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Linear Polarization Switchable Microstrip Array Antenna using Magic-T Circuit

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1. Introduction

Recently, the planar antenna technologies have been advancing due to the increasing demands for various wireless applications in the ubiquitous society. Furthermore, reconfigurable planar antennas have attracted much more attentions because of their versatility in various wireless systems in terms of frequency controllability and polarization diversity [1]. In this paper, an orthogonal linear polarization switchable microstrip four-element array antenna is proposed. The proposed antenna having a polarization switching function provides high design flexibility for wide variety of radio systems. In order to switch the polarization, the boundary condition of the array antenna is controlled by the ON/OFF condition of the diodes mounted on each antenna element. Magic-T circuits employing Both-sided MIC technology are effectively used to isolate the switching signal from RF signal [2].

2. Polarization switchable microstrip array antenna

Figure 1 shows the structure of the proposed antenna. The design frequency is 10 GHz. The sizes of the ground plane and each patch of the array are 60 mm and 9.5 mm square, respectively. Two switching diodes which are connected to the ground plane by via-holes of 0.6 mm diameter are mounted on each patch. The RF feed circuit is composed of microstrip lines and slot lines on the reverse side as shown in Fig. 1. The bias circuit is arranged on the top surface using a Magic-T in order to isolate the switching signal from RF signal. Teflon glass fiber substrate (ε_r=2.15 and thickness of 0.8 mm) is used.

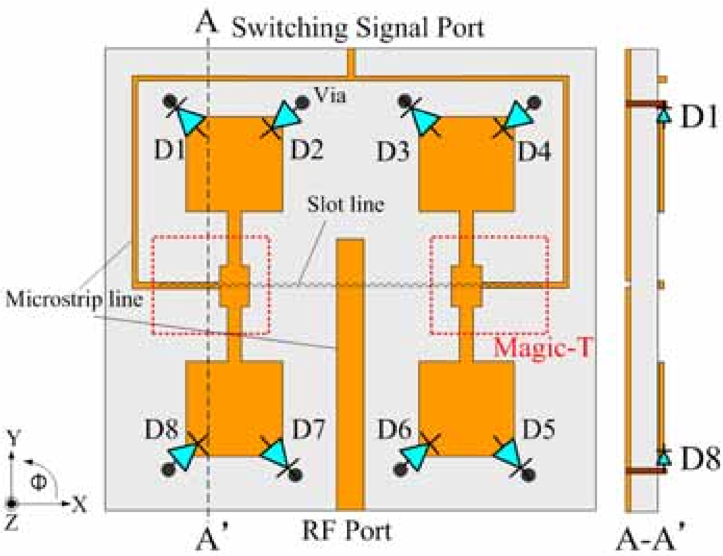


Fig. 1 Structure of the proposed antenna

Figure 2 shows the structure and behavior of the Magic-T. The RF signal is fed to the Port 1. The RF signal is divided into Port 2 and Port 3 in opposite phase with same amplitude, and it is not transmitted to Port 4. On the other hand, the switching signal is fed to the Port 4. The switching signal is divided into Port 2 and Port 3, and it is not transmitted to Port 1. The switching signal acts as a bias voltage of the diodes which are mounted on each antenna element. This Magic-T provides the bias circuit which has excellent isolation characteristics.

