Polarization Reconfigurable Frequency-scanning Antenna Based on Half Mode Substrate Integrated Waveguide

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***Abstract* - A novel polarization reconfigurable leaky-wave (LW) antenna based on half-mode substrate integrated waveguide (HMSIW) is presented. Compared with SIW antenna, HMSIW reduces the volume of antenna a lot with similar capability [1]. The proposed antenna consists of a pair of symmetrical +45°/-45° linearly polarized leaky lines. By changing the means of excitation, six different polarization states including four linear polarization (LP) states and two circular polarization (CP) ones are verified. Because the antenna is designed with a balanced composite right/left-handed (CRLH) structure, under each polarization states, the proposed antenna can achieve continuous beam-steering from left-handed (LH) region to right-handed (RH) region as frequency changes. Parameters including S-parameters, gain and axial ratio (for CP states) are demonstrated. Measured results are closely consistent with the simulation.**

***Index Terms* — polarization reconfigurable antenna, HMSIW, leaky lines, CRLH, beam steering.**

1. Introduction

Polarization is an important parameter for antennas especially when they are used as transmit end or receive end in the wireless communication systems. Polarization reconfigurable antennas are able to provide several different polarization states depending on the requirement. Compared with devices with multi antennas, reconfigurable antennas are more compact. They can achieve multiple functions in one antenna aperture. This characteristic can degrade the coupling among several antennas [2], [3].

A polarization reconfigurable frequency-scanning antenna based on HMSIW is proposed in this paper as follows. The configuration of the proposed antenna and its working principles are illustrated in Section 2. The results including S-parameters, gain and axial ratio are demonstrated in Section 3. Finally, Section 4 draws the conclusion.

2. Proposed Structure and Working Principle

(1) Geometrical Layout

The geometrical configuration of the proposed CRLH HMSIW LW antenna is demonstrated in Fig. 1 including the parameters of the unit-cell elements and the prototype of the entire structure with its orientations in the coordinate system. As shown, the interdigital slots etched on the HMSIW surface are ±45°inclined compared to the propagation direction (Y-directed), they can generate ±45° orthogonally linearly polarized waves. Two linearly polarized leaky lines are arranged side by side with a small substrate distance (w) to improve the isolation between them. Each of these two lines has 5 interdigital slots etched on the top layer of the HMSIW. The antenna can achieve balanced CRLH operation.

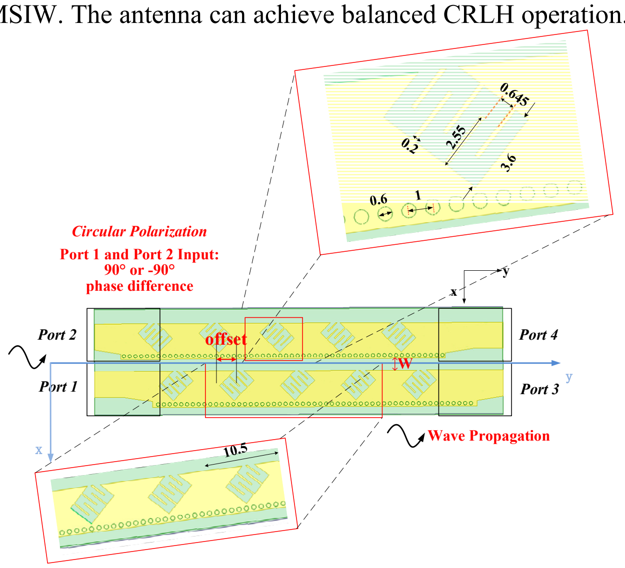

Fig. 1. Configuration of the reconfigurable antenna

(2) Polarization Reconfigurable Capability

The principles of radiating different polarization modes are explained in Table I. The two leaky lines radiate two orthogonally polarized waves. When excited at port 3 or 4 separately, a 45°or -45°LP radiation can be generated. When these two ports are excited by two equal and in-phase signals simultaneously, the Y-polarized wave can be produced, and when they are excited by two signals with same magnitude but 180° phase, the X-polarized waves can be obtained. Also, when excited at port 1 and port 2 with +90° phase difference, an ideal RHCP wave is obtained. Besides, when excited at port 1 and port 2 with -90° phase difference, an ideal LHCP wave is obtained. With the balanced composite right/left-handed structure, this reconfigurable antenna can achieve frequency-scanning under each polarization state.

TABLE I
Polarization configurable capability

Polarization State	Excitation Means	Electric Field Distribution	Working Scheme
+45° Linear-Polarization *Port 3*	$E_1 \neq 0, E_2 = 0$		
-45° Linear-Polarization *Port 4*	$E_1 = 0, E_2 \neq 0$		
Y-directed Linear-Polarization *Port 3 and Port 4, α=0°*	$E_1 = E_2$ And α=0°		
X-directed Linear-Polarization *Port 3 and Port 4, α=180°*	$E_1 = -E_2$ And α=180°		
Right-Handed Circular-Polarization *Port 1 and Port 2, α=90°*	$E_1 = E_2$ And α=90°		
Left-Handed Circular-Polarization *Port 1 and Port 2, α=-90°*	$E_1 = E_2$ And α=-90°		

3. Simulation and Experiment Results

Through full-wave simulation and optimization, we propose a reconfigurable antenna based on HMSIW. The proposed antenna is realized using Rogers RT/Duroid 5880 substrate with a thickness of 1.575mm and a relative permittivity of 2.2. The via holes of HMSIW have the diameter of 0.6mm. and center-to-center spacing of 1mm. Fig. 2 shows a photograph of the fabricated antenna.

