DESIGN OF SINGLE-PATCH CIRCULARLY POLARIZED MICROSTRIP ANTENNA WITH IMPROVED CP QUALITY

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1. Introduction

The present article presents the technique of using two feeds of out-of-phase and four feeds of 0°-90°-180°-270° phase shifts for feeding single-patch microstrip antennas to achieve improved circular polarization (CP) quality. In this study, the design with two feeds is applied to a corner-truncated square microstrip antenna, and the case with four feeds is applied to a simple circular microstrip antenna with an air substrate. Obtained experimental results demonstrate that CP quality of micrsotrip antennas can significantly be improved by the present feeding technique, especially for the design with four feeds in which the obtained CP bandwidth (2-dB axial ratio) reaches 38% and improved CP quality for frequencies over the entire bandwidth is obtained. Slow degradation of the axial ratio from the broadside direction to large angles is observed. Details of the antenna designs and experimental results of the obtained CP performances are presented and discussed.

2. Antenna Designs

The geometry of a corner-truncated square microstrip antenna with two feeds of equal amplitudes and 180° phase difference for CP radiation and four sequentially rotated feeds of 0°, 90°, 180° and 270° phase shifts to a circular patch antenna with a thick air substrate are shown in Fig. 1 and Fig. 2, respectively. Given in Fig. 1, the square patch has a length of L = 30 mm, and the truncated corners are of equal side length of ΔL = 4 mm. The patch substrate is of thickness 1.6 mm and relative permittivity 4.4, and the feed substrate is of thickness 0.8 mm and has relative permittivity 4.4. Two feeds are placed along the centerline, x-axis, of the square patch and have same distances of d = 7 mm away from the patch center. A Wilkinson power divider having a 180°-phase shift between its two outputs is printed on the feed substrate and connected through via holes in the ground plane to the two feeds at points A and B. Also note that the design in Fig. 2 gives right-hand CP radiation.

Given in Fig. 2, the circular radiating patch has a radius of R = 27.5 mm, and the air substrate's thickness is S_1 = 16 mm. The four feeds have a conducting disk of diameter R_c = 9 mm which is placed below the radiating patch with a distance of S_2 = 6.4 mm and supported by a conducting strip. The four feeds are with equal input powers and 0°, 90°, 180° and 270° phase shifts [1-3] and are arranged in the directions of ϕ = 0°, 90°, 180°, 270°, respectively. In the arrangement shown in Fig. 2, left-hand CP radiation is obtained. The supporting strips of the four feeds are all arranged to face the boundary of the circular patch, and have a same distance, d = 16 mm, away from the center axis (z-axis) of the patch. Three Wilkinson power dividers are used in the feed network, which provide equal input powers and respective phase shifts for the four feeds. One power divider provides a 180°-phase shift by a half-wavelength difference of its two output feed lines, and the other two power dividers have a quarter-wavelength difference in the two arms of their output feed lines to provide a 90°-phase shift.

3. Experimental Results and Discussion

The proposed antennas have been implemented and studied. Fig. 3(a) presents the measured results of the axial ratio versus frequency for the design with two feeds. Measured results of the reference antenna constructed based on the design of the conventional single-feed circularly polarized corner-truncated square microstrip antenna are also shown for comparison. The obtained 3-dB axial-ratio CP bandwidth for the proposed antenna is 37 MHz or about 1.55% with respect to the center frequency at 2390 MHz (the center frequency is defined to be with minimum axial ratio within the CP bandwidth in this study). As for the reference antenna, the CP bandwidth is 35 MHz or about 1.48% referenced to the center frequency at 2370 MHz. Both the CP bandwidths of the proposed antenna and reference antenna are thus about the same. Fig. 3(b) shows the measured axial ratio versus frequency for the design with four feeds. The obtained 2-dB axial-ratio bandwidth is 830 MHz (1750 to 2580 MHz) or about 38%, which is among the best CP performances for microstrip antennas that have been reported. Also, the obtained impedance bandwidth (10-dB return loss) of the four-feed design is greater than 100% referenced to the designed center frequency at 2200 MHz. The peak antenna gain is observed to be 7.6 dBi, with gain variation less than 2 dBi within the CP bandwidth.

Fig. 4 shows the measured radiation patterns in two principle planes for the two-feed design and the reference antenna at their respective center frequency. It is observed that the radiation patterns of the proposed antenna become more symmetric with respect to the broadside direction (θ = 0°), compared to those of the reference antenna. From the measured results, it is also found that the 6-dB axial-ratio beamwidth [i.e., the cross-polarization (RHCP) radiation is at least 9.5 dB less than the co-polarization (LHCP) radiation [4]] for the proposed antenna reaches θ = ±60°, which is much greater than that (about in the range between -40° and 50°) of the reference antenna. Fig. 5 shows the measured radiation patterns at 2400 MHz for the four-feed design. Experimental results for the case using a two-feed design with a 90°-phase shift are also plotted in the figure for comparison. The feed network of the two-feed design with a 90°-phase shift consists of only one Wilkinson power divider and is similar to that used in [5]. From the results, by comparing the four-feed design to the two-feed design with a 90°-phase shift, it can be seen that the 3-dB axial-ratio beamwidth [i.e., the cross-polarization (LHCP) is at least 15.3 dB less than the co-polarization (RHCP)] can be greater than 100° and the 6-dB axial-ratio beamwidth greater than 140°. This improvement in CP quality is mainly because the higher-order modes that are detrimental to the antenna's CP purity are suppressed in the proposed CP designs.

