

# DESIGN OF CIRCULAR POLARIZED MICROSTRIP PATCH ANTENNA FOR L BAND

<sup>1</sup>JOLLY RAJENDRAN, <sup>2</sup>RAKESH PETER & <sup>3</sup>KP SOMAN

<sup>1,2&3</sup>Amrita Vishwa Vidyapeetham, Coimbatore, India

<sup>1</sup>Email: Rajendran.jolly@gmail.com

**Abstract** - In this paper, we share our experience of designing a circularly polarized square patch antenna at L band. The antenna is designed using a relatively cheap substrate FR-4 with permittivity  $\epsilon_r = 4.4$  and loss tangent  $\tan\delta = 0.02$ . The antenna has a gain of 5dB. Simulated response shows that the designed antenna has an input impedance ( $Z_{in}$ ) of  $50\Omega$  approximately. An efficiency of 65% is obtained for a single patch. It has a narrow bandwidth and a high Q factor. The design procedure, feed mechanism and simulation results are presented in this paper.

**Keywords** - Dielectric substrates, L-band, Microstrip antennas, Patch antennas, Polarization, Circularly polarized square patch antenna. *Keywords - Precision farming, attribute oriented induction, data generalization.*

## I. INTRODUCTION

L-band frequencies are used in mobile satellite, cellular and personal communication systems. Circular polarized antennas are used for satellite communication between base station and a mobile unit [1][2]. Compact, directive antennas are required for the same. Microstrip patch antennas are compact, conformal to both planar and non-planar surfaces, have good efficiency and are easy to produce as arrays. They are cheaper and easy to install. These characteristics make them an ideal candidate for the communication applications. Radiation properties of microstrip structures has been known since mid 1950s. A microstrip patch antenna consists of a radiating patch which is made up of a conducting material like copper or gold on one side of a dielectric substrate and ground plane on the other side. The patch could be of different shapes viz. square, rectangular, circular, triangular or elliptical[3]. Usually rectangular and circular microstrip resonant patches are used in array configurations due to their simple geometry and ease of design. Microstrip patch antennas support both linear as well as circular polarization and capable of dual and triple frequencies. Circularly polarized antennas have been developed with single and dual feed arrangement. In this paper design of a circularly polarized rectangular patch with dual feed is proposed. Dual feed excites two orthogonal field components with equal amplitudes but a  $90^\circ$  phase difference.

## II. ANTENNA CONFIGURATION AND DESIGN PROCEDURE

The geometry of circularly polarized antenna is shown in Figure 1. The antenna consists of a rectangular patch etched on a 60 mil thick FR-4 substrate. The patch and ground plane are made of a high conductivity metal, copper and is of thickness 't'. The patch is of length 'L' and width 'W' and is etched on

a dielectric substrate of thickness 'h' and permittivity  $\epsilon_r$ .

### 2.1 Substrate

The dielectric constant of substrates used for microstrip patch antennas are typically in the range  $2.2 \ll \epsilon_r \ll 12$ . Lower the permittivity of the substrate, wider is the fringing field and better is the radiation. With the decrease of permittivity antenna bandwidth and efficiency increases. But lowering the permittivity decreases the input impedance and increases the size of the antenna. FR-4 substrate with  $\epsilon_r = 4.4$  is chosen for the design of the proposed antenna. Thickness of substrate is chosen such that

$$h > 0.06\lambda_g \quad (1)$$

where  $\lambda_g$  is the guided wavelength given by Equation (2).

$$\lambda_g = \frac{\lambda_0}{\sqrt{\epsilon}} \quad (2)$$

A tradeoff has to be made while selecting the substrate thickness. As thickness of substrate increases, surface waves are induced within the substrate. Surface waves results in undesired radiation, decreases antenna efficiency and introduces spurious coupling between different circuits or antenna elements. Also surface waves reaching the outer boundaries of an open microstrip structure are reflected and diffracted by the edges. These diffracted waves provide an additional contribution to radiation, degrading the antenna pattern by increasing the side lobe and cross polarization levels. Thus thickness should be chosen such that surface waves are suppressed. A thick substrate with low dielectric constant yields better efficiency, larger bandwidth and better radiation, where as a thin substrate with higher dielectric constant yields compact antenna,

with less efficiency and narrower bandwidth. Thus a compromise has to be made between the antenna dimensions and antenna performance. A 60 mil FR-4 substrate is used in the proposed design.

## 2.2 Patch Dimension

A square patch is chosen for symmetry.

### 2.2.1 Patch thickness

The patch is selected to be very thin such that  $t \ll \lambda_0$ , where  $\lambda_0$  is the free space wavelength given by Equation (3). The patch thickness is chosen to be 0.1 mm.

$$\lambda_0 = \frac{c}{f_0} \quad (3)$$

In Equation (1) 'c' is the velocity of light known as 3x10<sup>8</sup>m/s and  $f_0$  is the resonant frequency of patch which is chosen as 1GHz.

### 2.2.2 Design Equations

The effective permittivity of the FR-4 substrate ( $\epsilon_r = 4.4$ ) is found using Hammerstad and Jensen model[4] as follows.

