Reconfigurable Circular Polarization Antenna with Utilizing Active Devices for Communication Systems

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Abstract ─ In this paper, the reconfigurable antenna with circular polarization diversity is proposed for wireless local area network (WLAN) communication systems. The proposed antenna consisting of two PIN diodes are appropriately positioned to achieve polarization diversity. By switching the PIN diodes ON/OFF mode, the proposed antenna enables to operate either RHCP mode or LHCP mode. A good impedance match ($S_{11} \leq$ -10 dB) of 935 MHz (1.995~2.930 GHz) at RHCP mode, an impedance bandwidth ($S_{11} \leq$ -10) of 965 MHz (1.935~2.960 GHz) at LHCP mode. The experimental result shows that the proposed antenna has a circular polarization bandwidth (AR $\leq$ 3 dB) of about 415 MHz at the center frequency of 2.4 GHz for both RHCP and LHCP mode.

Index Terms ─ Circular polarization, microstrip antenna, PIN diode, reconfigurable.

I. INTRODUCTION

Circular polarization is one of the common polarization schemes used in current wireless communication systems, such as radar and satellite systems, since it can provide better mobility and weather penetration than linear polarization. With the rapid development of wireless communication systems, such as wireless local area network (WLAN), multi-input and multi-output (MIMO) and personal communications service (PCS), radio frequency terminals with multiple functions are required to adapt to various standards and systems. Reconfigurable antennas with frequency adjustability, radiation pattern selectivity, and polarization diversity are good candidates for these applications [1,2].

In general, a polarization reconfigurable antenna can be designed to switch between different linear polarizations, two circular polarizations (right hand and left hand circular polarization) and any number of elliptical polarizations (with different axial ratios and tilt angles). In most investigations the point refers to the switch between (right hand circular polarization) RHCP and (left hand circular polarization) LHCP in a desired frequency [3,4]. In some papers, antenna could switch to linear polarization in addition of RHCP and LHCP too [5-8]. In some cases, the polarization is switched between vertical and horizontal linear polarization [9,10]. Proposed [11-14]. Adopting an electrical and mechanical method as well as active elements may provide reconfigurable antennas in terms of frequency band [15-17], polarization [18], pattern [19] and multi-application [20] in some UWB antennas these elements are used to obtain alterable notched-bands. For this purpose some designs include RF MEMS [21], PIN diodes [22], microfluidic [23] and Varactor diodes [24,25,26].

In this paper, a novel CPW-Fed microstrip antenna which uses two PIN diodes to switch between RHCP and LHCP, is introduced. This antenna is designed to work in center frequency of 2.4 GHz which is applicable in WLAN system.

This proposed CP reconfigurable antennas with concise structure are easy to be manufactured and can be used in various wireless communication systems. Section 2 demonstrates the design principle and the configurations of CP reconfigurable patch antennas with L elements on the patch and on the ground. Section 3 describes the simulated and experimental performances of the two patch antennas in details. The conclusions are

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drawn in Section 4.

II. DESIGN PRINCIPLE AND ANTENNA CONFIGURATIONS

Figure 1 shows the geometry and dimensions of the proposed antenna, which consists of a rectangular ground plane with dimension of L and W and a square slot in the center of ground. Four inverted-L-shape grounded strips around the corners, and an inverse vertical T-shape strip between two upper inverted-L-shape strips are embedded in the square slot.

The proposed antenna is designed on an FR4 substrate with a loss tangent of 0.02, permittivity of 4.4, and a thickness of 1 mm. The antenna is fed by a 50-ohm CPW having a single strip of width W_{f1}=5 mm and two identical gaps of width g=0.4 mm. The single strip of the CPW is protruded into the slot by a width of W_{f1}, W_{f2}, W_{f3} and W_{f4}. Two parameters, W_{f1} and g are adjusted to produce 50 Ω impedance for feeding of the antenna. Other parameters of feeding strip such as W_{f2}, W_{f3}, W_{f4} and the width of them are embedded and adjusted for impedance matching and resonance bandwidth improvement.

