Linear Polarization Switchable Patch Array Antenna using Magic-T Bias Circuit and Orthogonal Feed

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Abstract— **In this paper, a linear polarization switchable patch array antenna is proposed. The orthogonal feed circuit and magic-T circuit is introduced to realize the proposed array antenna. The advantage of the magic-T circuit is the excellent isolation between the RF signal and the switching bias signal. The microwave integration technology is effectively employed to realize proposed linear polarization switchable array antenna. The proposed array antenna consists of four patch elements and 16 PIN diodes. In order to realize the ±45º polarization switching, four switching diodes are integrated with each patch elements. Using the ON/OFF condition of the diodes, the polarization axis can be easily switched to ±45º. The array antenna is realized in very simple and compact structure as all the antenna elements, feeding circuit and bias circuit are arranged on both sides of a dielectric substrate. The ability of the proposed array antenna to switch the polarization axis at ±45º at 10 GHz (X band) is confirmed by the experimental investigation.**

Keywords— Both-Sided MIC technology, Orthogonal polarized array antenna, Polarization Switching, Magic-T.

I. INTRODUCTION

Along with the rapid development of the wireless communication systems, the planar antenna technology is emerging and being widely used in various sectors of wireless communications systems due to their low profile, light weight, low cost and easy integration with active components [1, 2]. In the past decades, the planar antenna technologies had an enormous development in reconfigurable, compact, broadband, gain enhancement and so on to meet the requirements of the wireless communications and the ubiquitous society. Moreover, the evolution of the planar antenna technology keeps emerging. In addition, the integrated and active integrated antennas receive a great deal of attention because they can reduce the size, weight and cost of many transmit and receive systems [3]. Loading of circuit components such as semiconductor devices and various kinds of IC's in microwave resonators or antennas to build up the purposeful electromagnetic field on them, is referred as the Microwave Integration Technology [4]. There are some reports on this concept of Microwave Integration Technology [5-7]. There is a report on a polarization switchable slot antennas [8]. The authors of paper [8] have reported a 4-element slot-ring array antenna where 4 PIN diodes are loaded on each slot ring antenna totaling 16 diodes. However, the bias signal is superimposed with the RF signal to the co-axial feed. As a result, the cross-polarization isolation of the radiation pattern of the array antenna was not achieved better than -15 dB. For the proposed array antenna, the bias circuit is arranged with the feed line by using the magic-T junction. In this case the cross-polarization isolation is significantly improved to better than -20 dB. Momentum of the Advanced Design System (ADS, Agilent Technologies) is used for the simulation of the feed circuit and the bias circuit and the array antenna elements. The ON state diodes are replaced by short circuit for the experimental investigation.

II. THE PROPOSED ARRAY ANTENNA

Fig. 1 shows the schematic structure of the proposed array antenna. The Both-sided MIC technology [9-11] is effectively employed to realize the array antenna. The array antenna consists of four patch elements and 4 switching diodes are loaded on each patch elements which totals in 16 diodes. The feed and bias circuits are arranged by using the magic-T and air bridge as seen in the dotted square of Fig. 1. The antenna elements, diodes microstrip lines are arranged on the obverse side and the slot line is arranged on the reverse side of Teflon glass fiber substrate. The design of the magic-T and the antenna elements will be explained in this section.

