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A Wideband Polarization Reconfigurable Antenna for WLAN Applications

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Abstract—This paper proposes a wideband polarization reconfigurable antenna design for WLAN applications. It consists of a shorted annular patch (SAP) antenna as the source, a partially reflective surface (PRS) structure to enhance the gain, and a reconfigurable Wilkinson power divider as the feed network. The antenna can electronically alter its polarization between linear polarization (LP), left-hand circular polarization (LHCP), and right-hand circular polarization (RHCP), achieving an overlapped 10dB impedance bandwidth and 3 dB axial-ratio bandwidth of 4.68-5.33 GHz (13%), thus outperforming most of the reported polarization reconfigurable antennas in terms of the frequency bandwidth.

Index Terms—polarization reconfigurable antenna, reconfigurable feed network.

I. INTRODUCTION

In the last two decades, polarization reconfigurable antennas have attracted much interest in the wireless communication systems owing to their advantages of mitigating signal fading in multipath propagation environments and realizing double transmission channels for frequency-reuse transceivers [1]. Many polarization reconfigurable antennas have been designed that can switch between two orthogonal linear polarizations or two different circular polarization modes. However, relatively few antennas have been proposed to realize the switch between LP and two CPs because it is difficult to simultaneously achieve a good impedance match for both the LP and CP. Some work has been done to address the above problem by making the antenna more versatile. In [2], four pin-diodes were used on a corner-truncated square patch to produce LP and CP radiation with a small impedance bandwidth (2.5%). In [3], a U-slot microstrip patch antenna was proposed that can provide polarization switch between LP and CP. However, the overlapped operating frequency bandwidth is less than 6.1%. A square-ring microstrip antenna excited by a T-junction power divider and a pair of varactor diodes has been reported in [4]. It enables the polarization to be tuned among LP and two CPs across a bandwidth of 1.4% around 2 GHz. In [5], a branch line coupler with four microstrip feeding lines is employed as the feed network for an aperture-fed square patch antenna. Eight PIN diodes are inserted in the feed network to provide quad-polarization reconfigurability, in two orthogonal linear polarizations and two orthogonal circular polarizations. The impedance bandwidth achieved in this design is 3.67% at 2.45 GHz. A traditional annular slot antenna can achieve a wider bandwidth of 4.7% [6] by employing an arrow-shaped coupling

strip with a PIN diode inserted in each arm. In summary, it has been found that most of the reported antennas can switch their polarizations in LP and two CP modes across an overlapped impedance bandwidth less than 10%. As the wideband communication is commonplace for recent wireless communication systems, a wideband polarization reconfigurable antenna is highly desirable.

A wideband polarization reconfigurable PRS antenna, which employs a SAP antenna as the source and a reconfigurable Wilkinson power divider network, is proposed in this work to realize polarization switching among LP, LHCP, and RHCP, with an overlapped 10 dB impedance bandwidth and 3 dB axial-ratio bandwidth of 4.68-5.33 GHz (13%). The reconfigurable feed network utilizes the conventional Wilkinson power divider and achieves a phase difference of 0° or ±90° between the two output ports across a relatively wide frequency range by incorporating two phase shifters and eight PIN-diodes into the power divider, a phase difference of 0° or ±90° between the two output ports can be achieved across a relatively wide frequency range. The network is highly integrated in a way such that it does not require any additional impedance matching networks, hence the structure is compact.

II. RECONFIGURABLE FEED NETWORK

The configuration of the network is shown in Fig.1. It is based on a reformative Wilkinson power divider with a phase shifter inserted in each branch. The details of the phase shifter are shown in the inset of Fig.1 and its dimensions are listed in Table I. The phase shifter is comprised of two separate microstrip lines (a short one and a long one as shown in Fig.1) and each line has two gaps etched at the edges for inserting PIN diodes. The long microstrip lines are approximately $\lambda_g/4$ longer than the short microstrip lines, where λ_g is the guided wavelength at the resonant frequency. By switching the diodes on and off, the length of each branch of the power divider can be varied, which produces the phase difference between the two output ports and, in turn, realizes polarization reconfigurability. Four groups of PIN diodes are used in this design (A and A', B and B', C and C', D and D'). When either the diode groups A and D are switched on and the others are off, or when groups B and C are switched on and the others are off, no phase difference exists between the two branches. These two states are referred to as S1. When the diodes A, A' and C, C' are switched on, and the others are switched off, the left branch generates a 90° delay

to the right one, which is called S2; When the diodes B, B' and D, D' are switched on with the others off, a 90° phase lead can be produced at the left branch and this state is referred to as S3. The realized phase differences from the network can be used in a reconfigurable antenna design to realize polarization switching among LP, RHCP and LHCP.

