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A low-profile dual-polarization programmable dual-beam scanning antenna array

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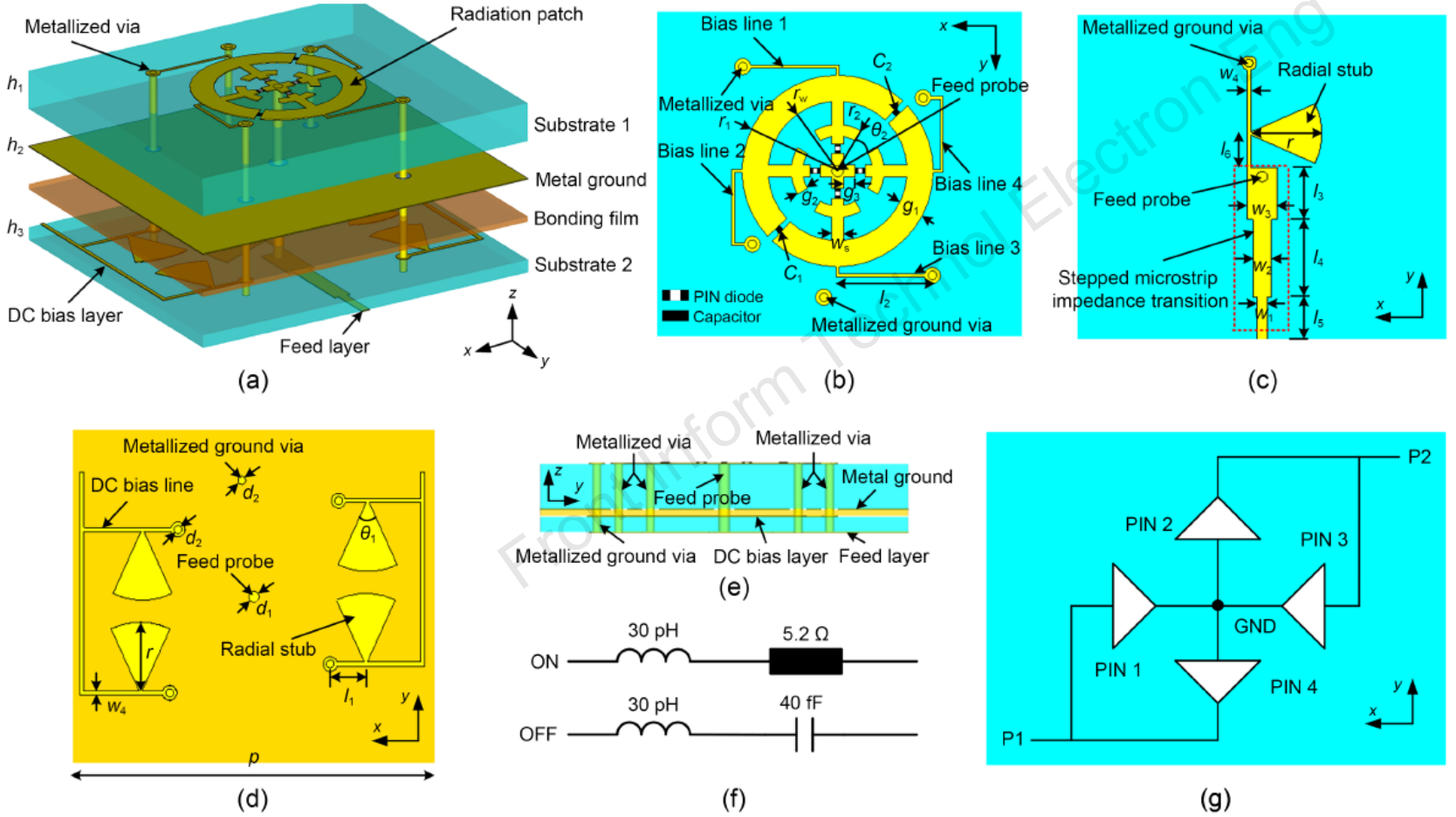
Innovation

- A low-profile dual-polarization dual-beam scanning antenna array is designed.
- The radiating elements are ingeniously designed to achieve reconfigurable polarization and modulation of the radiation phase by controlling the state of the PIN diodes integrated on each element.
- The two-dimensional (2D) dynamic and accurate deflection of the beam is achieved by a designed direct current (DC) bias circuit that digitally encodes the antenna array.

