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Polarization Reconfigurability Patch Antenna with Improved Axial Ratio Bandwidth

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Abstract—**In this paper, the patch antenna with polarization reconfigurability feature is proposed. The antenna composed of circular patch on the top substrate embedded with four equal-length slits, and is fed at the diagonal of the structure using the coaxial fed technique. To obtain the reconfigurability feature, four switches (copper strips) are appropriately located at the specific position across the slit. This will change the slot length, and then consequently altered the polarization excited by the antenna. By controlling the state of the switch, the polarization of the proposed antenna is able to be reconfigured between linear polarization, left-hand circular polarization and right-hand polarization. Triple layers of substrate are utilized in the design in order to have the broader axial ratio bandwidth. The simulated results of the proposed antenna are presented and discussed. This antenna is operated and covered the whole wireless local area network (WLAN) frequency band.**

Keywords—circular patch, slit perturbation, polarization reconfigurability, bandwidth enhancement.

I. INTRODUCTION

Reconfigurable antennas have recently gained considerable attention and become quite an active topic of research. This is due to their ability to improve and enhance the overall system capability through polarization diversity, frequency reuse and ability to reduce the multipath fading effect [1]. The main idea of having a reconfigurable antenna is the ability to meet the current demands and new specifications of the systems towards achieving flexible radio front-end smart antenna for modern wireless communication system. A reconfigurable antenna modifies the antenna's pattern, operating frequency/bandwidth or polarization to the desirable fashion [2].

Polarizations reconfigure antennas means single antenna that capable to switch the polarization excited, through the change of antenna's structure or feeding network. The changes lead to the alteration of the current flows on the structure, subsequently change the polarization sense produced by the antenna. To obtain the reconfigurability feature, electronically type of switches, like PIN diode are commonly used as a switch.

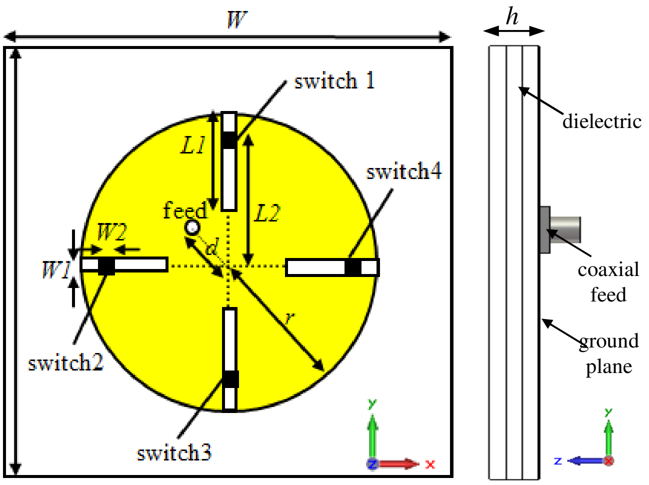
A lot of the previous works that have the polarization reconfigurability concentrates on the switching between left-hand circular polarization (LHCP) and right-hand circular polarization (RHCP) [3-5]. Relatively only few antennas that presented has the capability to switch between linear polarization (LP) and circular polarization (CP), due to the difficulty to achieve good impedance matching for both cases simultaneously. In addition, the available bandwidth of polarization reconfigurability type of antenna is mainly determined by the bandwidth of circular polarization. The author in [6] has successfully proposed the polarization reconfigure single layer patch antenna. However, narrow in axial ratio bandwidth limits the application for the antenna.

Hence, this paper proposes a simple approach to overcome the problem. Multilayer of substrate is introduced in the design in order to improve the axial ratio bandwidth of the antenna [7]. Even though through this approach the overall volume of the structure is increased, but it can enhance the bandwidth of the antenna, thus enable the antenna to support various types of application. In this design, ideal switches (copper strips) are used for proof of the concept and are positioned across the slits. Consequently, the polarization can be reconfigured depending on the state of the switch. Interestingly, the changes of polarizations are achieved with the frequency response of the antenna remain unchanged for each type of polarization mode. Details of the design are discussed and the performance of the proposed antenna is presented. The simulation process is performed using commercial software CST Microwave Studio.

