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A Novel Reconfigurable Polarization Dual-band Patch Antenna for WLAN and WiMAX Systems

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***Abstract*—This paper presents a novel dual-band annular patch antenna with functional microstrip circuit module to reconfigure the polarized modes of the antenna. The proposed antenna consists of two bonded FR4 print circuit boards and is excited at WLAN band and WiMAX band by this functional circuit module. This module includes two branches of microstrip lines, two PIN diodes and a DC bias circuit. Two PIN diodes are placed on the two microstrip lines. The polarization of the antenna can be simply shifted back and forth between RHCP and LHCP by modifying the modes of PIN diode. Simulation and experimental results have shown a good bandwidth of axial ratio and antenna gain in circularly polarized states.**

***Index Terms*—Reconfigurable polarization, Dual band, DC bias circuit, PIN diode, Annular patch antenna.**

I. INTRODUCTION

Due to the wireless communication products, such as smart phones and tablet PC, are broadened to the markets of multimedia, more and more wireless network systems are integrated in same devices and the needs for special functions of dual-band, broadband and ultra-wideband (UWB) are increased [1-3]. Patch antennas with reconfigurable polarizations can reduce the number of the required antennas [4, 5]. It also can be used to mitigate signal fading in multi-path propagation [6, 7]. Generally, a patch antenna, single-feed or dual-feed, can generate circular polarized modes with perturbation of surface current [8]. Dual-feed patch antennas have been frequently used with power divider to perturb the surface current by modifying the phases with the length of microstrip line [9]. Using dual-feed antennas may have a good bandwidth of axial ratio and easily produce dual polarized modes [10]. However, complicated feeding networks and structures are their drawbacks [11]. Single-feed patch antennas can be designed to modify the surface current and generate the polarized mode by adding the perturbation structures [12], but the drawback is that it is hard to produce dual polarized modes. Many perturbation structure designs have been proposed to modify the directions of surface current, for example, truncating corners on the radiator [13], adding stubs or slots to excite orthogonal modes [14, 15].

Recently, the use of PIN diode that is embedded into the single-feed antennas with perturbation structure to reconfigure the polarized modes has been reported [16]. Controlling the modes of PIN diode to adjust the surface current on radiator could be the alternative way to modify the polarization of the antenna [17]. In this paper, we propose a more effective design to reconfigure the circular polarizations of a single-feed patch antenna with a functional circuit module. This module uses two branches of microstrip lines and embeds with PIN diodes as the perturbation structure to modify the surface current of proposed patch antenna. As the modes of PIN diodes being controlled properly, dual circular polarized modes of the antenna can be easily achieved.

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II. ANTENNA CONFIGURATION

The geometry structure of the proposed antenna is shown in Fig. 1. The antenna is fabricated on two individual FR4 circuit boards, one with single metal layer (Layer 1) and the other with dual metal layers (Layer 2 and Layer 3). These two circuit boards are bonded 5mm apart via four nylon screws and eight nylon nuts. The overall size of each circuit board is $55\times55\times1.6mm^3$. In this antenna, an annular slot with inner radius r_1 and outer radius r_2 is printed on Layer 1. In addition, Layer 1 plays a role of ground plan as well. Layer 2 is the functional microstrip circuit module which includes a feed-line, two branches of microstrip lines, two PIN diodes and a DC bias circuit. The feed-line l_1 is designed to match 50Ω impendence at feeding input. Two branches of microstrip lines (l_2 and l_3) are designed as part of the perturbation structure and a PIN diode is placed on each path. The DC bias is provided via the microstrip $l_4\times w_4$ to adjust the states of PIN diodes. Two concentric annular-ring patches are printed on Layer 3. The annular-ring with inner radius r_3 and outer radius r_4 is named as the small-ring patch. The annular-ring with inner radius r_5 and outer radius r_6 is named as the large-ring patch. The proposed antenna is excited at dual-band, WLAN at 2.4GHz and WiMax at 3.5GHz, by the functional microstrip circuit module coupled to the annular slot and the annular-ring patches. The annular slot on Layer 1 is responsible for the operation of WLAN band and the annular-ring patches on Layer 3 is used for the operation of WiMAX band.

Initially, by calculating the quarter wavelength of the operation frequency for WLAN band and WiMAX band, the sizes of the annular slot and the annular-ring patches were determined. Then, the simulation software Ansoft HFSS was applied to optimize the geometry parameters of the proposed antenna. The configurable circularly polarized modes of the proposed antenna are shown in Fig. 2. Consequently, the PIN diode makes a good RF (radio frequency) switch. When the PIN diode 1 is kept in ON mode (short-circuited state) and the PIN diode 2 is in OFF mode (open-circuited state), left hand circular polarization (LHCP) is obtained. In the contrary, when the PIN diode 1 is kept in OFF and PIN diode 2 is ON, right hand circular polarization (RHCP) is thus obtained. For demonstration, the subdivisions of the implemented antenna are shown in Fig. 3 and Fig. 4.