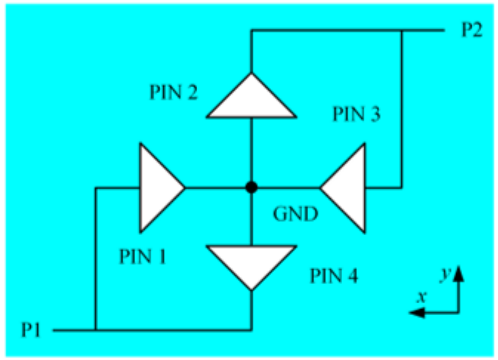
Antenna performance

Dual-polarization antenna element structure with phase adjustment



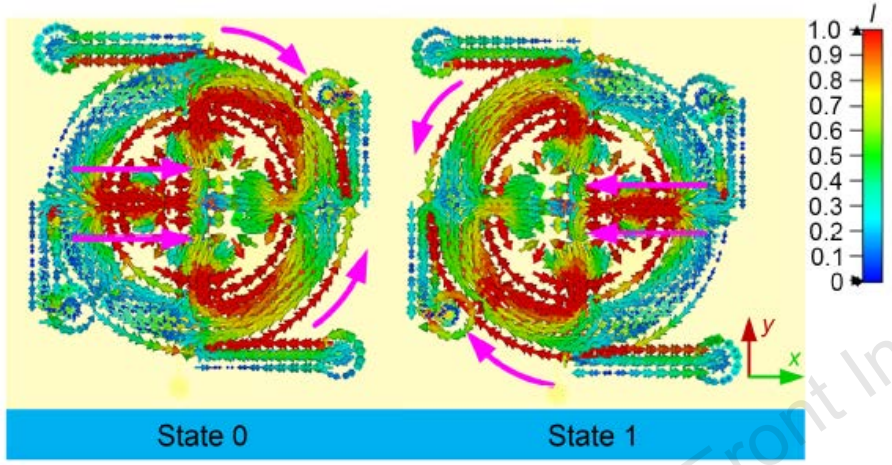
- Radiation characteristics
- Dual-polarization
- Two-phase states adjustable

