

# Reconfigurable Circularly Polarized Microstrip Antenna on a Slotted Ground

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*A compact square patch antenna with reconfigurable circular polarization (CP) at 2.4 GHz is proposed. Circular polarization is generated by an arc-shaped slot on the ground plane. In order to switch the CP orientation, the current flow direction of the patch is reconfigured via the PIN diodes mounted on the slot. As the slot and bias circuit are not placed on the patch side, the proposed antenna radiates a CP wave without alteration in the main beam direction. From the experimental results, the impedance and CP bandwidths of the proposed antenna have been demonstrated for up to 80 MHz and 25 MHz, respectively.*

*Keywords: Microstrip patch antenna, circular polarization, reconfigurable polarization, polarization diversity, PIN diodes.*

## I. Introduction

In recent years, multifunctional antennas have been widely studied because the major trend in new wireless communication systems is convergent to a single compact mobile terminal with multiservices. A reconfigurable antenna is one of the solutions for multifunctional antenna subsystems which have been issued on variable bandwidth [1], radiation characteristics [2], and polarization [3]. Circular polarization (CP) is used in some mobile applications such as RFIDs and

satellite communication systems because it can provide more reliable receiving sensitivity [4].

Reconfigurable CP antennas are applicable to polarization diversity, which can increase the system capacity, in order to avoid detrimental fading loss in a wireless local area network [5] and adapted to a CP modulation scheme in an RFID [6]. Although reconfigurable CP antennas with single layer and multilayer structures [7]-[9] have been proposed, these antennas have a bias circuit located on the patch side [7], [8] and a complex feeding structure [9]. Microstrip CP antennas with the slotted ground plane using two slots with unequal lengths have been discussed in [10], [11]. However, these antennas yield only a single sense of CP operation.

In this letter, a reconfigurable square patch antenna with a switchable CP sense on a slotted ground plane is proposed. The proposed antenna simply consists of a square patch and a semicircular slot with two PIN diodes on a ground plane. By alternating the states of two PIN diodes on the slot, the current rotation direction on the square patch antenna has to be reconfigured, and then the CP orientation can be changed.

## II. Reconfigurable Circularly Polarized Antenna Design

Figure 1 shows the configuration of the square microstrip patch antenna with a slotted ground. A quarter-wavelength transformer is designed for impedance matching between the square patch and  $50 \Omega$  input port. An arc-shaped slot is located on the backside of the patch.

Without a slot, a square patch antenna generates only a  $TM_{01}$  mode. With the arc-shaped slot and a length equal to the quarter-wavelength, the antenna has a  $TM_{10}$  mode of which the phase is shifted by  $90^\circ$  compared with that of the  $TM_{01}$  mode. The resonant frequency is slightly different because the

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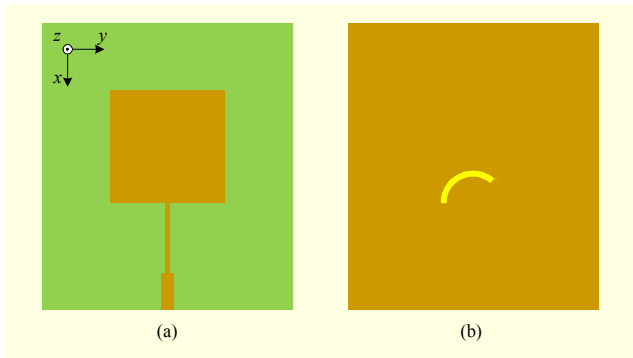


Fig. 1. Configurations of the RHCP antenna: (a) top view and (b) bottom view.

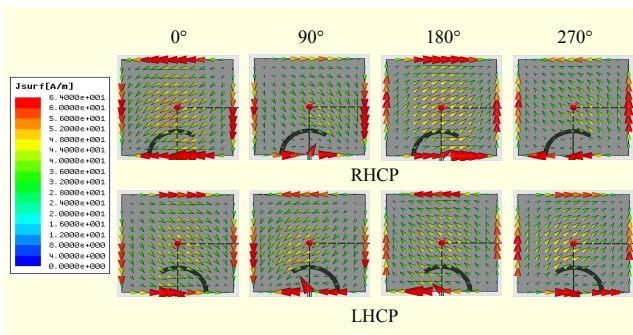


Fig. 2. Current distributions at 2.48 GHz.

