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A Reconfigurable Quadri-Polarization Diversity Aperture-Coupled Patch Antenna

Yi-Fan Wu, Chun-Hsien Wu, Don-Yen Lai, and Fu-Chiang Chen

Abstract—We present a novel reconfigurable quadri-polarization diversity aperture-coupled patch antenna which can provide four polarization states. By controlling the dc bias voltage of the pin-diodes on the feeding network, we can reconfigure the proposed antenna to provide a pair of orthogonal linear polarizations and a pair of orthogonal circular polarizations. Numerical and experimental results validate our design. This novel antenna provides potential polarization diversity features for wireless local area networks and multiple-input multiple-output systems.

Index Terms—Aperture-coupled patch antenna, dual-polarization, pin-diode, polarization-diversity, quadri-polarization, reconfigurable antenna.

I. INTRODUCTION

Polarization diversity is drawing a lot of attention in modern wireless communication systems due to its several advantages. First, polarization diversity is effective to avoid the fading loss caused by multipath effects [1]. Second, polarization diversity can be utilized to realize frequency reuse due to its useful polarization modulation scheme [2]. This property has been applied in active read/write microwave tagging systems [2]. In [3], the authors use two orthogonal dipole antennas to achieve the purpose of polarization diversity for Wireless Local Area Network (WLAN) applications. There are also other ways to implement the polarization diversity antenna by exciting dual orthogonal modes in a single patch. In [4], a patch antenna uses dual orthogonal H-slots to excite a pair of orthogonal modes in the patch.

In recent years, the pin-diodes provide versatility for polarization diversity applications. We can reconfigure the antenna to operate in different excitation modes by controlling the on/off states of the pin diodes in the antenna structures [1], [2], [5]–[9]. In [6], a reconfigurable microstrip patch antenna for switchable polarizations is proposed. The geometry consists of a corner-truncated square patch and two pairs of opposite corners with four pin diodes as conductors. By properly controlling the pin diodes ON or OFF, it can generate linear polarizations, or a left-handed circular polarization, or a right-handed circular polarization. For the first time, we propose a novel quadri-polarization diversity aperture coupling patch antenna with aperture coupling and dual-feed structure technique to provide a pair of orthogonal linear polarizations and a pair of orthogonal circular polarizations. The proposed antenna has not only quadri-polarization diversity but also a wide axial-ratio bandwidth. The geometry of the antenna is described in Section II. Details of the simulation and experimental results are presented in Section III. In conclusion, this novel reconfigurable patch antenna is a potential candidate for future polarization diversity applications in the WLAN and multiple-input multiple-output (MIMO) communication systems.

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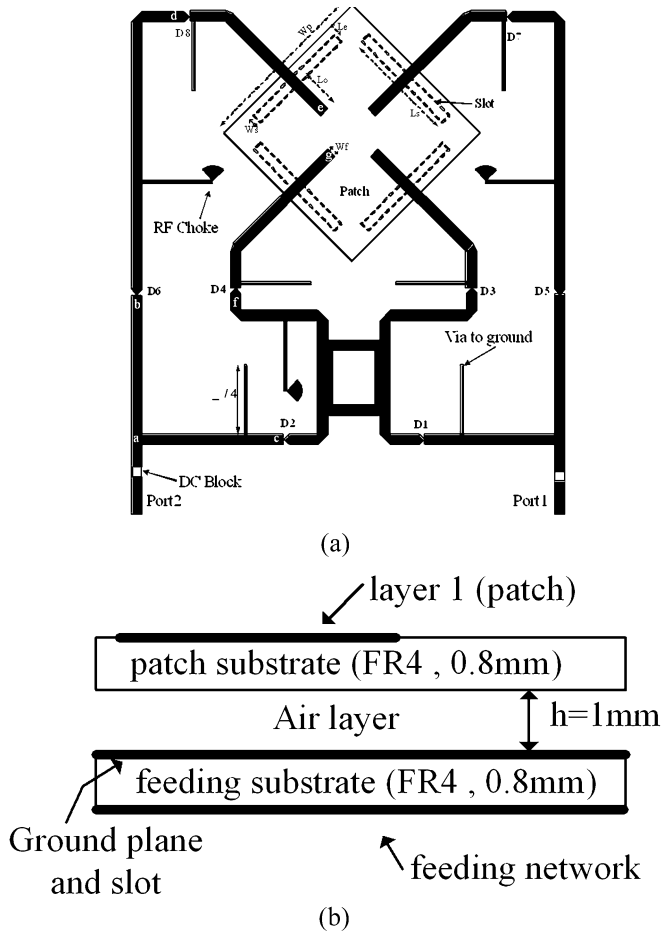


Fig. 1. Geometry of the quadric-polarization antenna. (a) Top view of the proposed antenna ($W_p = 42.5$ mm, $W_s = 1.15$ mm, $L_s = 22.5$ mm, $L_o = 6.5$ mm, $W_f = 1.55$ mm, $L_e = 2.25$ mm). (b) Side view of the proposed antenna.