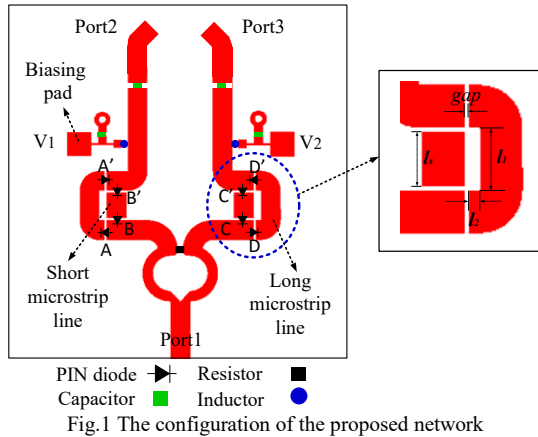
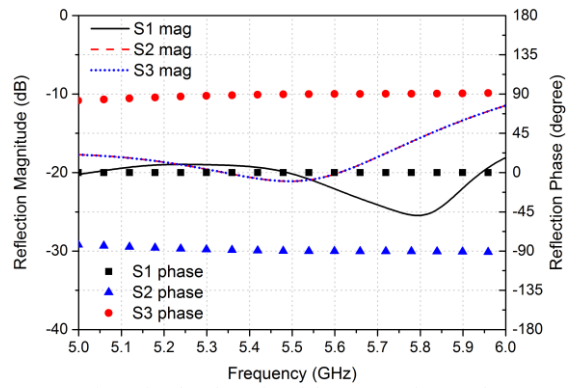


TABLE I

Parameter	l_1	l_2	l_s	gap
Value (mm)	5.5	0.7	4.8	0.35

In order to verify the operation of the proposed network, a prototype has been designed on an 80 mm × 50 mm × 1.524 mm Rogers4003 substrate and has been simulated. Based on the PIN diode datasheet of MA4FCP300, the diode is modelled as a series circuit consisting of a 4 Ω resistor and a 0.6 nH inductor for the on-state and a parallel circuit consisting of a capacitor of 0.04 pF and a resistor of about 20 kΩ for the off-state. The biasing network is also shown in Fig. 1. The PIN diodes on the two short microstrip lines are oriented in the same directions, and those on the two long microstrip lines are placed in the opposite directions. A capacitor is inserted on the top part of each branch not only to realize RF continuity, but to provide DC isolation for the two biasing voltages on the two branches. When V1 and V2 are connected together and applied to a negative voltage relative to Port-1 that is connected to the ground, the diodes group A and group D on the two long lines are switched on, which results in a 0° phase difference between Port-2 and Port-3 and leads to a linear polarization. A 90° phase difference between Port-2 and Port-3 can be achieved by applying a positive voltage to V1 and grounding V2 to obtain a right-handed circular polarization, and vice versa.

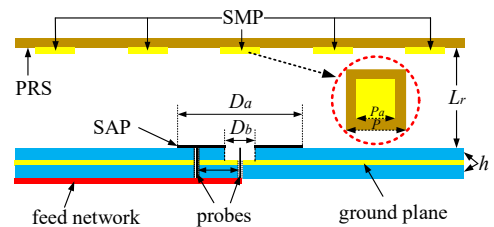
Here, we only study the magnitude of the input reflection coefficient for Port-1 ($|S_{11}|$) and the phase difference φ_{23} between Port-2 and Port-3. It is observed from Fig.2 that $|S_{11}|$ is below -10 dB across the frequency band ranging from 5 GHz to 6 GHz for all the three states. Furthermore, φ_{23} values for the three states (S1, S2 and S3) remain approximately 0°, -90°, and 90°, respectively, in this frequency band.



III. PRS ANTENNA DESIGN

Fig.3 shows the configuration of the proposed polarization reconfigurable PRS antenna. It consists of a PRS structure on top, an SAP antenna as the source located above the ground plane, and the proposed feed network underneath the ground plane. The dimensions of the entire antenna are 110 mm × 110 mm ($1.83\lambda \times 1.83\lambda$ at 5 GHz). The PRS material is constructed from a 0.8 mm thick FR4 substrate and consists of an array of 5 × 5 square metallic patches (SMP). The length of the patch cells (P_a) is 18 mm and the periodicity between two adjacent patches (P) is 24 mm, as shown in the inset of Fig.3. The cavity height (L_r) is set to be 32 mm.