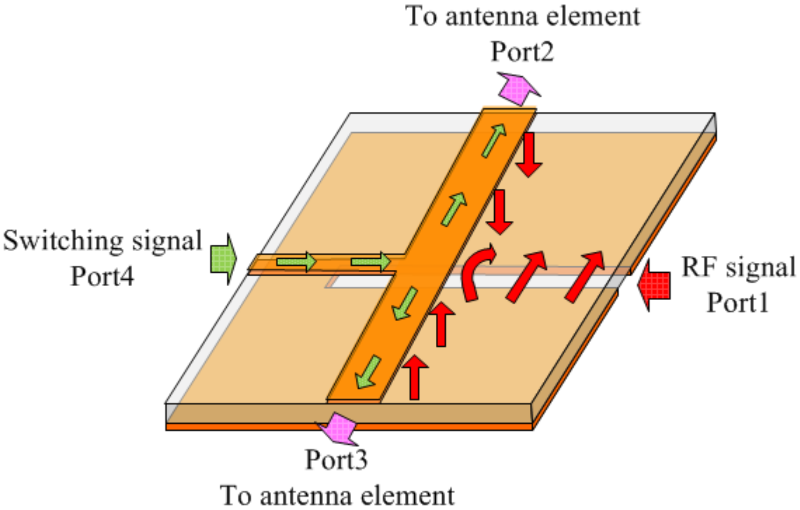
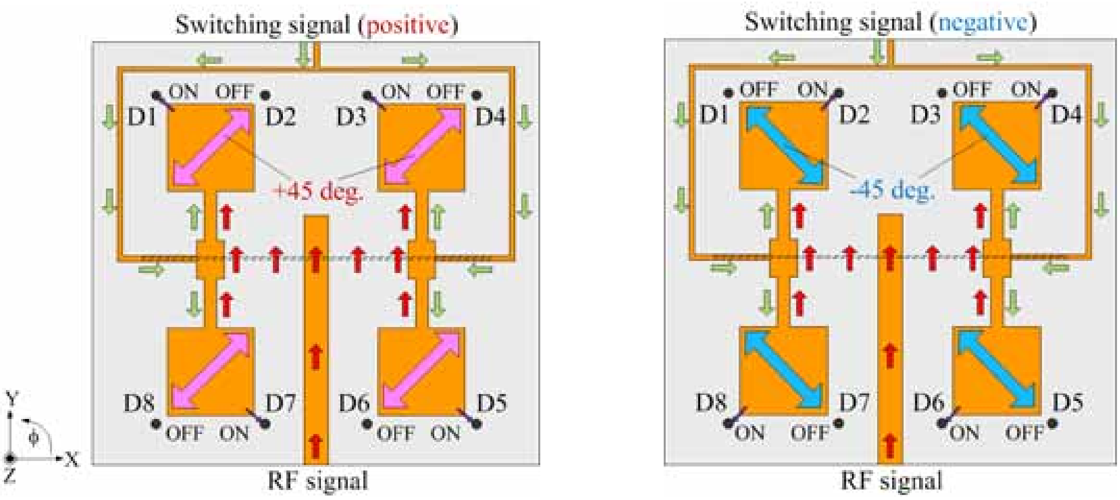


Fig. 2 Structure and behavior of Magic-T

Figure 3 shows the basic behavior of the proposed antenna. Input RF signals are transmitted to each patch through the microstrip-slot branch circuit located at the center of the array antenna and Magic-T. On the other hand, switching signals are fed to the each patch through the microstrip line and Magic-T. When positive bias voltage is applied to the switching signal port, the odd number diodes are ON state due to the forward bias condition, and the even number diodes are OFF state due to the reverse bias condition. As a result, the surface currents on the patches flow along the diagonal of +45deg. and the electric field is excited in the same direction. At that condition, the polarization angle is +45 degrees. When negative bias voltage is applied, the even number diodes are ON state and the odd number diodes are OFF state. Then the polarization angle of -45 deg. is obtained. Changing the switching signal's polarity, the linear polarization switching function can be achieved.

