Circular polarization and wideband filtering function switching device based on metasurface

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INTRODUCTION

This article proposes a switchable metasurface with dual functions of circular polarization and filtering. The device unit structure consists of two layers of dielectric substrates, three layers of metal surface and two PIN diodes. The simulation results show that by simultaneously controlling the ON and OFF states of the top and bottom PIN diodes, the metasurface device can achieve dual-function switching. When the two PIN diodes are OFF, the metasurface can realize wideband filtering. When the PIN diodes are turned ON at the same time, the metasurface has a line-to-circular polarization conversion function.

Novelty

There are few reports about transmissive line-circular polarization conversion and filter function switching metasurface devices.

DESIGN

Fig. 1 shows a schematic diagram of the structure of the active metasurface device. The device includes three layers of metal surfaces, of which the top and bottom layers are classic metal strip gates, with PIN diodes embedded in the middle. The middle layer is a circular metal patch, and the periodic unit is connected along the end of the y-axis. There are two dielectric layers separated between the three metal surfaces.

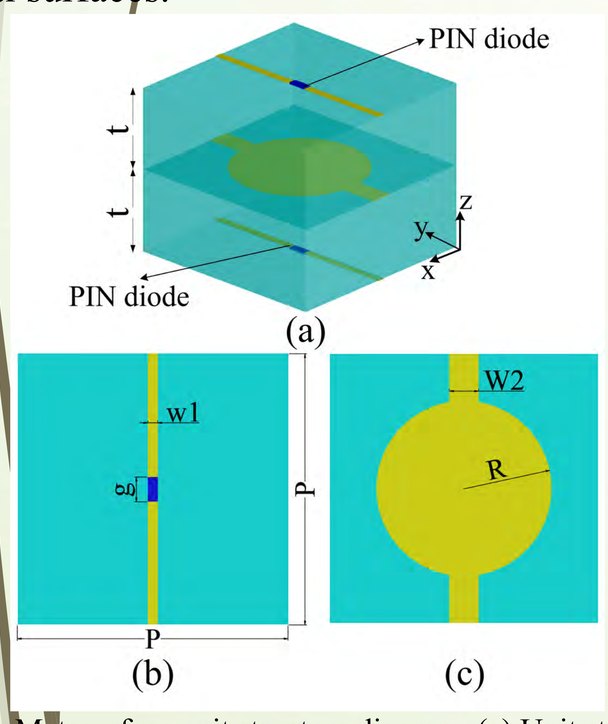

Fig.1. Metasurface unit structure diagram. (a) Unit structure three-dimensional diagram. (b) Top and bottom views. (c) Middle-level view.

The dielectric layer material is F4B, the thickness is t = 2.2 mm, the relative dielectric constant is 2.65, and the loss tangent is 0.001. Both the top and bottom PIN diodes are HSMP-3832, with an on-resistance of 1.5 Ω and an off-capacitance of 0.3 pF. The unit structure parameters of the metasurface device are as follows: p = 5.5 mm, w_1 = 0.2 mm, w_2 = 0.6 mm, R = 1.8 mm, g = 0.5 mm. The software CST is used to simulate the dual-function switching characteristics of metasurface devices. The unit structure of the device has the characteristics of periodic arrangement in the x and y axis directions, so the periodic boundary (Unit cell) is selected as the boundary condition in the x and y directions.

SIMULATION

The device is excited by the y-polarized wave propagating in the -z direction, and the simulation results are shown in Fig. 2. When the PIN diodes on the top and bottom layers of the metasurface are not biased (OFF), the proposed metasurface device has a broadband filtering function. The S_{11} parameter curve has two resonance points at 3.32 GHz and 3.63 GHz in the operating frequency, and the operating bandwidth below -10 dB is 3.22–3.72 GHz.

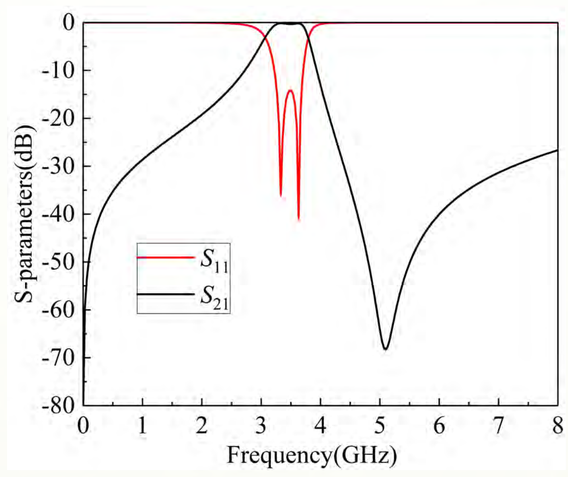

Fig. 2. Filter function of metasurface device under PIN diode (OFF) state.

The u-polarized wave whose polarization direction is 45° with the x-axis is incident on the metasurface device along the -z direction. To facilitate analysis, define the co-polarization transmission coefficient T_{uu} and the cross-polarization transmission coefficient T_{uv}. As shown in Fig. 3(a), in the frequency range of 18–28 GHz, the amplitudes of the co-polarization and cross-polarization transmission coefficients are approximately equal, and the phase difference is $\Delta\varphi = \varphi_{uv} - \varphi_{uu} = \pm 90°$. As shown in Fig. 3(b), in the 18–28 GHz frequency range, the axial ratio of the transmitted electromagnetic wave is less than 3dB, and the axial ratio relative bandwidth is 43.5%.