For proof of the concept, the switch is represented by copper strips with the dimension of 1 mm x 1 mm. The presence of the switch represents a switch is ON and denotes OFF state when the switch is absence.

II. ANTENNA STRUCTURE AND SWITCH CONFIGURATION

In this section, the geometry, coordinate system and approach taken in the proposed design is explained and discussed. The geometry of the proposed reconfigurable antenna structure is shown in Figure 1. In this design, substrate used is Taconic RF-35 which dielectric constant, εr of 3.52, thickness, h of 1.524 mm and a tangent loss, δ of 0.0018. Radiating circular patch with a radius of r, is etched on top of the surface and finite ground plane on the bottom layer.



(a) (b)

Figure 1: Configuration of proposed antenna (a) front view, and (b) side view.

To excite the antenna, probe feed is positioned diagonally with a distance of *d* from the center. This parameter greatly influenced the impedance matching.

Four equal length slits, with the dimension of *L1* x *W1* are incorporated on the circular patch, located at the edge (x-axis and y-axis) with ninety degrees apart from each other. For reconfigurability purposes, four switches with the size of *W2 x W2* are placed across the slits at the distance of *L2* from the center of the structure. The position of the switch is very crucial as its effect the optimum result of the axial ratio. To further improve the bandwidth of axial ratio produce by the antenna, multi-layer substrate technique is proposed. The thickness of the structure is *h* mm.

The mechanism of the structure can be explained using the cavity model. Due to the diagonal feeding, two near degenerated orthogonal modes are excited simultaneously. The existence of the perturbation slits drives the current path in the perpendicular direction and gives less effect to the surface current coming in the parallel direction. Furthermore, due to the presence of the switch, the current will travel through shortest distance, hence provide a phase delay between modes.

TABLE I

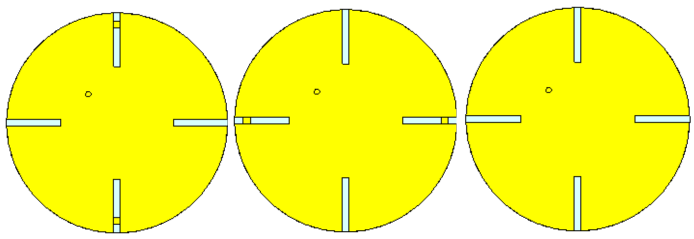
SWITCH CONFIGURATION FOR THE PROPOSED ANTENNA

Conf.	Switch state				Polarization
	S1	S2	S3	S4	
C1-LHCP	ON	OFF	ON	OFF	LHCP
C2-RHCP	OFF	ON	OFF	ON	RHCP
C3-LP	OFF	OFF	OFF	OFF	LP

TABLE III

DIMENSIONS OF THE PROPOSED ANTENNA

Parameters	*L*	*W*	*L1*	*L2*	*W1*
Value (mm)	55	55	8	15	1
Parameters	*W2*	*r*	*d*	*h*	
Value (mm)	1	16.3	6	4.572	



(a) (b) (c)

Figure 2: Physical structure of the proposed antenna used in the simulation. (a) C1-LHCP, (b) C2-RHCP, and (c) C3-LP

The asymmetrical slit length caused the two orthogonal modes to be generated. Hence, by proper adjustment of the position of the switch, at the appropriate length difference can make the two modes have equal in amplitude and 90º phase difference in the particular frequency, thus resulting the CP to be excited. Conversely, when there is no length difference between the slits at the *x*-axis and *y*-axis, both modes will have equal in amplitude and phase. In that occasion, LP will be excited.