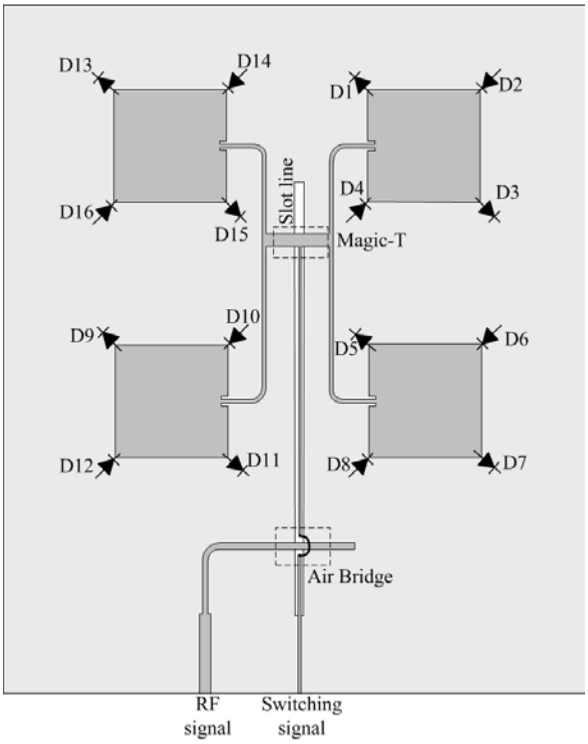

Figure 1. The proposed array antenna

A. The Magic T

Planar magic-Ts are used in microwave integrated circuits to split or combine in-phase or anti-phase signals. The magic-T can be very useful for balanced-mixers, discriminators, and beam-forming networks. The advantages of the magic-T are low insertion loss, high isolation, compact size, and fabrication simplicity [12]. There are some reports for realizing the magic-T using the co-planar waveguide (CPW) or microstrip (MS) to slot line (SL) mode conversion techniques [13-16].

Fig. 2(a) shows the structure of the magic T. Fig. 2(b) represents the RF and bias signal modes for the microstrip and slot lines. The RF signal propagates by the odd mode and the bias signal propagates by the even mode. When the RF signal is input to the port 1, the RF signal is split to the microstrip line in anti-phase and propagates to port 2 and port 3, which is known as the odd mode. The bias signal from port 4 can propagate to port 2 and port 3 by the means of even mode. As the even mode and the odd mode are orthogonal to each other, a good isolation between the RF signal and the bias signal can be realized. Fig. 3 shows the simulated S-parameter for the magic-T structure. The S_{11} for the structure is matched at the design frequency of 10 GHz. S_{41}, which is the isolation, also achieved better than -28 dB. In addition, the S_{21} and S_{31} are achieved around 4 dB for the simulation.

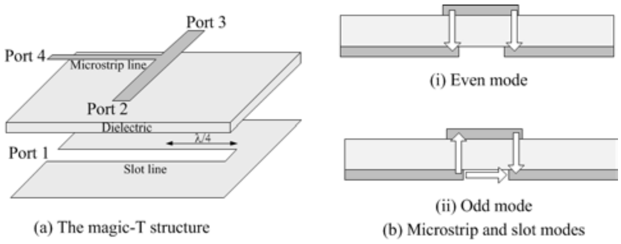

Figure 2. The magic-T structure

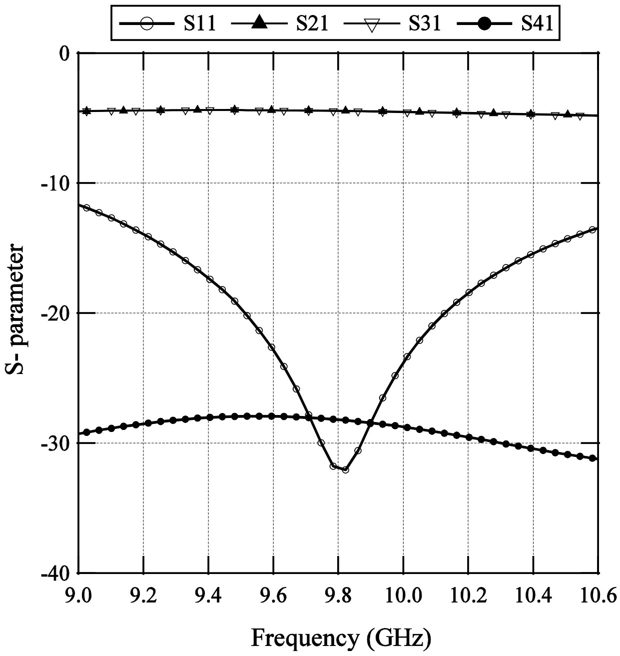

Figure 3. Simulated S-parameters of the magic-T structure

B. Basic Behavior of the array antenna

The basic behavior of the array antenna is explained in this section. The RF signal is fed to the antenna elements in same phase because of the parallel feed circuits. The switching bias signal is fed to the antenna elements through the microstrip line connected with the feed line in magic-T. Depending on the polarity of the bias voltage, the diodes of the antenna elements becomes ON/OFF.

When positive bias voltage is applied to the bias line, the odd numbered diodes D1, D3, D5, D7, D9, D11, D13 and D14 becomes ON due to the forward bias condition and the even numbered diodes D2, D4, D6, D8, D10, D12, D14 and D16 remains OFF state due to the reverse bias condition. In this case, the surface current of the array antenna elements flows as shown in Fig. 4(a). And in this case, the polarization axis is tilted to -45º. Same behavior can be applicable for the negative bias condition as shown in Fig. 4(b). And in this case, the polarization axis is tilted to +45º.

