

## Characteristics of a Compact Circularly Polarized Microstrip Antenna

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### Introduction

Single feed circularly polarized antennas are currently receiving much attention. Circular polarization is beneficial because current and future commercial and military applications require the additional design freedom of not requiring alignment of the electric field vector at the receiving and transmitting locations. A single feed allows a reduction in the complexity, weight and RF loss of any array feed and is desirable in situations where it is difficult to accommodate dual orthogonal feeds with a power divider network. Circularly polarized microstrip antennas have the additional advantage of small size, weight, suitability in conformally mounting and compatibility with microwave and millimeter wave integrated circuits, and monolithic microwave integrated circuits (MMICS).

A single patch antenna can be made to radiate circular polarization if two orthogonal patch modes are simultaneously excited with equal amplitude and  $\pm 90^\circ$  out of phase with the sign determining the sense of rotation. A patch with a single point feed generally radiates linear polarization, in order to radiate CP, it is necessary for two orthogonal patch modes with equal amplitude and in phase quadrature to be introduced. This can be accomplished by slightly perturbing a patch at appropriate locations with respect to the feed.

Various perturbation techniques for generating CP have been reported in literature [1], which operate on the same principle of detuning degenerate modes of a symmetrical patch by perturbation segments. In this paper a well-known method of producing a single feed circular polarization operation [1]- [3] of the square microstrip antenna by truncating a pair of patch at two opposite corners is presented. It is shown that this method can also be applied to a modified square microstrip patch with four semi-circular grooves along the four edges of the patch of equal dimensions to achieve a CP operation with compact design along with relaxed manufacturing tolerances. The compactness of the proposed CP design is achieved due to the semicircular grooves at the patch edges of the square patch. These grooves can result in forcing the current to follow extra semi circular patch, which effectively lowers the resonant frequency of the modified square patch. It is found that the required size of the truncated corners for CP operation increases with increasing antenna size reduction. This behavior gives the present design a relaxed

manufacturing tolerance for achieving a compact circularly polarized microstrip antenna. Details of the proposed compact CP design are described and typical simulation results are presented and discussed.

### Antenna Configuration

The antenna consists of a probe-fed square microstrip antenna with four semi circular grooves along the edges of the patch and a pair of truncated corners as shown in Fig.1.

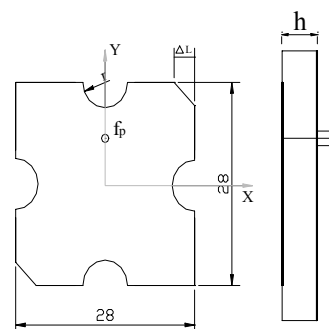


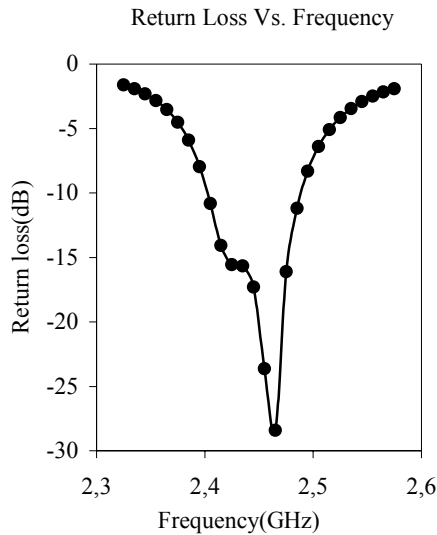
Fig. 1. Geometry of the compact CP square microstrip patch antenna with four semicircular grooves and a pair of truncated corners

The square microstrip patch has a side length  $L$ , truncated side length  $\Delta L = 3.2$  mm, and is printed on a substrate FR4 of a thickness  $h = 1.6$  mm and  $\epsilon_r = 4.4$  ( $\tan\delta = 0.0148$ ). The grooves are semicircular of equal dimensions with a radius  $r = 3.5$  mm and are cut at the four sides of the patch. The path of the surface current excited in the fundamental mode in this patch configuration is expected to be longer than the path in the usual square patch which makes the resulting CP operation to occur at a lower frequency. This characteristic makes the required antenna size of the proposed CP antenna smaller than that of the conventional design. This geometry also introduces additional parameter “ $r$ ” to the antenna that can be used to control its impedance, resonant frequency and bandwidth. The truncated corners are of equal side length  $\Delta L$ .

The single probe feed is placed at point A in the Y-axis at a distance 6.4 mm from the center of the patch for achieving a right hand CP operation. When the feed position lies on the X-axis, a left hand CP operation can be attained.

## Simulation Results

First, the dimension of the truncated corners was calculated from [5] for a simple CP square patch and the feed position was optimized at  $f_p = 6.8$  mm to produce the minimum return loss. Next the feed position was optimized at  $f_p = 6.4$  mm for the new configuration with four semicircular grooves. Finally, the simulation was performed on the proposed compact CP antenna with  $r = 3.5$  mm., side length of square patch fixed at 28mm. Fig. 2 shows typical return loss characteristics.

