A Low-Profile Switchable Quadripolarization Diversity Aperture-Coupled Patch Antenna

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***Abstract*—In this letter, we present a low-profile switchable quadripolarization diversity aperture-coupled patch antenna. The proposed antenna can provide four polarization states by controlling the dc bias voltage of four p–i–n diodes in the feeding network. The experimental results validate the novel antenna provides polarization diversity features for wireless local area networks (WLANs) and multiple-input–multiple-output (MIMO) systems.**

***Index Terms*—Aperture-coupled patch antenna, dual polarization, p–i–n diode, polarization-diversity, quadripolarization, switchable antenna.**

I. Introduction

RECENTLY, polarization diversity has gained significant attention in modern wireless communication systems. It is effective to avoid the fading loss caused by multipath effects [1]. Polarization diversity can be utilized to double the frequency spectrum to realize frequency reuse and improve the communications capacity significantly [2]. Polarization diversity for wireless local area network (WLAN) applications is usually accomplished by using two orthogonal dipole antennas [3]. Another way to implement the polarization diversity antenna is to excite a pair of orthogonal modes in a single patch. In [4], the cross-shaped slots have been used to excite a pair of orthogonal modes in the patch of the proposed antenna.

Over the last years, the p–i–n diodes provide flexibility to design antennas for polarization diversity applications. By controlling the ON/OFF states of the p–i–n diodes in the antenna structures, we can switch the antenna to operate in different excitation modes [1], [2], [5]–[9]. Furthermore, a novel reconfigurable quadripolarization diversity aperture-coupled patch antenna has been presented in [10]. By controlling the eight p–i–n diodes "ON" or "OFF" on the feeding network, the proposed antenna can provide a pair of orthogonal linear polarizations (LP) and a pair of orthogonal circular polarizations (CP).

In this letter, we present a new low-profile switchable polarization diversity aperture-coupled patch antenna, which has a superior feeding network comparing to the previous work in [10]. The feeding network with only four p–i–n diodes and two slots can provide four polarization states (dual linear polarization states and dual circular polarization states). Besides, we efficiently utilize the circuit area by placing the feeding network under the patch. Consequently, we require devices less and miniaturize the antenna size by 55% than the former design in [10]. The proposed antenna has not only quadripolarization diversity, but also a wide axial-ratio beamwidth.

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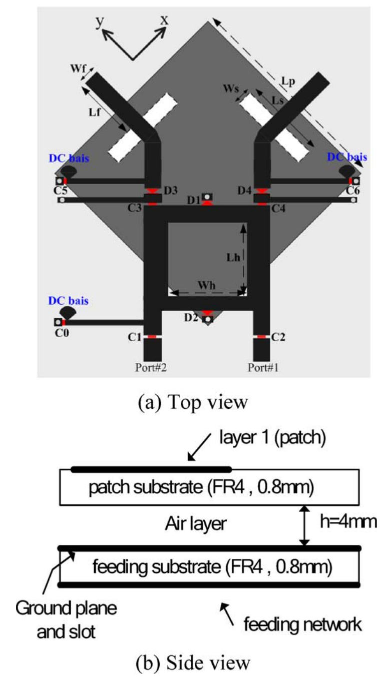

Fig. 1. Geometry of the proposed antenna. (a) Top view of the proposed antenna ($Lp = 47.5$ mm, $Ls = 30$ mm, $Ws = 1.5$ mm, $Lf = 5.5$ mm, $Wf = 1.5$ mm, $Lh = 16.1$ mm, $Wh = 14.5$ mm, $D1 \sim D4$ are p–i–n diodes, $C0 \sim C6 = 100$ pF). (b) Side view of the proposed antenna.

This letter is organized as follows. The geometry of the antenna and the principle of operation are described in Section II. The measurement results are presented in Section III. This switchable patch antenna is a potential candidate for future polarization diversity applications in the WLAN and MIMO communication systems.

II. Proposed Structure

The geometry of the proposed structure is shown in Fig. 1. The proposed antenna consists of two rectangular apertures on the ground plane fed by a pair of orthogonal microstrip feeding lines, a branch-line coupler, four p–i–n diodes, and a square patch. The layout parameters of the proposed structure are shown in Fig. 1(a), and the entire size of the proposed antenna is 75 mm × 75 mm. The antenna is designed to operate