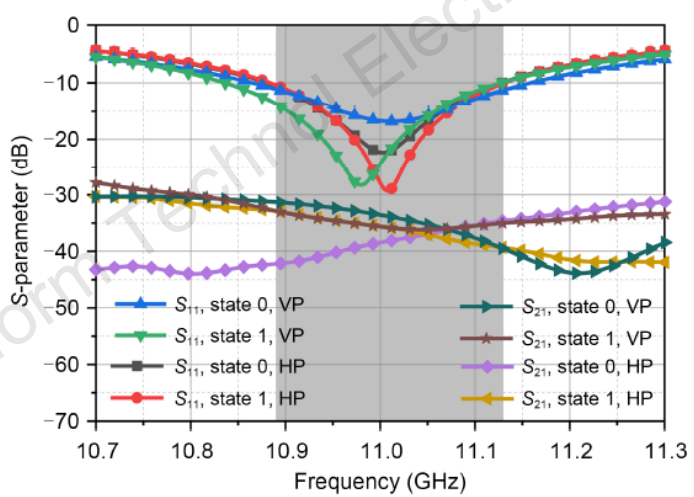
Antenna performance

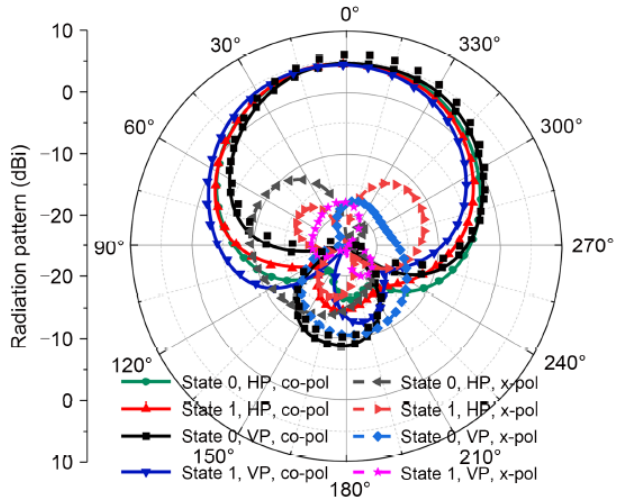


Voltage of DC ports (V)		PIN 1	PIN 2	PIN 3	PIN 4	Phase (°)
P1	P2					
1.3	0	ON	OFF	OFF	OFF	0*
0	1.3	OFF	OFF	ON	OFF	180*
−1.3	0	OFF	OFF	OFF	ON	0**
0	−1.3	OFF	ON	OFF	OFF	180**

