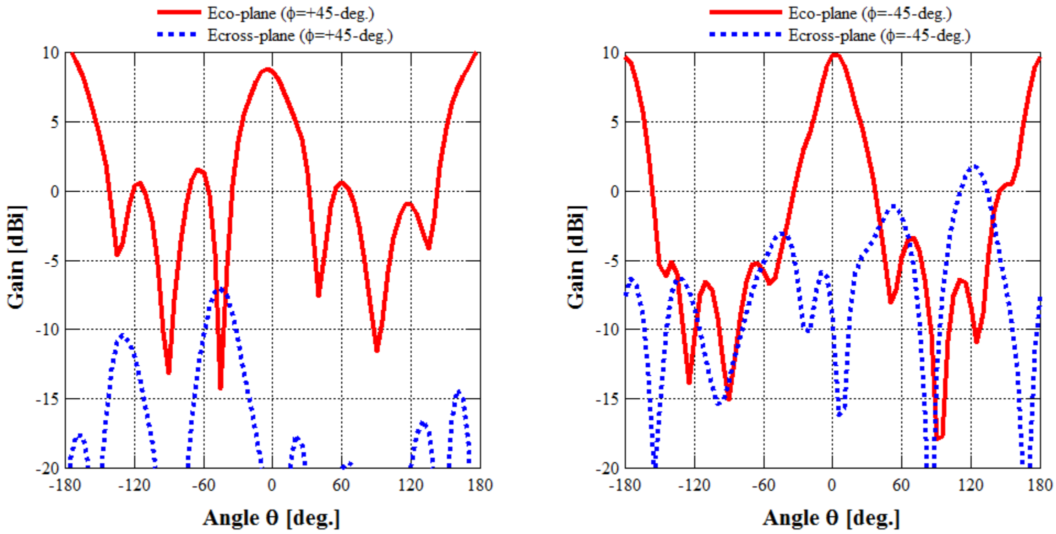


(a) (b) (c) (d)

Figure 2: Schematic electric fields of the slot-ring array antenna (a) the +45-deg. LP (b) the -45-deg. LP (c) the RHCP (d) the LHCP

3. Basic behavior of the array antenna

Figure 2 shows the schematic electric fields on the slot-ring array antenna. The slot-ring array antenna works with four behaviors according to the phase condition of the Magic-T. The RF signal transmits to the antenna elements through the feed circuit as shown in Fig. 2. In this array, the four-mode operations are achieved with very simple structure using a combination odd and even transmission mode on the feed circuit. When the RF signal from Port 4 is fed to the antenna elements through the feed circuit. The +45-deg. LP is excited as shown in Fig. 2 (a). In the same way, the -45-deg. LP is excited when the RF signal from Port 5 is fed (Fig. 2 (b)). It is possible to feed the antenna array with ±90-deg. phase difference signals as well. When the phase of Port 5 is 90-deg. advanced to Port 4, the LHCP is excited. In the same way, the RHCP is excited when the phase of Port 4 is 90-deg. advanced to Port 5.



(a) (b)

Figure 3: Radiation patters of the ±45-deg. LP (a) The E-plane of the +45-deg. LP (b) The E-plane of the -45-deg. LP

