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Wideband Pattern Reconfigurable Printed-Yagi Antenna Array Based on Feed Structure

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***Abstract*—A pattern reconfigurable antenna array with two elements is designed in this paper. The antenna element is made up of a printed Yagi and feed structure with variable phase. By changing the states of diodes in the feed structure of these two elements, the far-field radiation phase of both elements can be changed. That is, the pattern reconfigurable function of the array is realized. In this way, the impedance bandwidth of array is 75.9% (2.7~6.0 GHz), in which the peak gain direction can be switched between -θ, 0 and +θ (θ = 10°~16° at different frequencies). With the simple reconfigurable structure, the peak gain direction can be adjusted according to demands. It can be applied to broadband investigation systems. To verify the feasibility, a prototype is fabricated, measured, and reasonable agreement between the simulated and measured results is obtained.**

***Index Terms*—** Pattern reconfigurable, antenna array, printed-Yagi, wideband.

I. INTRODUCTION

Recently, reconfigurable antennas are the focus of research because they have more flexibility than normal antennas under the same aperture. Thus, reconfigurable antennas can meet additional requirements of various modern wireless systems. Generally, reconfigurable antennas are classified as frequency [1], [2], polarization [3], [4] pattern [5]-[10], and hybrid reconfigurable antennas [11], [13]. In particular, reconfigurable patterns include three beam forms: broadside and conical switchable beams [5], [6], azimuth switchable beams [7], [8] and elevation switchable beams [9]-[11]. In this paper, antennas with elevation switchable beam are discussed.

In [9], the main beam of antenna can be switched to five directions by using the principle of the switchable director and reflector. However, its structure is so complex that it is not suitable for reconfigurable arrays. In [10], and [11], two patch antennas are also designed by the principle of switchable directors with simple structure, but the bandwidth of 5.6% and 1.7% is not appropriate for investigation systems. Therefore, pattern reconfigurable antenna arrays with wideband performance are needed.

In this paper, a two-element array is designed, the pattern of which can be changed by four groups of radio frequency (RF) switches on each element to achieve the reconfigurable pattern in elevation plane. The impedance bandwidth of the array is 75.9%, and the peak gain direction can be switched among -θ, 0 and +θ (θ = 10°~16°at different frequencies). The remainder of this paper is organized as

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follows. The antenna configuration and detailed design are depicted in the 2nd section. Then, a prototype is simulated, manufactured, and measured in the 3rd section. Finally, a conclusion is given in the last section.

II. ANTENNA DESIGN AND CHARACTERISTICS

It can be seen that the antenna array includes two reconfigurable antenna elements and a metal ground in *Fig.* 1. In order to facilitate the installation, the metal ground is trenched and fixed to the antenna element. The direct current (DC) bias circuit is printed on the upper surface of the ground, which is easy to be soldered with the DC bias circuit of the element. In addition, A and B are the soldering points of the external circuit. Each element has four groups of PIN diodes. The PIN diodes of the two elements are installed in opposite position to ensure the formation of different far-field radiation phases. The specific structural parameters of the antenna array are given in Table I.