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \times \left(1 + \frac{10h}{W}\right)^{-ab} \quad (4)$$

with

$$a = 1 + \frac{1}{49} \ln \left[ \frac{(u^4 + (\frac{u}{52})^2)}{u^4 + 0.432} \right] \quad (5)$$

$$b = 0.564 \left[ \frac{\epsilon_r - 0.9}{\epsilon_r + 3} \right]^{0.093} \quad (6)$$

$$u = \frac{W}{h} \quad (7)$$

Effective length is given by [3]

$$Leff = \frac{c}{2f_0} \times \sqrt{\frac{1}{(\epsilon_{eff})}} \quad (8)$$

Scattering length  $\Delta$

$$\Delta = 0.412h \frac{\epsilon_{eff} + 0.3}{\epsilon_{eff} - 0.258} \times \frac{u + 0.264}{u + 0.8} \quad (9)$$

Real Patch Length L is given by

$$L = Leff - \Delta \quad (10)$$

For a rectangular patch, the length of the patch L controls the resonant frequency and width W controls the input impedance and radiation pattern. The wider

the patch, the larger is the input impedance. The nearly square patch ( $L=W$ ) is used for the proposed antenna. Length is chosen as 59.08 mm as calculated from the above design equations.

## 2.3 Feed

The feedlines are directly coupled to the resonant patch. Critical coupling is achieved at resonant frequency via a quarter wave transmission line section of characteristic impedance  $Z_T$  given by

$$Z_T = \sqrt{Z_f R_r} \quad (11)$$

where  $R_r$  is the input impedance of the resonant patch and  $Z_f$  is the characteristic impedance of transmission line feed which is 50 Ohms (width = 2.892 mm). The width and length of the quarter wave transmission line section ( $Z_T = 89.744$  ohms) was found out using LineCalc tool in ADS for resonant frequency 1.147GHz and was found to be 0.1438 mm and 36.77 mm respectively. The position of the feed controls the input impedance.

The resonant patch is fed via a 90° branch line coupler. The branch line coupler divides the power equally into the two output ports. The signal is fed via one of the ports, while the other port is grounded through a 50Ω resistor. The signal arriving at the two output ports of the branch line coupler are 90° out of phase. The feed lines are extended further and bend such that the total delay produced in the two feed lines are the same. The resonant patch is thus fed at two points as shown in Figure 1 such that the signals have a 90° phase difference. This dual feed arrangement excites two orthogonal field components with equal amplitude but 90° phase difference resulting in circular polarization.

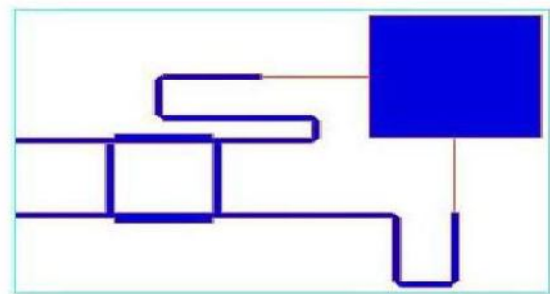


Fig. 1: Geometry of Circular polarized patch antenna

## III. SIMULATION RESULTS

The antenna is modelled and simulated using Momentum. Figure 2.a and 2.b gives the magnitude and phase of  $S_{11}$  vs frequency. The resonant

frequency  $f_0$  of the antenna is 1.14 GHz. The fractional bandwidth is given by

$$BW = \frac{f_2 - f_1}{f_0} \quad (12)$$

The antenna has a very narrow bandwidth, approximately 0.9% and has a high Q factor. Q factor is given by

$$Q = \frac{f_0}{BW} \quad (13)$$

Q factor was found to be 111. Figure 2.c shows the antenna has an input impedance( $Z_{in}$ ) of  $56.25 + j12.2\Omega$ . Thus the designed antenna is almost matched to the characteristic impedance  $Z_0$  which is assumed to be 50 ohms. The reactive part  $+j12.2\Omega$  could be cancelled out by adding a series capacitor of 39pF during fabrication. From the simulation results shown in Figure 3.a and Figure 3.c, the antenna has a gain of 5 dB and efficiency of 65%. Figure 4.a and Figure 4.c shows the magnitude and phase of electric field for various values of  $\theta$ . The antenna is right circular polarized. The two orthogonal components which are same in magnitude and in phase quadrature results in circular polarization. These components could be described by the Equation(14)(15) and the circularly polarized wave by (16).

$$E_{right} = E_0 \sin(\omega t - \beta z) \mathbf{a}_x \quad (14)$$

$$E_{left} = E_0 \cos(\omega t - \beta z) \mathbf{a}_y \quad (15)$$

$$\mathbf{E} = \mathbf{E}_{right} + \mathbf{E}_{left} \quad (16)$$

The 3-D radiation pattern is shown in Figure 5. Figure 4.b and Figure 4.d shows the magnitude and phase of axial ratio for different values of  $\theta$ .

#### IV. CONCLUSION

Finally we complete our discussion with the fundamental issues that need to be addressed in future. Though compact when compared to conventional antennas, the antenna has a very low efficiency and narrow bandwidth. The bandwidth could be improved by incorporating lossy material or resistors. Also slots could be introduced to improve bandwidth. Furthermore the antenna could be formed into arrays to get better directivity.