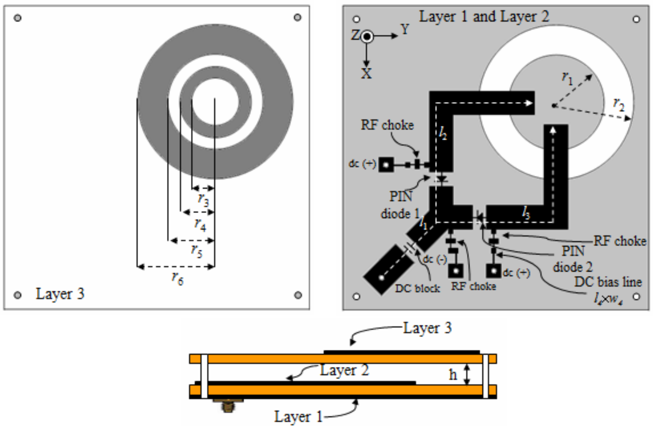

Fig. 1. Geometry structure of the proposed antenna (r_1=8.5mm, r_2=14.5mm, r_3=5.5mm, r_4=7mm, r_5=7.5mm, r_6=12.5mm, l_2=l_3=32mm, l_1=12mm and $l_4 \times w_4 = 3 \times 1mm^2$)

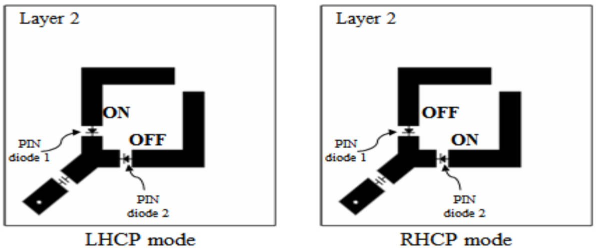

Fig. 2. Configurable polarizations of the proposed antenna.

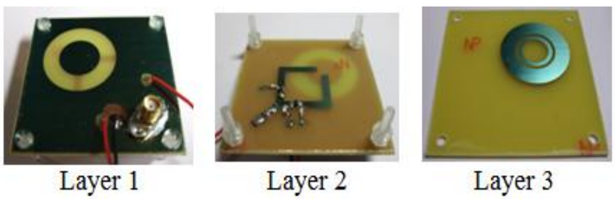

Fig. 3. The subdivisions of proposed antenna. (Layers of circuit board)

Fig. 4. The DC bias circuit of proposed antenna

III. Measurements and Simulations

The return loss of the antenna is depicted in Fig. 4 and Fig. 5. As seen in Fig. 4, the antenna without Layer 3 is operated at WLAN band only and, with adding of Layer 3, the antenna is then operated at dual-band. In addition, the comparison of the measured and simulated return loss of the antenna is also plotted in Fig. 5. The measured two-dimensional patterns and the simulated three-dimensional patterns for LHCP and RHCP of the proposed antenna are shown in Fig. 6 and Fig. 7, respectively. As in Fig. 6, E_θ of x-z plane for LHCP mode at 2.4GHz is shaped like a number of "8" and E_Φ of x-z plane is shaped like omni-directional radiation. As the ground of the antenna affects the radiation pattern at 3.5GHz, the E_θ and E_Φ of x-z plane are shaped like a number of "8". Comparatively, in 3D simulation pattern, it is confirmed in Fig. 6 that the radiation in Z direction is demonstrated the same as in 2D measuring. The radiation patterns of RHCP mode have the same performances and shown in Fig. 7. The proposed antenna has thus good performances of the radiation pattern. The measured bandwidths of the proposed antenna for LHCP mode are demonstrated 23.3% at WLAN band and 18.3% at WiMAX band, respectively. The bandwidths for RHCP mode are also demonstrated 24.2% at WLAN band and 17.7% at WiMAX band. Details of the simulation and measurement results are listed in Table 1.

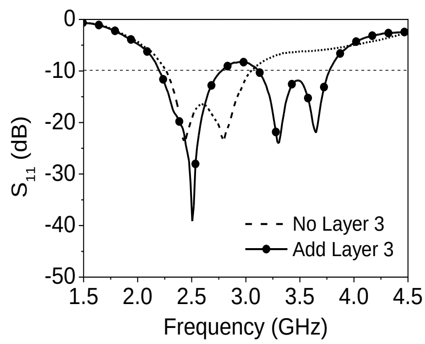

Fig. 4. Return loss of the proposed antenna, the comparison of with and without Layer 3.

