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Compact Circular Polarization Design for Equilateral Triangular Micro Strip Antenna

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***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 antenna. The single feed antennas[3-4] have specific surface perturbation so as to produce two orthogonal modes, with slightly different current distributions along two orthogonal axes.

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.

II. ANTENNA DESIGN

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]

$$f_r = \frac{ck_{mn}}{2\pi\sqrt{\varepsilon_r}} = \frac{2c}{3a\sqrt{\varepsilon_r}}\sqrt{m^2+mn+n^2}$$

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

$$\frac{\Delta S}{S} = 1/2Q_0$$

where ΔS is the area perturbed in the patch antenna $\Delta S = \Delta S_1 + \Delta S_2$

ΔS_1 and ΔS_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

$$\frac{1}{Q} = \frac{1}{Q_{rad}} + \frac{1}{Q_{sw}} + \frac{1}{Q_{di}} + \frac{1}{Q_{cu}}$$

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.

$$Q_{di} = {}^{1}/_{\tan\delta};\ Q_{cu} = {}^{t}/_{d_s}$$

here $d_s = (\pi f \mu \sigma)^{-1/2}$ is skin depth of the conductor.

The Q_{rad} is given by

$$Q_{rad} = {}^{2\omega\varepsilon_h K}/_{t\left(\frac{G}{l}\right)}$$

here $\left(\frac{G}{l}\right)$ is associated with conductance per unit length of radiating cavity and

here $K = \iint |Er|^2\, dA / \left(\int_0^{perimeter} |Er|^2 dl\right)$

In a rectangular/square patch operating in the TM_{10} mode, K is $b/4$ and $\left(\frac{G}{l}\right)$ is $\frac{G_{rad}}{a}$. Here

$$G_{rad} = \frac{1}{R_{rad}}$$

here R_{rad} is the radiation resistance and here G_{rad} is the radiation conductance.

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$$R_{rad} = \frac{Q_r}{\omega C_{10}}$$

here Q_r is the radiation quality factor

$$Q_r = {Re(k_{10})}/{2Im(k_{10})}$$

where,

$$k_{10} = \left(\frac{\pi}{b}\right) - \left(\frac{\Delta_4}{b}\right)$$

here

$$\Delta_{p+1} = \frac{2(a_{10}b)(\pi - \Delta_p)}{((a_{10}b)^2 + 2\Delta_p\pi - \Delta_p{}^2 - \pi^2)} - \frac{\Delta_p{}^3}{3}$$

with $\Delta_0 = 0$ as seed value.

$\alpha_{10} = j2\pi Z_0 Y_w t/\lambda_0 a$

here a , b are radiating (width) and non- radiating (length) edges of the rectangular patch antenna respectively.

where t is thickness of the substrate,

Z_0 is characteristic impedance of the patch,

λ_0 is wavelength at the operating frequency,

Y_w is wall admittance of the patch cavity,

and $Y_w = G_w + jB_w$

where G_w is wall conductance

and B_w is wall susceptance

These values are mathematically calculated using relations

$$G_w = \left(\frac{\pi}{376}\right)\left(\frac{a}{\lambda_0}\right)$$

$$B_w = 0.01668\left(\frac{\Delta_1}{t}\right)\left(\frac{a}{\lambda_0}\right)\varepsilon_e$$

where

$$\frac{\Delta_1}{t} = 0.412((\varepsilon_e + 0.300)/(\varepsilon_e - 0.258))\left(\left(\frac{a}{t} + 0.262\right)/\left(\frac{a}{t} + 0.813\right)\right)$$

and ε_e is an effective dielectric constant

$$\varepsilon_e = \frac{(\varepsilon_h + 1)}{2} + \left(\frac{(\varepsilon_h - 1)}{2}\left(1 + \frac{10t}{2}\right)\right)^{-1/2}$$

and $C_{10} = (1/2)C_{dc}\cos^{-2}(\pi y_0/b)$

(x_0, y_0) are the co-ordinates of the feed point for co-axial feed

C_{dc} is dc patch capacitance $(\varepsilon ab\ /\ t)$

A circularly polarized equilateral triangular patch antenna is designed which satisfies the above mentioned equations. The antenna has been slotted at three positions for achieving circularly polarized radiation and an array of shorting pins has been embedded in the dielectric substrate of the radiating patch edge. The improvement in gain is observed after embedding cylindrical metallic pins in the dielectric substrate.

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 1.8mm^2 and 1.85 mm^2 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.

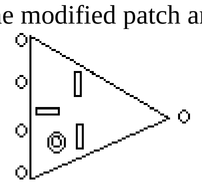

Fig. 2. Proposed circularly polarized Antenna design

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.

Table1. Parametric study of the slot width

S.No.	Slot length(mm)	Gain(dB)
1	0.148 λ_0	1.71
2	0.207 λ_0	2.44
3	0.267 λ_0	3.12
4	0.326 λ_0	5.67
5	0.356 λ_0	6.98
6	0.415 λ_0	4.70

Table2. Parametric study of slot length

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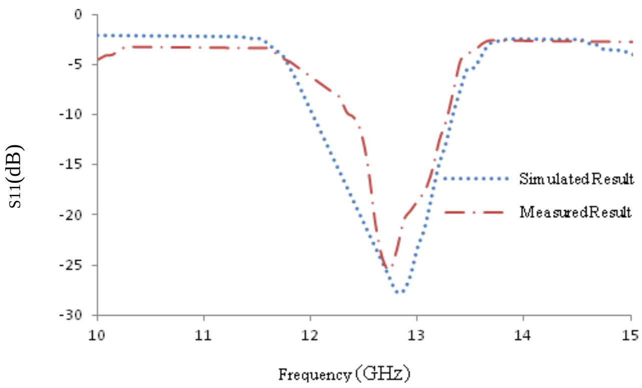
The improvement of 3.23dB is observed after embedding shorting pins.

IV. RESULTS

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

Fig. 3 Circularly Polarized Antenna structure fabricated



Graph1. Graph showing the reflection coefficient characteristics for the novel circularly polarized antenna

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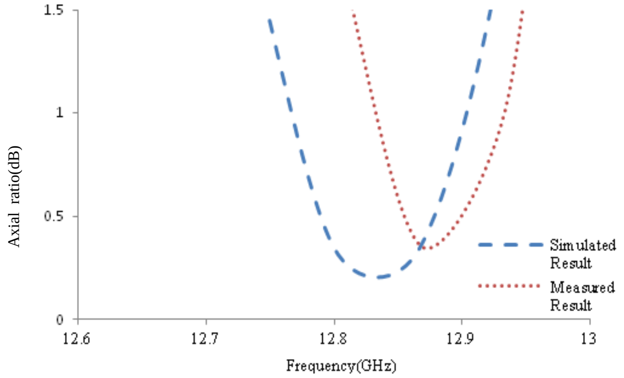

Graph2. Graph showing the axial ratio characteristics for the novel circularly polarized antenna

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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