DC: direct current. * Horizontal polarization; ** Vertical polarization



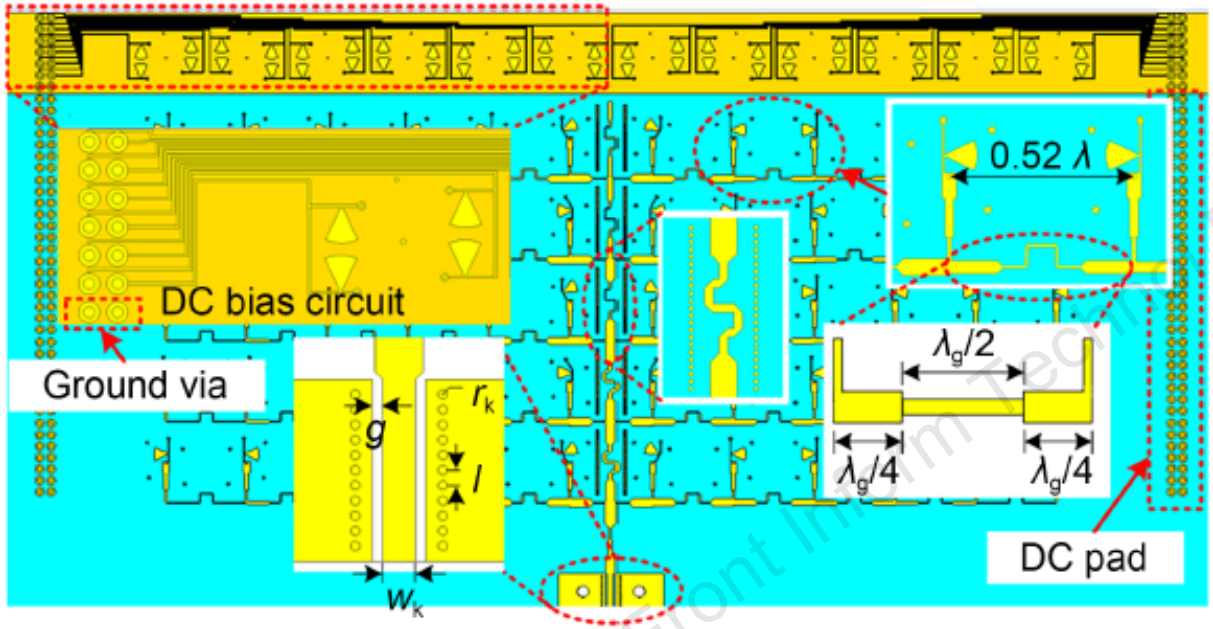


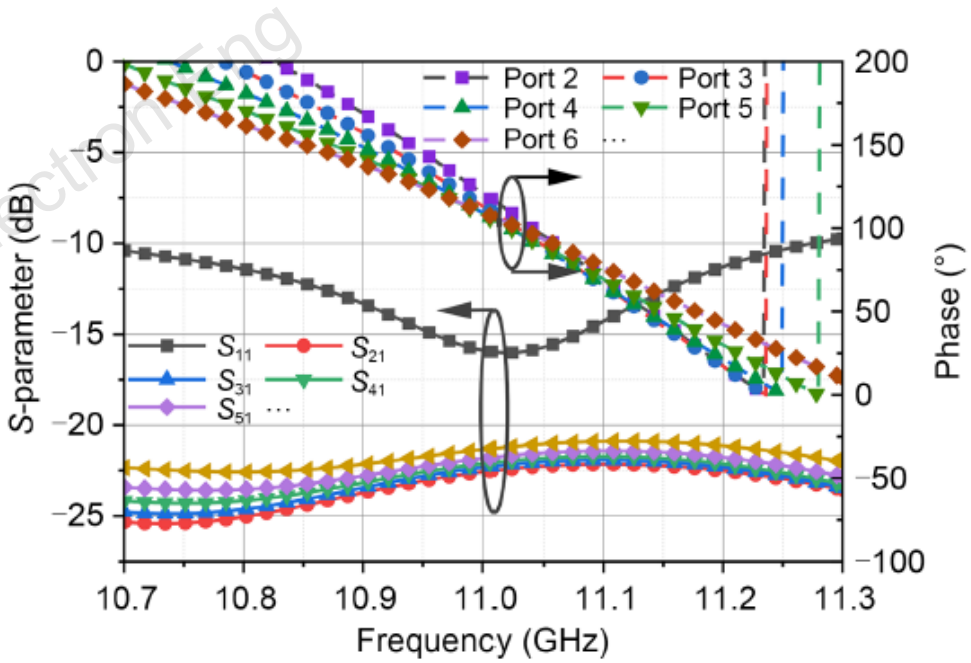


- The characteristic of the radiated state is characterized by two states in which the current is in opposite directions.
- The S_{11}'s of the antenna element in the HP and VP are basically the same, and the −10-dB impedance bandwidth is 10.89–11.15 GHz.
- The radiation patterns of the four states do not differ much, and the maximum gain reaches 4.7 dBi. For the dual-polarization characteristics, the cross-polarization performance is good in the main radiation direction.