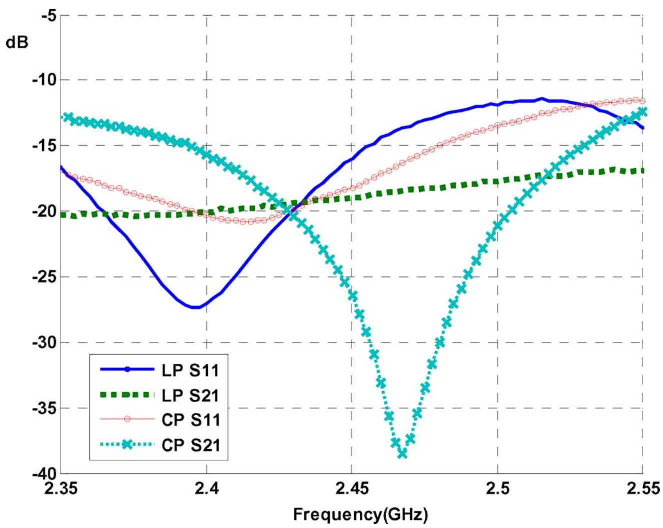

Fig. 2. Measured S-parameters data of the linear polarization (LP) and the circular polarization (CP).

TABLE I
STATUSES OF THE PROPOSED ANTENNA

	Pin-Diode State	Polarization
Antenna Excited from Port1	(D1,D2,D4) ON (D3) OFF	LP(x-axis)
	(D3,D4) ON (D1, D2) OFF	LHCP
Antenna Excited from Port2	(D1,D2,D3) ON (D4) OFF	LP(y-axis)
	(D3,D4) ON (D1,D2) OFF	RHCP

at 2.45 GHz for the WLAN ISM-band ($2400 \sim 2483.5$ MHz) applications. The antenna was made by using an inexpensive FR-4 substrate of thickness 0.8 mm. Fig. 1(b) shows that the two apertures on the ground plane and the feeding network under the ground plane are printed on the different sides of the same dielectric substrate. The substrate of the radiating patch and the substrate of the ground plane are also separated by an air layer of thickness $\mathrm{h} = 4$ mm.

The feeding network, shown in Fig. 1(a), consists of a quadrature hybrid, seven dc block capacitors, three RF choke, and four p–i–n diodes. The quadrature hybrid can provide the 90° phase difference with the same magnitude to produce circular polarization states. By switching the four p–i–n diodes embedded in the feeding network of the antenna, the proposed antenna can provide quadripolarization states. The dc block capacitors with a very low impedance and the RF choke inductors with a very high RF impedance at the RF frequency can properly supply a dc bias for the p–i–n diodes. A quarter-wavelength microstrip line is utilized on the FR-4 substrate to work as the RF choke inductor and the quarter-wavelength microstrip line is via-grounded to realize the dc ground. The dc block capacitors, whose values are 100 pF, and the RF choke inductors can separate the dc signal and the RF signal in the feeding network efficiently such that interference can be blocked. The forward-bias of the p–i–n diode is 0.95 V. The p–i–n diode model number is Infineon BAR50-02L.

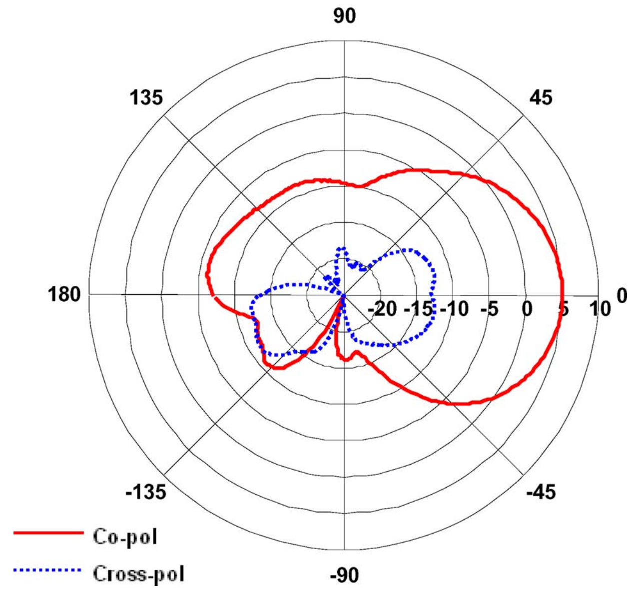

Fig. 3. Measured linear polarization (the x axis polarization) radiation pattern on E-plane of the proposed antenna. (The y-axis polarization radiation pattern is similar to the x-axis polarization.).