Overall, the antenna is able to work in three types of polarizations, either LP, LHCP or RHCP, depending on the configuration of the switch. The dimensions of the proposed antenna are tabulated in Table I and the switching conditions of all switches with the respected modes are tabulated in Table II. Figure 2 shows the physical structure used in the simulation.

III. SIMULATION RESULTS

Simulated result of S-parameters for all switch configurations is shown in Figure 3. The impedance bandwidth, determined by -10 dB reflection coefficient, are 200 MHz (2.4-2.6 GHz) and 110 MHz (2.388-2.498 GHz) for both CPs configuration and C3-LP, respectively. It is also demonstrates that the two orthogonal resonant modes (TM_{01} and TM_{10}) are excited at the close frequency for CP and excited at the same frequency for LP. That consequently gives the operating bandwidth for CP to become more wider compare to LP. Figure 4 presents the simulated axial ratio of the proposed antenna. The CP bandwidths, referred to 3dB axial ratio, are about 54 MHz (2.422-2.476) and 50 MHz (2.427-2.477 GHz) for C1-LHCP and C2-RHCP, respectively. It has to be noted the bandwidth for LP totally covers the bandwidth for CP. As the proposed antenna performs the reconfiguration of polarization at one particular frequency, hence the total available bandwidth is mainly determined by the bandwidth of the CP configurations.

Figure 5 shows the simulated variation of gain over frequency from 2.4 GHz up to 2.6 GHz. It is observed that the simulated gain for CP modes is about 6.34 dBi, 0.27 dBi above the simulated gain for C3-LP. The simulated 3D radiation pattern for configuration C2-RHCP is shown in Figure 6. Broadside radiation pattern with more than 90º is achieved for all switch configurations. It does also clearly can be seen that

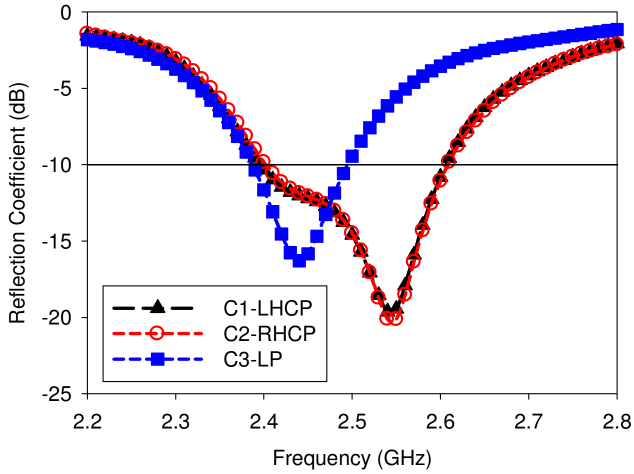


Figure 3: Simulated reflection coefficient for all switch configurations

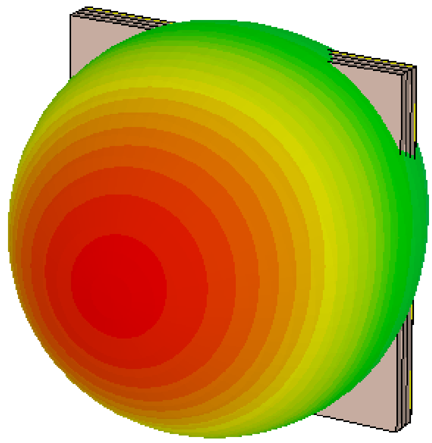


Figure 6: 3D perspective view of radiation pattern for C2-RHCP at 2.55 GHz.