II. ANTENNA DESIGN

The geometry of the proposed antenna is shown in Fig. 1. The antenna consists of four rectangular apertures on the ground plane fed by four microstrip feeding lines, a branch line coupler, 8 pin-diodes, and a square patch. The antenna is designed to operate at 2.45GHz for the WLAN applications. The antenna was made by using a low-priced FR-4 substrate of thickness 0.8 mm with a relative permittivity 4.4. Fig. 1(b) shows that the four apertures on the ground plane and feeding network under the ground plane were printed on the different side 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 $h = 1$ mm (the supporting posts not shown in the figure). As shown in Fig. 1(a), the antenna structure comes with the following layout parameters: the width of the square patch is W_p , the width of the slot is W_s , the length of the slot is L_s , the length from the open end of the feed line to the center of the slot is L_o , the distance from the edge of the patch to the slot is L_e , and width of the feed line is W_f . The entire size of the proposed polarization diversity antenna is 120 mm \times 110 mm.

The proposed antenna can provide quadri-polarization states by switching the eight pin-diodes embedded in the feeding network of the antenna shown in Fig. 1(a). To properly supply a dc bias for the pin-diodes, we need to design the RF choke inductors with a very high RF impedance, the dc block capacitors with a very low impedance at the RF frequency, and the quarter-wavelength microstrip line

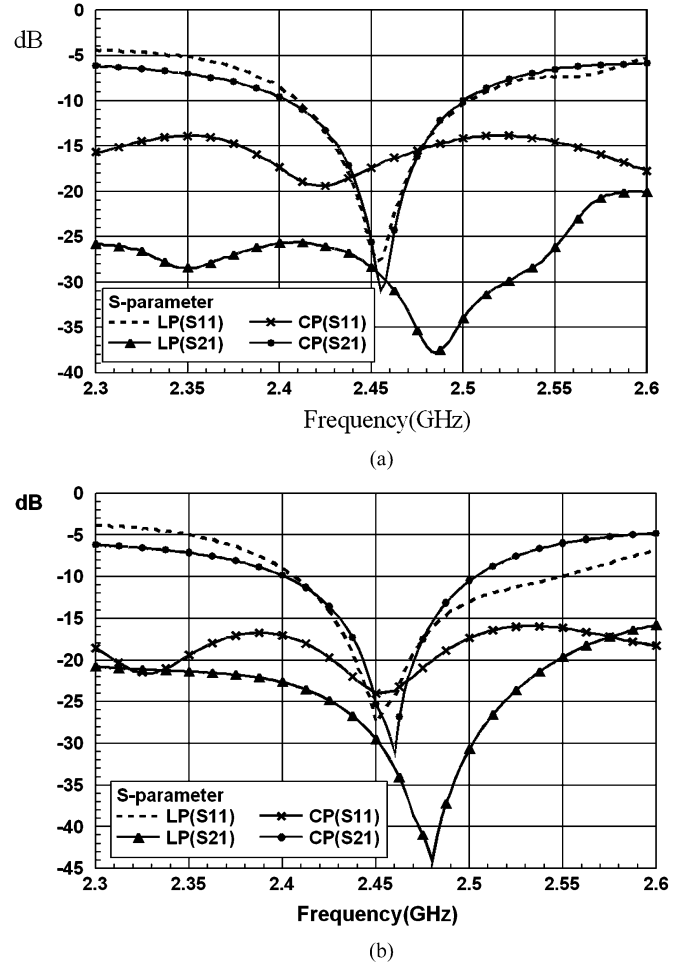


Fig. 2. Simulated and measured S-parameters data: (a) Simulation. (b) Measurement.

which is via-grounded to realize the dc ground. A quarter-wavelength microstrip line is utilized on the FR-4 substrate to work as the RF choke inductor. The dc block capacitors and the RF choke inductors can separate the dc signal and the RF signal in the feeding network efficiently such that unwanted interference can be prevented. The forward-bias of the pin-diode is $V_F = 0.95$ Volt. The pin-diode model number is Infineon BAR50-02L. A dc block capacitor with $C = 100$ pF with a very low impedance at the RF frequency is used. The design considerations for the quadri-polarization are described in detail in the following subsections.