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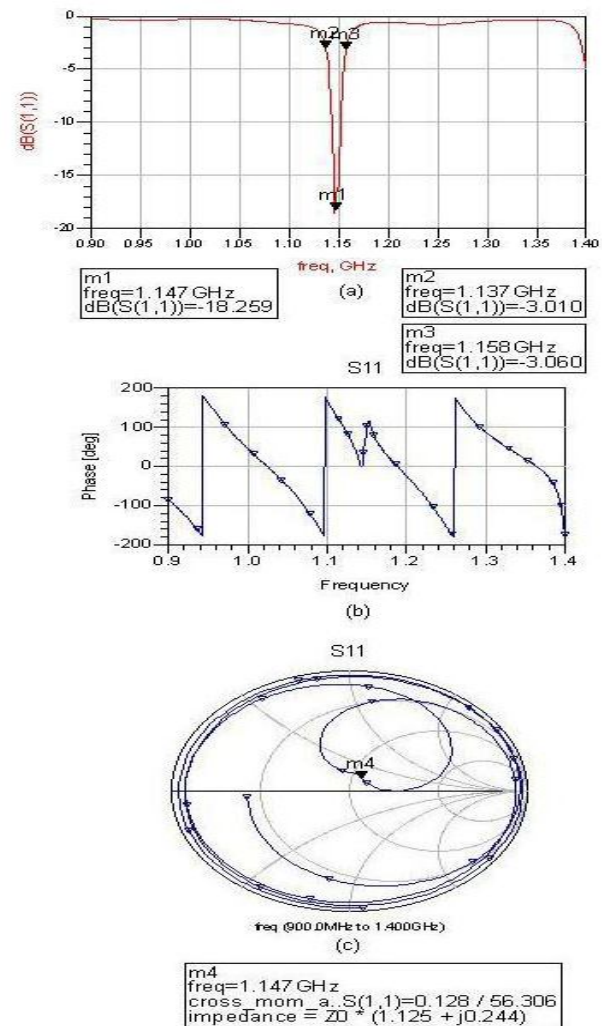


Fig. 2 : (a) Return loss vs. frequency( magnitude plot) (b) Return loss vs. frequency(phase plot) (c) S11 plot on Smith Chart

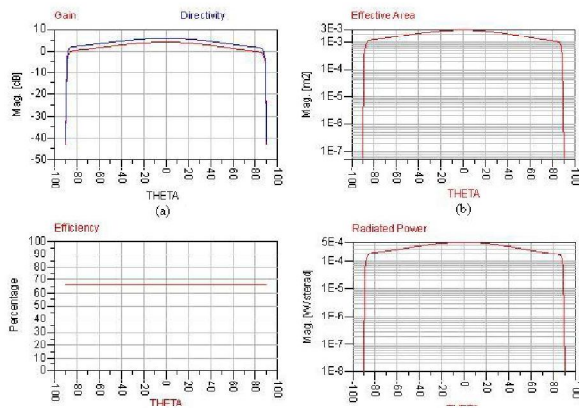


Fig. 3 : (a) Gain and Directivity vs. Theta (b) Effective Area vs. Theta (c) Efficiency vs. Theta (d) Radiated Power vs. Theta

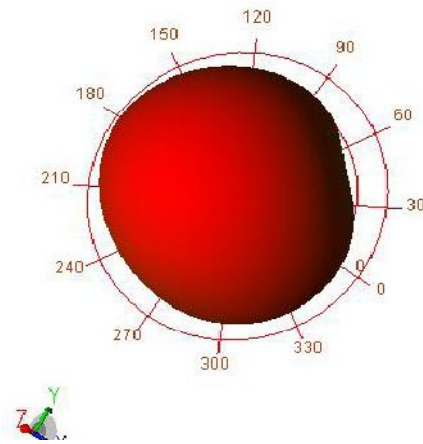


Fig. 5 : Three dimensional radiation pattern

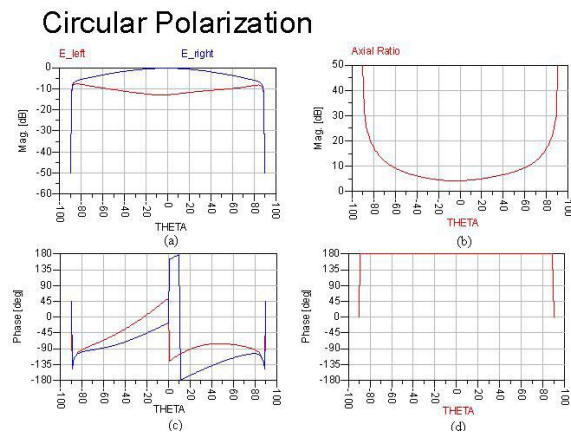


Fig. 4 : (a) Electric Field vs. Theta(magnitude plot) (b) Axial Ratio vs. Theta(magnitude plot) (c) Electric Field vs. Theta(phase plot) (d) Axial Ratio vs. Theta(phase plot)