The CP operation of the proposed antenna is chiefly related to the four grounded inverted-L strips inserted around the corners of the square slot.

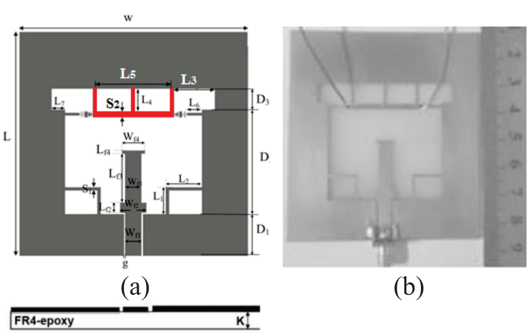


Fig. 1. (a) Geometry of the proposed antenna, (b) photograph of the fabricated antenna, and (c) dimension of proposed antenna: **L_1**=9, **L_2**=11, **L_3**=12.5, **L_4**=7.5, **L_5**=23, **L_6**=5.5, **L_7**=4, **S_1**=1, **S_2**=2, **D_1**=14, **D_2**=35, **D_3**=7, **W_{f1}**=5, **W_{f2}**=8, **W_{f3}**=5, **W_{f4}**=7, **L_{f2}**=3.3, **L_{f3}**=16.5, **L_{f4}**=1, **g=0.4, K=1** (unit: mm).

In Fig. 1 the path of current in upper strips can be controlled by use of two PIN diodes. To feed PIN diodes by DC supply, two stubs with dimension of 1×1.5 mm are used. Each stub has one 100 pF capacitor in one side and other side is connected to PIN diode. To make diodes ON we can use these stubs for giving positive DC voltage to diodes [22].

When diode is in the OFF-state, it works like a small capacitor which can be considered as an open circuit. When diode is in ON-state it works like a small resistance. In an ideal state, this resistance can be considered as a short circuit.

PIN diodes used in the proposed antenna are BAR64-02W diodes. According to datasheet of this diode, in ON-state it has 2.1 Ω resistance and in OFF-state it equals to 0.17 pF capacitance.

III. EXPERIMENTAL RESULTS AND DISCUSSION

In each step of the design procedure, the full-wave analyses of the proposed antenna were performed using Ansoft HFSS (ver. 13). For simulation of the diodes in on state we model them by a resistance of 2.1 Ω. We also model the diodes in off state with a capacitance of 0.17 pF.

The proposed antenna with dimensions in Fig. 1 (c) has been fabricated on an FR4 substrate with a loss tangent of 0.02, permittivity of 4.4, rectangular dimensions of 75×70 mm, and thickness of 1 mm. The photograph of fabricated antenna is shown in Fig. 1 (b). In Fig. 2, the measurement and simulated results of in RHCP and LHCP state are shown. An Agilent E8363C vector network analyzer has been used to measure antenna parameters. Embedding inverted-L-shape grounded strips at the upper corner of square slots make the CP polarization possible. These strips are separated by two PIN diodes. When D1 is ON and D2 is OFF, the polarization of the antenna will be RHCP, and when D2 is ON and D1 is OFF, the polarization of the antenna will be LHCP. So by making the diodes ON or OFF different polarization will be obtained.

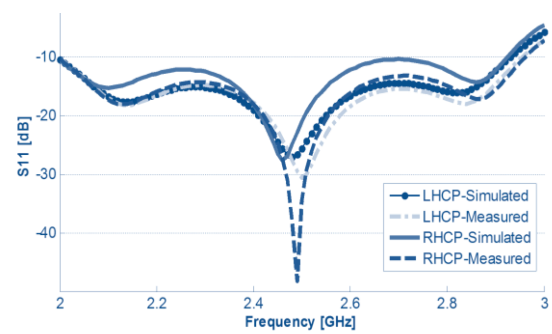
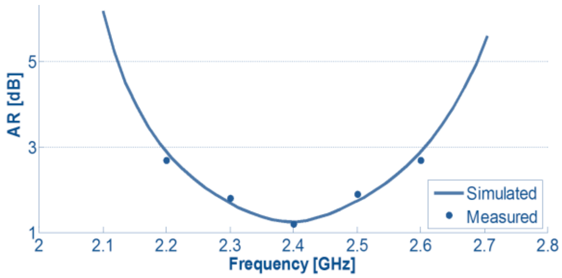


Fig. 2. Simulated and measured reflection coefficient of the antenna for RHCP and LHCP.

