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A Simple Design for Single-feed Circularly-Polarized Microstrip Antennas

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ABSTRACT

A new circular polarization (CP) design for single-feed microstrip antennas is presented and experimentally studied. This design technology is achieved by embedding a narrow slot at the center of the microstrip antenna and placing a single feed at the diagonal for the square patch or along the 45° axis for the circular patch. By properly adjusting the length of the narrow slot, the circular polarization wave can be easily excited. Typical experimental results of the CP microstrip antennas obetained by applying this design method are presented and discussed.

Key Words: circular polarization, microstrip antenna, narrow slot

I. Introduction

Microstrip antennas are widely used as efficient radiators in many communication systems. One of the most interesting applications is their use in circular polarization. Based on the number of feeding points, a circularly polarized microstrip antenna can be classified as single- or dual-feed. Without the complexities inherent in dual-feed devices, the single-feed circularly-polarized (CP) antenna can be regarded as one of the simplest radiator for exciting circular polarization. For single probe feed types, CP microstrip antennas with a truncated-corner square or diagonal-fed nearly square patch have been studied (Sharma and Gupta, 1983; Richards et al., 1981; James and Hall, 1989). As for the circular microstrip antennas, approaches which set the perturbation segment to the edge of the disk patch or use a nearly circular patch to produce CP radiation have been also reported (James and Hall, 1989). Additionally, a diagonal slot has been employed to obtain circularly polarized radiation for both square and circular microstrip antennas of the probe-fed (Sharma and Gupta, 1983) or stripline-feed (Carver and Mink, 1981) type. However, due to perturbation of the wide diagonal slot, the patch surface currents in the x and y directions are simultaneously affected, which

make the manufacturing tolerance rigorous for CP operation. This difficulty motivated the present study. In this study, by embedding a narrow slot, located at the center of the microstrip antenna with an intersecting angle of 45° relative to the feed loci, the simple CP design technique was applied to single probe-feed square and circular microstrip antennas. The feed position along the diagonal for the square patch or along the 45° axis for the circular patch was very close to the location without a narrow slot. This means that the feed position was varied slightly to make it easier to implement the CP patch antenna. Therefore, due to the effect of slot perturbation, CP radiation of the square and circular microstrip antennas was easily obtained by only adjusting the length of the narrow slot so as to excite a resonant frequency of one mode slightly below or above that of the other. The operating frequency between the two resonant modes could be easily chosen in order to obtain equal amplitudes with 90° phase differences. The input impedance of one mode for the CP microstrip antennas was inductive and the other mode was capacitive. Experiments in which this simple design method was applied to both square and circular microstrip antennas have been carried out, and the related experimental results are presented and discussed here.

Circularly-Polarized Microstrip Antenna

II. Antenna Design and Experimental Results

Figure 1 depicts the geometry of a single-feed circularly polarized microstrip antenna. The patch antennas with a side length L for the square case





Fig. 1. The geometry of the CP microstrip antennas with a narrow slot; the feed at point C is for the right-hand CP antenna, and that at point D is for the left-hand CP case. (a) The square patch antenna. (b) The circular patch antenna.

and a diameter d for the circular case were printed on a substrate with a thickness of 1.6 mm (h) and a relative permittivity of 4.4 (ε_r), respectively. For both square and circular microstrip antennas, a narrow slot



Fig. 2. The Smith chart of the simulated and measured input impedance for the microstrip antennas with a narrow slot for right-hand CP operation; h = 1.6 mm, $\varepsilon_r = 4.4$, w = 1 mm, (a) the square patch case: L = 37.5 mm, l = 12 mm, AC = 17.0 mm (~0.3 AB); (b) the circular patch case: d = 42 mm, l = 11.5 mm, AC = 12.8 mm (-0.3 AB).

of length | and width w (| >> w) was embedded at the center of the microstrip patch with an intersecting angle of 45° relative to the feed loci, which was the diagonal for the square patch or the diameter for the circular case. Since the feed probe was located along the diagonal/diameter of the square and circular microstrip antennas, respectively, both the x- and y-oriented modes were excited with equal amplitudes and phase. The single mode (x or y-oriented) could be selected by placing the narrow slot, which resulted in a perturbation segment, parallel to the x or ydirection srin order to shift the resonant frequency of one mode below or above that of the other mode so as to radiatiate right-hand circularly polarized (RHCP) or left-hand circularly polarized (LHCP) waves. This frequency shift was easily obtained by properly adjusting the length of the narrow slot (about 0.32 times the side length of the square patch or 0.27 times the diameter of the disk patch). These two orthogonal modes with equal amplitude and 90° phase differences could radiate a good CP wave.