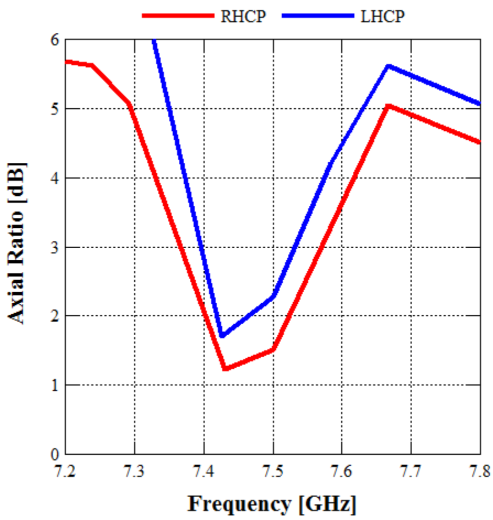


Figure 4: Axial ration

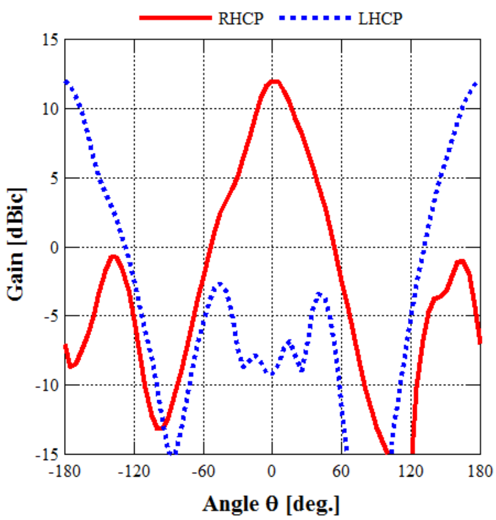


Figure 5: Radiation patter of the RHCP

4. Simulated Results

The slot-ring array antenna is simulated by the Agilent electromagnetic simulator (EMPro, FEM). The Teflon glass fiber with the relative dielectric constant ε_r of 2.15 and the thickness is 0.8 mm is used as a substrate. The design frequency is 7.5 GHz. In this simulation, two phase shifters are replaced by the delay microstrip lines.

Figures 3-5 show the simulated results. In Fig. 3, the radiation patters of the ±45-deg. LPs at 7.5 GHz are shown. The simulated cross-polarizations are approximately -30 dB at 7.5 GHz. The good cross-polarization suppressions are obtained for linear polarization switching. Fig. 4 shows the axial ratios of both the RHCP and LHCP. It is confirmed that both the RHCP and LHCP are excited. The 3 dB bandwidth of the axial ration is about 2.8 %. Fig. 5 shows the simulated radiation pattern of the RHCP. The radiation patterns of the LHCP are omitted because it is almost the same with the results of the RHCP. In Fig. 5, the simulated cross-polarization is -20 dB. The good cross-polarization suppressions are confirmed as well as the linear polarizations. Hence, it is possible to realize four polarizations with the slot-ring array antenna using the Magic-T.

5. Conclusion

A novel polarization agile slot-ring array antenna was presented and investigated by simulation. It is confirmed that the proposed array antenna has the orthogonal liner polarizations, RHCP and LHCP switching function.. Since the Magic-T enables us to remove any switching devices for polarization switching, this slot-ring array antenna with polarization switching function is much simpler than the conventional reconfigurable antennas with polarization switching. The proposed slot-ring array antenna has an advantage of the design flexibility to extend to array size such as 4×4 and 8×8 arrays etc. The good cross-polarization suppressions of four polarizations are confirmed in the simulation. These simulated data show that the slot-ring array antenna has an excellent basic performance of four polarizations (the ± 45-deg. LPs, RHCP and LHCP). Therefore, the array antenna is very promising in wide wireless application areas, such as radar systems and various kinds of RF sensors. The array antenna is practically attractive for advanced wireless communication systems as well as the other diversified wireless applications.

Acknowledgments

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References

[1] A. Ramanda, M. Al-Husseini, K. Y. Kabalan, and A. El-Hajj, C. G. Christodoulou, "A Polarization Reconfigurable Slot Antenna," Proc. The 5th European Conf. on Antennas and Propagation, pp. 402 - 404, 2011.

[2] P. Qin, A. R. Weily, Y. J. Gue, and C. Liang, "Polarization Reconfigurable U-Slot Patch Antenna," IEEE Tran. on Antennas and Propagation, Vol. 58, No. 10, pp. 3383 - 3387, 2010.

[3] W. M. Dorsey, A. I. Zaghloul, and M. G. Parent, "Perturbed Square-Ring Slot Antenna With Reconfigurable Polarization," IEEE Antennas and Wireless Propagation Letters, Vol. 8, pp. 603 - 606, 2009.

[4] W. Liao, S. You, and H. Chou, "A Polarization Reconfigurable Patch Array Antenna," Proc. IEEE International Conference on Wireless Information Technology and Systems, 2010.

[5] M. S. Parihar, A. Basu, and S. K. Koul, "Polarization Reconfigurable Microstrip Antenna," Proc. Asia-Pacific Microwave Conference, pp. 1918 - 1921, 2009.

[6] S. Feng, E. Nishiyama, and M. Aikawa, "Linear Polarization Switchable Ring-Slot Array Antenna Using SPDT Switch Circuit," Microwaves, Antennas & Propagation, IET, pp. 142 - 148, 2011.

[7] M. Aikawa and H. Ogawa, "Double-sided MIC's and their applications", IEEE Trans. Microw. Theory Tech., Vol. 37, No.2, pp. 406 - 413, Feb. 1989.

[8] T. Hirota, Y. Tarusawa, and H. Ogawa, "Uniplanar MMIC Hybrids – A Proposed New MMIC Structure", IEEE Trans. Microw. Theory Tech., Vol. 35, no.6, pp. 576 - 581, June 1987.