Antenna performance

Array feeding network and DC bias circuit

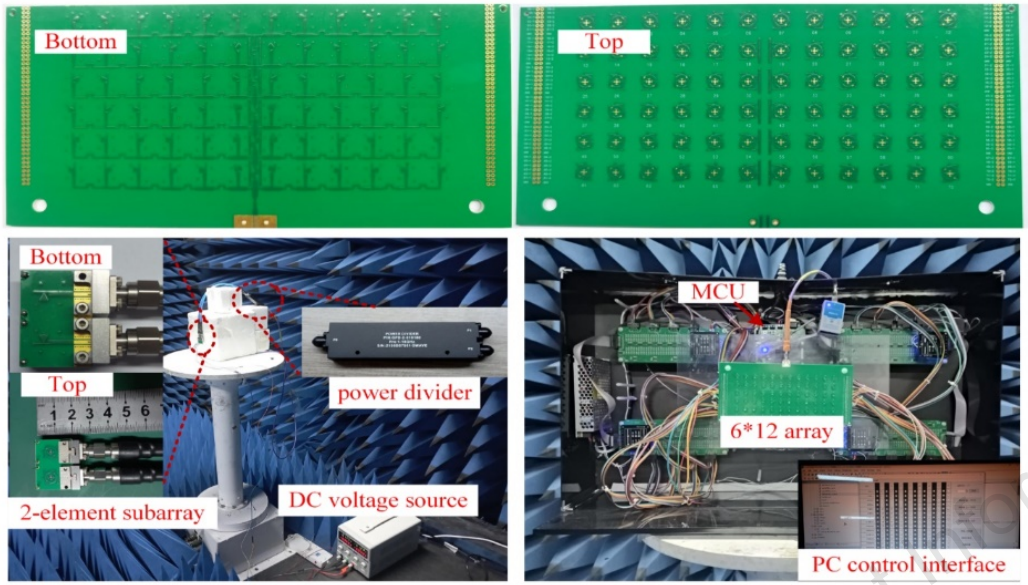




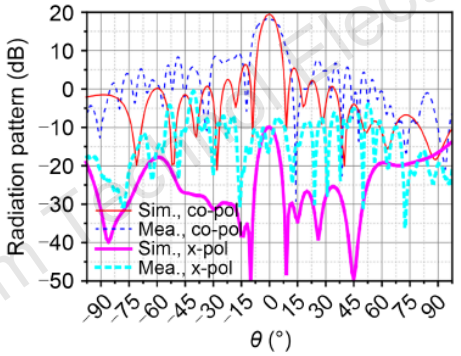
- The amplitude and phase of the *S*-parameters of the feeding network, where S_{11} less than −15 dB is at 11 GHz, and the amplitudes of all output ports are basically the same, and the phase difference is within 12°.

Antenna performance

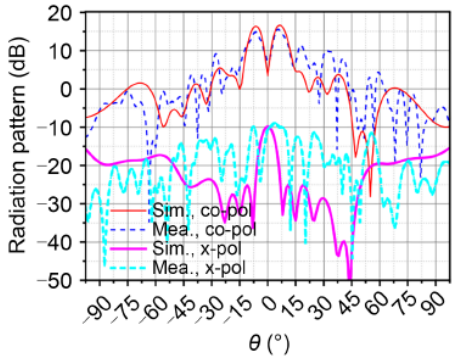
Antenna prototype and simulation and measurement results



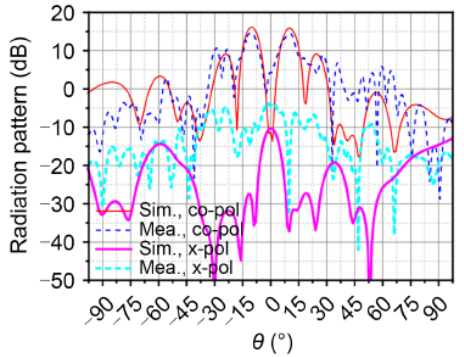
- The array is controlled by the microcontroller to control the extended I/O port output to specify the level to achieve real-time adjustment of the encoding.