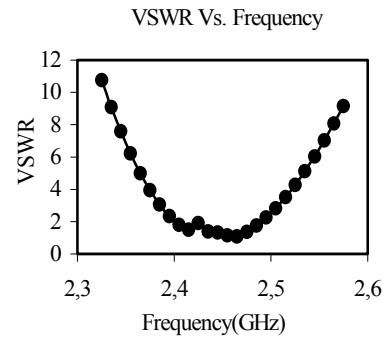


**Fig. 2.** Return loss for the proposed antenna with four semicircular grooves with radius  $r = 3.5$  mm

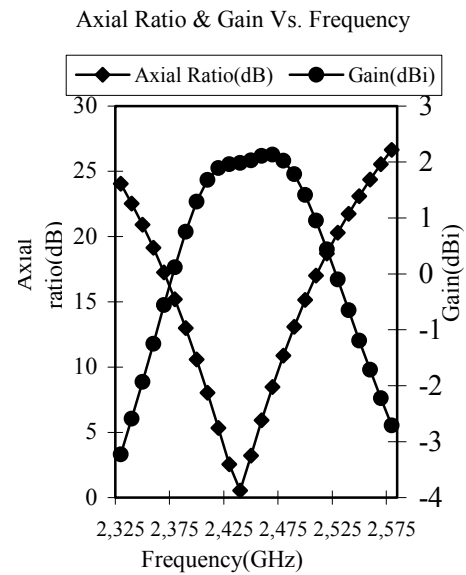
The comparative CP performance is listed in Table I, in which the reference antenna is constructed based on the design using a simple corner-truncated square patch. The center frequency  $f_c$ , defined here to be the frequency with minimum axial ratio in the operating bandwidth is observed to be 2.465 GHz for the proposed antenna and 2.56 GHz for the reference antenna. It can be seen that, by comparing to the reference antenna, the center frequency of the proposed antenna is lowered by 3.71 %. The lowering in the center frequency can correspond to an antenna size reduction by using the proposed design in place of the conventional CP design (reference antenna) at a fixed operating frequency. Fig 3 shows the axial ratio in the broadside direction for the proposed antenna and the gain characteristics. The CP bandwidth, determined from 3 dB axial ratio, is found to be 30 MHz. This means CP bandwidth of 1.32 % and impedance bandwidth of 3.7 % centered on 2.465 GHz.

**Table 1.** The comparative CP performance

Type of Antenna	Radius 'r' of semicircular groove (mm)	Truncated side length $\Delta L$ (mm)	Feed Post. $f_p$ (mm)	Resonant Frequency (GHz)	CP bandwidth 3dB axial ratio (MHz)	Antenna Gain (dBi)	Axial ratio dB	Return loss (dB)
Square patch	0	3.2	6.8	2.56	34	2.8	1.56	-17.48
Proposed antenna	3.5	3.2	6.4	2.465	30	2.13	0.56	-28.42



**Fig. 3.** VSWR for the proposed antenna



**Fig. 4.** Gain & axial ratio in broad side direction for the antenna shown in the fig. 1

## Conclusions

A single CP corner truncated square microstrip antenna with four semicircular grooves has been investigated. In addition to good CP radiation, a significant antenna size reduction for operating at a fixed frequency can be obtained using the proposed antenna in place of the conventional CP antennas. The proposed antenna is shown to provide a 3-dB axial ratio bandwidth of 1.32 % and 2.13 dBi gain.

## References

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### **V.R. Gupta, N. Gupta. Kompaktinės apskritiminės poliarizacijos mikrostripinės antenos charakteristikos // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2004. – Nr. 3(52). – P. 10-12.**

Aprašoma naujos konstrukcijos mikrostripinė antena, kuriai sužadinti naudojama įranga Zeland IE3D. Įrodoma, kad cirkuliarinė poliarizacija užtikrina minimalius antenos matmenis. Visapusiški teoriniai ir eksperimentiniai tyrimai įrodė, kad cirkuliarinė poliarizacija yra optimali. Il. 4, bibl. 4 (anglų kalba; santraukos lietuvių, anglų ir rusų k.).

### **V.R. Gupta, N. Gupta. Characteristics of a Compact Circularly Polarized Microstrip Antenna // Electronics and Electrical Engineering. – Kaunas: Technologija, 2004. – No. 3(52). – P. 10-12.**

A novel compact circular polarization (CP) operation of a microstrip antenna with four semicircular grooves along the four edges of the patch and a pair of truncated corners is proposed and investigated. The simulation is performed using Zeland IE3D, an integrated full wave electromagnetic simulation and optimization package for the analysis and design of three dimensional microstrip patch antennas. The simulation results show that the proposed compact CP design can have an antenna size reduction as compared to the conventional corner truncated square microstrip antenna at a given operating frequency. Details of the design considerations of the proposed antenna are described, and simulation results of the obtained CP performance are presented and discussed. Ill. 4, bibl. 4 (in English; summaries in Lithuanian, English and Russian).

### **В.Р. Гупта, Н. Гупта. Характеристики компактной микрополосовой антенны для круговой поляризации // Электроника и электротехника. – Каунас: Технология, 2004. — № 3(52). – С. 10-12.**

Описывается новая конструкция микрополосовой антенны, которая возбуждается при помощи устройства Zeland IE3D. Доказано, что этим способом возможно получить минимальные габариты антенн. Всесторонние теоретические и экспериментальные исследования доказали, что циркулярная поляризация во всех случаях является оптимальной. Ил. 4, библи. 4 (на английском языке; рефераты на литовском, английском и русском яз.).