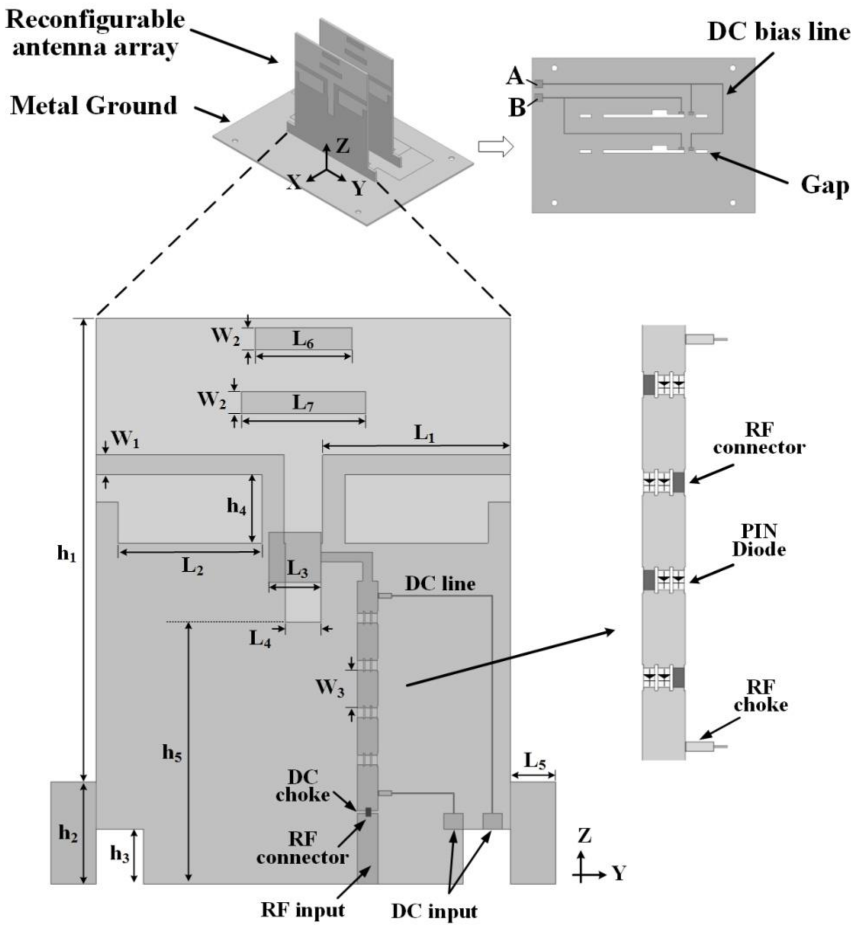

Fig. 1. Designs for the reconfigurable antenna.

The PIN diodes, RF connector and RF choke are labeled in the partial enlargement map, as shown in *Fig. 1*. A RF connector is connected in parallel with two RF switches to connect 50 Ω transmission lines. They are called a group of switches. As shown in *Fig. 2*, when the switches are all turned on, it is equivalent to a common 50 Ω transmission line. It can be noted that the arrangement of adjacent switches is different. Therefore, when the switches are all turned off, the current will take a detour in

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transmission process, that is, the physical length of the path is maximized. In this way, the phase of each element is different and the pattern can be reconstructed. What's more, the radiation pattern can also be adjusted to meet the requirements of larger angle migration by enlarging the number of PIN diodes.

Moreover, the specific RF switch voltage control is given in Table I to describe the working modes of Case 1, Case 2 and Case 3.

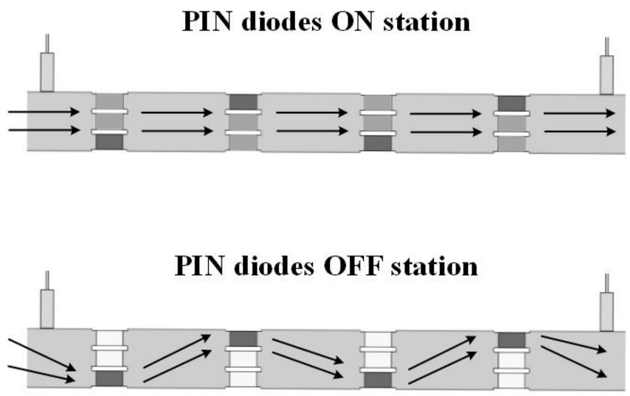

Fig. 2. The schematic diagram of current on the ON/OFF station of PIN diodes.

In order to better explain the working mode, the parameters of the antenna are analyzed by ANSYS HFSS software. In *Fig. 3*, the two curves of antenna element relative phase of far-field radiation with ON station and OFF station are given at different frequencies. It can be seen that the phase change tends to increase with the increase of frequency within limits of 2.5~6.0 GHz. And the phase change at 6.0 GHz is the maximum of Δφ ≈ 36.9° (φ means the far -field radiation phase of antenna element). So two elements can be designed to get a phase diversity by changing the ON station or OFF station, which can forms a patterns selectivity array.