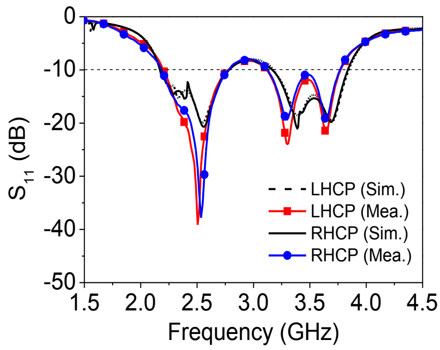

Fig. 5. The measured and simulated return loss of the antenna.

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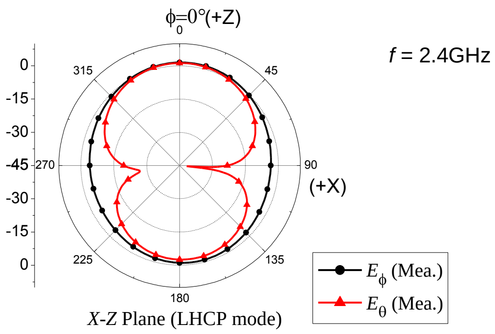
Table 1: Simulations and measurements of proposed antenna.

Mode: LHCP, Diode 1: ON, Diode 2: OFF				
Bands [GHz]	S11 [dB]		Bandwidths[%]	
	Sim.	Mea.	Sim.	Mea.
2.4	-13.8	-20.5	25	23.3
3.5	-15	-12.1	18.9	18.3
	3dB Axial Ratio Bandwidths [%]		Gain [dBi]	
2.4	7.9		4.61	
3.5	2.9		6.47	
Mode: RHCP, Diode 1: OFF, Diode 2: ON				
Bands [GHz]	S11 [dB]		Bandwidths[%]	
	Sim.	Mea.	Sim.	Mea.
2.4	-15.3	-18	25.4	24.2
3.5	-15.7	-11	18.8	17.7
	3dB Axial Ratio Bandwidths [%]		Gain [dBi]	
2.4	7.8		4.65	
3.5	3.1		6.68	



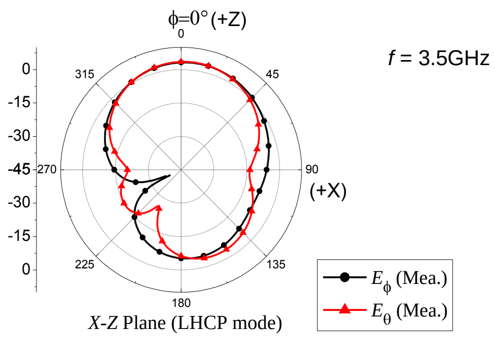
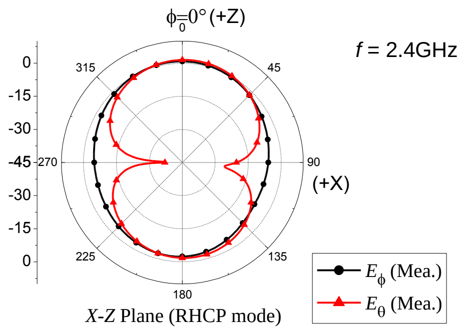


Fig. 6. Measured (2D) and simulated (3D) patterns of the proposed antenna (LHCP mode).



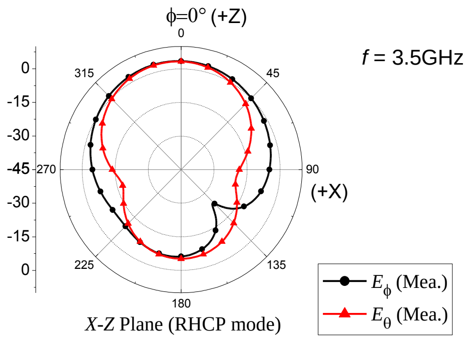


Fig. 7. Measured (2D) and simulated (3D) patterns of the proposed antenna (RHCP mode).

IV. Conclusion

In this research, a novel circular polarized dual-band annular patch antenna for WLAN and WiMAX was presented. The antenna uses a single probe feed and two branches of microstrip lines, perturbing the surface current, to reconfigure the circular polarized states. Meanwhile, the polarization states can be manipulated by the ON/OFF modes of PIN diodes placed on each microstrip line. The calculated and measured results confirmed that our proposed antenna has good performance and the module can be functioned as what we manage with.

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