A Wideband Reconfigurable-Polarization Slot-Ring Phased Array Antenna for Sub-6 GHz

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***Abstract*— This paper introduces a wideband slot-ring phased array antenna for sub-6 GHz applications. Incorporating meandered lines in the slot ring significantly improves the bandwidth performance of this antenna. The operation frequency of this antenna ranges from 2.87 to 4.91 GHz corresponding to a fractional bandwidth of 53%. The spacing between antenna elements in the 2×2 array is maintained at $0.5\lambda_0$ at the center frequency. This array demonstrates the ability of beam steering to ±30 degrees. In addition, the gain of the 2×2 array is shown to be 10 dBi. The coax-to-microstrip feeding technique is used to excite each antenna element. Notably, this array is able to achieve different polarization states (horizontal, vertical, and circular) by simply changing the phase at each port.**

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

I. Introduction

In modern wireless communication systems, there is a growing demand for wide frequency coverage, which can be accomplished by either increasing the antenna bandwidth or utilizing multiband antennas [1]. However, the performance of these antennas is frequently limited by the polarization mismatch between the transmitting and receiving antennas. As a result, reconfigurable-polarization antennas are becoming popular day by day. In recent years, numerous antennas have been proposed for reconfigurable polarizations but are limited in terms of beam steering performance [2, 3]. In [4], a novel diagonal feeding technique was proposed to achieve reconfigurable polarizations at both *S* and *C* bands along with beam steering capability. While this approach is attractive, it is not suited for single-band operation and is too complicated in hardware implementation. For this reason, a much simpler slot-ring phased array antenna was proposed in [5] for *C* band. This antenna achieved 37% fractional bandwidth (FBW), 98% radiation efficiency, and 7.6-dBi realized gain.

This paper focuses on improving the bandwidth performance compared to the work presented in [5] for sub-6 GHz applications. Characteristics mode analysis (CMA) has been used to design this antenna. Similarly, this antenna is fed by a coaxial cable which is terminated with a microstrip line on top of the dielectric substrate at the diagonal direction of the square slot ring as shown in Fig. 1. To improve the bandwidth performance of this antenna, meandered lines are incorporated in both the narrow-strip ground plane and the patch in the middle. 53% FBW can be realized in the design. The realized gain of this 2×2 array increases from 7.6 dBi [5] to 10.1 dBi in this paper. In simulations, this antenna shows 94% radiation efficiency, <0.1 dB axial ratio (circular polarization), and good beam squinting performance in the operational frequency range. Additionally, this antenna is capable of beam steering to ±30° at any polarization state.

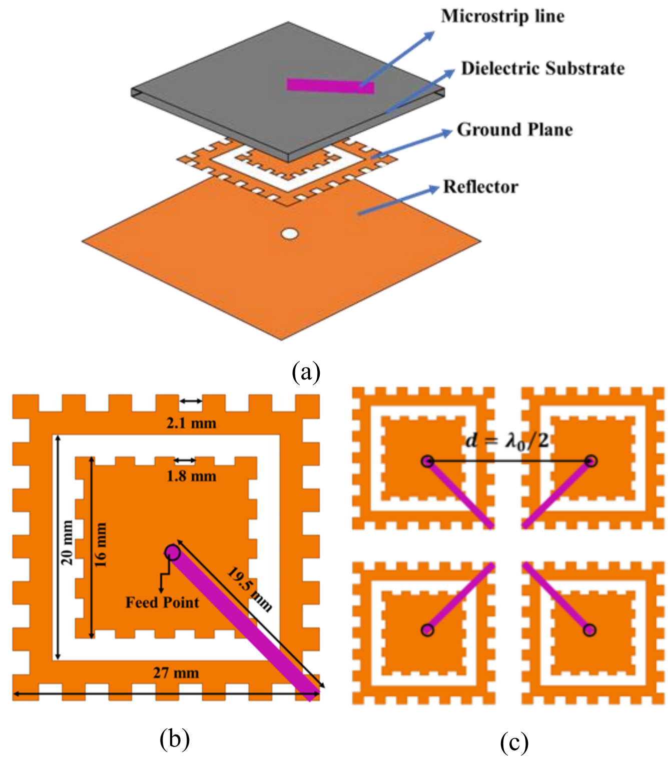

Figure 1. (a) 3D and (b) top view of the slot-ring antenna and (c) the schematic of 2×2 array.

II. Antenna Design

The physical structure of a single element of the slot-ring phased array antenna is shown in Fig. 1(a) and (b). The lateral sizes of the square patch and narrow strip ground are 16 and 27 mm, respectively. CMA has been used herein to find the optimal dimensions of the meandered lines. The incorporation of these meandered lines can effectively move the two resonances which are caused by the center patch and narrow ground away from each other, and therefore a much wider bandwidth is realized. The meandered lines are equally spaced, with a gap of 2.1 mm within the narrow strip ground and a gap of 1.8 mm within the square patch. The length and width of the microstrip lines are adjusted to achieve good impedance matching. The inner conductors of the coaxial cables are connected to the microstrip

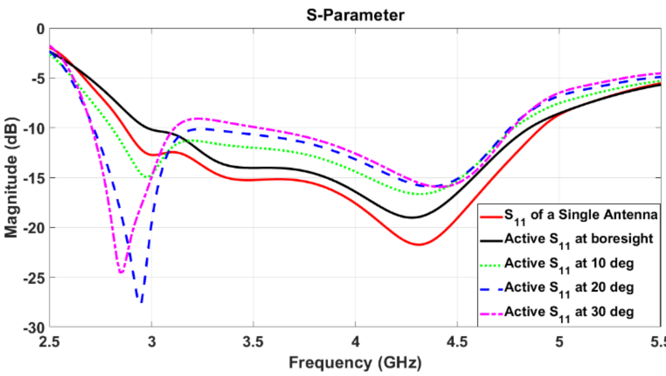

Figure 2. S parameter of a single element and 2 × 2 array at different scanning angles, respectively.