equivalent reactance of the antenna is changed due to the slot. Hence, the surface current on the patch rotates counter clockwise, and the antenna can generate a right-handed CP (RHCP) wave. When the arc-shaped slot is flipped along the  $x$ -axis, the CP sense of the antenna is switched to a left-handed CP (LHCP). Figure 2 shows the simulation results of the current distributions of each CP sense at 2.48 GHz. The current flow on the patch is changed from counterclockwise to clockwise and vice versa with respect to the configuration of the arc-shaped slot. Therefore, a reconfigurable CP antenna can be designed with a semicircular slot and PIN diodes on the slot. As shown in Fig. 3, two PIN diodes,  $D_1$  and  $D_2$ , are placed on the semicircular slot. When the PIN diode is on, the slot becomes a short point. Thus, it is divided into two unequal-length arc-shaped slots. Hence, the CP sense can be determined for the configuration of the longer arc-shaped slot, while the short parasitic one has little effect on the antenna properties in the operation band. The CP polarity is decided by the state of the pin diodes. When  $D_1$  is on and  $D_2$  is off, LHCP is generated. In the opposite case, RHCP is generated. In order to bias the two PIN diodes, the ground plane is divided into two parts with a narrow slit,  $W_2$ , along the semicircular slot. To sustain the ground plane, capacitors,  $C_1$  and  $C_2$ , are mounted between the slits. Since the bias circuit is located on the ground plane, no RF choke is required to isolate it from the radiation element. Therefore, the

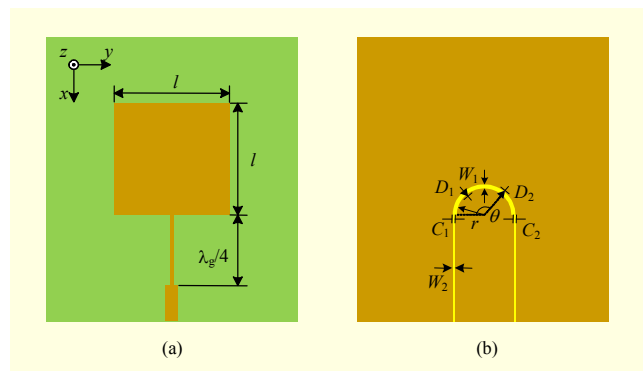


Fig. 3. Configurations of the proposed switchable CP antenna: (a) top view and (b) bottom view.

bias circuit can avoid affecting the radiation pattern.

### III. Implementation and Experimental Results

Figure 4 shows the photographs of the implemented antenna. The proposed reconfigurable antenna has been designed at 2.4 GHz band. The substrate is an FR4 with parameters of  $\epsilon_r=4.4$  and  $t=1.6$  mm. The square patch with side lengths of  $l=27.5$  mm, the quarter-wavelength transformer, and the 50  $\Omega$  microstrip line are implemented on the top side. The antenna has been simulated with the Ansoft HFSS<sup>TM</sup>, and each parameter of the semicircular slot is designed to have an optimum axial ratio (AR) and a good CP bandwidth. The semicircular slots with parameters of  $r=6.5$  mm and  $W_1=1$  mm are located on the bottom ground plane of the substrate. To achieve the alternative shorting path for switchable CP, two PIN diodes of BAR64-02W (Infineon Technologies) are located at an angle  $\theta$  of  $130^\circ$  from the slot center. For a DC isolation, narrow slits with widths of  $W_2=0.2$  mm are placed on the ground plane, and two capacitors,  $C_1$  and  $C_2$ , of 10 pF are utilized to have short circuits.

The impedance bandwidths are measured via a network

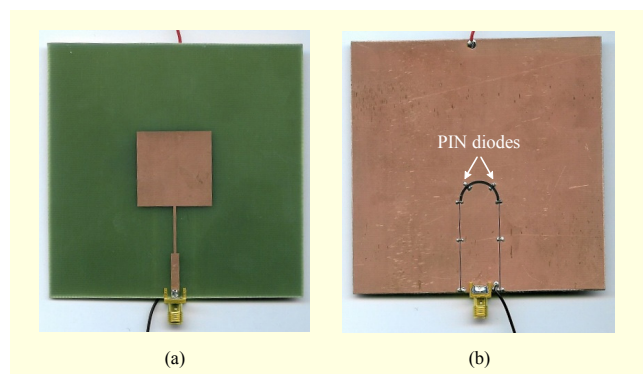


Fig. 4. Photos of the implemented antenna: (a) top view and (b) bottom view.

