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Polarization Reconfigurable Circularly Polarized Planar Antenna Using Switchable Polarizer

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***Abstract*— A novel polarization reconfigurable planar low-profile antenna is presented. The antenna consists of an electronically reconfigurable polarizer and a slot antenna. The polarizer is loaded by PIN diodes and by changing the states of the PIN diodes, the linearly polarized (LP) wave generated by the slot antenna can be converted to either right-hand circularly polarized (RHCP) or left-hand circularly polarized (LHCP) wave. The polarizer contains 16 unit cells, which are arranged as a 4×4 array. Each of the unit cells has two layers and is printed on two sides of the substrate. The presented antenna radiates RHCP waves when the PIN diodes of top side are ON while it radiates LHCP waves when the PIN diodes of bottom side are ON. An analysis of the antenna is provided by using equivalent circuits. To verify the design concept, one prototype at 2.5 GHz band is designed and fabricated. Good agreement between the measurement and simulation results is obtained. The measured results show that the antenna achieves a gain better than 8.5 dBic in both RHCP and LHCP with 70% aperture efficiency. It is also shown that the presented design can be easily extended to the design of large-scale arrays without increasing the complexity of the DC bias circuit. The advantages of the proposed design are simple planar structure, low profile, flexibility in designs, high isolation between DC bias circuit and RF signals, high power handling, high gain and low cost. The proposed design can also be applied to the design of antennas at other frequency bands.**

***Index Terms*—polarization reconfigurable, low profile, circular polarization, polarizer**

I. Introduction

CIRCULARLY polarized (CP) antennas are widely applied in wireless communication system because no strict alignment between transmitting and receiving antennas is needed. Also, CP antennas can reduce the ‘Faraday rotation’ effect of the ionosphere [1]. Polarization reconfigurable CP antennas have the advantages of both CP antennas and polarization diversity. Hence, it attracted much research interest recently. It can enable more reliable wireless connection in dynamic communication environmental conditions [2].

CP patch antenna can be achieved by either using multi-feed or a single feed [3]. Slot antenna using multi-feeds techniques can also generate CP [4]. Crossed dipole antenna is also a common structure to realize circular polarization [5]. The helix antenna [6] and spiral antenna [7] are well-known examples of broadband CP antennas. Apart from the antennas mentioned above, CP antennas can also be achieved by using a polarizer to convert the LP wave to CP wave [8-10]. One main advantage of utilizing a polarizer is that it can enhance the gain of CP antenna without resorting to an array antenna which requires a complicated feed network. In [8], using meander lines to design a polarizer consisting of four substrate layers was reported. In [9] and [10], metasurfaces were used to convert LP wave to CP wave. Compared to the conventional CP antenna array, using a polarizer to generate CP waves does not need a complex, lossy feed network. Thus, a CP antenna with a polarizer has the potential of achieving higher efficiency, in particular at higher frequencies when the loss in feed networks becomes significant. It is also possible to achieve high-gain CP antennas using a partially reflective surface (PRS) [11]. However, the PRS CP antenna typically requires about 1/2 wavelength distance between the PRS and the ground plane while the distance between a polarizer and source antenna can be reduced only to approximately 1/17 wavelength [9]. Thus, a CP antenna using a polarizer can have a minimal profile and high gain.

Polarization reconfigurable CP antennas have also been studied by many researchers [12]. The polarization reconfiguration can be obtained by introducing PIN diodes or varactors to the feed networks of antennas [13-16], using multiport networks to switch antenna polarizations [17, 18] and modifying the antenna geometry to alter its polarization [19-24]. For example, in [16], the corresponding feed probe of a corners-truncated patch antenna was switched by adding PIN diodes to the feed network to realize different polarization. In [18], the author used a 90^0 hybrid coupler to feed the antenna and polarizations can be switched by choosing the corresponding input ports. In [20], two perpendicular slots were introduced on a patch antenna. Each of the two slots was loaded by one PIN diode. By controlling the states of PIN diodes, polarization could be altered. However, disadvantages of using these techniques are that the antennas have a complicated DC controlling circuitry, and it is rather difficult to extend them to

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a large-scale array antenna design for high gain CP antenna applications.

In this paper, a polarization reconfigurable planar antenna consisting of an active polarizer loaded by PIN diodes and a slot antenna is presented. Instead of modifying the structure of feed networks, changing the input ports of feed networks or the geometry of antenna to realize polarization reconfiguration, an electronically polarization reconfigurable polarizer (EPRP) is used to realize reconfiguration. There are four advantages of using EPRP in this design: 1) The DC circuit of PIN diodes is completely isolated from the RF signal. Thus, DC blocking capacitors are not needed in the feed networks of antennas, which simplifies the design of feed networks. 2) The PIN diodes are not mounted on the RF feed networks. Thus, the loss of the PIN diodes has less effect on the total radiation efficiency of the antenna. 3) It increases the power handling of antennas compared with the design reported in [13-24]. In the presented design, 32 PIN diodes are mounted on the polarizer. The average current on each diode is much smaller than that the ones used in [13-24]. Therefore, the antenna can radiate more power without damaging the diodes. 4) The gain of antennas is improved after introducing the EPRP.

Although one polarization reconfigurable antenna with a polarizer was reported in [10], it was obtained by mechanically rotating the polarizer, which has the disadvantage of slow switching. Besides these advantages mentioned above, it will also be demonstrated in this paper that the proposed polarization reconfigurable CP antenna using EPRP can be easily extended to a large-scale array antenna if higher gain is needed with minor modifications to the feed networks and bias circuits. To the best knowledge of the authors, it is the first time an electronically polarization reconfigurable CP antenna with a single-substrate polarizer is reported.