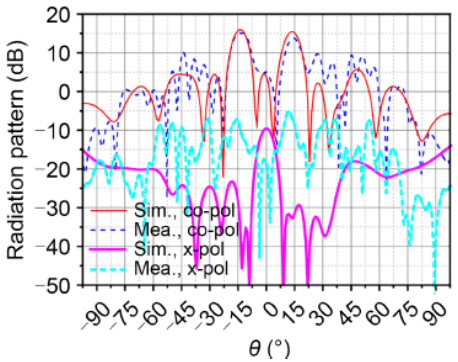
$\theta_0 = 0°, \phi_0 = 0°$



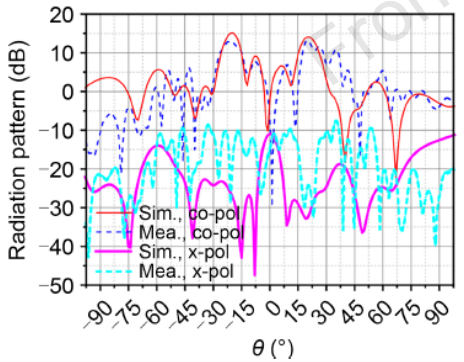
$\theta_0 = \pm 5°, \phi_0 = 0°$



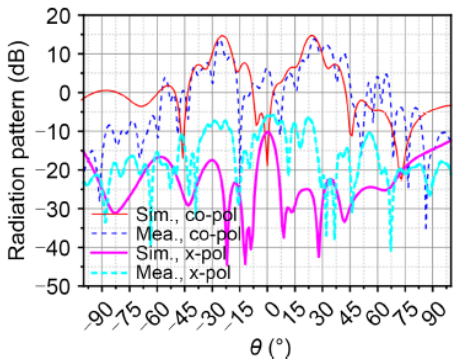
$\theta_0 = \pm 10°, \phi_0 = 0°$



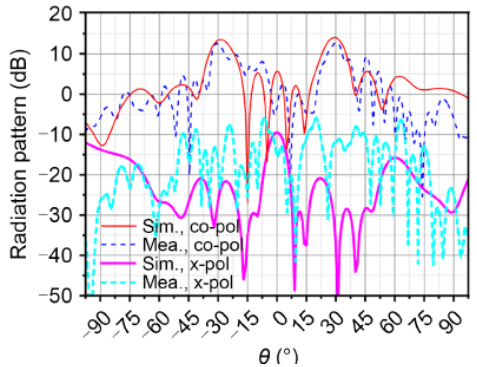
$\theta_0 = \pm 15°, \phi_0 = 0°$



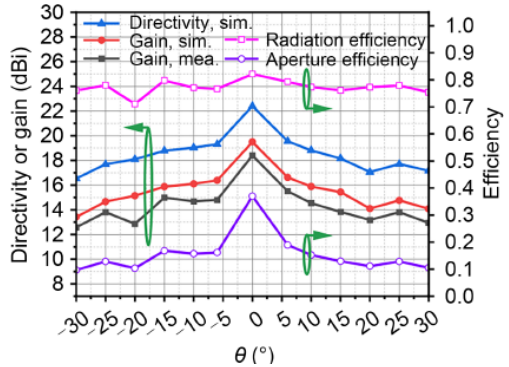
$\theta_0 = \pm 20°, \phi_0 = 0°$



$\theta_0 = \pm 25°, \phi_0 = 0°$



$\theta_0 = \pm 30°, \phi_0 = 0°$



Antenna performance

Comparisons between the proposed beam scanning antenna and other reported antennas

Reference	Frequency (GHz)	Antenna type	Number of elements	Profile	Polarization	Max gain (dBi)	Scanning angle step (°)	Max aperture efficiency (%)
Wang ZL et al., 2020	12.5	Reflectarray	14×14	High	Single	17.07	10	13.2
Yang HH et al., 2017	11.1, 14.3	Reflectarray	40×40	High	Single	30.80	10	21.6, 18.1
Liu et al., 2020b	6.0	Transmitarray	16×16	High	Single	19.30	15	–
Zhang et al., 2020	3.5	Radiation-type	4×4	Low	Single	17.80	–	–
Pan et al., 2022	10.0	Radiation-type	1×32	Low	Single	17.80	10	–
This paper	11.0	Radiation-type	6×12	Low	Dual	18.50	5	37.0

Max: maximum

Conclusions

- In this paper, a dual-polarization beam scanning antenna array of low profile, low cost, and easy integration is designed and verified. This antenna system excels in applications in fields such as radar systems and smart antennas.
- The antenna also has excellent performance with a beam scanning step angle of 5° under the condition of ensuring gain, which has great advantages over similar beam reconfigurable antennas.

Shichao ZHU received his BS degree in the School of Electrical and Automation Engineering, East China Jiaotong University, Nanchang, China in 2020. He received his MS degree in the College of Electrical and Information Engineering, Hunan University, Changsha, China, under the supervision of Prof. Gaosheng LI. His research interests include reconfigurable antennas, phased array, and electromagnetic metamaterials and their antenna applications.

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