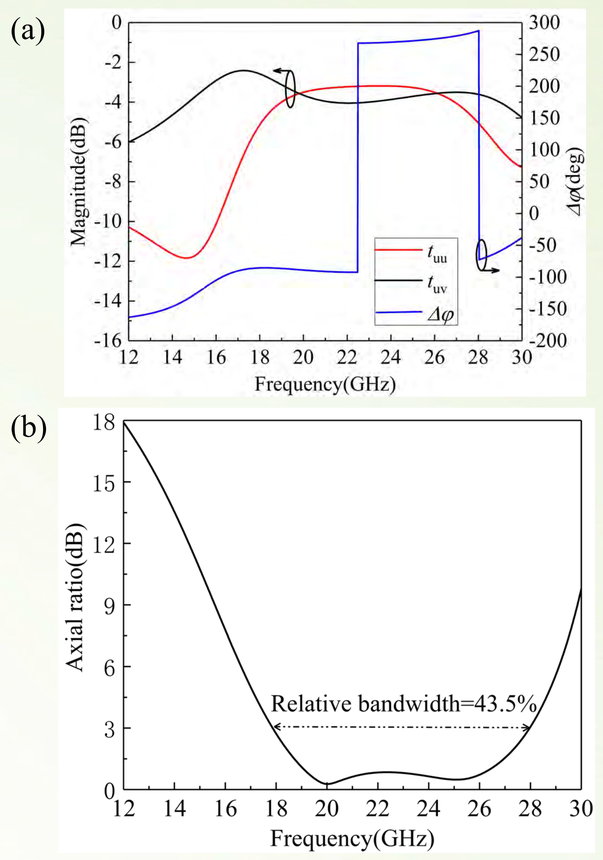

Fig. 3. (a) The line-to-circular polarization conversion function of the device in the PIN diode (ON) state, and (b) axial ratio.

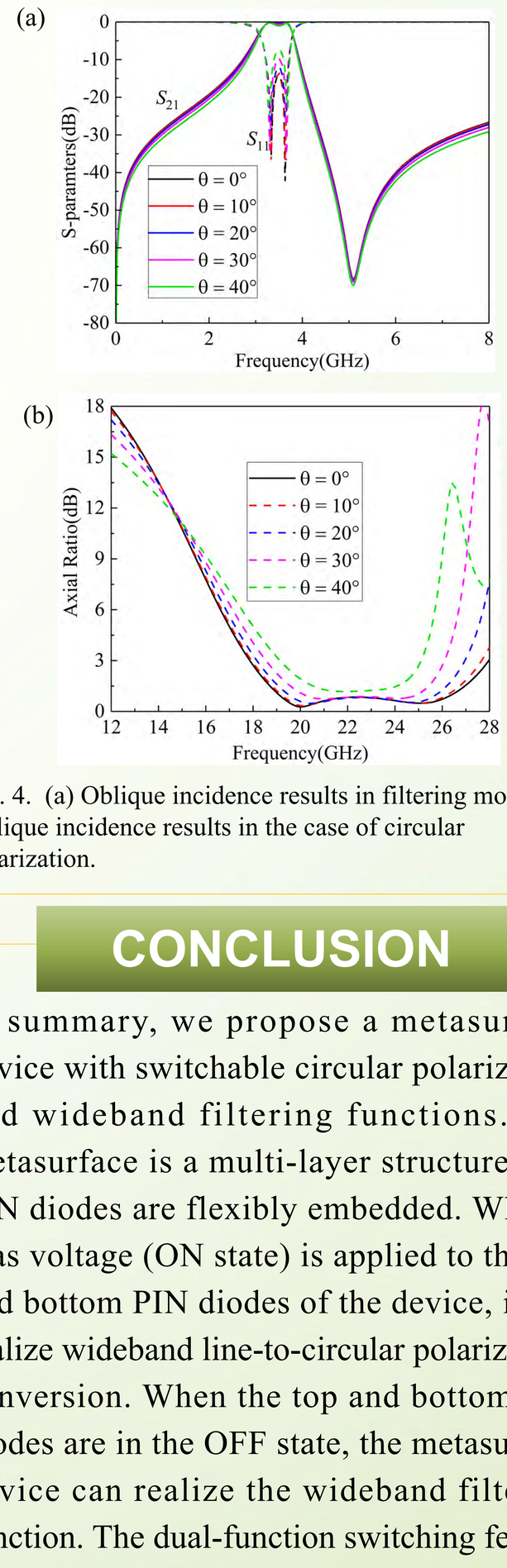

Fig. 4. (a) Oblique incidence results in filtering mode. (b) Oblique incidence results in the case of circular polarization.

CONCLUSION

In summary, we propose a metasurface device with switchable circular polarization and wideband filtering functions. The metasurface is a multi-layer structure, and PIN diodes are flexibly embedded. When a bias voltage (ON state) is applied to the top and bottom PIN diodes of the device, it can realize wideband line-to-circular polarization conversion. When the top and bottom PIN diodes are in the OFF state, the metasurface device can realize the wideband filtering function. The dual-function switching feature of the metasurface is very suitable for wireless communication systems.