This paper is organized as follows. The detailed design of polarization reconfigurable CP antenna using EPRP is presented in section II. The working principle of the antenna and some important parameters are analyzed in section III. Simulated and measured results are given in section IV. Section V concludes this paper.

II. Design of The Polarization Reconfigurable Antenna Using EPRP

Fig. 1 shows the configuration of the polarization reconfigurable antenna. The antenna consists of a polarizer and a feed antenna where the polarizer is placed above the feed antenna. The polarizer is the critical component of achieving the reconfigurable CP radiation. A slot antenna is employed as a feed due to its simple structure. In principle, other types of antennas such as a patch can also be used as a feed.

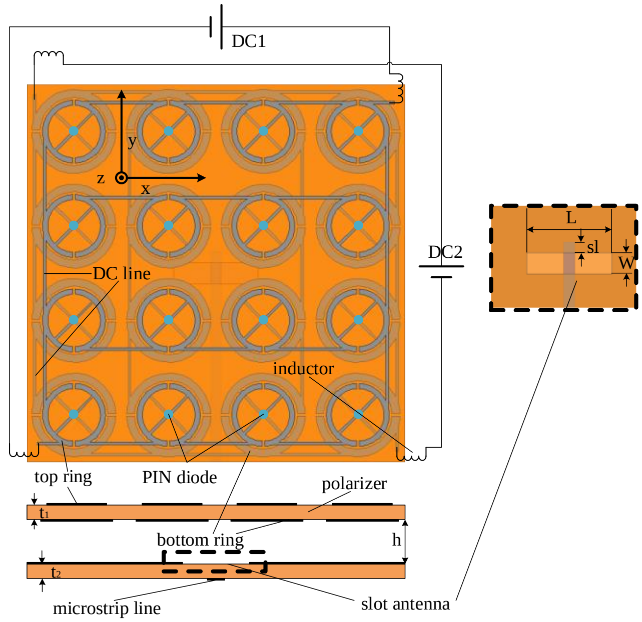
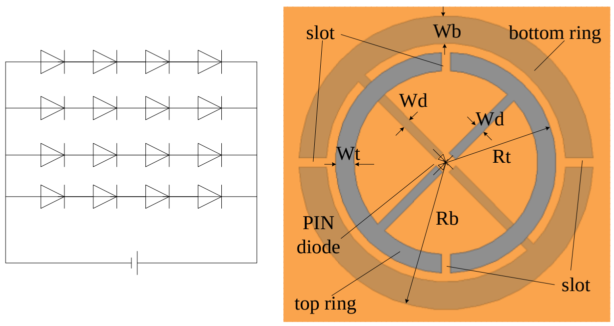


Fig. 1. Configuration of polarization reconfigurable antenna.

The polarizer contains 16 unit cells which are arranged as a 4×4 array. The unit cell has two rings with diagonals printed on each side of the substrate (Rogers RO4003C). The detailed view and parameters of this unit cell are shown in Fig. 2(b). It should be noted that the size of top rings and bottom rings are approximately the same. The differences between them in Fig. 2(b) are enlarged to clarify the structure of the cell. This also applies to Fig. 3(a) and Fig. 3(b). The perimeter of each ring is approximately equal to one effective wavelength on the substrate. Diagonals are introduced to the rings as perturbers to generate circular polarization. The diagonal of the top ring is perpendicular to that of the bottom ring. PIN diodes (SMP1345-079LF) are loaded in the middle of each diagonal. The diagonals should be cut off in the middle so that there is space for PIN diodes to be placed. Both top rings and bottom rings are divided into two parts by two slots so that PIN diodes can be biased by DC power. Slots on the top ring are aligned vertically while slots on the bottom ring are aligned horizontally. Simulated results show that adding these slots have some effects on the center frequency of axial ratio (AR) bandwidth. Compared to rings without slots, the center frequency of AR bandwidth of rings with slots shifts slightly to a higher frequency. The width of these slots is 0.2mm. The width of diagonals on both top and bottom ring *Wd* is identical. Except for the different sizes, the bottom ring can be seen as just rotating the top ring by 90^0 counterclockwise.

PIN diodes of the polarizer are controlled by two pairs of DC line, which can change the bias voltage on the PIN diodes of the top and bottom rings respectively. The structure of these two pairs of DC line is identical, which is demonstrated in Fig. 2(a). For the top ring in Fig. 1, each of the four PIN diodes in the same row forms a series circuit. Then these four branches are biased by DC power in parallel. The radiation from DC line (caused by the induced current) on the polarizer can affect the axial ratio of the antenna. To reduce this effect, the layout of the

DC networks of the top ring is perpendicular to that of the bottom ring so that DC networks can have more rotational symmetry; thus, those unwanted linear radiations from the induced current of DC line can be canceled as much as possible. When the PIN diodes of top rings are off and those of bottom rings are on, the antenna works as an RHCP antenna; when the PIN diodes of top ring are on and those of bottom rings are off, the antenna operates as an LHCP antenna.



(a) (b)

Fig. 2. (a) DC circuit diagram of PIN diode. (b) unit cell of polarizer.

To verify the design concept, an antenna prototype working at 2.5 GHz is designed, which can be used in S-band satellite communication. The thickness of polarizer t_1 is 0.813 mm. The distance between polarizer and antenna h is initially set 1/17 wavelength according to [9]. Then, the value of h is chosen to be 8.2 mm ($0.07\lambda_0$) after performing optimizations in EM simulator in order to have the center frequency of axial ratio at 2.5 GHz. The dimension of the whole antenna is 120×120 mm^2. To achieve the compact size, the distance between adjacent unit cells of the polarizer is 27 mm, which is only larger than the diameter of bottom rings by 0.6 mm. Other parameters are given in TABLE I. In order to increase the overlapped AR bandwidth between LHCP and RHCP, radius and width of bottom rings are designed to be slightly larger than those of top rings.

