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A High Gain Polarization and Pattern Reconfigurable Antenna

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***Abstract*—In this paper, a novel polarization and pattern reconfigurable antenna operating in the 5.15-5.85 GHz band is proposed for advanced wireless applications. The proposed design features four L-shaped steel dipoles with partially tapered bowtie-shaped radiating elements arranged diagonally on an FR4 substrate. Eight PIN diodes are strategically integrated into the feeding network to achieve dynamic phase control through two 1-to-2 power dividers, enabling four distinct radiation modes including dual-beam and broadside patterns. The antenna demonstrates excellent performance with a 14% bandwidth, peak gain of 8.2-11.1 dBi, and stable radiation efficiency of 0.75-0.85 for all modes. Given the polarization and beam reconfigurability, the proposed antenna presents a promising solution for advanced wireless communication systems.**

***Index Terms*—high gain antenna, pattern reconfigurable antenna, polarization reconfigurable antenna**

I. Introduction

With the rapid development of emerging wireless communication systems, the multifunctionality of advanced antenna technologies has become increasingly critical to support diversified and intelligent wireless communication systems. As a result, reconfigurable antennas have garnered extensive attention. Frequency, polarization, and radiation pattern are commonly considered as three main adjustable parameters in reconfigurable antenna design [1]- [3]. Compared to single-parameter reconfigurable antennas, multi-parameter reconfigurable antennas offer greater flexibility and diversity, which bring significant advantages to wireless communication systems [4]- [8]. Among various types of reconfigurable antennas, polarization and pattern reconfigurable antennas have attracted widespread interest in recent years [5]- [8]. By dynamically switching the radiation beam to predefined directions and reconfiguring the polarization state, these antennas can effectively improve signal quality and system performance in wireless communications.

This paper presents a polarization and pattern reconfigurable antenna operating in the 5.15–5.85 GHz frequency band. The proposed antenna achieves dual-polarization dual-beam radiation modes and broadside radiation modes through four folded steel dipoles and a reconfigurable feeding network. The polarization and radiation characteristics can be dynamically reconfigured by controlling the states of PIN diodes integrated into the feeding network. Besides, the proposed antenna features a high gain of 8.2-11.1 dBi and a stable radiation efficiency of 0.75-0.85 under all states. With high gain and polarization and beam reconfigurability, the proposed design demonstrates promising potential for high performance communication applications.

II. Antenna Configuration and Operating Principle

A. Antenna Configuration

The proposed antenna comprises four L-shaped steel dipoles arranged along diagonal directions on an FR4 substrate, where each dipole consists of a vertical supporting wall and a suspended horizontal radiating section, as illustrated in Fig. 1. The ground plane and feeding network are implemented on the top and bottom layers of the FR4 substrate, respectively. The dipole units are excited through dumbbell-shaped slots by two 1-to-2 power dividers. Each dipole unit consists of two folded steel strips with a partially tapered bowtie-shaped radiating element, which is designed to optimize impedance matching performance. To achieve reconfigurable functionality, eight PIN diodes are strategically integrated into the feeding network to control the switching states of individual feeding branches. The detailed geometry parameters of the proposed antenna are summarized in Table I.

B. Operating Principle

For two dipoles excited out-of-phase, radiation cancellation occurs in the direction perpendicular to the array axis, resulting in an 8-shaped radiation pattern along the array axis. Conversely, when two dipoles excited in-phase, their radiation

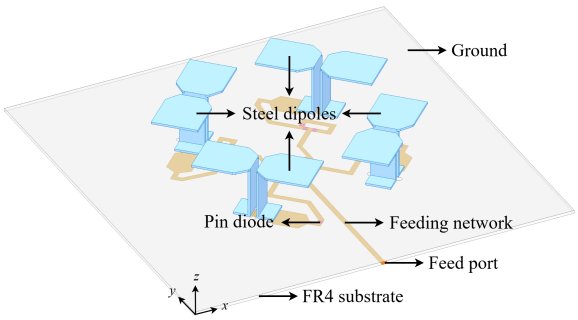

Fig. 1. Configuration of the proposed antenna.