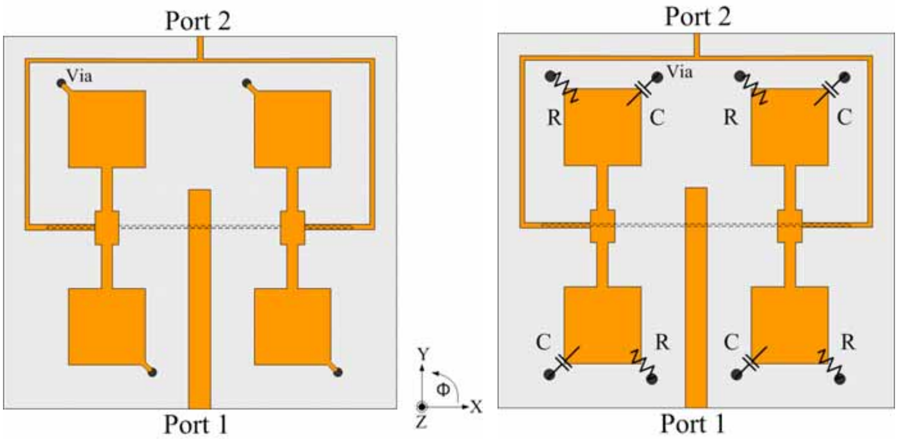


(a) Positive bias voltage (b) Negative bias voltage

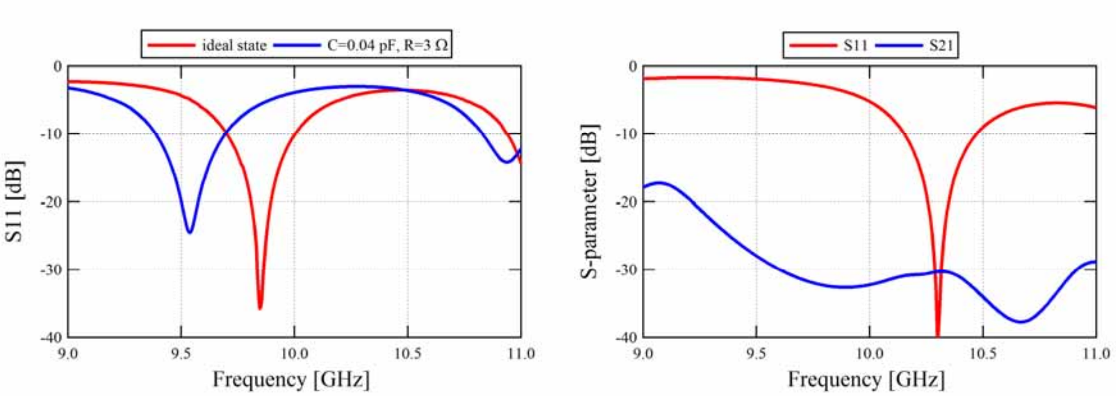
Fig. 3 Basic behavior of the proposed antenna

3. Simulated and experimental results

Figure 4 shows the simulated results using ADS and EMPro (Agilent Technologies). Simulation model #1 is the ideal model to analyze the basic characteristics. The ON state diodes are replaced by the short-circuit conductors. Simulation model #2 is used to analyze the parasitic effect of the diodes. Assuming the positive bias voltage is applied to Port 2 and the diodes are PIN diodes, the ON state diodes are replaced by the resistance (R=3 Ω) and the OFF state diodes are replaced by the capacitance (C=0.04 pF). Fig. 4 (c) shows the simulated result of these models. Resonant frequency is decreased about 300 MHz because of the diodes' junction capacitance. Considering this result, the resonant frequency in the ideal state of the proposed antenna is designed 10.3 GHz to obtain a 10 GHz prototype antenna. Fig. 4 (d) shows the design results of S21 and S11. The S11 is -40 dB and S21 is -30 dB at 10.3 GHz. Good return and isolation characteristics are obtained.