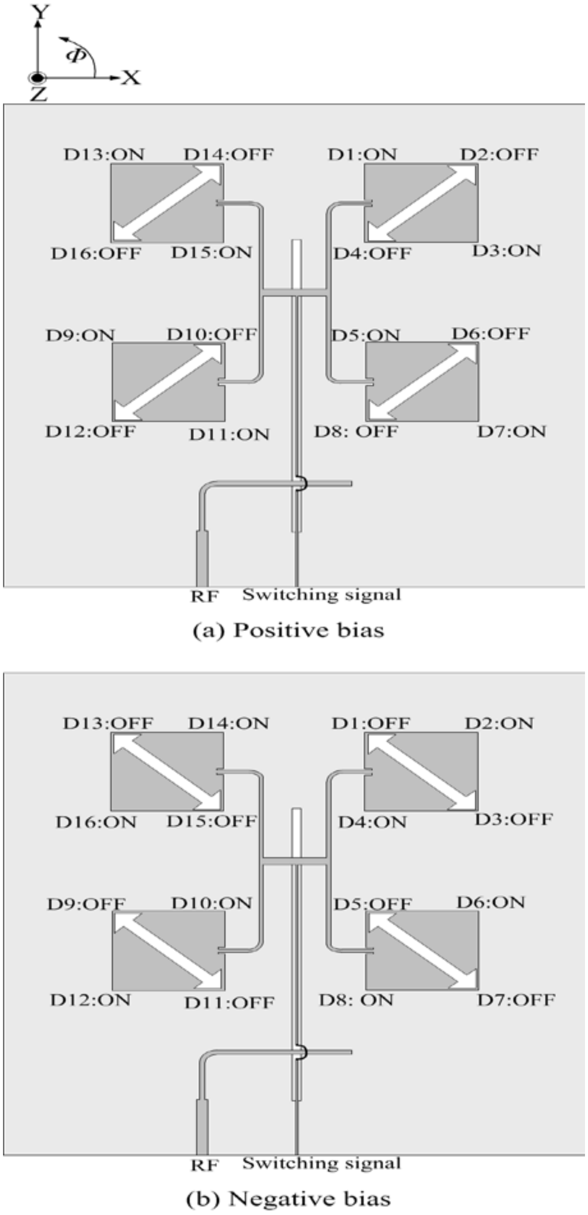

Figure 4. Basic behavior of the array antenna

III. DESIGN OF THE ARRAY ANTENNA

Fig. 5 shows the dimension of the proposed array antenna. The size of the antenna element is 9.23 mm×9.23 mm at the design frequency of 10 GHz. Four PIN diodes are loaded on four corners of each antenna element in order to realize polarization switching. The other ends of the diodes are connected with the ground plane by conductor through via hole. The characteristic impedance of the microstrip lines connected with the antenna elements is 110 Ω and the width of the microstrip line is 0.55 mm. The input impedance of antenna element is adjusted to the microstrip lines by properly inserting a pair of notches at the patch [17-18]. The width of the notch is 0.2 mm and length is 0.4 mm. The 110 Ω microstrip lines connect with another microstrip line which is used to realize the Magic-T. Impedance of this microstrip line is 55 Ω and the width is 2.4 mm. The width of the bias line is maintained at 0.2 mm in order to achieve a high impedance of 154 Ω. A slot line of 0.2 mm width and length of 30 mm is arranged exactly below the bias line on the ground plane of the array antenna. The bias line is connected with the bias port through air-bridge. A 110 Ω RF microstrip line is arranged on the obverse plane upon the slot line as a microstrip-slot parallel branch circuit. This RF microstrip line is connected with the 50 Ω RF port using a quarter wavelength ($\lambda_g/4$= 5.55 mm) impedance transformer whose impedance is 71 Ω and width is 1.36 mm. The size of the Teflon glass fiber substrate and the ground plane is 48 mm × 54 mm. The thickness of the substrate is 0.8 mm with the relative dielectric constant of 2.15.