TABLE I
PARAMETERS OF THE UNIT (UNIT:MM)

Wd	*Rb*	*Rt*	*Wb*	*Wt*	*sl*
0.8	13.2	13	1.7	1.05	1.1

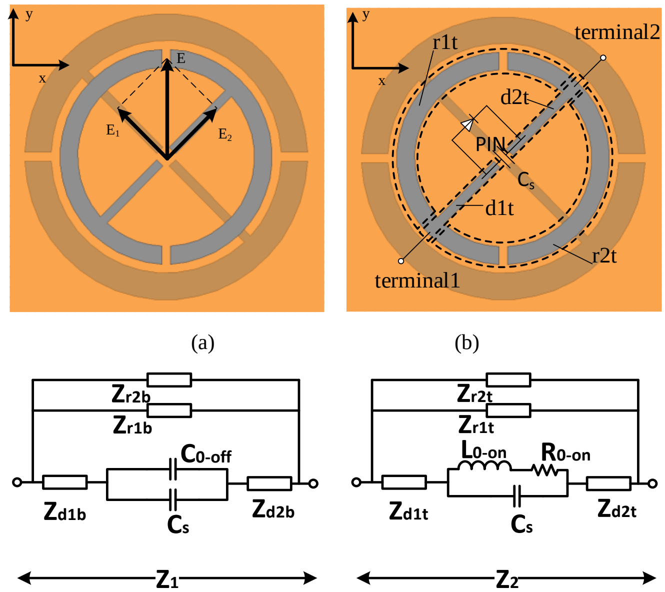
The slot antenna is printed on another substrate (Rogers RO4003C), of which the thickness t_2 is 1.524 mm. The length of the slot L is 34 mm, and the width W is 5.8 mm. The slot antenna is fed by a microstrip line of which the width is 5.8 mm.

III. THEORETICAL ANALYSIS

The LP waves from the slot antenna can excite the rings of the polarizer to radiate. Then the LP waves are converted to LHCP waves or RHCP waves by the polarizer according to the status of PIN diodes on the polarizer. In this section, the equivalent circuit is derived to explain how the polarizer works, and some critical parameters are studied.

A. Analysis of equivalent circuit

Assuming that the slot antenna is placed along the x-axis and the polarization of LP waves generated by the slot antenna is along the y-axis. Its E-field can be decomposed into two orthogonal components E_2 and E_1. E_2 is along the diagonal of the top ring while E_1 is along that of the bottom ring. Both of them are shown in Fig. 3(a).



(c)

Fig. 3. (a)E-field and its components E_1 and E_2. (b) The explanation of the equivalent impedance of top ring. (c) The equivalent circuit of Z_1 and Z_2 when antenna works as LHCP antenna.

When PIN diodes of top rings are on, and those of bottom rings are off, along E_2 and E_1, the equivalent impedance of the cell on the polarizer is represented by Z_2 and Z_1, respectively.

The top ring and diagonal are divided into d1t, d2t, r1t and r2t, which are shown in Fig. 3(b). Their impedance is Z_{d1t}, Z_{d2t}, Z_{r1t} and Z_{r2t}. Then, Z_2 is given by

$$Z_2=(Z_{d1t}+Z_{d2t}+\frac{(j\omega L_{0-on}+R_{0-on})\cdot\frac{1}{j\omega C_s}}{j\omega L_{0-on}+R_{0-on}+\frac{1}{j\omega C_s}})//(Z_{r1t}//Z_{r2t}) \quad (1)$$

L_{0-on} and R_{0-on} are the series inductance and resistance of PIN diode when it is on. C_s is the equivalent capacitance resulting from the slot at the middle of diagonal of the ring. Because of the geometrical symmetry, $Z_{d1t}=Z_{d2t}$ and $Z_{r1t}=Z_{r2t}$. So,

$$Z_2=(2Z_{d1t}+\frac{(j\omega L_{0-on}+R_{0-on})\cdot\frac{1}{j\omega C_s}}{j\omega L_{0-on}+R_{0-on}+\frac{1}{j\omega C_s}})//\frac{Z_{r1t}}{2} \quad (2)$$

Similarly, the bottom ring and diagonal are divided into d1b, d2b, r1b and r2b. Z_1 is given by

$$Z_1=(2Z_{d1b}+\frac{1}{j\omega(C_s+C_{0-off})})//\frac{Z_{r1b}}{2} \quad (3)$$

$C_{0\text{-off}}$ is the capacitance of PIN diode when it is off. As the size of the slot is the same for both top and bottom ring, C_s is the same for Z_2 and Z_1. Considering the differences in width and radius between top rings and bottom rings are quite small,

Z_{r1b} and Z_{r1t} have approximately the same value. So do Z_{d1b} and Z_{d1t}.

Apart from Z_{r1b} and Z_{r1t}, Z_1 and Z_2 can both be seen as consisting of two parts. The first part is the equivalent impedance from the diagonals and the second part is the equivalent impedance from the PIN diodes and the slot at the middle of diagonals of rings. When PIN diode is off, it is mainly capacitive. So the second part of Z_1 can be seen as two shunt capacitors. When PIN diode is on, it basically acts as series inductor and resistor. Therefore, the second part of Z_2 is an RLC hybrid circuit. Components of Z_2 are shown in Fig. 3(b) and the equivalent circuit of Z_1 and Z_2 is shown in Fig. 3(c).