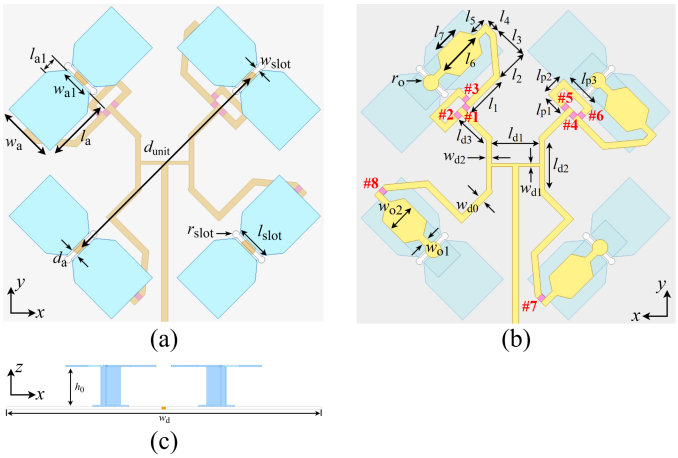

Fig. 2. Geometry of the proposed antenna. (a) Top view, (b) bottom view, (c) side view.

fields constructively superimpose in the broadside direction while canceling out in the horizontal direction(endfire direction). To achieve switchable radiation patterns, phase delay lines controlled by PIN diodes are integrated into the feeding network stubs, enabling dynamic phase control of the binary array. As shown in Fig. 2 (b), PIN diodes #1, #4, #7, and #8 control the switching states of the four dipole units, while PIN diodes #2, #3, #5, and #6 manage the switching states of the two phase delay lines. Table II summarizes the PIN diode switching states corresponding to the four radiation modes.

In Mode 1, two reversed dipoles located at φ = 45^o are excited to generate a dual-beam pattern with +45^o. Mode 2 operates following the same principle and generates a dual-beam pattern with -45^o polarization. For Mode 3, the two dipoles located at φ = 45^o are excited in-phase, forming a broadside beam with +45^o polarization. Mode 4 operates similarly to Mode 3 and yields a broadside beam with -45^o polarization.

TABLE I
ANTENNA PARAMETERS (UNIT:MM)

w_d	h_0	d_a	w_a	l_a	w_{a1}	l_{a1}	w_{slot}
95	12	1.5	11	13	5.7	3	0.8
l_{slot}	r_{slot}	d_{unit}	w_{d0}	w_{d1}	w_{d2}	l_{d1}	l_{d2}
5.8	0.65	45	1.2	0.6	0.9	9.2	9.3
l_{d3}	l_{p1}	l_{p2}	l_{p3}	l_1	l_2	l_3	l_4
6.7	4.5	4.2	7.9	9	5	6	2.8
l_5	l_6	l_7	r_o	w_{o1}	w_{o2}		
3	9	6	1.5	1.3	6		

TABLE II
STATES OF THE PROPOSED ANTENNA

State	#1	#2/3	#4	#5/6	#7	#8
Mode 1	ON	OFF	OFF	OFF	ON	OFF
Mode 2	OFF	OFF	ON	OFF	OFF	ON
Mode 3	OFF	ON	OFF	OFF	ON	OFF
Mode 4	OFF	OFF	OFF	ON	OFF	ON

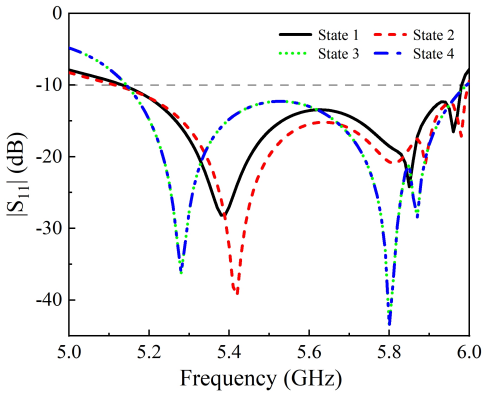

Fig. 3. Simulated $|S_{11}|$.