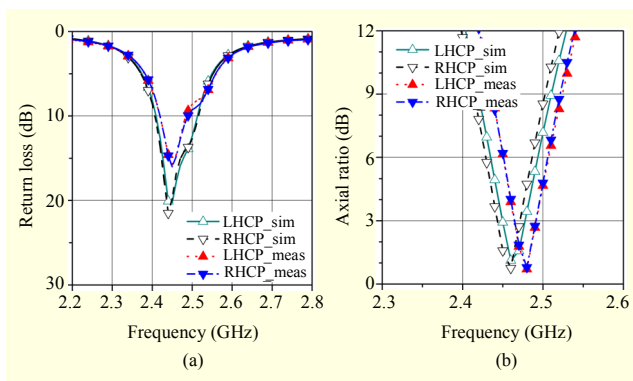


Fig. 5. Experimental results for (a) return loss and (b) axial ratio.

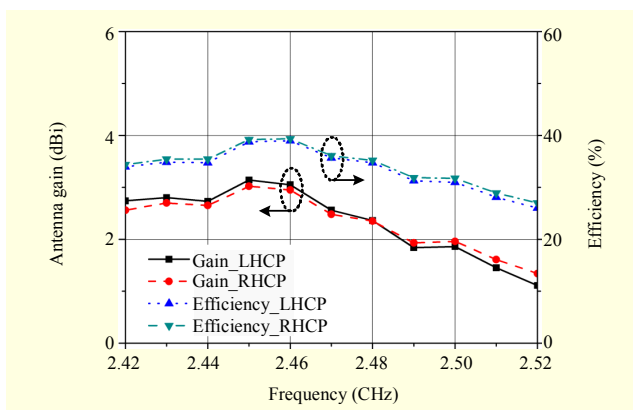


Fig. 6. Measured antenna gains and efficiencies.

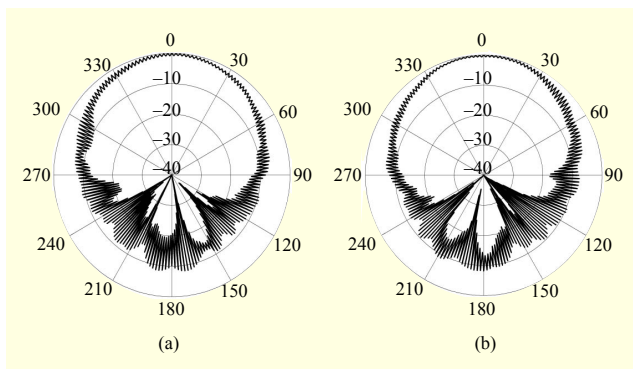


Fig. 7. Measured linearly spinning patterns at 2.48 GHz: (a) RHCP and (b) LHCP.

analyzer (E5071C, Agilent). The AR and the radiation pattern had previously been experimented with in an anechoic chamber. Figure 5 shows the measured return losses and the ARs of the proposed antenna. The impedance bandwidth for both RHCP and LHCP is from 2.43 GHz to 2.51 GHz. The CP bandwidth of the 3 dB AR is from 2.465 GHz to 2.49 GHz, and the minimum AR is 0.8 dB for both CPs at 2.48 GHz, as shown in Fig. 5(b). The experimental results show good agreement with the simulated ones.

Figure 6 shows the peak gains and the radiation efficiencies of each CP antenna. The peak gain of 2.35 dBi for both CP senses is obtained at 2.48 GHz. As the proposed antenna has been fabricated on a FR4 substrate with a relatively large loss tangent of about  $\tan \delta = 0.02$ , the antenna may yield low radiation efficiencies and gains. Figure 7 shows the measured linear spinning patterns, where the ripples of the spinning pattern represent the AR at each angle of theta. Figure 7 shows the linear CP gain of co-polarization and cross-polarization for LHCP and RHCP. From measured results, it is noted that the proposed antenna yields good CP performance and excellent polarization controllability.

#### IV. Conclusion

A simple microstrip patch antenna with a switchable CP sense has been presented. The antenna is designed with a square patch and slotted ground plane. As the perturbation is achieved on a ground plane and no bias circuit is required on the patch side, the proposed antenna has less distortion on the radiation pattern. The experimental results show the excellent controllability of the CP sense at 2.4 GHz to 2.5 GHz.

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