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Circularly polarized co-designed filtering annular slot antenna

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ABSTRACT

In this paper, a compact circularly polarized co-designed filtering annular slot antenna (ASA) is proposed. The antenna comprises a distributed capacitor-loaded annular slot radiator to produce circular polarization (CP) radiation, which is seamlessly integrated with a microstripline bandpass filter (BPF) to enhance out-of-CP-band suppression. Two tightly coupled arc branches protruding into the annular slot are used to provide the required perturbation capacitance. The filter is designed by employing three concentric arc-shaped coupled microstripline resonators. The ground plane is shared by the annular slot radiator and the filter to reduce size occupation. It is found that the proposed antenna can not only yield high frequency selectivity, but also obtain widened CP bandwidth under the assistance of the filtering circuit. An antenna prototype has been fabricated and measured, showing that the antenna achieves a 10 dB return loss impedance bandwidth of around 13.7%, enclosing a 3 dB axial ratio (AR) bandwidth of more than 10.6%. Details of design considerations and experimental results are presented and discussed.

1. Introduction

In recent decades, slot antennas have been attracted significant attention to generate circular polarization (CP) radiation, because of the advantages including much wider achievable CP bandwidth and more tolerant to inevitable fabrication inaccuracies [1–8]. Though commonly recognized as circularly polarized antennas, further observation can reveal that these slot antennas typically exhibit an impedance bandwidth, defined by 10 dB return loss, of several times larger than the CP bandwidth defined by 3 dB axial ratio (AR). Considering Ref. [1] as an example, the impedance bandwidth of the devised shorted annular slot antenna (ASA) is 1514 MHz–2185 MHz (671 MHz), which is more than 4.6 times that of the corresponding CP bandwidth, i.e. 1625 MHz–1769 MHz (144 MHz). Consequently, as far as CP operation is concerned, undesirable signals and interferences will pass through the non-CP bands covered within the impedance bandwidths for such slot antenna designs, imposing heavy burdens on the RF transceivers.

Filtering antennas, usually abbreviated as filtennas, nowadays have received much research interests [10–18]. Various types of antennas, such as microstrip patch antennas [10–14] and printed monopole antennas [15–18], have been developed to acquire the filtering functionality. However, very few investigations on designing filtering slot antennas can be found in the literature [19], [20]. Unfortunately, these reported filtering slot antennas are restricted to linear polarization operation and have to increase physical dimensions to accommodate the filtering circuits. Therefore, slot antennas simultaneously possessing CP radiation and filtering characteristic without enlarging size occupation are more attractive for modern compact multi-channel communication systems, which suffer severely from more and more serious multi-path propagation environments.

In this paper, we propose a compact circularly polarized co-designed filtering ASA, which is implemented on a single layer substrate. The antenna is based on an annular slot radiator loaded by a distributed capacitor to excite CP radiation. Two tightly coupled arc branches are protruded into the annular slot to offer the necessary perturbation capacitance. Furthermore, a third-order Chebyshev bandpass filter (BPF) which is composed of three concentric arc-shaped coupled microstripline resonators is integrated inside the antenna feed line underneath the ground plane, which thus eliminates extra size occupation. Simulations and experiments have been conducted to demonstrate the antenna design concept. The measured and simulated results are in good agreement, showing that the filtering circuit simultaneously enhances the frequency selectivity and broadens the CP bandwidth. To the best of our knowledge, the proposed antenna is the first circularly polarized filtering slot antenna. In contrast to the conventional circularly polarized ASAs, the proposed antenna outperforms on achieving much wider CP bandwidth and better out-of-CP-band suppression.

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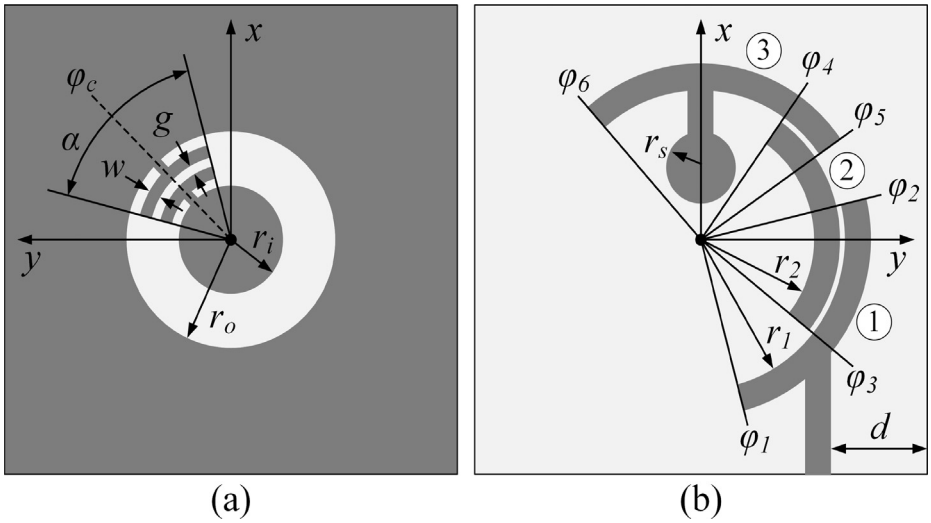

Fig. 1. Schematic configuration of the proposed circularly polarized filtering ASA. (a) Top view. (b) Bottom view.