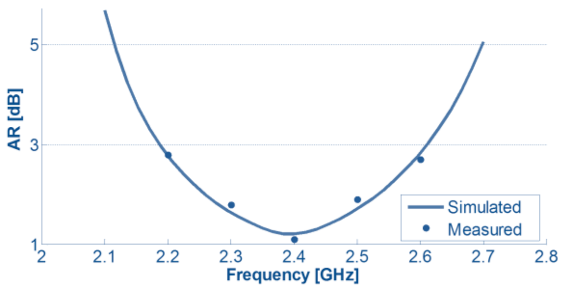
The simulated and measured axial ratio (AR) results in RHCP and LHCP states is shown in Fig. 3. As it is seen, the AR for RHCP and LHCP states is the same and in frequency range of 2.180~2.595, the AR is lower than 3 dB. In this bandwidth, it can be considered a circular polarization for proposed antenna.

The L-shape strips at the lower corners are for AR improvement and increasing of the antenna bandwidth. Center frequency of AR are affected by length of L6.

This length is chosen to have minimum axial ratio at frequency of 2.4 GHz. As we can see in Fig. 4, by increasing the length L6 the axial ratio bandwidth shifts to lower frequencies.



(a)



(b)

Fig. 3. Measured and simulated AR for: (a) RHCP and (b) LHCP.

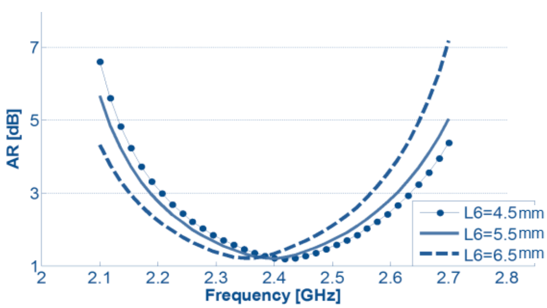
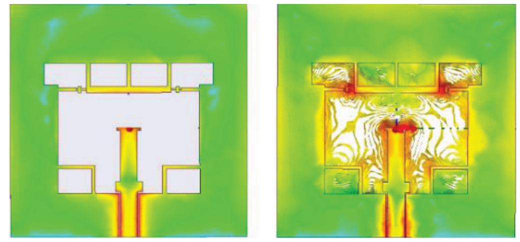


Fig. 4. Simulated AR values for different values of L6.

Current distributions on the patch antenna when it is fed from OFF/ON state of PIN diode are shown in Fig. 5, respectively. The symmetry in current distributions is mainly due to preserved symmetry in the antenna design. When diodes are ON, the current distribution is stronger and enforces the current distribution on the main patch for circular polarization.

The inversed T-shape strip embedded between upper L-shape strips will increase the gain of the antenna and make it smoother in the bandwidth. The simulated results for the gain of the proposed antenna in RHCP and LHCP state are shown in Fig. 6. In this figure, the measured results of the gain in LHCP state is shown too.



(a) (b)

Fig. 5. Simulated current distribution on the antenna frequency 20.4 GHz: (a) PIN diode OFF and (b) PIN diode ON.