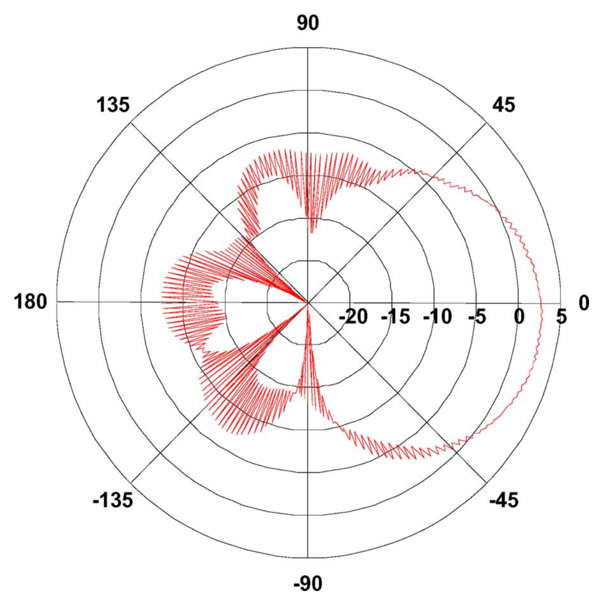

Fig. 4. Measured circular polarization (the RHCP) radiation patterns of the proposed antenna. (The LHCP radiation pattern is similar to the RHCP.).

The analysis for the quadripolarization is described in detail in the following subsections.

A. Dual Linear Polarization Design

By controlling the dc bias voltage of the four p–i–n diodes properly, the antenna can provide a pair of orthogonal linear-polarizations. By switching D1, D2, D4 on and D3 off, and a signal path is created from the right side feeding line of port-1 excitation to the right side slot. Then, the right side slot couples the signal to the patch. Because D1 and D2 are on, the hybrid has been split and the power pass the right hand side, so that it generate a linear polarization state (x-axis polarization). Similarly, because the geometry is symmetrical, by switching D1, D2, D3

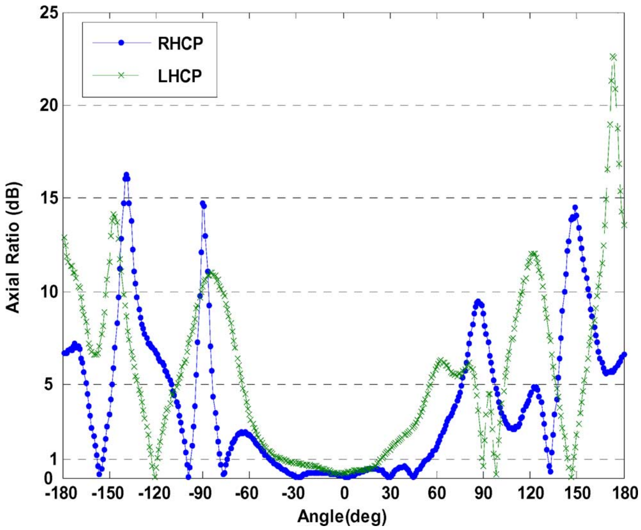

Fig. 5. Axial ratio as a function of the rotation angle.

on, and D4 off, at port-2 excitation, we can get another orthogonal linear polarization state (y-axis polarization). Therefore, this antenna can provide two orthogonal linear polarizations, respectively.

B. Dual Circular Polarization Design

The antenna can also provide a pair of orthogonal circular-polarizations. By switching D1, D2 off, and switching D3, D4 on, we can create a signal path from the branch line coupler feeding line of port-1 excitation to both of the two slots. Then the two slots couple the signal to the patch and generate a circular polarization state. Owing to a 90° phase difference provided by the branch line coupler, the circular polarization is LHCP. On the other hand, the geometry of proposed antenna is symmetrical so the signal path from port-2 excitation can generate another orthogonal circular polarization state which is RHCP. Therefore, this antenna can produce a pair of orthogonal circular polarizations. All the different polarization states are listed in the Table I.

III. Measurement Results

The return loss and isolation for the linear polarization mode and circular polarization mode are measured in Fig. 2 and the measured 10-dB impedance bandwidths at 2.45 GHz are good for LP and CP states.

Fig. 3. shows the measured gains of the copolarization and the cross-polarization of the E-plane for the LP mode. Both the measured gain of the two LP (the x-axis polarization and the y-axis polarization) patterns is about 5 dBi.

The measured CP radiation pattern of the proposed antenna is shown in Fig. 4. Both the measured gain of the two CP (the RHCP and the LHCP) patterns is about 3 dBi. Moreover, a wide axial-ratio beamwidth is shown in Fig. 5. The axial-ratio beamwidth of the CP radiation pattern curve below 1 dB is about 65°, and it demonstrates the proposed antenna is an excellent CP antenna.

IV. Conclusion

In this letter, a low-profile switchable quadripolarization diversity aperture-coupled patch antenna is proposed for multi-polarization diversity applications. The antenna can operate in either dual-linear polarizations or dual-circular polarizations according to different dc bias voltages and ON/OFF states of the p–i–n diodes. Our experimental results show that the design antenna has good performance in S-parameters, gain, and axial ratio beamwidth. Our quadripolarization diversity antenna can be a good candidate for future polarization diversity application in the WLAN and MIMO communication systems.

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