A Reconfigurable Polarization Converter Based on Active Metasurface

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***Abstract*— We present a reconfigurable polarization converter which is composed of an active metasurface and a dielectric plate backed with metallic gratings. The unit cell of the active metasurface is a butterfly-shaped structure embedded with voltage controlled varactor diodes. By controlling the bias voltage of the varactor diode, the proposed polarization converter is able to switch its functions between linear polarization converter and circular polarization converter. For biased voltage of 0V, the proposed device acts as a linear polarization converter; whereas for the bias voltage of -19 V, it is switched to be a circular polarization converter.**

Keywords*— *Reconfigurable, active metasurface, polarization conversion

I. INTRODUCTION

Polarization is an important property of electromagnetic (EM) waves and has been applied in many aspects in the electromagnetic field. To realize the communication between two systems with different polarization ways, the polarization conversion of EM wave is necessary. The metasurface-based polarization converters have been proposed as an excellent way to control the polarization state of EM wave due to their many unique features, such as high efficiency, broadband or multi-band and ultra-thin thickness. Up to now, some metasurface-based polarization devices with diverse functionalities, including linear to linear, linear to circular, and circular to circular polarization conversion, have been demonstrated [1]-[2]. Though, these polarization devices occupy many good performances, such as broadband and high efficiency, their functionalities are not reconfigurable, which limit many practical applications.

With the development of the radio technology, to realize the integration of multiple functionalities and the miniaturization of system, the reconfigurable techniques is gradually becoming the hot spot of research. In this context, several works have been focused on reconfigurable polarization converters based on metasurface [3], which are achieved by mechanical rotation. But the switch time of the polarization converter is too long. To solve this problem, an active polarization converter loaded with p-i-n diodes is proposed [4]. By changing the states of the p-i-n diodes, the polarization conversion of the device can be switched. However, this device operates in transmission mode that brings out low polarization conversion efficiency.

In this letter, we designed a reconfigurable reflective polarization converter that is composed of butterfly-shaped active metasurface printed on a dielectric substrate backed with a metallic grating. The simulation results show that the polarization state of reflective wave can be switched among cross polarization, elliptical polarization and circular polarization, with the DC voltage varying from 0 V to -19 V.

II. RESULTS

The schematic sketch of the proposed polarization converter is shown in Fig. 1. The unit cell [see Fig. 1(b)] of the active metasurface is composed of a butterfly-shaped patch printed on a F4B backed with a copper ground plane. The relative permittivity and the thickness of the dielectric plate is $\varepsilon_r = 4.4$ and h = 6 mm, respectively. At the center of butterfly-shaped patch, a gap is etched along the *y*-direction, and a varactor diode is integrated into this gap and connected to the patches on both sides. The geometric parameters of the unit cell are ws = 0.3mm, lx = 6.35 mm, ly = 8 mm, and p = 16 mm, respectively. To provide the bias voltage for varactor diodes, a modified ground plane is developed, where a narrow gap along the *y*-direction is introduced to separate the ground plate into strip grid. Then, the left and right trapezoid patches are connected to the strip grid by metal vias, respectively, as shown in Fig. 1(c). As a result, the bias voltage of the varactors can be provided by the bias lines #1 and #2, as illustrated in Fig. 1 (d).

To study the performance of the proposed polarization converter, we simulate the reflection coefficients using the commercial software CST Microwave Studio 2016. When the proposed polarization converter is excited by a *u*-polarized wave, the co-polarized and cross-polarized reflectance is shown in Fig. 3. Here, we define the R_{uu} and R_{vu} to denote the *u*-and *v*-polarized reflection coefficients. When the bias voltage is 0V, the simulated results are shown in Fig. 3(a), from which we see that the cross-polarized reflectance R_{vu} is higher than -1.5 dB in the frequency range from 4.1 to 7.7 GHz, whereas the co-polarized reflectance R_{uu} is lower than -10 dB in this frequency range. Thus, the proposed device effectively converts a linearly polarized wave into its cross-polarization. For the bias voltage of -19V, the simulation results are shown in Fig. 3(b). We observe that, in the frequency range from 4.9 to 8.2 GHz, the magnitudes of the cross-polarized reflectance R_{vu} and the co-polarized reflectance R_{uu} are approximately equal to -3 dB, and their phase difference $\Delta\varphi_{vu}$ is close to 90°. It reveals that the proposed device realizes the linear-to-circular polarization conversion. Besides, the proposed converter can reflect linear polarization wave to elliptical polarization wave when the bias voltage is changed from 0V to -19V.

