Compact Circular Polarization Design for Equilateral Triangular Micro Strip Antenna

Manidipa Roy, Ashok Mittal

Abstract: This article focuses on designing a single-feed circularly polarized equilateral triangular microstrip patch antenna. The axial ratio bandwidth of the antenna is around 190 MHz. The antenna has been etched at specific locations for achieving circular polarization. The suppression of surface waves is also being focused upon for gain enhancement. The array of cylindrical metallic pins is embedded near the radiating side of the patch antenna. The gain enhancement of around 3.23 dB is observed. The antenna is designed for use in satellite communications.

Index Terms: compact, circular polarization, slots, axial ratio.

I. INTRODUCTION

The planar, small-sized microstrip patch antennas embedded on thin dielectric substrates are extensively used for mobile and wireless applications. Alongwith other advantages the microstrip patch antennas find its place in modern communications because of its capability to radiate circularly polarized waves. The circular polarization can be obtained by using dual feed antennas[1-2]. The dual feed of 90 degrees phase and equal magnitude are being fed at the two specific locations on the metallic patch antenna surface. This produces two near degenerate orthogonal modes in the patch antenna surface. The cylindrical metallic pins are being embedded near the radiating edge of the patch antenna to suppress the surface wave propagation.

II. ANTENNA DESIGN

This article focuses on the generation of circularly polarized radiation in an equilateral triangular antenna with slotted geometry. The slots are being etched to obtain compactness in the antenna design. The gain improvement is also being focused upon, for this the cylindrical metallic pins are being embedded near the radiating edge of the antenna to suppress the surface wave propagation.

The slotted geometry of the patch is also being improvised here in this article so as to obtain compact antenna characteristics from the same patch antenna. The perturbations are adopted for compactness of the patch antenna. The electrical length of the antenna is being modified. The antenna designed is an equilateral triangular patch antenna operating at 13 GHz. The objective behind using this patch is to achieve compact design and two achieve circular polarization by generating two near degenerate orthogonal modes. The advantages of using this patch antenna is that the radiation characteristics are nearly same as that of rectangular patch antenna and the design is compact. The size is further reduced by introduction of slots in the patch antenna surface. The cylindrical metallic pins are introduced for enhancing the gain characteristics.

The triangular patch antenna is designed. The resonant frequency of the equilateral triangular patch is [1]

\[ f_r = \frac{c}{2\pi} \frac{\pi n}{3m^2 + mn + n^2} \]

The dimension of the patch antenna follows the given radiation condition [1-4]

\[ \frac{\Delta S}{S} = 1/2Q_0 \]

where \( \Delta S \) is the area perturbed in the patch antenna \( \Delta S = \Delta S_1 + \Delta S_2 \). \( \Delta S_1 \) and \( \Delta S_2 \) are the areas of the slotted sections perturbed.

\( S \) is the area of the patch \( Q_0 \) is the quality factor of the patch antenna.

The circularly polarized rectangular patch antenna is designed at 13 GHz on FR4 Epoxy substrate. The quality factor[4] is

\[ Q = Q_{rad} + Q_{sw} + Q_{di} + Q_{cu} \]

The term involving \( Q_{sw} \) is associated with the surface wave loss, \( Q_{di} \) is associated with dielectric loss and \( Q_{cu} \) is associated with Copper loss.

\[ Q_{di} = \frac{1}{\tan \delta}; \quad Q_{cu} = \frac{d_{s}}{(\pi f_{cu})^{1/2}} \]

where \( d_{s} \) is skin depth of the conductor.

The \( Q_{rad} \) is given by

\[ Q_{rad} = \frac{2\omega \epsilon_{r} K}{\sqrt{\frac{S}{1}}} \]

where \( \sqrt{\frac{S}{1}} \) is associated with conductance per unit length of radiating cavity and

\[ K = \frac{1}{\int \text{E}^2 \text{d}A / \int \text{E} \text{d}A} \]

In a rectangular/square patch operating in the \( TM_{10} \) mode, \( K = b/4 \) and \( \sqrt{\frac{S}{1}} = \frac{\epsilon_{rad}}{\alpha} \). Here

\[ G_{rad} = \frac{1}{R_{rad}} \]

where \( R_{rad} \) is the radiation resistance and here \( G_{rad} \) is the radiation conductance.

\[ R_{rad} = \frac{Q_{r}}{2\pi f_{10}} \]
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III. PARAMETRIC ANALYSIS

Parametric Study of dimensions of the slots has been done. The length and width of all the slots are same. The table below shows the parametric study of the slots done in the proposed structure.

| S.No. | Slot length(mm) | Gain(dB) |
|-------|-----------------|----------|
| 1     | 0.148 \lambda_0 | 1.71     |
| 2     | 0.207 \lambda_0 | 2.44     |
| 3     | 0.267 \lambda_0 | 3.12     |
| 4     | 0.326 \lambda_0 | 5.67     |
| 5     | 0.356 \lambda_0 | 6.98     |
| 6     | 0.415 \lambda_0 | 4.70     |

The improvement of 3.23dB is observed after embedding shorting pins.

IV. RESULTS

The novel structure has been simulated on Ansoft HFSS v12 software and fabricated. The simulation and fabrication results are shown:

Graph 1. Graph showing the reflection coefficient characteristics for the novel circularly polarized antenna

The parametric study of the dimensions of the slots was carried out. The side length of the square patch is 14mm and the perturbed triangular areas are having 1.8mm² and 1.85 mm² respectively. The dimensions of all the slots are same with a length of 12mm and width of 1mm. The resonant frequency comes out to be around 8.9GHz after etching the slots on the patch surface. The axial ratio bandwidth is around 100MHz for the modified patch antenna.

Fig. 2. Proposed circularly polarized Antenna design

Graph 1. Graph showing the reflection coefficient characteristics for the novel circularly polarized antenna
Graph 2. Graph showing the axial ratio characteristics for the novel circularly polarized antenna

V. CONCLUSION

The circularly polarized antenna has been designed theoretically. Apart from obtaining circular polarization the compactness of the antenna is also being focussed upon the antenna is designed at 12.8 GHz initially to produce the circularly polarized radiation. The modified antenna is suitable for its use in satellite applications.

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Manidipa Roy is M.Tech. in RF and Microwave Engineering. She had been associated with AIACT&R, Delhi. Currently she is working as Assistant Professor in ABES Engineering College, Ghaziabad, Uttar Pradesh. She has teaching and research experience of around seven years. She had been a Research fellow at Ambedkar Institute of Advanced Communication technologies and Research, Delhi. She had guided many under graduate and post graduate students in their projects. She has several publications in International and National Journals and Conferences. She is involved in several Sponsored projects and consultancy projects. She has been awarded Gold Medal in M.Tech. RF and Microwave from Guru Gobind Singh Inderprastha University, Delhi.

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