4. Conclusions

CP designs of using two feeds of a 180°-phase shift or four feeds of 0°, 90°, 180° and 270° phase shifts have been demonstrated. Prototype antennas constructed based on the present feeding method show a much improved CP quality for the radiation from the antenna's broadside direction at $\theta = 0°$ to large angles. Moreover, for the four-feed design applied to a simple circular microstrip antenna with a thick air substrate to be operated at the designed center frequency 2200 MHz, the obtained CP bandwidth (2-dB axial ratio) is as large as 38%, with the impedance bandwidth (10-dB return loss) greater than 100% and the peak antenna gain about 7.6 dBi. More experimental results will be given in the presentation.

5. References

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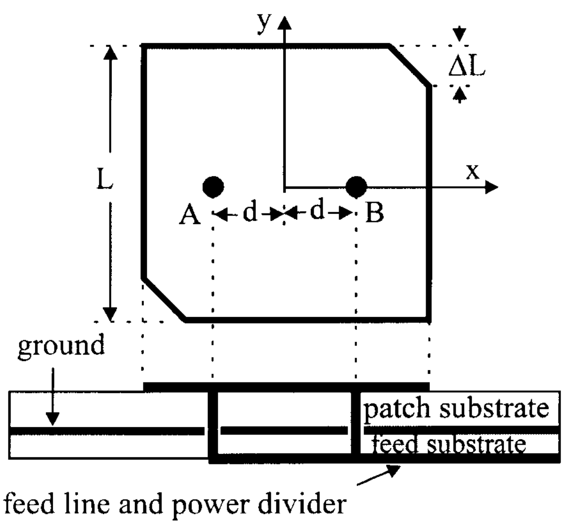

Fig. 1 Geometry of a corner-truncated square microstrip antenna with two feeds for improved CP quality.

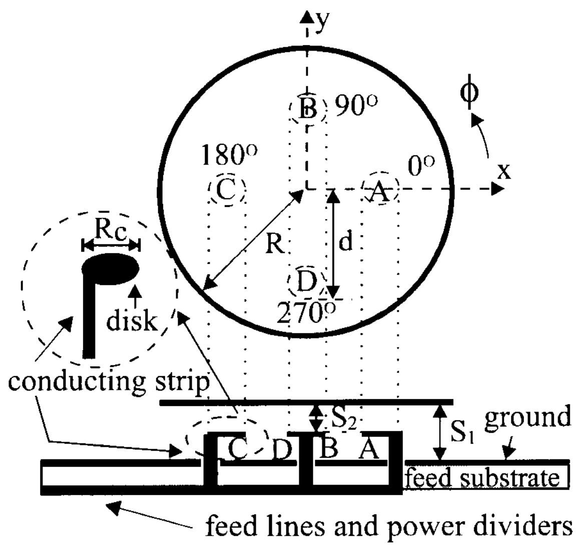

Fig. 2 Geometry of a circular microstrip antenna with four feeds for improved CP quality.

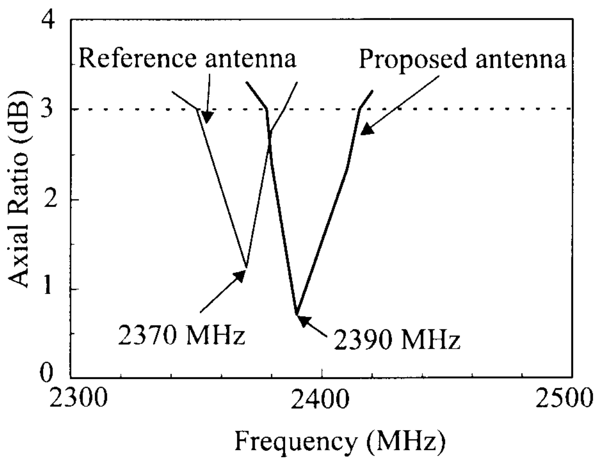

Fig. 3(a) Measured axial ratio versus frequency for antenna shown in Fig. 1.

