

Circularly Polarized Microstrip Antennas Using Single-Fed EM Coupled Ring Resonators

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1. Introduction

Microstrip antennas have been widely used for aerospace applications and in small portable wireless communication equipments because of their compactness, light-weight, low-profile, and relative ease of fabrication. The small size is an important requirement for portable applications. There are various types of microstrip patch configurations. In general, the size of a microstrip patch is about one-half effective wavelength on a dielectric at a fundamental mode resonant frequency. Changing the basic patch shape may yields a substantial size reduction. A square-ring antenna is one of the smallest circularly polarized microstrip antennas with a size of $\lambda_g/4 \times \lambda_g/4$ [1]. Circular polarization (CP) of a microstrip antenna can usually be achieved by feeding two detuned orthogonal signals to the radiating and non-radiating edges of a square patch antenna [2]. However, this dual-feeding mechanism has disadvantages of more complex geometry, larger size, and higher loss at a feeding network compared to a single feed one. Recently, ring radiating elements, such as square and annular rings, are drawing more attentions [3-8]. When operating in TM_{11} mode, a ring antenna has smaller in size than that of a circular and rectangular patch [8]. Square rings, which have been proposed for linear polarization, show that the width of the ring radiating element is critical for impedance matching [1], [5]. In the case of CP, two closely degenerated resonant modes of the rings are generated by either cutting diagonal slits or inserting symmetrical perturbation strips to the rings [3], [4]. Moreover, additional impedance transformers are required to match to the 50- Ω input port. In this paper, a simple feeding method has been proposed to obtain CP in microstrip square ring antennas. Impedance transformers, add-on slits, notches and strips are not required for circularly polarized radiation.

2. Theory

Fig. 1 shows the proposed CP ring antenna structures. The square ring microstrip patch has an outer side length of L_2 and an inner side length of L_1 . A 50- Ω microstrip feed line is electromagnetically coupled to the patch resonator. The coupling width is about a quarter guided wavelength at the resonance frequency ($\lambda_g/4$). The coupling gap between the patch and the feed line is optimized to obtain both the impedance matching and the CP operation. Hence, it is not necessary to insert any impedance transformer to the feed line for good impedance matching.

The surface currents on the square ring and the feed line are shown in Fig. 2. The size and orientation of the arrows represent the magnitude and polarity of the current, respectively. At the feed line, the input current is electromagnetically coupled to the ring patch and there is little reflected current from the open end. And the induced current on the ring antenna is directed to the feeding direction. In the proposed antenna, the feed current flows from right to left, so the current on the coupled ring antenna flows in a clockwise direction. This clockwise flowing current on the square ring contributes to a left-handed circular polarization (LHCP). Once right-handed circular polarization (RHCP) is necessary, we can simply feed the signal from the opposite side instead.

3. Antenna Design and Analysis

Square ring antennas are designed with a TACONIC TLY-5 substrate with a dielectric constant of 2.2, a loss tangent of 0.0009, and a thickness of 1.5748 mm. The electromagnetic simulation software ZELAND's IE3D [4] is used for analysis. In Table 1, the antenna parameters shown in Fig. 1 and the resulting antenna performance are presented. The outer side length of L_2 is fixed to 48 mm. The 50- Ω microstrip line has the width of 4.8 mm. Antenna 1 and 2 are a square ring patch with the inner side length of 24 mm and 36 mm, respectively. Antenna 3 is a meander ring which has a longer circumference than a normal square ring. Antenna 4 is an ordinary square ring. In this case, an impractical tight coupling gap is needed. So the results are shown only for comparison purpose. The return losses are shown in Fig. 3. As increasing the inner side length of L_1 , the resonant frequency is decreased but the bandwidth becomes narrow. The meander ring antenna resonates at the centre frequency of 1005 MHz which is about a half of the normal square patch antenna. The radiation patterns of the meander loop antenna at 1005 MHz are shown in Fig. 4. The coupled feed line does not significantly affect the radiation pattern at xz - and yz -plane. In all cases, a good LHCP characteristic is presented.

4. Conclusion

A compact single-layered single-fed electromagnetically coupled square ring and meander ring microstrip antennas are presented. Compared to a conventional square patch, the proposed ring antenna shows the reasonable size reduction. With the same area, the resonance frequency of the meander loop antenna is halved. Moreover, the compact single-layer single-fed structures eliminate a quarter-wave matching section, a 90 degree phase delay line, and DC block capacitors for active antenna applications.

