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Design of A Reconfigurable-Polarization Slot-Ring Phased Array Antenna

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***Abstract*—In this paper, a reconfigurable-polarization slot-ring phased array antenna with narrow strip ground plane has been proposed for *C*-band applications. This antenna operates from 5.42 to 7.87 GHz, achieving 37% fractional bandwidth, and 7.6 dBi gain. The microstrip line is placed diagonally and is within the perimeter of a single antenna element which makes the antenna scalable. A 2×2 array has been constructed with $0.5\lambda_0$ element spacing. The array is fed from the center of each element through a coaxial line. This array is capable of vertical, horizontal or circular polarization by properly feeding each port of the antenna element. In addition, this array is shown to be able to scan to ±30 degrees.**

***Index Terms* — beam steering, diagonal feeding, reconfigurable polarization, slot-ring antenna.**

I. Introduction

Reconfigurable-polarization antennas are increasingly gaining attention in modern wireless communication systems as they can mitigate multipath fading and avoid polarization mismatch [1]. To achieve reconfigurable-polarization antennas, three methods were demonstrated in [2]. The first one was to adopt a reconfigurable feeding network. The second one was to introduce controllable perturbation segments in the antenna structure while the third method was using dielectric liquid. Recently, many reconfigurable-polarization antennas have been proposed to switch the polarization among linear (vertical or horizontal), left-hand circular polarization (LHCP), and right-hand circular polarization (RHCP) [2, 3]. These antennas require PIN diodes to control the polarization states and are limited in beam steering capability. In addition, a dual-polarized antenna was presented in [4] which can switch between *S* and *C* bands. This antenna requires one feed port for each linear polarization, respectively. To reduce hardware complexity, a new arraying technique (diagonal feeding technique) was proposed in [5] for digital phased array antennas. This technique helps to improve the isolation between antenna elements by reducing the number of feeding ports by 50 percent.

However, the antenna demonstrated in [5] requires complex circuitry to operate in two frequency bands. Moreover, the microstrip feeding line exceeds the perimeter of a single antenna element which will make extending to a larger array difficult when half-wavelength spacing is necessary. By adopting this novel diagonal feeding technique, a reconfigurable-polarization antenna array is proposed in this paper which can switch polarization among horizontal, vertical, LHCP, and RHCP for single-band operation without the need of any PIN diode.

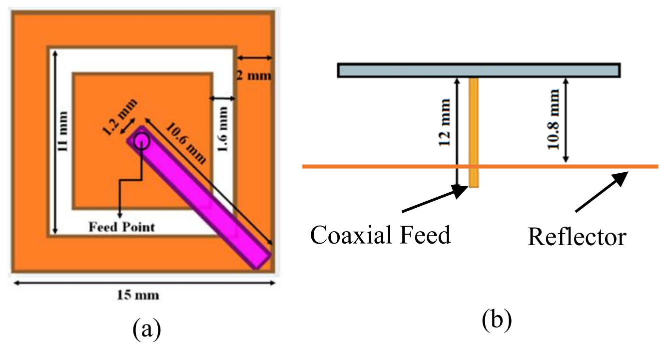

Figure 1. (a) Top and (b) side view of the slot-ring antenna.

This antenna is fed from the center of the structure and the microstrip line is placed diagonally to make the main beam symmetrical in the entire bandwidth. The microstrip line is completely within the perimeter of a single antenna element. Besides, a reflector has been placed at the back of the narrow-strip ground plane and the distance is kept approximately $\lambda_0/4$ to achieve the single-sided radiation. Simulation results of this antenna show 37% fractional bandwidth (FBW), 98% radiation efficiency, 7.6 dBi realized gain, <1.75 dB axial ratio and constant radiation patterns across the operational bandwidth. Furthermore, this proposed antenna is capable of scanning the beam to ±30˚.

II. Design Methodology

The schematic diagram of a single element of the slot-ring antenna is shown in Figure 1. The antenna is designed on Rogers RT/Duroid 5880 substrate whose dielectric constant is 2.2. The side of the slot is approximately $\lambda_0/4 \approx 11$mm and the width of the slot is kept at 1.6 mm. The length and width of the microstrip line is 10.6 mm and 1.2 mm, respectively and the feeding point is placed in the center of each antenna element. All the dimensions mentioned above were optimized to achieve the best antenna characteristics.

The schematic of the 2×2 slot-ring antenna array is shown in Figure 2. The spacing among the elements is optimized at $0.5\lambda_0$ distance to increase the beam scanning angle with grating lobes.