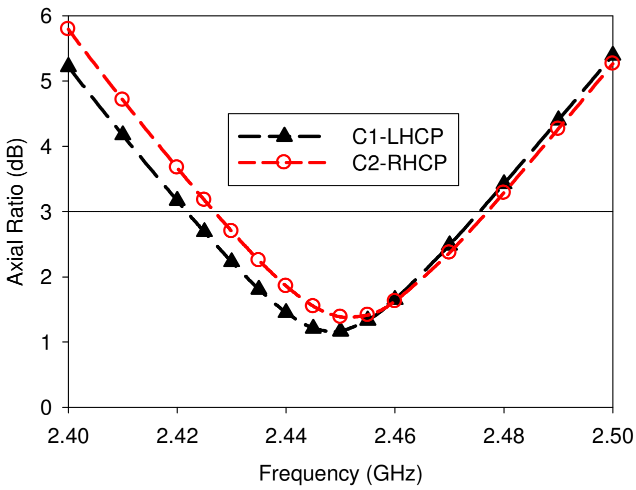


Figure 4: Simulated axial ratio for CP mode

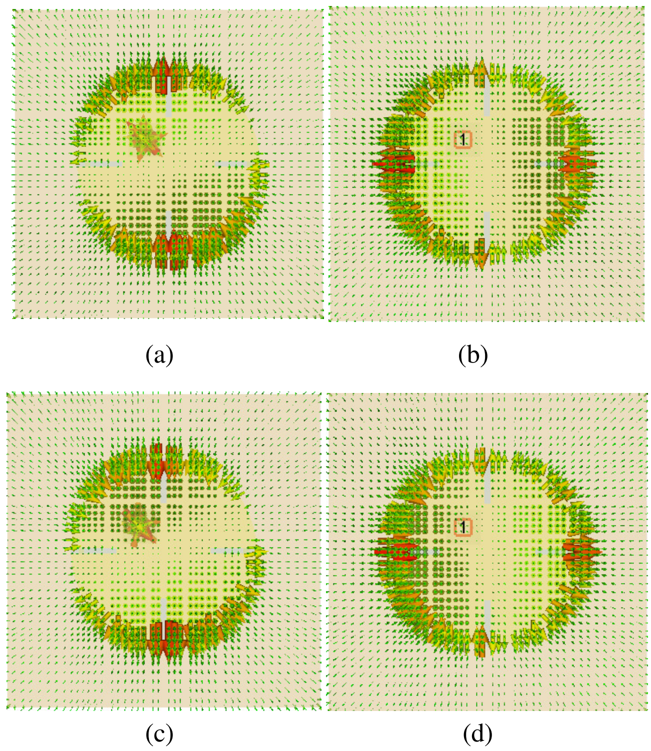


Figure 7: E-field at 2.45 GHz for C2-RHCP at the phase (a) 0º, (b) 90º, (c) 180º, and (d) 270º.

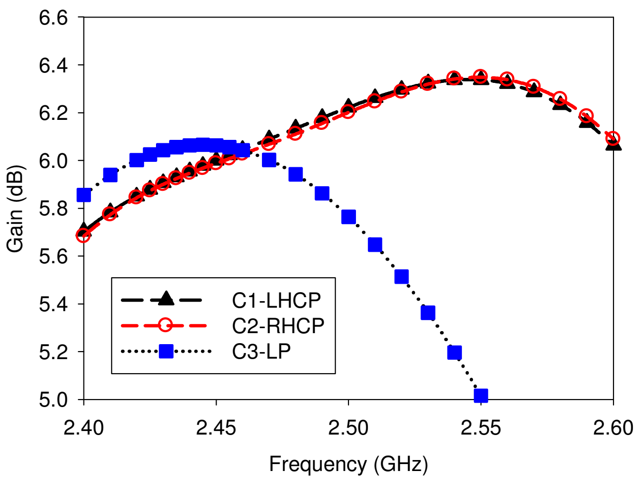


Figure 5: Simulated gain for all switch configurations

the results for LHCP and RHCP is similar, due to the symmetrical of the structure. They only difference is the rotation of the electric field as the change of the state of the switches consequently modifying the rotation either in clockwise or anti-clockwise direction. The rotation of the electric field for C2-RHCP is demonstrated in Figure 7.