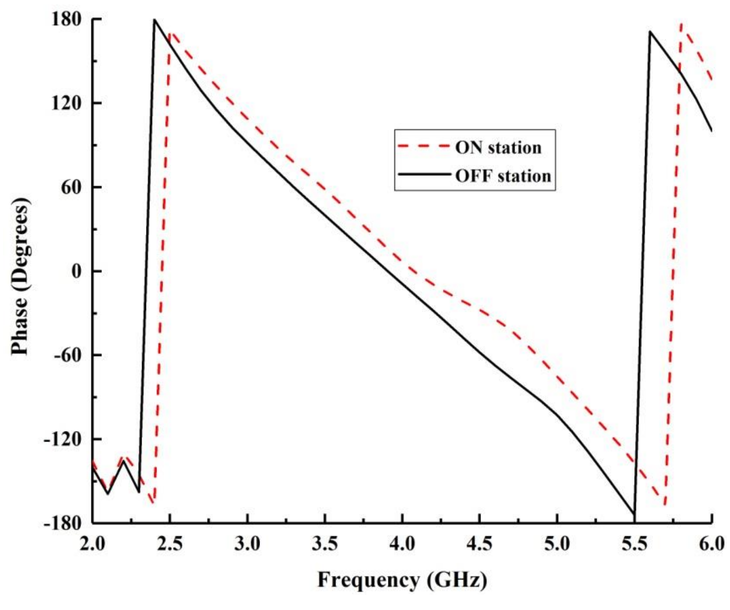

Fig. 3. The antenna element relative phase of far-field radiation with ON station and OFF station at different frequencies.

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TABLE I. ANTENNA DIMENSIONS

Parameter	Value (mm)	Parameter	Value (mm)
L_1	23.8	W_2	2.8
L_2	18.2	W_3	4.4
L_3	6.7	h_1	58.8
L_4	4.6	h_2	13.0
L_5	5.8	h_3	7.0
L_6	12.3	h_4	8.8
L_7	15.8	h_5	33.3
W_1	2.5		

TABLE II. CONFIGURATIONS OF THE A AND B PORTS TO ACHIEVE RECONFIGURABLE ANTENNA

Mode	A Port	B Port	Peak Gain Direction
Case 1	0V	0V	0°
Case 2	4V	0V	$-\theta$ (θ = 10°~16°)
Case 3	0V	4V	$+\theta$ (θ = 10°~16°)

III. EXPERIMENTAL RESULTS AND COMPARISON

Simulations were performed using ANSYS HFSS. To validate the design, a prototype of the proposed antenna array is simulated, fabricated and tested. The structures of the array are fabricated on FR4 substrates, with a dielectric constant of 4.4 and a loss tangent of 0.02. The reflection coefficients were measured using the Wiltron 37269A Network Analyzer and the radiation patterns were measured by the time-gating method. The comparison method is used to measure the realized gain. Then, the simulation and test results of VSWRs and Gain are all given in *Fig. 4*. The *Fig. 5* shows the directional patterns including the co-polarized and cross-polarized patterns at 2.8 GHz, 4.4 GHz and 5.8 GHz. Photos of prototype are shown in *Fig. 6*.

The selected components for the prototype were: PIN diodes (SMP1345-079LF) for switches; Inductors (220 nH) adopted in the DC-biasing circuits for RF chokers; Capacitors (22 uF) act as RF connectors.