It is evident that Z_1 is more capacitive than Z_2. Therefore, the phase of Z_2 leads that of Z_1.When LP waves generated by the slot antenna excites the rings of the polarizer to radiate, E_1 and E_2 have different impedance Z_1 and Z_2. If

$$\begin{cases} |Z_1| = |Z_2| \\ ang(Z_1) - ang(Z_2) = -90^0 \end{cases} \tag{4}$$

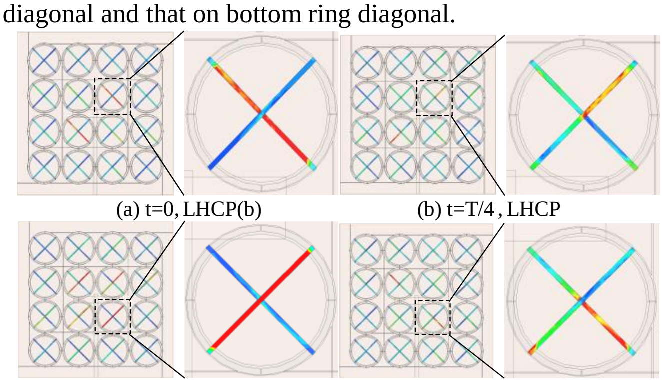
is satisfied[9], the phase of E_1 leads that of E_2 by 90^0 after E_1 and E_2 go through the polarizer. As a result, LHCP radiation can be obtained.

Similarly, when PIN diodes of top rings are off, and those of bottom rings are on, Z_2 is more capacitive than Z_1. If

$$\begin{cases} |Z_1| = |Z_2| \\ ang(Z_1) - ang(Z_2) = 90^0 \end{cases} \tag{5}$$

is satisfied, the phase of E_2 advances E_1 by 90^0 after going through the polarizer and E-field becomes RHCP field after passing through the polarizer.

Fig. 4 shows the current distribution on diagonals of the polarizer when the presented antenna works as an LHCP or RHCP antenna. In the case of LHCP radiation, it can be seen that the amplitude of the current on the diagonal of the bottom ring reaches maximum while current on diagonal of the top ring reaches minimum when t=0. When t=T/4, the maximum current amplitude is observed on diagonal of the top ring. It indicates that there is a 90^0 phase difference between current on top ring diagonal and that on bottom ring diagonal.



(a) t=0, LHCP(b) (b) t=T/4 , LHCP

(c) t=0, RHCP (d) t=T/4, RHCP

Fig. 4. Current on diagonals of the polarizer for LHCP and RHCP.

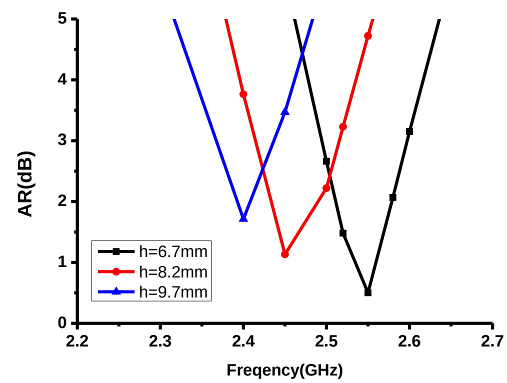
B. Parametric Study

In this section, some important parameters of the polarizer unit cell are discussed. The following parameters are studied when the antenna works as an RHCP antenna. Fig. 5(a) shows the effect of *h* on the AR of the antenna. When *h* increases from 6.7 mm (0.056λ_0) to 9.7 mm (0.081λ_0), the center frequency of AR band (AR≤3dB) is reduced from 2.55 GHz to 2.4 GHz, which makes it quite convenient to adjust the center frequency of AR band. However, it should be noted that AR deteriorates, and AR bandwidth (ARBW) becomes narrower if the value of h is increased.

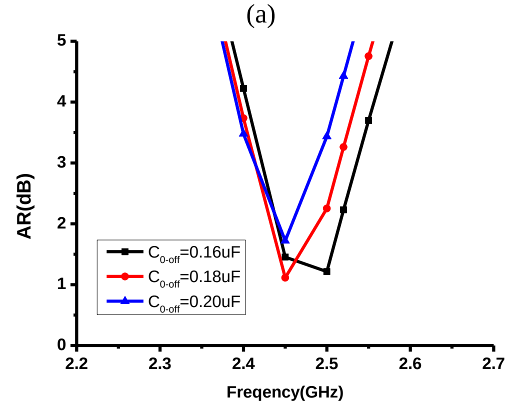
The effect of $C_{0\text{-off}}$ of PIN diode is also studied. Fig. 5(b) shows that ARBW (AR≤3 dB) of the antenna becomes narrower (from about 150 MHz to 100 MHz) when the value of $C_{0\text{-off}}$ varies from 0.16uF to 0.20uF. The AR also deteriorates when C_0 goes up. It indicates that it is better to choose PIN diodes with lower $C_{0\text{-off}}$ when design this antenna so that better ARBW can be obtained.

The AR with different values of the radius of top ring *Rt* and bottom ring *Rb* is demonstrated in Fig. 5(c) and (d). It can be seen the effect of *Rt* and *Rb* is similar to that of *h*. When *Rt* increases from 13mm to 13.15mm, the center frequency of AR band decreases from 2.55 GHz to 2.45 GHz. When *Rb* increases from 13mm to 13.15mm, the center frequency of AR band decreases from 2.55 GHz to 2.475 GHz. However, increasing *Rt* and *Rb* does not lead to AR deteriorating. Therefore, *Rt* and *Rb* are used to adjust the frequency of the antenna during the designing process of this antenna.

The effect of the parameters when the antenna works as LHCP antenna is similar to that of RHCP.



