Square-Ring Microstrip Antenna with a Cross Strip for Compact Circular Polarization Operation

Wen-Shyang Chen, *Member, IEEE,* Chun-Kun Wu, and Kin-Lu Wong, *Senior Member, IEEE*

***Abstract*— A novel design of square-ring microstrip antenna with a cross strip for achieving compact circular polarization (CP) operation is proposed and experimentally studied. The cross strip can be placed in the centerlines or diagonals of the square-ring patch. Either design can make its excited fundamental-mode patch surface current path much longer than that in a conventional square microstrip antenna with same antenna size. By incorporating a small tuning stub for splitting the fundamental mode into two near-degenerate resonant modes with equal amplitudes and 90° phase-difference compact CP operation for the proposed design can be obtained.**

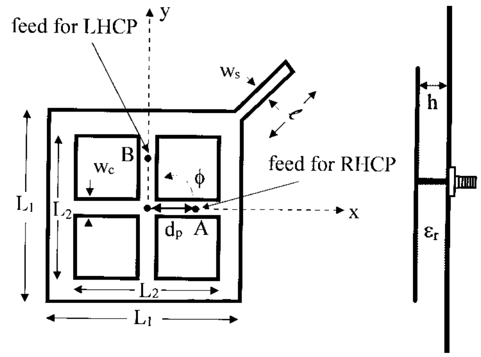
***Index Terms*— Circular polarization, microstrip antenna, printed antennas.**

I. INTRODUCTION

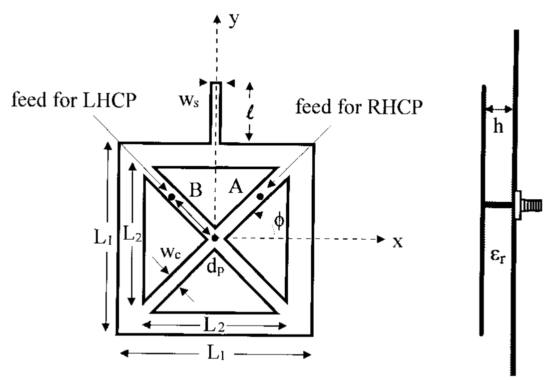
RECENTLY, in order to meet the miniaturization requirement of portable communication equipment, the studies of compact microstrip antennas received much attention and many related compact designs with broad-band characteristic [1], dual-frequency operation [2], [3], and circularly polarized radiation [4]–[6] have also been reported. In this paper, we demonstrate that a modified square-ring microstrip antenna with a cross strip can also be applied in the compact circular polarization (CP) operation. The cross strip can be placed in the centerlines or diagonals of the square-ring patch. By further incorporating a small tuning stub [7] to the modified square-ring microstrip antenna, the symmetry of the structure can be perturbed, which makes it possible for the excitation of two near-degenerate orthogonal modes for CP operation. Measured results of the CP performance for the design with two different arrangements (a centerline cross strip and a diagonal cross strip) are presented and discussed.

II. ANTENNA DESIGN

Fig. 1(a) and (b) shows the proposed compact CP designs. The square-ring microstrip patch, having an outer side length of L_1 and an inner side length of L_2, is printed on a substrate of thickness h and relative permittivity ε_r. The two arms of the cross strip are of equal width w_c. A small narrow tuning stub of length ℓ and width w_s ($\ell \gg w_s$) is protruded at the patch corner for the case with a centerline cross strip [see Fig. 1(a)] or at the center of the patch edge for the case with a diagonal cross strip [see Fig. 1(b)]. With a tuning stub of proper length and a single probe feed at a position in the two arms of the cross strip [see Fig. 1(a) and (b); point A for right-hand CP operation and point B for left-hand CP operation], the proposed design can perform CP radiation with a compact antenna size compared to the conventional CP designs [8].



(a)



(b)

Fig. 1. Geometries of square-ring microstrip antennas with a cross strip for compact CP operation. (a) The case with a centerline cross strip. (b) The case with a diagonal cross strip. The tuning stub in both cases is for CP tuning.

III. THE SQUARE-RING PATCH WITH A CENTERLINE CROSS STRIP

Fig. 2 shows the measured axial ratio. The feed position is at point A for right-hand CP radiation. The outer side length of the square-ring patch (L_1) is fixed to 34 mm. Two cases of $L_2 = 29.0$ mm ($\approx 0.85L_1$) and 31.5 mm ($\approx 0.93L_1$) are investigated and denoted as antennas 1 and 2 here. The corresponding CP performance is listed in Table I. First note that the center frequency (f_c), defined to be the frequency with minimum axial ratio in the operating bandwidth, is 1725 and

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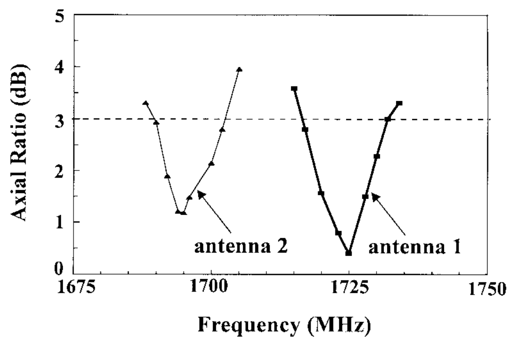

Fig. 2. Measured axial ratio against frequency in the broadside direction for the case with a centerline cross strip; $L_1 = 34$ mm, $\varepsilon_r = 4.4$, $h = 1.6$ mm, $w_s = 1$ mm, $w_c = 2$ mm, feed at point A. Antenna 1: $L_2 = 29$ mm, $\ell = 5.5$ mm, $d_p = 8$ mm. Antenna 2: $L_2 = 31.5$ mm, $\ell = 4.0$ mm, $d_p = 7.0$ mm.

