A Polarization-Agile Stub-Loaded Square Patch Antenna with Proximity Coupled Feed

Hsinju Chen and Shih-Yuan Chen
Graduate Institute of Communication Engineering
National Taiwan University
Taipei 10617, Taiwan
r06942011@ntu.edu.tw; shihyuan@ntu.edu.tw

***Abstract*—A novel design of a polarization-agile microstrip-line-coupled-fed patch antenna is proposed. The simple structure of the proposed antenna consists of a square patch symmetrically loaded with two PIN-diode connected short-circuited stubs, and the use of proximity-coupled feed allows inherent impedance matching and RF and DC signal isolation without the need of DC blocking components. The fabricated 1.6-GHz prototype of our proposed antenna, when biased with different DC voltages, can achieve linear and right- and left-handed circular polarizations, respectively.**

***Keywords*—dc bias circuits, polarization-agile antennas, proximity-coupled feed, square patch antennas.**

I. Introduction

Polarization-agile antennas have been gaining popularity along with the development of wireless and satellite communications due to their capabilities of frequency reuse, fading mitigation, signal enhancement, etc. [1] By realizing polarization agility with a patch antenna, it provides easy attachment to surfaces with its lightweight and low-profile planar structure, and desirable conformability with RF circuitry, which is especially suitable for satellite applications [2]. In this work, we present a simple polarization-switchable, stub-loaded, proximity-coupled single-fed square patch antenna for achieving agility among linear and right- and left-handed circular polarizations (LP, RHCP and LHCP).

II. Proposed Polarization-Agile Patch Antenna

A. Antenna Structure and Design

Fig. 1 depicts the geometry of the proposed antenna. The square patch antenna is symmetrically loaded with two short-circuited stubs connected by two PIN diodes for polarization switching. The polarities of the two PIN diodes, D_1 and D_2, are oriented as shown in Fig. 1. The relation of its operational states with polarizations are tabulated in Table I. While normal square patches (without the two stubs or without connection with both stubs) are linearly polarized, the addition of the stubs allows the square patch to be circularly polarized when electrically connected to one of the short-ended stubs. In our proposed design, we use inset gap-coupled microstrip feedline for the antenna. With the coupling gap, the microstrip feedline is disconnected from the patch, resulting in inherent RF and DC signal isolation. For verification, a series of prototype antennas designed to operate near 1.6 GHz for GNSS applications are fabricated using 1.6-mm FR4 dielectric slabs.

TABLE I. Relation between Diode States and Polarization States

		Diode D1	
		OFF	ON
Diode D2	OFF	LP	LHCP
	ON	RHCP	

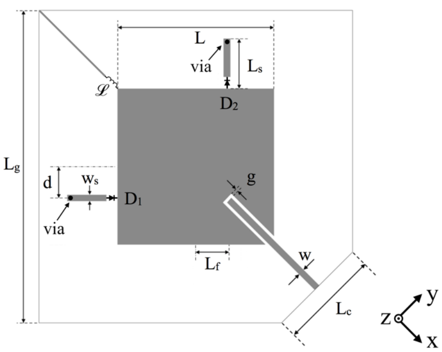

Fig. 1. Layout of the proposed patch antenna. (L_g = 100 mm, L = 43.9 mm, L_f = 11 mm, L_s = 11 mm, d = 6 mm, w_s = 1 mm, w = 1 mm, g = 0.1 mm, L_c = 20w)

B. Operational Mechanism of Proposed Antenna

A CP wave can be achieved by two perpendicular LP waves of the same amplitude and in-phase quadrature. The equal amplitudes can be readily achieved by orienting the microstrip feedline along the diagonal direction of the patch. So, if we can create 90° phase difference for the two LP waves at two perpendicular edges of a square patch antenna, we would be able to generate CP radiation. Since the edge of the square patch antenna is equivalent to an open-circuited microstrip line, we can add either short or open stub with an approximate length of one-eighth of the guided wavelength (λ_g) at one edge to attain the 90° phase difference (lead or lag) from an open circuit. In our design, we use short-circuited stubs for ease of DC grounding from the backside of the antenna. Accordingly, the control DC bias voltage is applied to the square patch, which is isolated from the RF feedline as mentioned above. As indicated in Fig. 2, E_1 is a LP component of the electric-field vector, and E_2 is perpendicular to E_1. By having the short stub connected to the left edge of the patch, the stub virtually moves the open boundary $\lambda_g/8$ into the patch, thereby creating a 90° lead for E_1, and the structure operates as an LHCP patch antenna. If the short stub is at the top edge, the antenna is of RHCP. Without the stubs, the structure works as a normal LP patch antenna at a slightly lower frequency band. Last but not least, by adjusting the offset d of the short stubs from the center line of the patch,

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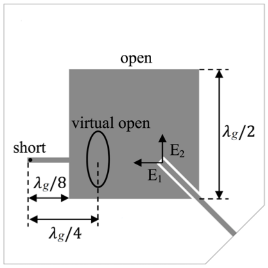
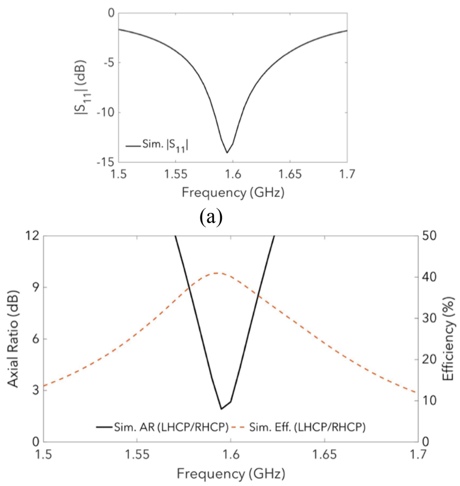


Fig. 2. Illustration of the CP working mechanism.