(a)



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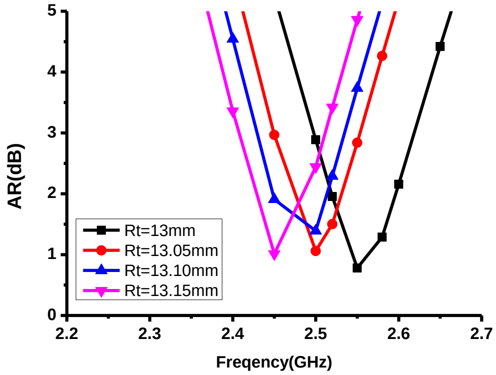

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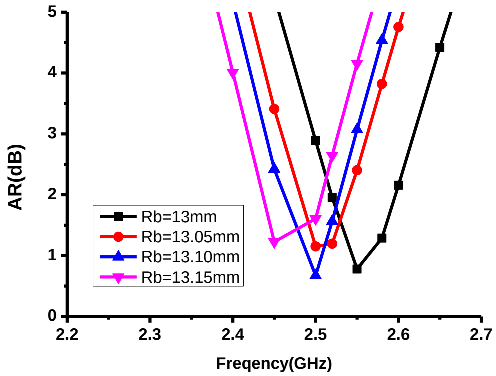
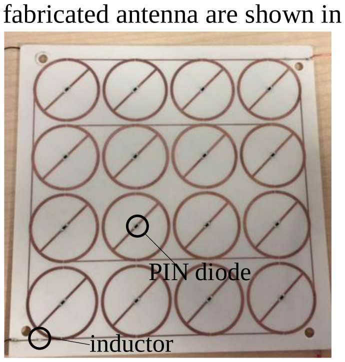


(d)

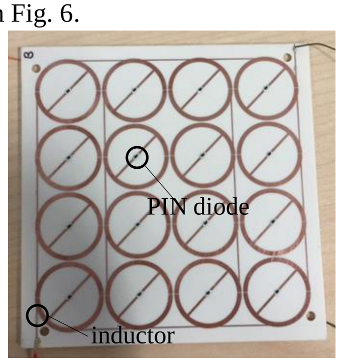
Fig. 5. Simulated AR of RHCP with different h (a), $C_{0\text{-off}}$ (b), Rt (c),Rb (d).

IV. SIMULATED AND MEASURED RESULTS

The polarization reconfigurable antenna is simulated and optimized in CST MWS before fabrication. The photos of the fabricated antenna are shown in Fig. 6.



(a)



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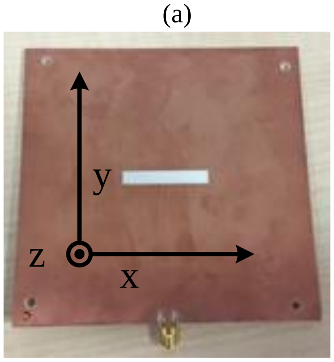

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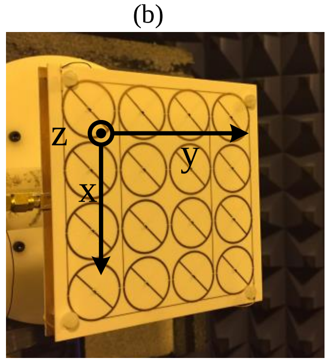


(d)

Fig. 6. Top side of polarizer (a), bottom side of polarizer (b), slot antenna (c), side view of polarization reconfigurable antenna

A. *Simulated and Measured Results of the Polarization Reconfigurable Antenna*

1) *Reflection Coefficient*

The simulated and measured $|S_{11}|$ are shown in Fig. 7 for both RHCP and LHCP. It can be observed that the simulated and measured results agree well. For LHCP, the resonant frequency is 2.5 GHz. The measured $|S_{11}|$ band ($|S_{11}|\leq 10$ dB) is from 2.3 GHz to 2.63 GHz, which is slightly narrower than the simulated results, from 2.27 GHz to 2.69 GHz. For RHCP, the simulated and measured resonant frequency is 2.475 GHz, 25 MHz lower than that of LHCP. The measured $|S_{11}|$ band ($|S_{11}|\leq 10$ dB) is from 2.27 GHz to 2.65 GHz, which is also narrower than the simulated results. The overlapped impedance bandwidth for both polarizations is from 2.3 GHz to 2.63 GHz. The difference between simulated and measured results is mainly caused by the tolerance of fabrication accuracy.

2) *Axial Ratio*

Fig. 8 shows the simulated and measured AR of the antenna at broadside. In the simulation, the 3-dB ARBW is from 2.42 GHz to 2.52 GHz for RHCP antenna and from 2.45 GHz to 2.56 GHz for LHCP antenna. The measured 3-dB ARBW of RHCP antenna is 90MHz (3.6%), from 2.48 GHz to 2.57 GHz while ARBW of LHCP is 110MHz (4.3%), from 2.53 GHz to 2.64 GHz. Therefore, the overlapped RHCP and LHCP bandwidth of the antenna is from 2.53 GHz to 2.57 GHz (1.6%). The narrow bandwidth is limited by the EPRP. Using multi-layer substrates to design the EPRP can increase the bandwidth, but it will also increase the complexity. It can be seen that the measured ARBW shifts to the higher frequency for both RHCP antenna and LHCP antenna.