The source is a two-layer structure fed by two probes with a diameter of 1.3 mm. For the first layer, an SAP antenna is etched on the upper side of a 1.524-mm-thick Rogers 4003 substrate. The diameter of the annular patch (D_a) is 24.6 mm. The patch is shorted to the ground by plating a metallic via hole with a diameter of 11.6 mm (D_b). The metal of the other side of the substrate serves as the ground plane. For the second layer, the feed network is printed on one side of another 1.524-mm-thick Rogers4003 substrate and the metal of the other side of this substrate is etched off. The SAP antenna and the feed network are connected by two metal probes with a diameter of 1.3 mm. The probes are located at 7.4 mm (L_f) from the center of the SAP antenna and are sequentially rotated by 90°. The probes are isolated from the ground by cutting two circular slots, with a radius of 1 mm around them.



IV. ANTENNA RESULTS

Figs. 4 show that the simulated 10 dB impedance bandwidth can cover a frequency band from 4.65 GHz to 5.33 GHz for LP and from 4.63 GHz to 5.84 GHz for LHCP and RHCP. Fig. 5

gives the simulated axial ratios for the CP modes. It can be seen that from 4.68 GHz to 5.46 GHz (15.4%) the axial ratio is below 3 dB for both LHCP and RHCP. Considering the overlapped 10 dB impedance bandwidth of the three polarizations and the 3 dB axial ratio bandwidth, the overlapped frequency bandwidth ranges from 4.68 GHz to 5.33 GHz (13%) for realizing polarization switching between LP and two CP modes. Fig.6 shows the simulated realized gains for the three polarizations. The results for LP ranges from 7.5 dBi to 11.3 dBi while the results for CP ranges from 7.3 dBic to 11.2 dBic.

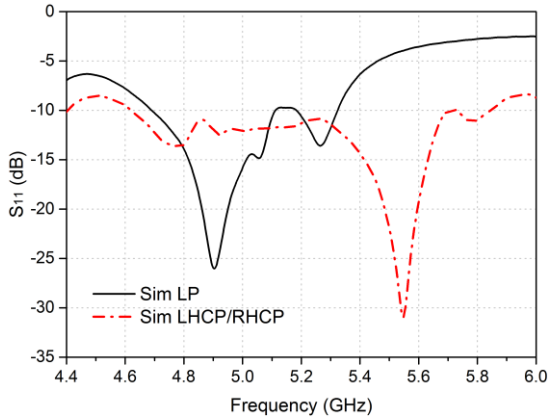


Fig.4 Input reflection coefficients of the proposed antenna for LP and CP

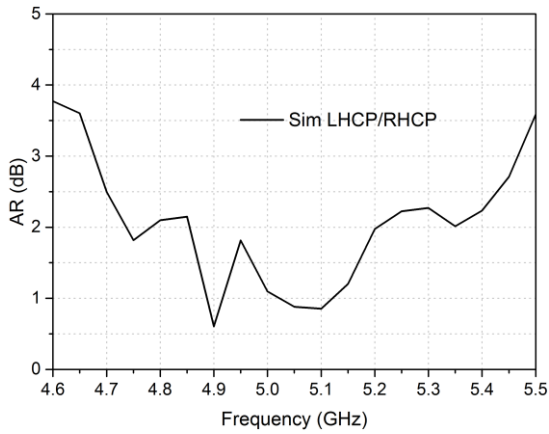


Fig.5 Axial ratio of the proposed antenna

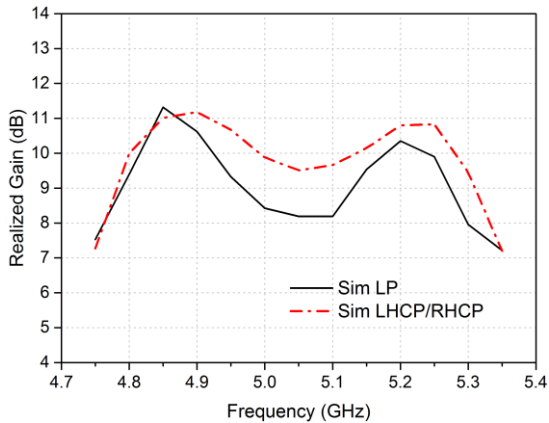


Fig.6 Realized gain of the proposed antenna

V. CONCLUSION

A wideband polarization reconfigurable PRS antenna has been proposed in this work. By controlling four PIN diodes embedded in each branch of a Wilkinson power divider, the antenna can be reconfigured to generate LP, RHCP, and LHCP radiation patterns. Compared to most of the reported designs, a wider overlapped frequency range (13% impedance bandwidth) has been realized. The measured radiation patterns and realized gains will be included in the presentation.

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