III. RESULTS AND DISCUSSION

Fig. 3 presents the simulated reflection coefficient,while Fig. 4 shows the peak gain, and radiation efficiency under four radiation modes. The antenna maintains consistent $|S_{11}|$ performance within 5.15–5.85 GHz (14.4% relative bandwidth). As Fig.4 shows, the peak gain varies from 8.2-9.1 dBi in modes 1-2 and increases to 9.4-11.1 dBi in modes 3-4, while the radiation efficiency remains stable between 0.75-0.85 across all modes. Fig. 5 (a) and (b) show the radiation patterns of the dual-beam mode at 5.5 GHz, while Fig. 5 (c) and (d) presents the broadside mode radiation pattern in two principal planes. These results demonstrate the antenna's capabilities of high gain, low cross-polarization, polarization and pattern reconfigurability within the operating bandwidth.

IV. CONCLUSION

In this paper, a polarization and pattern reconfigurable antenna operating in the 5.15–5.85 GHz frequency band is proposed. The design features four L-shaped steel dipoles with partially tapered bowtie-shaped radiating elements, arranged diagonally on an FR4 substrate. Eight PIN diodes are strategically integrated into the feeding network, enabling dynamic phase control through two 1-to-2 power dividers. Simulation

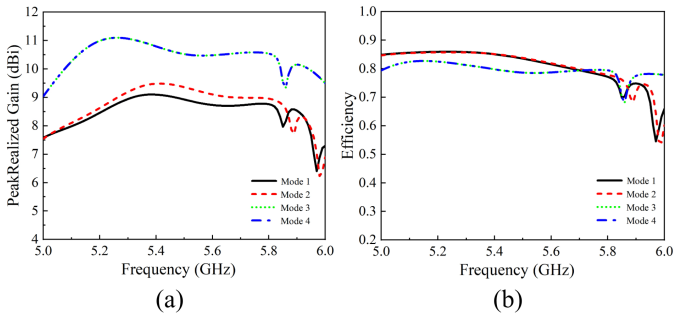

Fig. 4. Simulated results. (a) Peakrealized gain, (b) radiation efficiency.

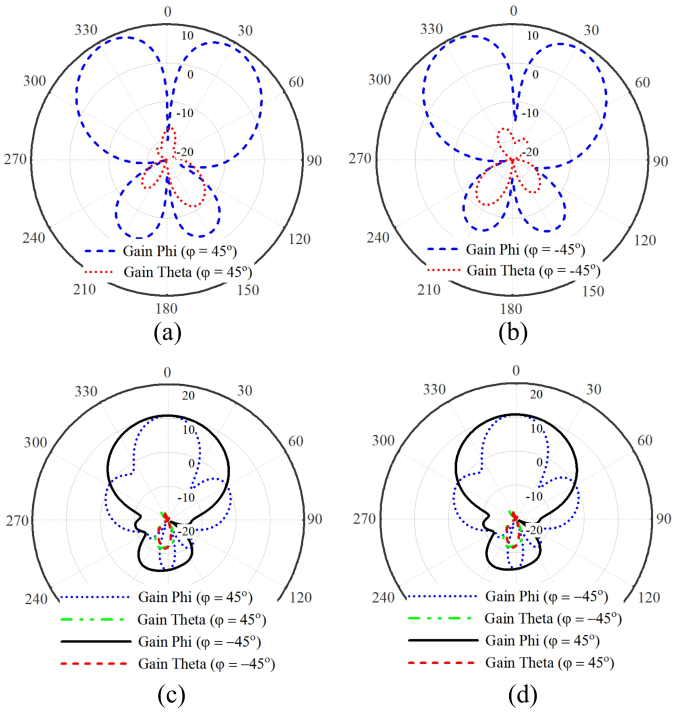

Fig. 5. Radiation pattern at 5.5 GHz. (a) Mode 1, (b) Mode 2, (c) Mode 3, (d) Mode 4.

results demonstrate excellent performance with consistent reflection coefficients, high peak gain (8.2-11.1 dBi), stable radiation efficiency (0.75-0.85), and low cross-polarization across all radiation modes. Due to these metrics, the proposed antenna could be a promising solution for advanced wireless communication systems.

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