A. A Pair of Orthogonal Linear-Polarizations Design

By controlling the dc bias voltage of the pin-diodes D5, D6, D7, and D8 properly, the antenna can provide a pair of orthogonal linear-polarizations. By switching on the above four pin-diodes, we can create a signal path from the right side feeding line of port-1 excitation to upper slot. Then the upper slot couples the signal to the patch that can generate a linear polarization state. In this condition, we design the half-wavelength \bar{ac} to achieve an infinite input impedance from a to c. Under this condition, the input power can be fed to right-upper slot totally. At the same time, the other pin-diodes D1, D2, D3, and D4 are switched off to block the possible excitation of unwanted modes from the branch line coupler feeding. On the other hand, because the geometry of proposed antenna is symmetrical, the signal path from the left side feeding line of port-2 excitation can generate another orthogonal linear polarization

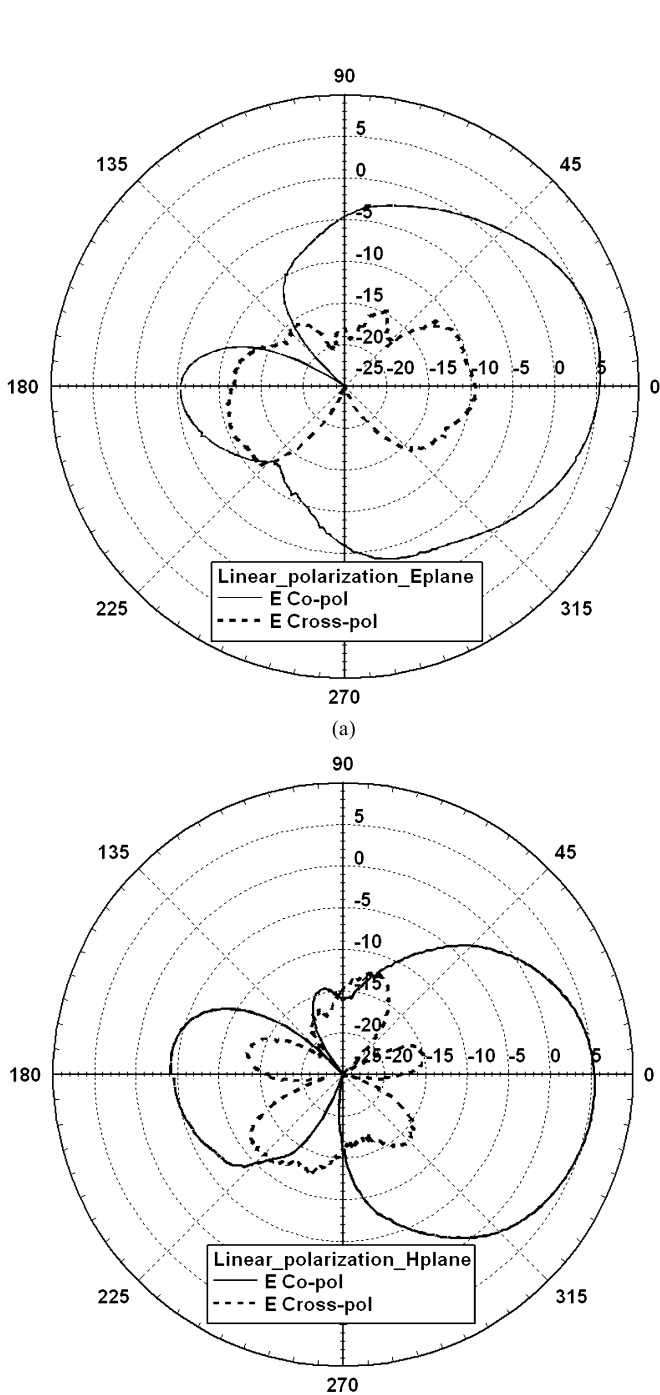


Fig. 3. Measured linear polarization radiation patterns of the proposed antenna. (a) E-plane. (b) H-Plane.

state. Therefore, this antenna can produce a pair of orthogonal linear polarizations.