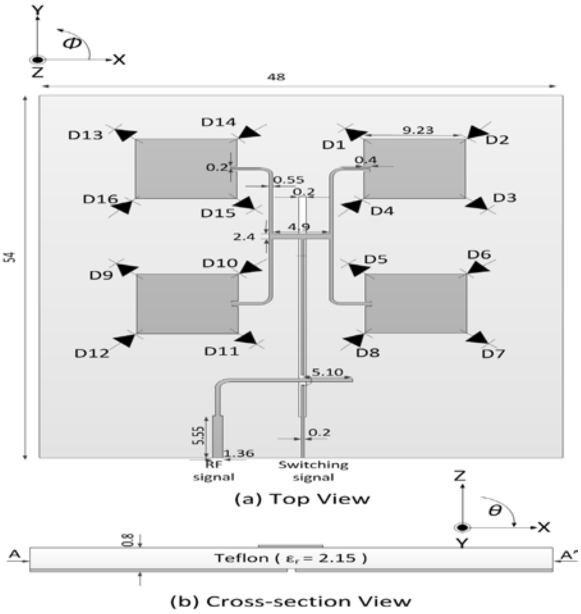

Figure 5. Dimension of the proposed array antenna (scale in mm)

IV. EXPERIMENTAL RESULTS AND DISCUSSION

After you As already mentioned the ON state diodes are replaced by the short circuit and the OFF state diodes are replaced by the open circuit for the experiment of the array antenna. The experiment was performed in an anechoic chamber. Impedance matching is the most important issue for the design of the array antenna which is represented by the s-parameters. Fig. 6 shows the experimental result for the S-parameter characteristic of the array antenna. For both positive and negative bias voltage, the S_{11} better than -20 dB is achieved at 10 GHz which proves the feed circuit is matched with the array antenna at the design frequency. The isolation of the switching signal and the RF signal was also achieved better than -40 dB, which is a very good result. Fig. 7 shows the experimental results of the frequency characteristics of the polarization angle of the array antenna. The polarization angle is around +45° for the antenna. The radiation pattern is the measure of the signals radiated by the antenna. The radiation pattern measured at the design frequency of 10 GHz is shown in Fig. 8. The cross polarization isolation of better that -20 dB is achieved. Therefore, compared with [8], the proposed array antenna confirms a better performance of the array antenna with better cross-polarization isolation.

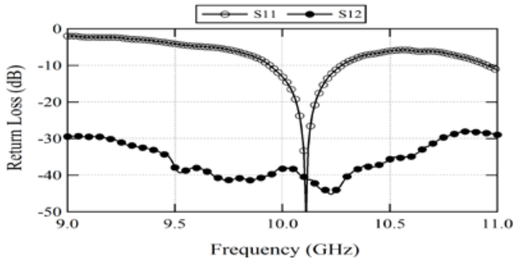

Figure 6. Experimental S-parameter for the array antenna

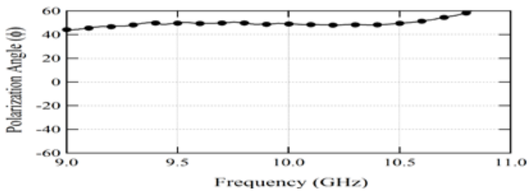

Figure 7. Experimental result for the polarization angle

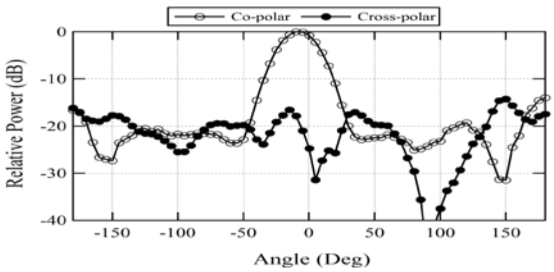

Figure 8. Experimental result for the radiation pattern of the array antenna

V. CONCLUSION

In this paper, a linear polarization switchable patch array antenna is proposed. The orthogonal feed circuit and magic-T bias circuit is used to realize the array antenna. The microwave integration technology is effectively employed to realize proposed linear polarization switchable array antenna. In order to realize the ±45º polarization switching, two switching diodes are integrated with each patch element. Using the ON/OFF condition of the diodes, the polarization axis can be easily switched to ±45º. The experimental results confirm the ability of the proposed array antenna to switch the polarization axis at ±45º at 10 GHz (X band). The proposed array antenna confirms some better performances compared with [8] which are listed below:

I) Antenna configuration become more simple

II) The cross-polarization isolation of radiation pattern is significantly improved to -20 dB which was -15 dB for [8].

The proposed array can be an attractive candidate for the application of polarimetric sensors, polarization diversity and wireless data transmission etc.

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