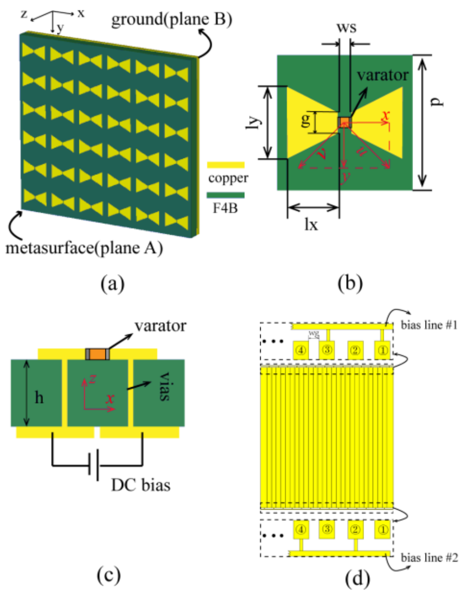

Fig.1 Schematic of the proposed polarization converter. (b) The top view of a unit cell. (c) Side view of the unit cell. (d) The bottom view in which the bias lines are shown.

To further investigate the performance of polarization conversion under bias voltages of 0 V and -19 V. We calculate the polarization conversion ratio (PCR) for linear polarization conversion and the axial ratio (AR) for circular polarization conversion, respectively. As shown in Fig. 4, the value of PCR is over 80% in the frequency range from 4 GHz to 7.9 GHz. And the bandwidth with AR better than 3dB is from 4.9 GHz to 8.2 GHz. The calculation results indicate that the proposed polarization converter occupies excellent performance under the two bias voltages of 0V and -19V.

III. Conclusion

We proposed a reconfigurable polarization converter composed of a butterfly-shaped metasurface embedded with varactor diodes, a dielectric spacer, and a modified ground plane. By changing the bias voltage from 0 V to -19 V, the proposed device can reflect linear polarization wave to cross-polarization, elliptical polarization, and circular polarization waves. Especially, when the bias voltage is 0V, the proposed device can realize linear-to-linear polarization conversion in the frequency range of 3.9 to 7.9 GHz, with a PCR over 80%. When the bias voltage is changed to -19V, the proposed device is switched to a circular polarization converter in the frequency range of 4.9 to 8.2 GHz, with AR better than 3dB.

Acknowledgment

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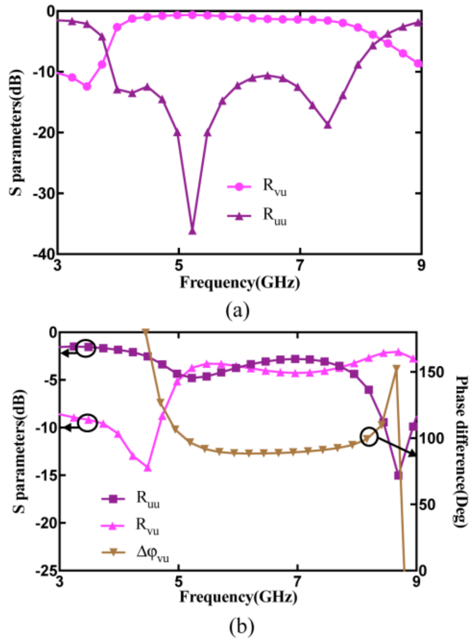

Fig.3 Simulated reflectance R_{uu} and R_{vu} for different bias voltages, (a) 0V, (b) -19V.

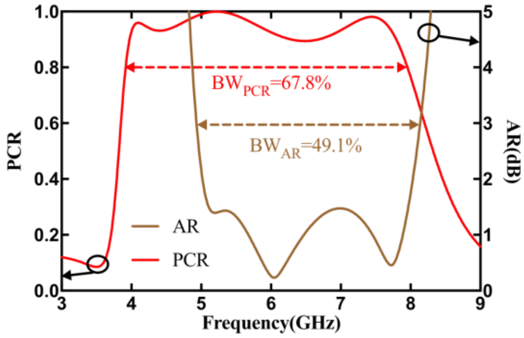

Fig. 4 The calculated PCR for 0V bias voltage and AR for -19V bias voltage

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