TABLE I

CP PERFORMANCE FOR THE SQUARE-RING MICROSTRIP ANTENNA WITH A CENTERLINE CROSS STRIP (ANTENNAS 1 AND 2) AND WITH A DIAGONAL CROSS STRIP (ANTENNAS 3 AND 4); $L_1 = 34$ mm, $\varepsilon_r = 4.4$, $h = 1.6$ mm, $w_s = 1$ mm, $w_c = 2$ mm, FEED AT POINT A. THE REFERENCE ANTENNA IS CONSTRUCTED USING THE DESIGN WITH A CONVENTIONAL NEARLY SQUARE MICROSTRIP ANTENNA [8], WHOSE PATCH DIMENSIONS ARE 34 mm × 33.14 mm

	L_2 (mm)	f_c (MHz)	Max. Received Power (dBm)	CP Bandwidth (3dB axial ratio)	ℓ (mm)	d_p (mm)
antenna 1	29.0	1725	-51.8	0.93%	5.5	8.0
antenna 2	31.5	1695	-51.9	0.89%	4.0	7.0
antenna 3	29.0	1692	-51.9	0.95%	8.3	7.5
antenna 4	31.5	1614	-52.3	0.81%	6.7	7.0
reference	---	2070	-50.0	1.40%	---	---

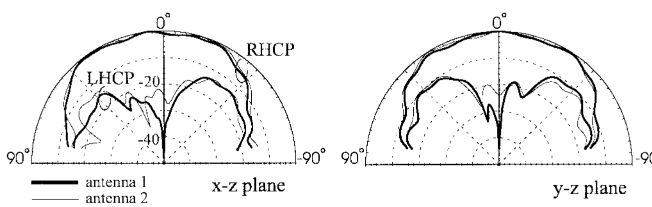

Fig. 3. Measured radiation patterns in two orthogonal planes for antenna 1 at 1725 MHz and antenna 2 at 1695 MHz; antenna parameters are given in Fig. 2.

1695 MHz for antennas 1 and 2, respectively. By comparing to the reference antenna, the center frequency of antenna 2 is lowered by about 18%. This lowering in center frequency can correspond to an antenna size reduction of about 33% by using the proposed design in place of the conventional CP design at a fixed frequency. Measured radiation patterns for antennas 1 and 2 at their respective center frequency are also plotted in Fig. 3 and good right-hand CP radiation for both cases is observed.

IV. THE SQUARE-RING PATCH WITH A DIAGONAL CROSS STRIP

The case with a diagonal cross strip is also studied. By using the same parameters described in Section III, the measured axial ratio for two different patch dimensions ($L_2 = 29.0$ mm for antenna 3 and 31.5 mm for antenna 4) are presented in Fig. 4. Obtained CP performance are also listed in Table I. The center frequencies are seen at 1692 and 1614 MHz, respectively, for antennas 3 and 4. For antenna 4, the center frequency is lowered by about 22% as compared to that of the reference antenna. Again, this suggests that an antenna size reduction about 40% can be obtained by using the proposed design at a fixed frequency. Also, good radiation patterns of antennas 3 and 4 are observed (for brevity, results are not shown).

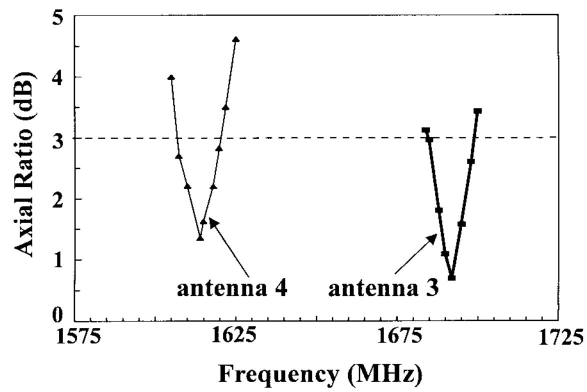

Fig. 4. Measured axial ratio against frequency in the broadside direction for the case with a diagonal cross strip; $L_1 = 34$ mm, $\varepsilon_r = 4.4$, $h = 1.6$ mm, $w_s = 1$ mm, $w_c = 2$ mm, feed at point A. Antenna 3: $L_2 = 29$ mm, $\ell = 8.3$ mm, $d_p = 7.5$ mm. Antenna 4: $L_2 = 31.5$ mm, $\ell = 6.7$ mm, $d_p = 7.0$ mm.

V. CONCLUSIONS

A modified square-ring microstrip antenna with a centerline cross strip or a diagonal cross strip for compact CP operation has been experimentally investigated. Results show that for the same square-ring patch dimensions, the design with a diagonal cross strip is more effective in reducing the required antenna size for a given operating frequency. By comparing to the conventional design using a nearly square microstrip antenna, the present proposed design with a diagonal cross strip can reach an antenna size reduction as high as 40%.

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