III. Simulation Results and Discussions

The array is simulated in ANSYS High Frequency Structure Simulator (HFSS). The coaxial feeding lines go

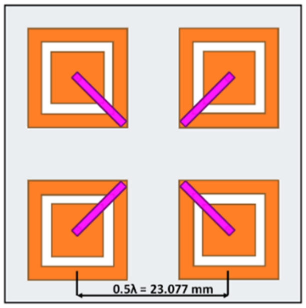

Figure 2. Schematic of the reconfigurable-polarization antenna array.

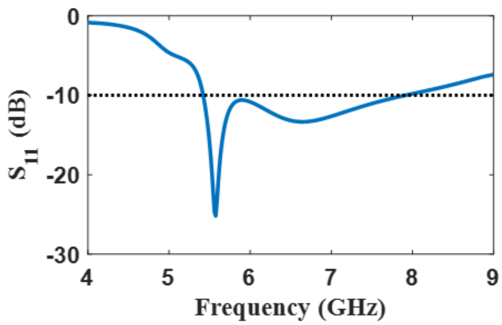

Figure 3. Return loss of a single slot-ring antenna.

through the reflector and their inner conductors are attached to the microstrip lines. The outer conductor of each coaxial line is connected to the reflector and the middle patch inside each slot ring. Figure 3 shows the return loss characteristics of a single slot-ring antenna, and the bandwidth from 5.42 to 7.87 GHz, representing a 37% FBW.

The radiation patterns for different polarization of the antenna array are shown in Figure 4. It should be noted here that because the radiation pattern in the entire frequency range is almost identical, it can be used without any limitation for the entire bandwidth. By changing the phases of the four feeding lines (demonstrated in Figure 4), this array achieves vertical, horizontal, or circular polarization with <0.2 dB axial ratio from 5.42 to 7.3 GHz, and <1.75 dB from 7.3 to 7.9 GHz.

In addition to reconfigurable polarization, this array has beam steering capability. Figure 5 shows the 30-degree beam steering for horizontal, vertical, and circular polarization, respectively.

IV. CONCLUSION

A reconfigurable-polarization phased array slot-ring antenna has been presented in this paper. This array operates at *C* band and achieves 37% FBW and 7.6 dBi gain. In addition, the array is suitable for different polarizations and beam steering without the help of any PIN diode switch. Microstrip feed lines remain in the perimeter of the single antenna element meaning this antenna configuration can easily be extended to a larger array. This antenna array is most suited to digital phased arrays which can generate the required phases for different polarizations.

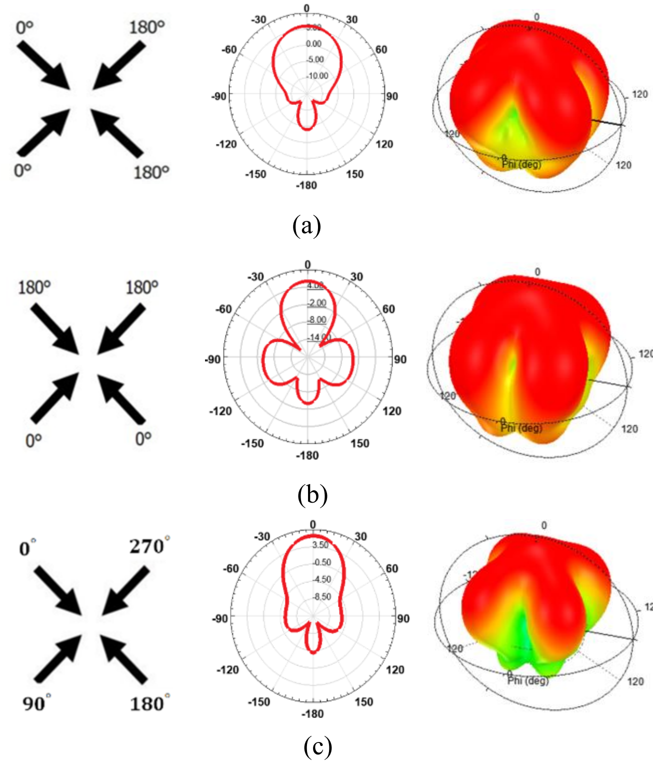

Figure 4. Radiation pattern for (a) horizontal, (b) vertical, and (c) circular polarization at 0° phi angle.

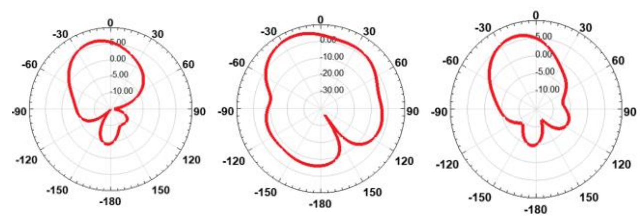

Figure 5. Beam steering for horizontal, vertical, and circular polarization at 0° phi angle.

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