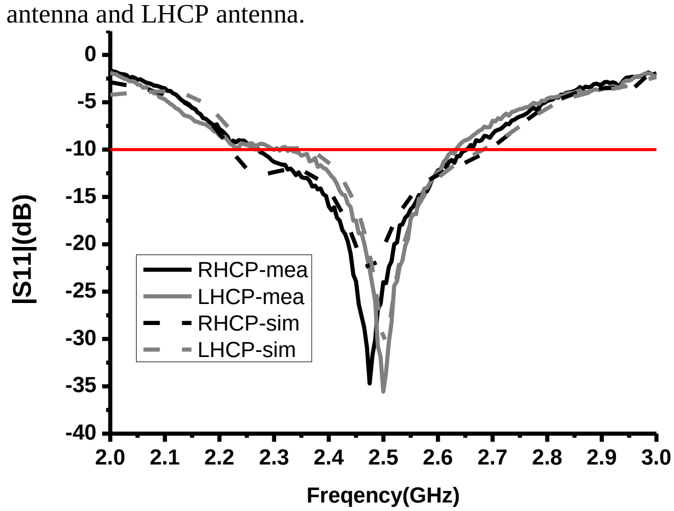


Fig. 7. Simulated and measured $|S_{11}|$ for RHCP and LHCP

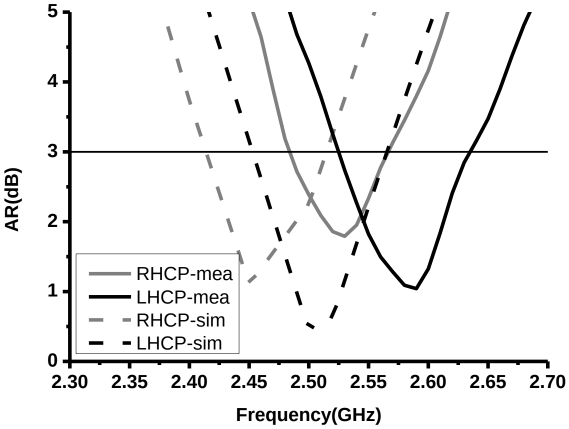
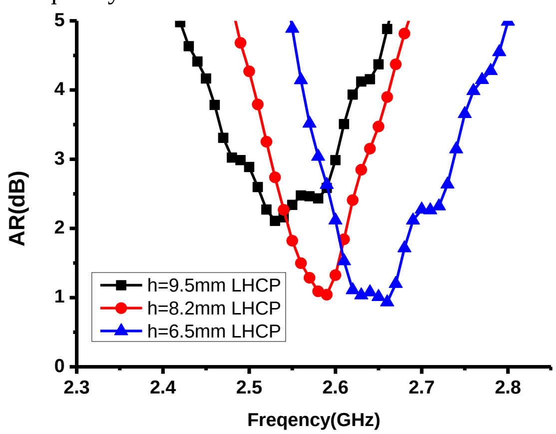
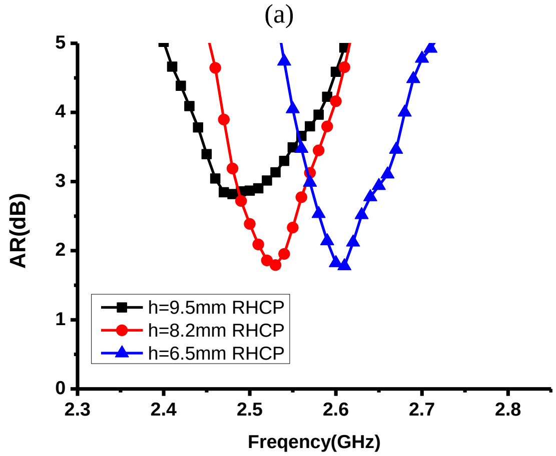


Fig. 8. Simulated and measured AR of the antenna

As discussed in Section III, the center frequency of ARBW can be tuned to lower frequency by increasing *h*. The effect of *h* on AR is also investigated during the measurement. Fig. 9 shows the measured AR of LHCP and RHCP antenna with different values of *h*. For LHCP antenna, when *h* increases from 6.5mm to 8.2mm, the center frequency of ARBW decreases from 2.65 GHz to 2.59 GHz, and the AR does not deteriorate. However, if *h* increases from 8.2mm to 9.5mm, AR deteriorates and the minimum value of AR increases from below 1dB to above 2dB. The effect of *h* on the AR of RHCP antenna is similar to that of LHCP antenna, which is shown in Fig. 9(b). It reveals that *h* cannot be too large although it can adjust the center frequency of ARBW.



(a)



(b)

Fig. 9. Measured AR for LHCP(a) and RHCP(b) with different *h*

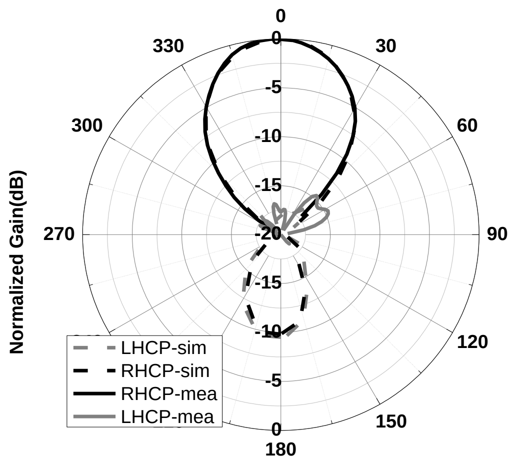
3) Radiation Patterns and Gain

Fig. 10 shows the normalized radiation patterns of RHCP antenna and LHCP antenna in YOZ plane. As the center frequency shifts to a higher frequency in measurement, the simulated pattern in Fig. 10 is at 2.5 GHz, and the measured pattern is at 2.55 GHz. It can be seen that there is a good agreement between the simulated and measured results.