The simulated reflection coefficient and axial ratio between multi-layers of substrate are compared and studied. In this process of adding the layer, it has to be noted that the same properties of substrate are implemented in the design in all layers. Figure 8 presents the comparison of reflection coefficient for C2-RHCP. It is clearly can be seen that the impedance bandwidth is broadening when the additional layer of substrate is introduced. The impedance bandwidth with respect to -10 dB reflection coefficient, are 76 MHz, 150 MHz and 200 MHz, for single layer, double layer and triple layer, respectively. The improvement of the bandwidth of impedance matching has enhanced the axial ratio bandwidth to be broadened as well, as shown in Figure 9. The bandwidth for triple layer is improved about 270% when compared to the single layer, and about 143% when compared to the double layer of substrate.

As mentioned earlier on, since the proposed design works for reconfigurability of polarization, the available working bandwidth is mostly controlled by the bandwidth of the axial ratio, hence this proposed antenna has proven ability to provide better performance in terms of axial ratio bandwidth and overcome the drawback of limited bandwidth discussed in [6]. For each addition of layers, minor adjustment is made in the parameter in order to obtain optimum results.

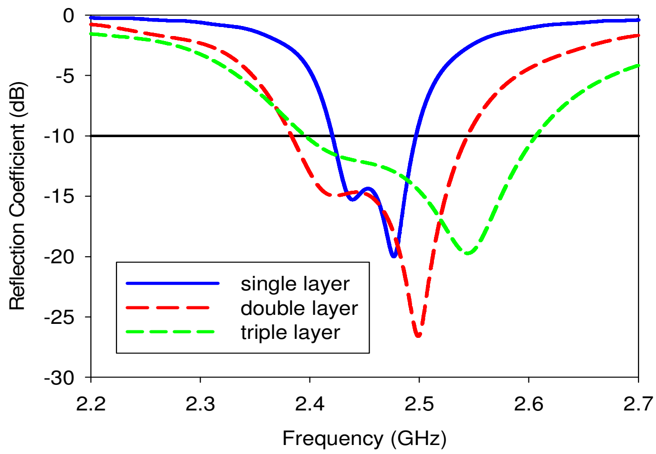


Figure 8: Comparison of simulated reflection coefficient for configuration C2-LHCP with multi-layer of substrate

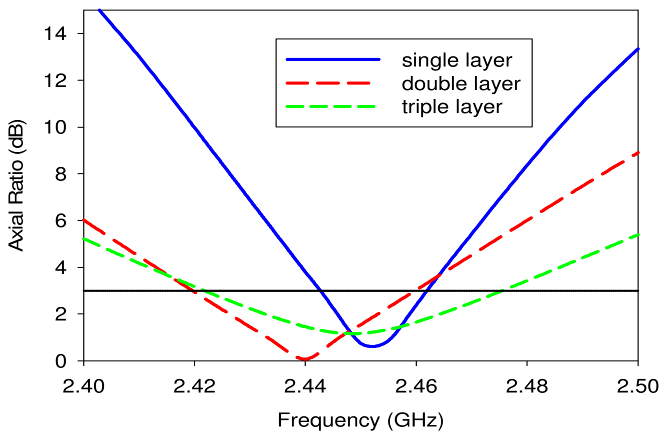


Figure 9: Comparison of simulated axial ratio for configuration C2-LHCP with multi-layer of substrate

IV. Conclusion

This paper proposed polarization reconfigurable antenna with wider axial ratio bandwidth. By changing the state of four switches utilized in the design, the antenna is capable to excite triple type of polarization; LP, RHCP or LHCP that operated in WLAN frequency band. To broaden the bandwidth, additional layer of substrate is imposed on the structure. The additional of the substrate layer increased the thickness of the structure, consequently wider the operational bandwidth and axial ratio bandwidth. The axial ratio bandwidth improved about 270% when compared between single layer and triple layer of substrate. This has improved the previous antenna and able to cover about 80% of the WLAN frequency band.

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