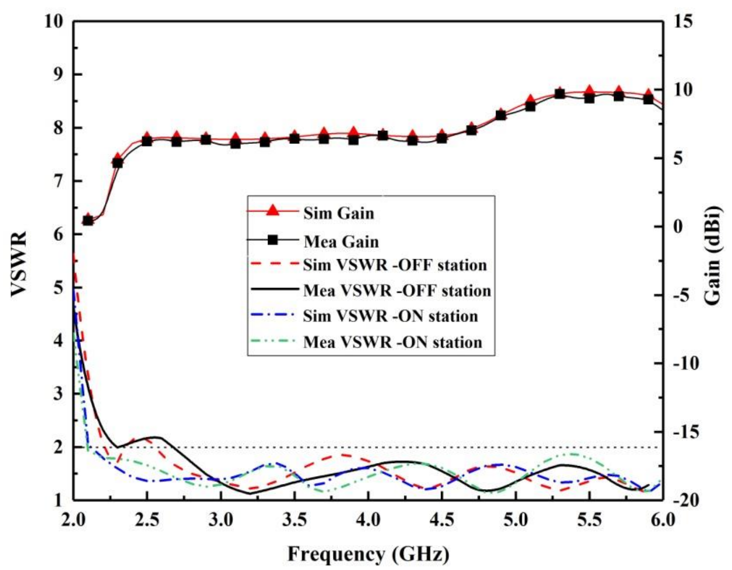

Fig. 4. Measured and simulated VSWRs and Gains of the proposed antenna.

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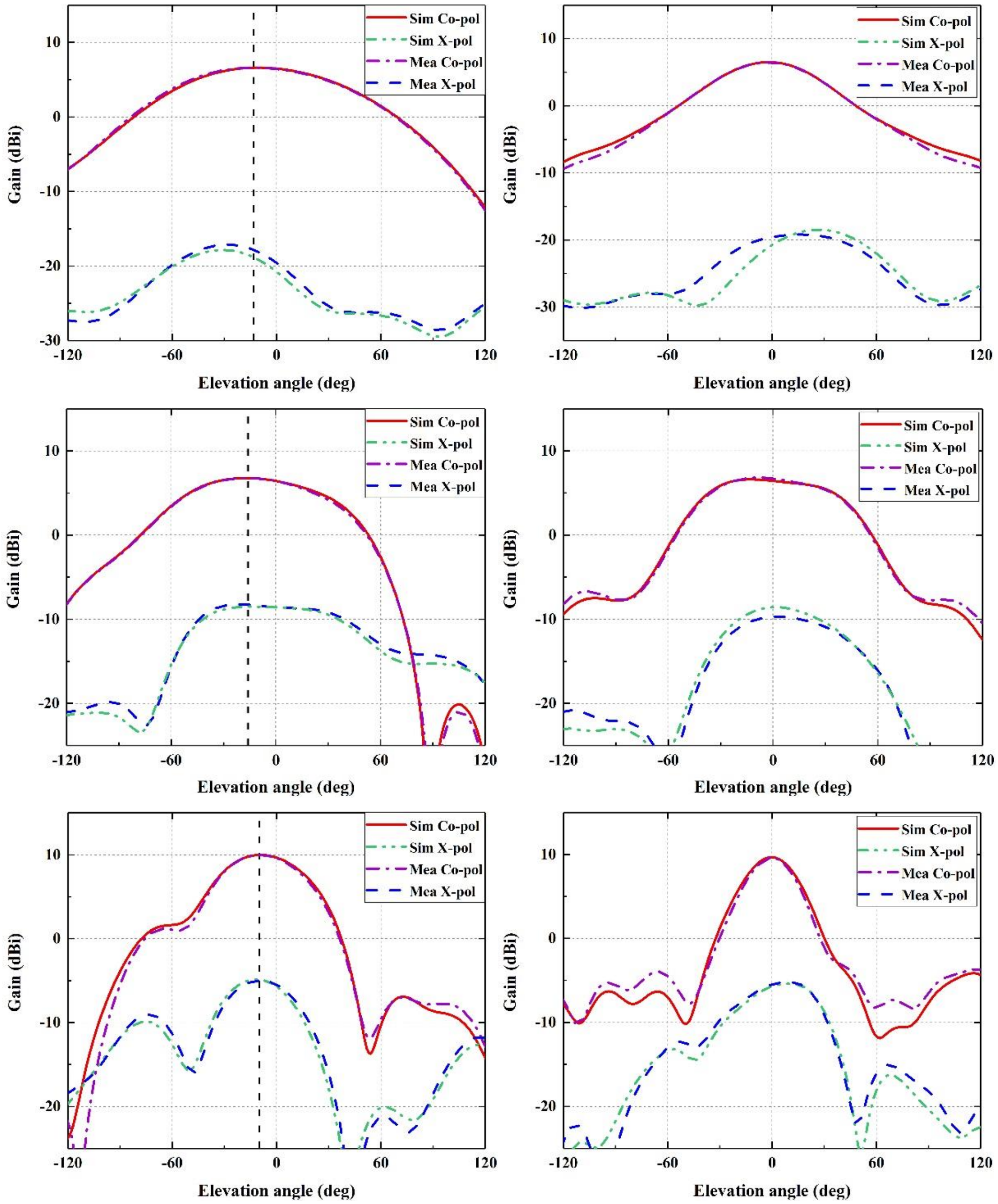