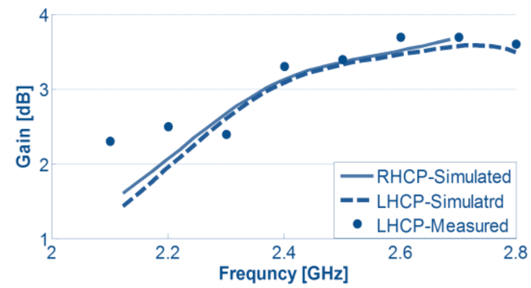


Fig. 6. Measured and simulated results for antenna gain in RHCP and LHCP.

The gain of proposed antenna is upper than 2 dB in the desired bandwidth and in center frequency 2.4 GHz it is 3.2 dB. In Fig. 6, it can be seen that as the operation frequency increases, the antenna gain is increased too. The antenna gain in the AR bandwidth in the best mood is 3.6 dB. The gain of the antenna has a direct relationship with the length of the antenna. Figure 7 shows the gain of the antenna for different values of L. Increasing the length of the antenna will increase the gain of the antenna and it has a negligible effect on the AR and return loss. The radiation pattern of the proposed antenna is demonstrated respectively in Fig. 8 (a) H-plan and Fig. 8 (b) E-plan. Also Figs. 9 (a) and (b) shows respectively comparison of radiation pattern for RHCP and LHCP.

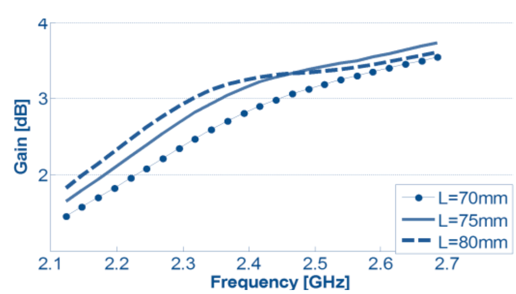
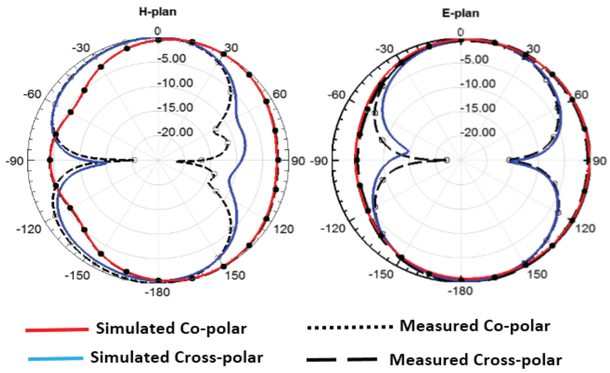
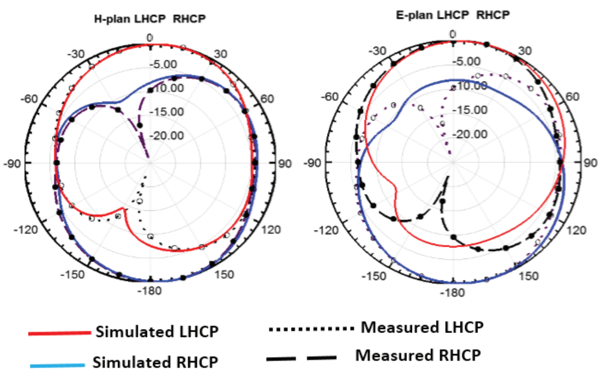


Fig. 7. Gain of the proposed antenna for various values of L.



(a) (b)

Fig. 8. Radiation pattern of antenna: (a) H-plan and (b) E-plan.



(a) (b)

Fig. 9. Radiation pattern of antenna: (a) RHCP antenna and (b) LHCP antenna.

IV. CONCLUSION

A novel polarization reconfigurable antenna has been presented. The antenna is simple to design and fabricate and exploits PIN diode switches to deliver reconfigurable capability. This antenna uses four inverted-L grounded strips for the excitation of two orthogonal resonant modes for CP radiation. Measured results have good agreement with simulated ones. The proposed antenna is suitable for Bluetooth/WLAN (2400–2484 MHz) frequencies.

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