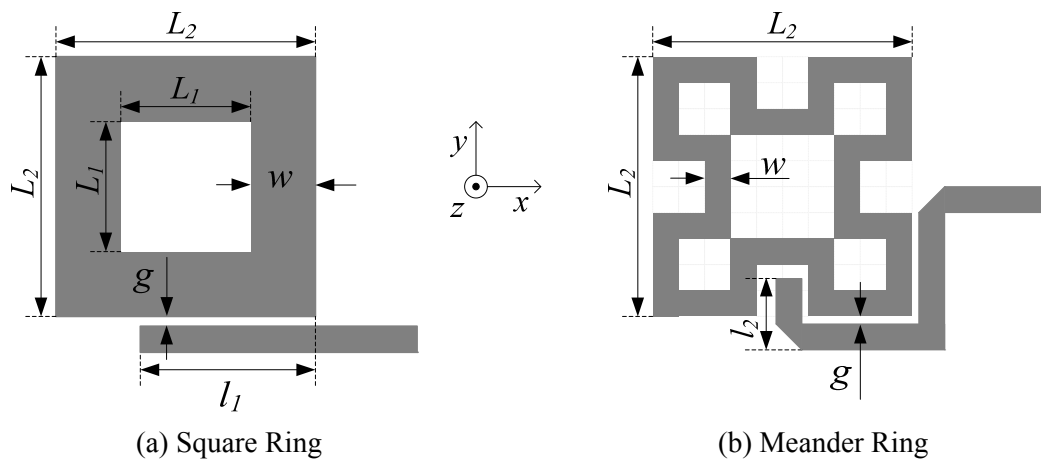
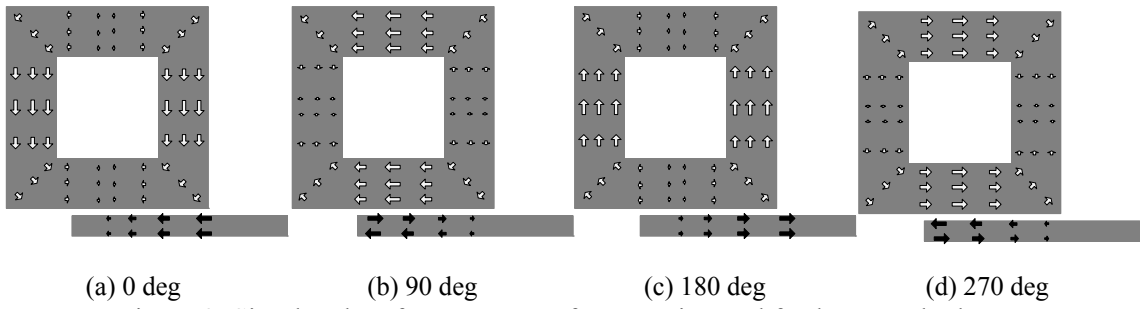


Figure 1. Proposed antenna structures.



(a) 0 deg (b) 90 deg (c) 180 deg (d) 270 deg
 Figure 2. Simulated surface currents of square ring and feeder at each phase.

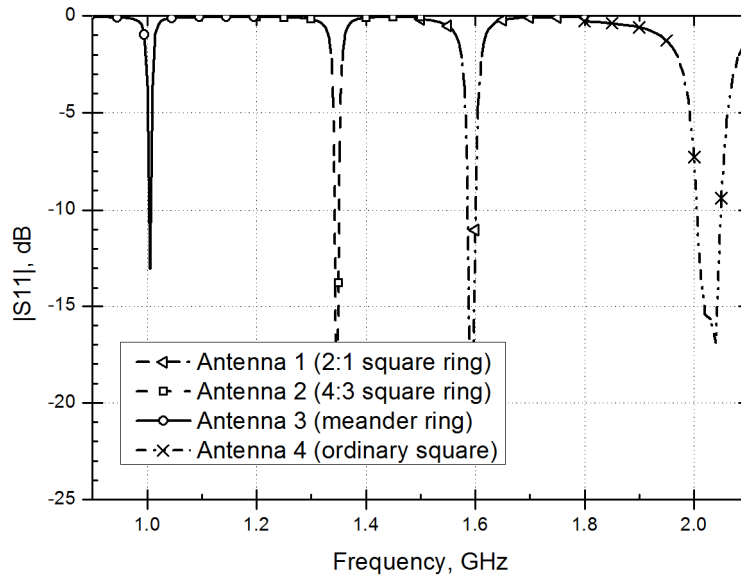
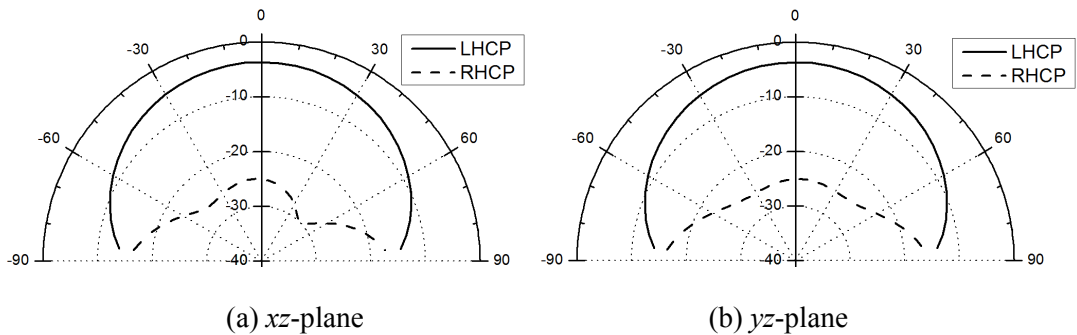


Figure 3. Return loss of proposed antennas.



(a) xz-plane (b) yz-plane
 Figure 4. Radiation patterns of meander ring antenna at 1005 MHz.

Table 1. Antenna parameters and simulated results for various ring antennas.

	L_2 (mm)	L_1 (mm)	w (mm)	l_n (mm)	g (mm)	f_c (MHz)	3-dB AR BW (MHz, %)	Gain (dBic)
Antenna 1	48	24	12	33	0.4	1594	3.3, 0.21 %	5.2
Antenna 2	48	36	6	34	0.9	1347	2.0, 0.15 %	2.8
Antenna 3	48	-	4.8	10.4	0.8	1005	1.5, 0.15 %	-3.6
Antenna 4	48	0	-	33	0.001	2026	12, 0.6 %	6.5

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