(a) Simulation model #1 (b) Simulation model #2



(c) Difference between model #1 and #2 (d) Design result

Fig. 4 Simulation results

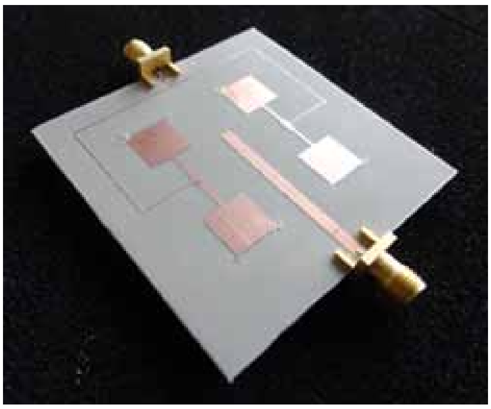
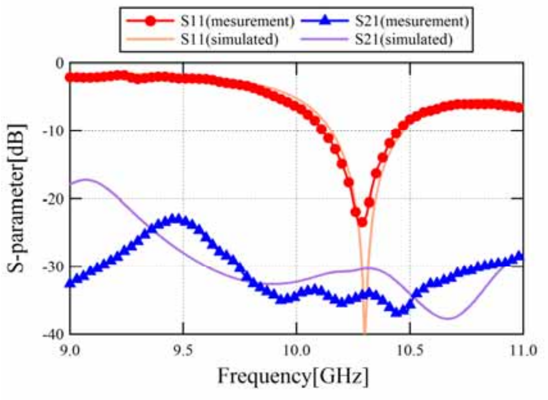
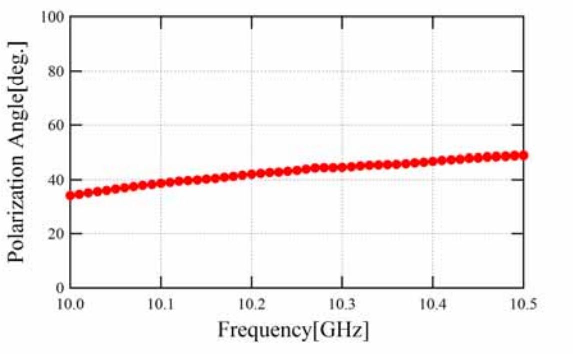


Fig. 5 The fabricated antenna

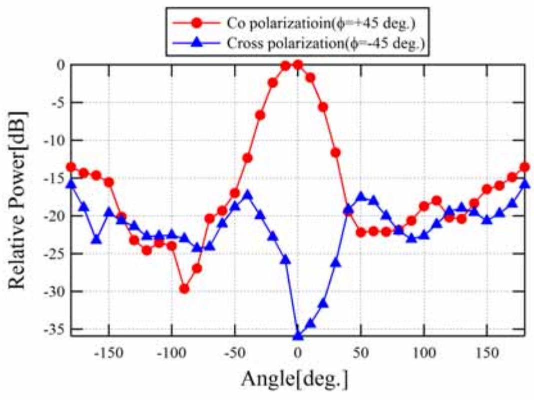
Figure 5 shows a photo of the fabricated antenna. The ON state diodes are replaced by the short-circuit conductors as simulation model #1 of Fig. 4. Figure 6 shows the experimental results. S11 is -23 dB and S21 is -33 dB at 10.3 GHz as shown in Fig. 6-(a). Fig. 6-(b) shows the polarization angle. The polarization angle of +45 deg. is obtained at 10.3 GHz. Fig. 6-(c) shows the radiation pattern at 10.3 GHz. The cross polarization interference of -35 dB is obtained. Excellent characteristics are obtained.



(a) S-parameter



(b) Polarization angle



(c) Radiation pattern at 10.3 GHz

Fig. 6 Experimental results

4. Conclusion

In this paper, the orthogonal linear polarization switchable microstrip array antenna is proposed. The proposed antenna has a very simple structure due to the both-sided MIC technology and the Magic-T. Basic characteristics of the array antenna were experimentally confirmed and excellent performances were obtained. As a next step, the array antenna loading diodes will be discussed in order to confirm the linear polarization switching characteristics.

References

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[2] M. Aikawa and H. Ogawa, "Double-sided MIC's and Their Applications," IEEE Trans. on Microwave Theory and Techniques, Vol. 37, no. 2, pp. 406-413, Feb, 1989.