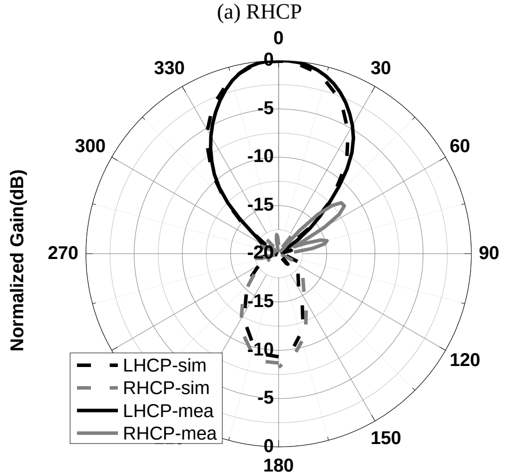
Fig.11 shows the simulated and measured realized gain from 2.45 GHz to 2.6 GHz. The gain of the slot antenna without EPRP is also shown in Fig.11. It can be seen the gain of the slot antenna is enhanced significantly by EPRP. The fluctuation of measured realized gain with frequency comes from measurement tolerance and fabrication inaccuracy. For both RHCP and LHCP, the measured realized gain is higher than 8.6 dBic from 2.45 GHz to 2.6 GHz. The maximum realized gain can achieve 9.6 dBic from 2.53 GHz to 2.57 GHz where the antenna can work either as an RHCP antenna or an LHCP antenna. Some performance comparison between the present antenna and other reported antennas in the similar topic is given in Table II. Compared with the antenna reported in [10, 13-24], which are not easy to be extended to an array antenna, the presented antenna achieves the highest aperture efficiency. When the antenna works at 2.53 GHz, the gain is higher than 9.5 dBic, and the aperture efficiency is 70%.

TABLE II
PERFORMANCE COMPARISON OF POLARIZATION RECONFIGURABLE CP ANTENNA

Ref. No.	Method to realize polarization reconfiguration	Center frequency(GHz)	Overlapped bandwidth	Dimension(mm)	Max gain (dBic)	Aperture efficiency
[13]	Adding PIN diodes to feed slot	5	4%	13.5×18×3.8	5.5	-
[14]	Controlling the structure of feed networks based on CPW	5.8	0.7%	Not given	6.02	-
[15]	Using PIN diodes to change the structure of feed networks	2.45	Not given	42.5×42.5×2.6	5	-
[16]	Adding PIN diodes to feed networks of corners truncated patch antenna	2	8.6%	150×150×16.6	7	-
[17]	Exciting antenna with different input port	2.68	1.3%	80×60×3.6	8	-
[18]	Changing input port	4.02	Not given	140×140×3	8.68	-
[19]	Adding PIN diodes to slot on patch antenna	4.55 &4.20	0%	60×60×3.18	Not given	-
[20]	Same with [19]	4.64	2.7%	40×40×3.18	Not given	-
[21]	Using PIN diodes to change geometry of ring slot antenna	2.38	3.4%	Not given	4	-
[22]	Using PIN diodes to change geometry of corners truncated patch antenna	1.6	1.5%	225×225×1.6	5.3	-
[23]	Changing distance between antenna and dielectric perturbers	5.82	0.7%	Not given	5.4	-
[24]	Using PIN diodes to change the slot distribution on ground	2.49	1.2%	Not given	2.97	-
[10]	rotating the metasurface above the source antenna	3.5	11.4%	π×39×39× not given	7	61%
This paper	Using polarizer loaded by PIN diodes	2.55	1.2%	120×120×8.2	9.6	70%



(a) RHCP



(b) LHCP

Fig. 10. Simulated and measured patterns of the antenna in YOZ plane

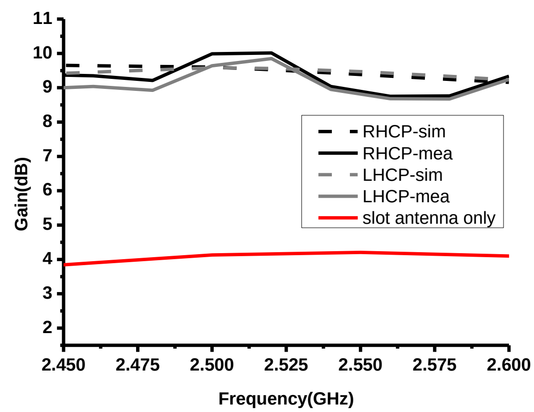


Fig. 11. Gain of the slot antenna with and without EPRP .

B. *Array antenna study*

As mentioned in section I, this polarization reconfigurable CP antenna can be easily extended to a large-scale array antenna. To prove this, a 2×2 array antenna is designed and simulated in this section. Fig. 12 shows the structure of the EPRP of the array antenna. It can be seen that the position of DC feed points do not change when the antenna is extended to a 2x2 array antenna. Thus, a $2^n \times 2^n$ array antenna can be obtained by scaling from the 2x2 array antenna in the same way. Here, the 2×2 array antenna is shown to demonstrate the scalability of the presented design. As shown, when the presented antenna is used as the unit cell to design an array antenna, only minor modifications to the DC bias circuit is required, which is one of the main advantages of the presented design.

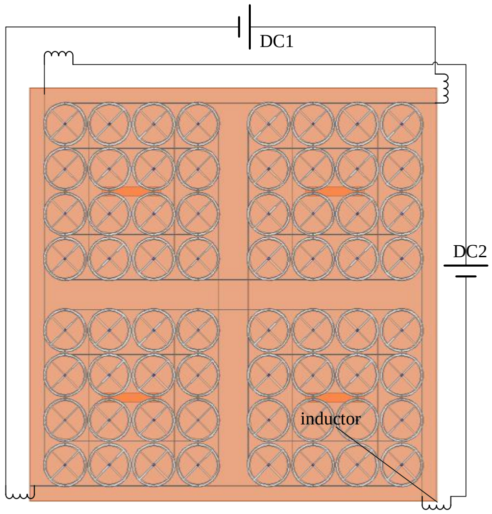


Fig. 12. Structure of EPRP of array antenna.