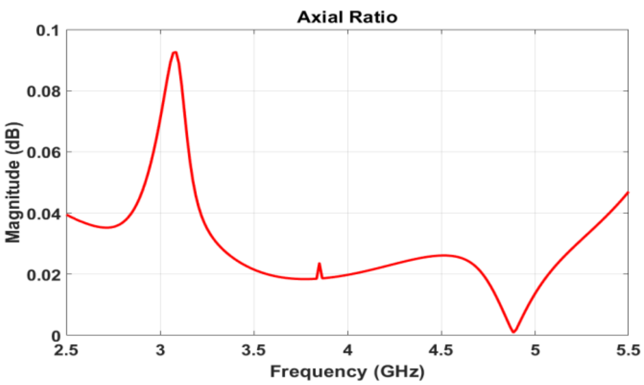

Figure 3. Axial ratio of circularly polarized 2 × 2 array.

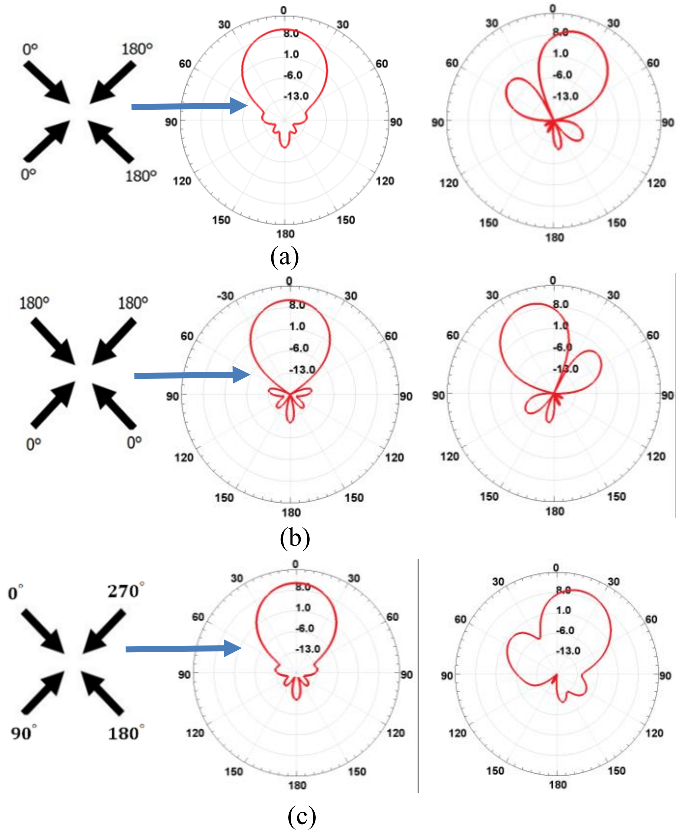

Figure 4. Radiation patterns at boresight and 30° for (a) horizontal, (b) vertical, and (c) circular polarization.

lines, while the outer conductor is soldered to the reflector and square patch. It is important to note that the location of the feed point is strategically chosen to achieve uniform radiation pattern across the entire operational bandwidth.

III. Simulation Results and Discussions

In Fig. 2, the return loss characteristics of the slot-ring antenna are illustrated. The impedance matching of the antenna elements in this array is not much deteriorated when the mutual coupling is considered at all scan angles. The fractional FBW is found to be 53% (2.87-4.91 GHz). At the circular polarization operation state, the axial ratio is shown to be < 0.1 dB across the entire operating frequency range, as shown in Figure 3.

The radiation patterns for different polarization states and at different scan angles of the 2 × 2 array is illustrated in Fig. 4. The phases required to realize vertical, horizontal, or circular polarization states for the boresight radiation are shown in Fig. 4. In order to steer the beam, an additional phase difference needs to be added on top of the aforementioned phases. The right column of Fig. 4 presents the beam scanning to 30 degree each polarization state. Also, the radiation patterns have been checked which are very stable across the frequency bandwidth.

IV. Conclusion

This paper presents a wideband slot-ring phased array antenna for the sub-6 GHz applications. The proposed antenna covers a near octave bandwidth and the array element spacing is half wavelength at the center frequency. This wideband array can support many sub-bands for 5G NR with beam steering capability. Moreover, the reconfigurable polarization capability allows this array to realize maximum signal-to-noise ratio under complex propagation environments. It should also be noted that the proposed array is scalable to much larger size for massive MIMO applications.

V. Acknowledgements

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