Typical designs utilizing this simple design method were implemented and studied along with simulated results obtained using the 1E3D^{TM⁻} simulated softwar. Figure 2(a) shows the Smith chart of the simulated and measured input impedance of the square microstrip antenna. The results show satisfactory agreement for the present circular polarization design of a simple square microstrip antenna. Furthermore, it can be seen that a dip in the measured impedance locus near 1850 MHz was obtained, which indicated that two resonant modes were excited at very similar frequencies (If the two modes were excited at frequencies far apart, a loop instead of a dip would be observed in the impedance locus as in the simulated results; and if only one resonant mode was excited, there would be no dip or loop in



Fig. 3. Measured axial ratio for the CP microstrip antennas shown in Fig. 2. (a) The square case. (b) The circular case.

Table 1. Comparison between the Antennas with Different Patches

	Side length or Diameter (mm)	Slot length ℓ (mm)	10 dB Band- width (MHz)	center freq. (MHz)	3 dB axial ratio (%)
Square Patch	37.5	12.0	75.0	1850	1.14%
Disk Patch	42	11.5	79.0	1942	1.08%

Note: h = 1.6 mm, $\varepsilon_r = 4.4$, w = 1 mm.



Fig. 4. Measured radiation patterns in two orthogonal planes for the CP microstrip antennas shown in Fig. 2. (a) The square case at 1850 MHz. (b) The circular case at 1942 MHz.

the impedance locus). To radiate a good right-hand CP wave, the feed point was located at point C at a distance from corner A of approximately 0.3 times the diagonal, AB, and the length of the narrow slot was 12 mm (about 0.32L). Figure 2(b) shows the Smith chart of the simulated and measured input impedance for the right-hand circularly polarized disk patch. The length of the narrow slot was 11.5 mm, (about 0.27d), and the feed point was at a position about 0.3AB away from the boundary of the disk. The measured axial ratios for the square and circular microstrip antennas are shown in Fig. 3. It is seen that the CP bandwidth, determined from the 3 dB axial ratio, was 21 MHz and 22 MHz (or about 1.14% and 1.08% relative to the center frequency with the minimum axial ratio) for the square and circular microstrip antennas, respectively. The corresponding data shown in Fig. 3 for both the square and circular microstrip antennas are also listed in Table 1 for comparison. Compared with the results obtained in study which used a diagonal slot (Sharma and Gupta, 1983), the CP bandwidth for the

Circularly-Polarized Microstrip Antenna

present study is better. Typical measured radiation patterns in two orthogonal planes for the square and circular microstrip antennas at the center frequency (1850 MHz and 1942 MHz, respectively) are also plotted in Fig. 4(a) and (b). It can be seen that good right-hand CP radiation was obtained.

III. Conclusions

A simple CP design for single-feed microstrip antennas with an embedded narrow slot has been demonstrated. By properly adjusting the length of the narrow slot and using a single probe feed, the right-hand or left-hand radiation can be easily obtained. The simple CP design demonstrated here can be easily implemented in single-feed microstrip antennas to radiate a good circularly polarized wave.

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單同軸饋入圓形極化微帶天線之設計

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摘要

本文旨在設計單同軸饋入圓形極化微帶天線,其設計方法為在方形或圓形微帶天線的中心處嵌入一狹長槽孔且 饋入點位於與槽孔呈45度夾角的斜線上。經適當調整槽孔之長度可容易得到圓形極化波的特性,並將對於應用此方法所 得到的實驗結果加以探討。