Fig. 5. Measured and simulated radiation patterns of (a) H-plane (b) E-plane at 2.8 GHz and (c) H-plane (d) E-plane at 4.4 GHz and (e) H-plane (f) E-plane at 5.8 GHz

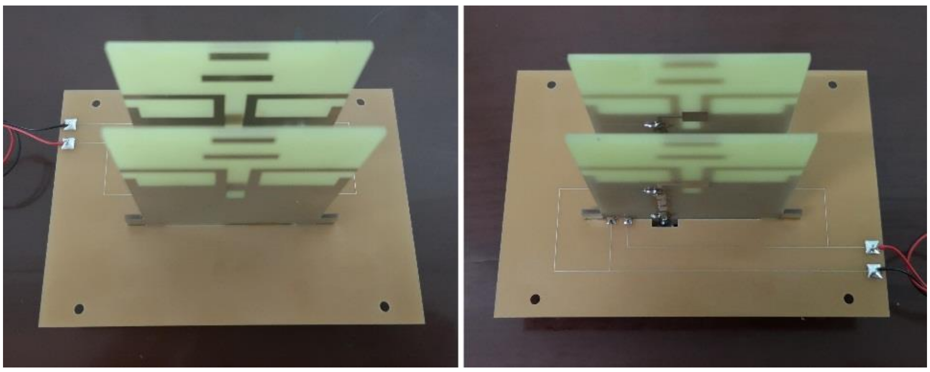

Fig. 6. Fabricated reconfigurable antenna array.

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In *Fig. 4*, it is known that the simulation and test results of VSWRs and Gain coincide. The impedance bandwidth is 75.9% (2.7~6.0GHz), and the stability Gain is more than 6.0 dBi. In *Fig. 5*, the simulation of the pattern is also consistent with the test results. At begin of the band, the radiation direction of pattern is at θ = -13°, and the gain is 6.6 dBi with the 24.4 dB of the cross polarization. At center of the band, the radiation direction of pattern is at θ = -16°, and the gain is 6.8 dBi with the 15.3 dB of the cross polarization. At end of the band, the radiation direction of the pattern is at θ = -10°, and the gain is 10.0 dBi with the 15.0 dB of the cross polarization. Therefore, in this paper, the test performance of array achieves the requirement of reconfigurable performance.

IV. CONCLUSION

In this paper, a pattern reconfigurable antenna array with two elements is designed. The impedance bandwidth is 75.9% (2.7~6.0GHz), and the stability Gain is more than 6.0 dBi. The radiation direction can be adjusted on the H-plane to achieve a switching among -θ, 0 and +θ (θ = 10°~16° at different frequencies). The measured antenna is consistent with the simulation results and can be applied to the reconnaissance system. Because of the simple reconfigurable structure, the radiation pattern will be adjusted to meet the requirements of larger angle migration.

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