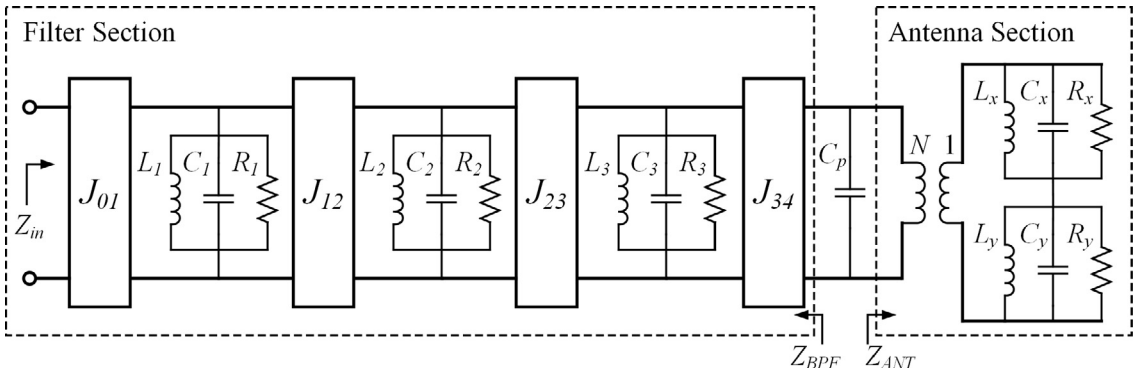

Fig. 2. Equivalent circuit of the proposed circularly polarized filtering ASA.

Table 1
Optimal parameters of the proposed circularly polarized filtering ASA.

Parameter	r_o	r_i	r_1	r_2	r_s	w	g	d
Value (mm)	13.5	11.5	19.7	15.8	2.8	0.7	0.1	11.65
Parameter	φ_1	φ_2	φ_3	φ_4	φ_5	φ_6	φ_c	α
Value (°)	175.4	87.7	126.6	18.7	52.3	−38.7	45.0	43.0

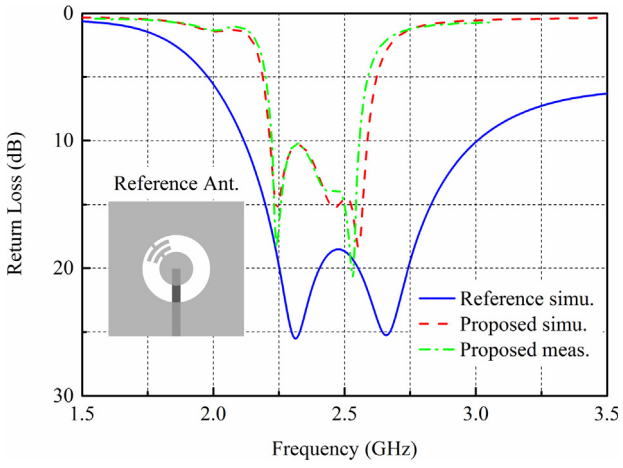

Fig. 3. Simulated and measured return loss of the proposed and conventional antennas.

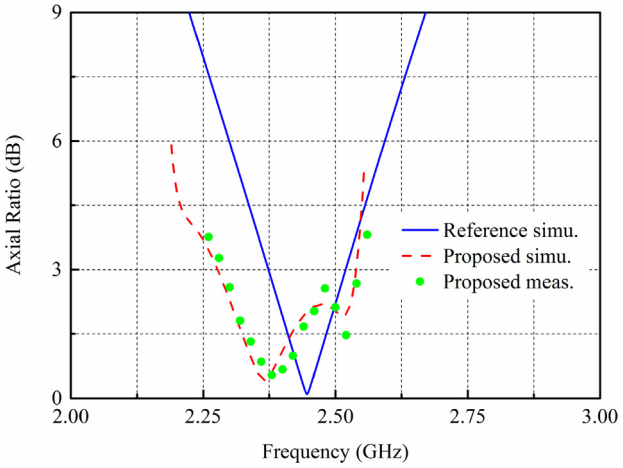

Fig. 4. Simulated and measured broadside AR of the proposed and conventional antennas.

2. Antenna design and discussion

2.1. Geometrical configuration

The schematic configuration of the proposed circularly polarized filtering ASA is presented in Fig. 1. The antenna is constructed on a low cost 1.6 mm thick FR4 substrate with a relative dielectric constant of 4.4 and a loss tangent of 0.02, whose overall size is 50 mm × 50 mm.