B. A Pair of Orthogonal Circular-Polarization Design

By controlling the dc bias voltage of the pin-diodes D1, D2, D3, and D4 properly, the antenna can provide a pair of orthogonal circular-polarizations. By switching on the above four pin-diodes, we can create a signal path from the branch line coupler feeding line of port-1 excitation to two lower slots. Then the two lower slots couple the signal

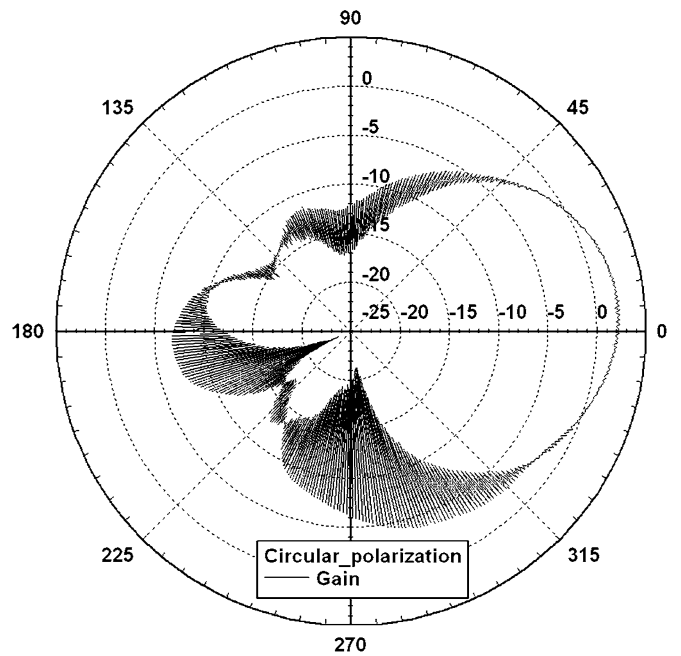


Fig. 4. Measured circular polarization radiation pattern of the proposed antenna.

to the patch that can generate a circular polarization state. Owing to a quarter phase difference made by the branch line coupler, the circular polarization is LHCP. We design a half-wavelength ab as to achieve an infinite input impedance from a to b . Under this condition, the input power can be fed to both lower slots totally. It is important that we must design a good performance branch line coupler which has equal power output at the directional port and the coupled port to achieve a perfect circular polarization in the designed frequency band. At the same time, the pin-diodes D5, D6, D7, and D8 are switched off to block the possible excitation of unwanted modes from outside feeding line. 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.

III. SIMULATION AND EXPERIMENT

This proposed aperture coupling patch antenna is simulated by a 3D-full wave MOM solver, IE3D. Similar to [5], we utilized the equivalent lengths of metal tapes to represent the conducting pin-diodes. When the pin-diodes are in the OFF state, they are removed from the simulation. The return loss and isolation for the linear polarization modes and circular polarization modes are simulated and measured. The simulated results and the measured results are shown in Fig. 2. In Fig. 2(b), the measured 10-dB impedance bandwidth for 2.45 GHz band is about 3.67% for the LP mode. The 10-dB impedance bandwidth is about 3.88% for the CP mode. Satisfactory agreement between simulation and measurement is observed.

Fig. 3 shows the measured gains of the co-polarization and cross-polarization of the E-plane and H-plane for the LP mode. The measured CP radiation pattern of the proposed antenna is showed in Fig. 4. We found that the obtained antenna gain is about 2 dBi received by a linear isotropic antenna; hence, the total gain of the proposed antenna is the measured gain plus 3 dBi for the absolute gain of the antenna referenced to a circularly polarized isotropic antenna [10]. Therefore, in the CP mode, the gain of the proposed antenna is about 5 dBi for a polarization-pure CP signal. Moreover, the fluctuation of the CP radiation

pattern curve is very small around 0 degrees; therefore it demonstrates the proposed antenna is an excellent CP antenna.

IV. CONCLUSION

A novel reconfigurable quadri-polarization diversity antenna is proposed for multipolarization diversity applications. Using pin-diodes on the feeding network paths, the antenna can be operated either in dual-linear polarizations state or in dual-circular polarizations state according to different dc bias voltages of the pin-diodes. Our experimental results show that the design antenna has good performance in S-parameters, gain and axial ratio. Our novel quadri-polarization diversity antenna can be a good candidate for future polarization diversity applications in the WLAN and MIMO communications systems.

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