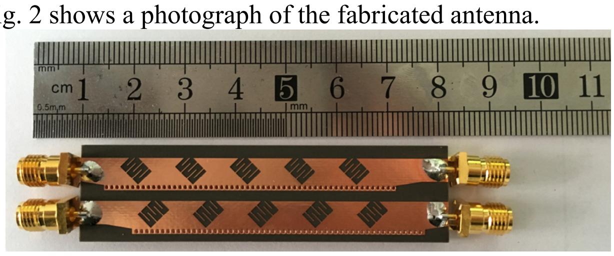

Fig. 2. Prototype of the fabricated antenna

Fig. 3 shows the measured and simulated S-parameters of the antenna. They are all below -10 dB which means most energy radiates through slots. It can be seen that measured results are closely consistent with the simulation.

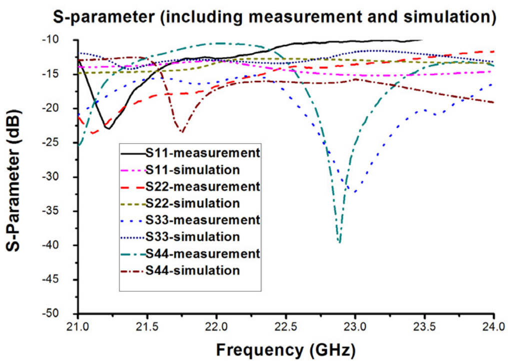

Fig. 3. S-parameters of the antenna

As table I shows, circularly polarized antenna is obtained by exciting two orthogonally polarized radiating structure with 90° or -90° phase difference. The phase difference is achieved by a 90° hybrid from Pulsar Microwave Corporation. Fig. 4 shows the simulated gain patterns in the LH region, broadside, and RH region for RHCP and LHCP respectively. The detailed scanning angles can also be seen. Fig. 5 shows the simulated axial ratio of the main beam at different frequencies under these two conditions.

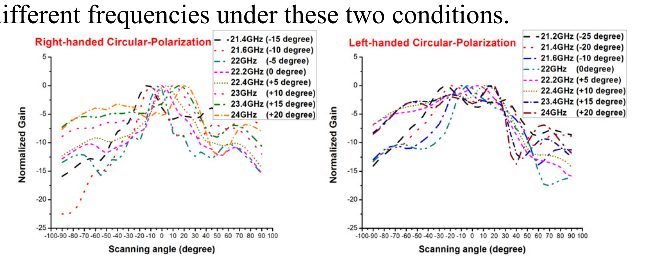

Fig. 4. Circular polarization frequency-scanning results

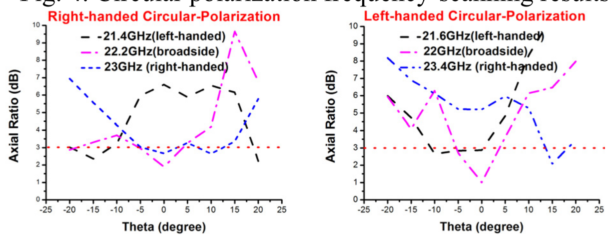

Fig. 5. Axial ratio for RHCP and LHCP

The linearly polarization is obtained by exciting port 3 and port 4. Fig. 6 shows four kinds of linear polarization.

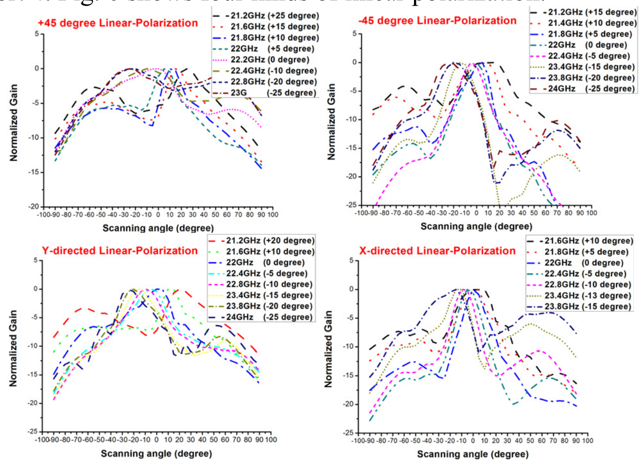

Fig. 6. Linear polarization frequency-scanning results

4. Conclusion

In this paper, a HMISW polarization reconfigurable antenna is proposed. Under six polarization states, the antenna can achieve beam steering from left-handed region to right-handed region with balanced CRLH structure.

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