(b)

Fig. 3. Simulated results of the CP prototype antenna with ideally connected stubs. (a) $|S_{11}|$ and (b) AR and antenna efficiency.

we can align the CP operating band with the frequency range with the best impedance matching.

C. Simulated results of CP Prototypes with Ideally Connected Stubs (Without PIN Diodes)

To verify our design concept, the CP prototypes with the copper-connected (to replace the ON-state PIN diode) stubs are simulated. All the simulations in this study were carried out using Ansys HFSS. Fig. 3 shows the simulated reflection coefficients. The antenna is well matched ($|S_{11}| \le -10$ dB) between 1.584 GHz and 1.609 GHz. As for the axial ratio (AR), the antenna exhibits AR ≤ 3 dB for frequency range between 1.592 GHz and 1.601 GHz, which is fully covered by the impedance matched band. At the CP frequency of 1.595 GHz, the simulated realized gain is 2.77 dBi with antenna efficiency of 43%. The lower gain and efficiency are attributed to the higher dielectric loss of the FR4 substrate in use.

D. Results of Prototype with Diodes and DC Biasing Circuit

Since the inset gap-coupled feed can provide inherent DC and RF signal isolation, we can directly apply DC voltage to the patch without the need of DC block capacitors. To provide the biasing voltage while not affecting the resonant current mode on the patch, an area with the least surface current distribution is identified and chosen for DC voltage application as shown in Fig. 4. At the opposite corner of the feedline, a 45.6-nH Murata inductor is inserted as RF choke before connecting to the DC power supply. In our simulations, the PIN diodes (Skyworks SMP1322-040LF) are modeled as 0.8 Ω for ON state and as 2.1 kΩ in parallel with 0.3 pF for OFF state. The simulated and

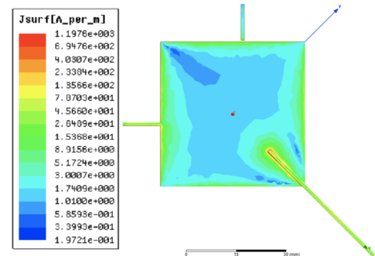
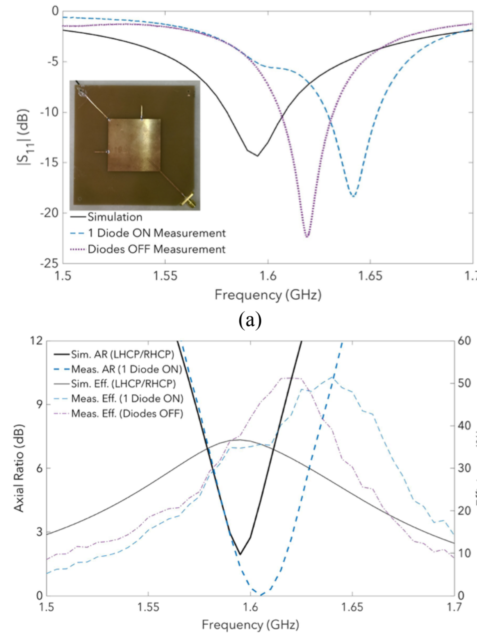


Fig. 4. Surface current distribution of proposed antenna at CP modes.



(b)

Fig. 5. Simulated and measured results of the polarization-agile prototype antenna at different modes. (a) $|S_{11}|$ and (b) AR and antenna efficiency.

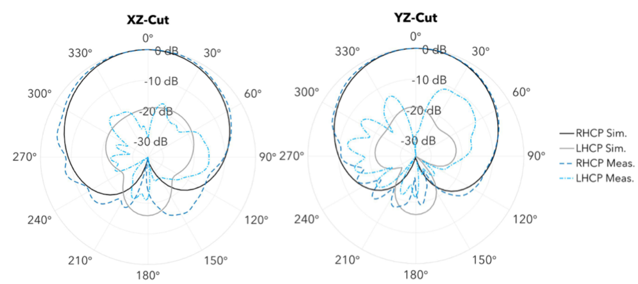


Fig. 6. Patterns of the polarization-agile prototype antenna at RHCP mode.

measured responses of $|S_{11}|$, AR, and antenna efficiency of the diode-loaded polarization-agile prototype antenna operating at the associated modes are shown in Fig. 5. The simulated and measured principle-plane patterns of the CP mode are plotted in Fig. 6, and they are in good agreement. Indeed, the proposed antenna can switch among LP, RHCP, and LHCP when the patch is biased at 0 V, +0.8 V, and –0.8 V, respectively.

REFERENCES

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