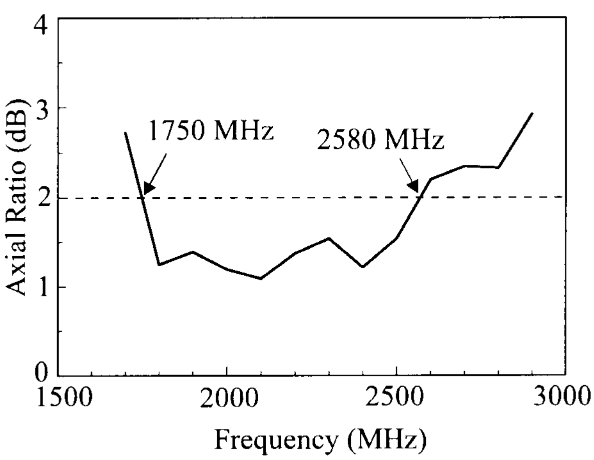

Fig. 3(b) Measured axial ratio versus frequency for antenna shown in Fig. 2.

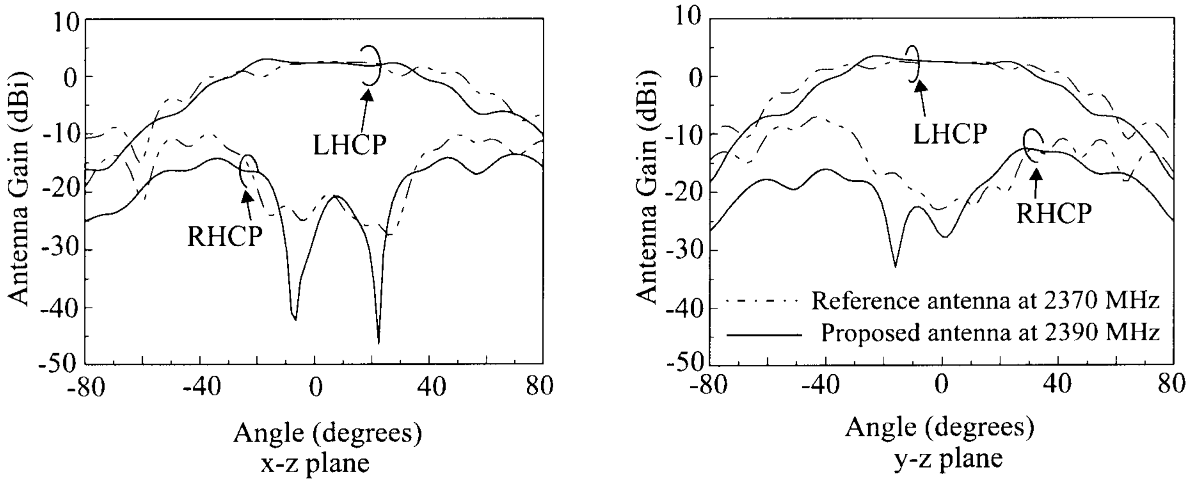

Fig. 4 Measured radiation patterns of antenna shown in Fig. 1 with f = 2390 MHz and the reference antenna with f = 2370 MHz.

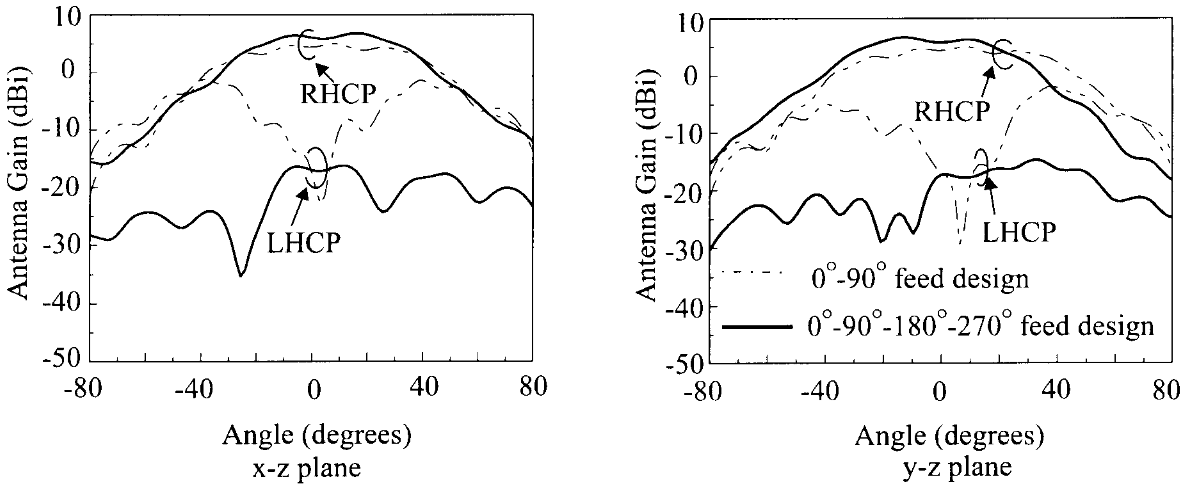

Fig. 5 Measured radiation patterns for antenna shown in Fig. 2 and the reference antenna; both at f = 2400 MHz.