All the DC circuits have been considered during the EM simulation. The polarization is still controlled by two pairs of DC line. When the PIN diodes of the top rings are on, the array antenna works as an LHCP antenna; When PIN diodes of bottom rings are on, the array antenna works as an RHCP antenna.

Fig. 13 shows the simulated AR of 2×2 array antenna at broadside. It is shown in Fig. 14 that the gain of the array antenna is about 6 dB higher than that of polarization reconfigurable CP antenna alone, which agrees well with theoretical results. Fig. 15 shows simulated and calculated radiation patterns of the array antenna at 2.5 GHz. The calculated patterns are from pattern multiplication for an array antenna. The simulated and calculated patterns agree well, indicating the minor modifications to bias circuit have little effect on the radiation patterns of the array antenna. Due to the limitation of the available size of the laminates, the large size array is not fabricated.

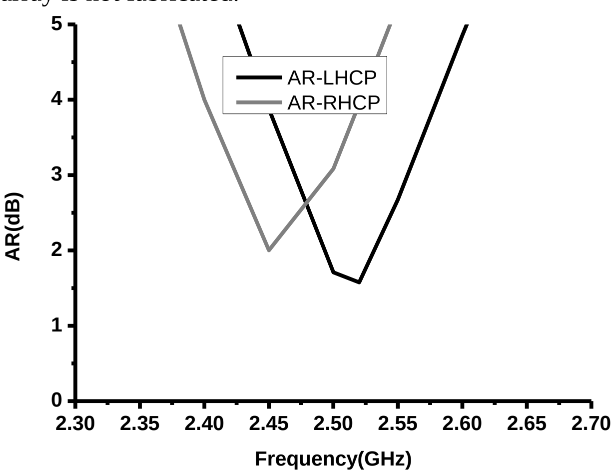


Fig. 13. Simulated AR of the array antenna.

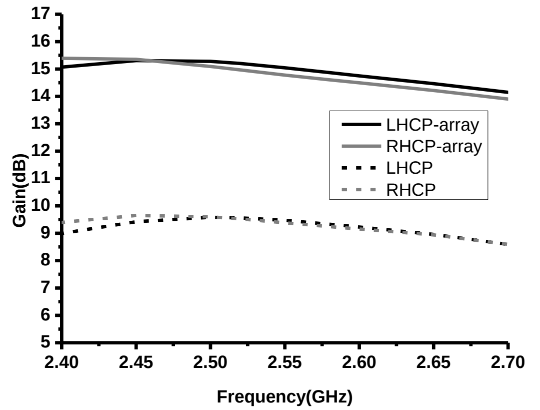
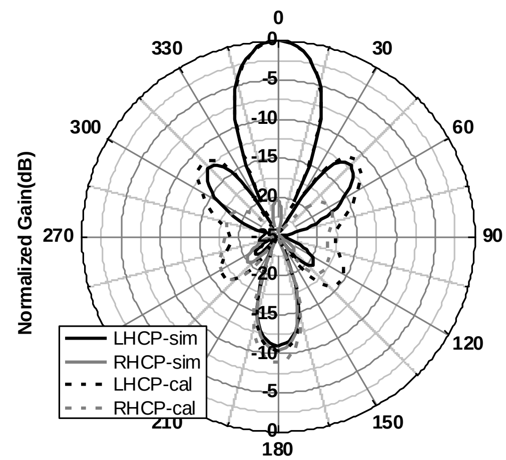
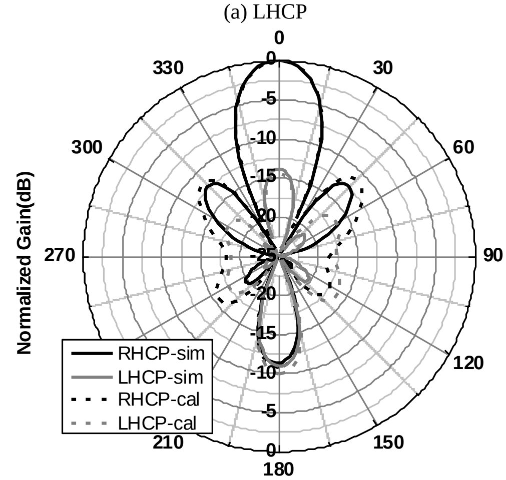


Fig. 14. Simulated gain of the antenna and array antenna.



(a) LHCP



(a) RHCP

Fig. 15. Radiation patterns of the array antenna in XOZ plane.

V. CONCLUSION

A novel polarization reconfigurable CP antenna consisting of a polarizer and a slot antenna has been presented. The polarization of antenna can be electronically switched to LHCP or RHCP by changing the states of PIN diodes on the polarizer. Moreover, it is demonstrated that the design is scalable to large-scale array antennas with minor modifications to the DC bias circuit. To prove the design concept, a prototype of polarization reconfigurable CP antenna at 2.5 GHz band is fabricated and measured. The measured results and simulated results agree well. The measurement results show that the ARBW of LHCP is from 2.48 GHz to 2.57 GHz (3.6%) while that of RHCP is from 2.53 GHz to 2.64 GHz (4.3%). The overlapped ARBW is from 2.53 GHz to 2.57 GHz (1.6%). The gain of the antenna is above 8.5 dBic for both polarizations in the operational band, and the highest aperture efficiency of 70% is obtained.

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