CIRCULAR POLARIZED RECTANGULAR MICROSTRIP ANTENNA FOR 4G SYSTEM

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ABSTRACT-*Aiming at the request of the proposed antenna used for 4G system with circular polarized operations, we first analyze the characteristics of microstrip antenna based on cavity model and design methods of size structure with help of Transmission line model, and then simulate with MATLAB and EM simulator IE3D which based on MOM method then comparer the parameter and advantages of the microstrip antenna with simulated and practical results.*

Keywords: Cavity model, microstrip antenna, MOM, Circular Polarized, directivity

I. INTRODUCTION

Microstrip patch antennas (MPAs) have attracted widespread interest due to their small size, light weight, low profile and low cost as well as to the fact that they are simple to manufacture, suited to planar and non planar surfaces, mechanically robust, easily integrated with circuits, allow multifrequency operation to be achieved [1].However, their further use in specific systems is limited because of their relatively narrow bandwidth. In principal, wide bandwidth of microstrip patch antennas (MPAs) or bandwidth enhancement can be achieved by several efficient approaches [2].In this paper, coaxial feed techniques are applied to the rectangular microstrip patch antenna. Because, coaxial feed is a widely used one. The inner conductor of coaxial cable is connected to the radiating patch and the outer conductor is connected to the ground plane. This feed is also easy to match and it has low spurious radiation by using teflon conector. The advantage of this feed is that it occupies less space than the other feeds [3]. Microstrip antenna is one of these kinds of antenna with low section, panel structure of typical model, which develops with the request of modern communication development. There are many methods to discuss the electromagnetism radiation characteristic of the antenna. The typical model adopted is the Cavity Model[4].

II. ANTENNA ANALYSIS

Rectangular patch antennas can be designed by using a cavity model [5] suitable for moderate bandwidth antennas. The lowest-order mode, TM_{10}, resonates when the effective length across the patch is a half-wavelength. “Fig.1”, demonstrates the patch fed below from a coax along the resonant length. Radiation occurs from the fringing fields. These fields extend the effective open circuit (magnetic wall) beyond the edge.

a) Resonance frequency

The resonance frequency f_{mn} depends on the patch size, cavity dimension, and the filling dielectric constant, as follows:

$$f_{mn} = \frac{k_{mn} c}{2\pi\sqrt{\varepsilon_r}} \qquad (1)$$

Where m, n=0, 1, 2… k_{mn} = wave number at m, n mode, **c** is the velocity of light, ε_r is the dielectric constant of substrate, and

$$k_{mn} = \sqrt{\left(\frac{m\pi}{W}\right)^2 + \left(\frac{n\pi}{L}\right)^2} \qquad (2)$$

For TM_{01} mode, the length of non-radiating rectangular patch's edge at a certain resonance frequency and dielectric constant according to equation (1) becomes

$$L = \frac{c}{2 f_r \sqrt{\varepsilon_r}} \qquad (3), \qquad W = \frac{c}{f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (4)$$

Where f_r = resonance frequency at which the rectangular microstrip antennas are to be designed. The radiating edge W, patch width, is usually chosen such that it lies within the range L<W>2L, for efficient radiation. The ratio W/L=1.5 gives good performance according to the side lobe appearances. In practice the fringing effect causes the effective distance between the radiating edges of the patch to be slightly greater than L. Therefore, the actual value of the resonant frequency is slightly less than f_r. Taking into account the effect of fringing field, the effective dielectric constant for TM_{01} mode is derived using [6,7] By using above equation we can find the value of actual length of the patch as,

$$L = \frac{c}{2 f_r \sqrt{\varepsilon_{eff}}} - 2\Delta l \qquad (5)$$

Where ε_{eff} =effective dielectric constant and Δl =line extension which is given as:

$$\varepsilon_{eff} = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r + 1)}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \qquad (6), \qquad \frac{\Delta l}{h} = 0.412\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \qquad (7)$$

b) *Cavity Field*

From the cavity model explained above, the electric field is assumed to act entirely in the z-direction and to be a function only of the x and y coordinates i.e.

$$\vec{E} = \hat{Z} E_Z(x, y) \qquad (8)$$

The z-component of the electric field E_z satisfies the two-dimensional wave equation

$$\frac{\partial^2 E_Z}{\partial x^2} + \frac{\partial^2 E_Z}{\partial y^2} + k^2 E_Z = 0 \qquad (9)$$

The outward current flowing on the perimeter of the patch must be zero (since the patch boundary is an open-circuit). So

$$\frac{\partial E_Z}{\partial n} = 0 \tag{10}$$

Where n is the outward normal vector at the perimeter of the patch by using the separation of variables, the electric field of the m and n mode numbers [9]

$$\mathrm{E}_Z = \mathrm{E}_O Cos\left(\frac{m\pi x}{W}\right)\left(\frac{n\pi y}{L}\right) \tag{11}$$

c) *Far Field*

In order to calculate the far field, the aperture model is used. The resonator surface is considered to be a set of four slots of width 2a [8]. By using Green's function the following general form of the far field for any (m, n) mode

$$\mathrm{E}(r) = \frac{jke^{-jkr}}{2\pi r}\left\{\bar{i}_\theta\left[\mathrm{E}_x \cos\varphi + \mathrm{E}_y \sin\varphi\right] + \bar{i}_\varphi\left[-\mathrm{E}_x \sin\varphi\cos\theta + \mathrm{E}_y \cos\varphi\cos\theta\right]\right\} \tag{12}$$

Where

$$\mathrm{E}_x = \left[\left(-1-(-1)^m\right) j\sin\left(\zeta\frac{W}{2}\right) + \left(1-(-1)^m\right)\cos\left(\zeta\frac{W}{2}\right)\right]$$

$$h\mathrm{E}_Z \frac{L}{2}\sin c(\zeta a) j^n\left[\sin c\left(\eta\frac{L}{2}+\frac{n\pi}{2}\right) + (-1)^n \sin c\left(\eta\frac{L}{2}-\frac{n\pi}{2}\right)\right] \tag{13}$$

and

$$\mathrm{E}_y = \left[\left(-1-(-1)^n\right) j\sin\left(\eta\frac{L}{2}\right) + \left(1-(-1)^n\right)\cos\left(\eta\frac{L}{2}\right)\right]$$

$$h\mathrm{E}_0 \frac{W}{2}\sin c(\eta a) j^m\left[\sin c\left(\zeta\frac{W}{2}+\frac{m\pi}{2}\right) + (-1)^m \sin c\left(\zeta\frac{W}{2}-\frac{m\pi}{2}\right)\right] \tag{14}$$

Then the far field components are

$$\mathrm{E}_\theta = \frac{jke^{-jkr}}{2\pi r}\left(\mathrm{E}_x \cos\varphi + \mathrm{E}_y \sin\varphi\right) \quad (15), \quad \mathrm{E}_\phi = \frac{jke^{-jkr}}{2\pi r}\left(-\mathrm{E}_x \sin\varphi\cos\theta + \mathrm{E}_y \cos\varphi\cos\theta\right) \quad (16)$$

Where $\zeta = k\sin\varphi\cos\theta, \eta = k\sin\theta\sin\varphi, k = \frac{2\pi}{\lambda_0}$, and λ_0 =wavelength in free space.

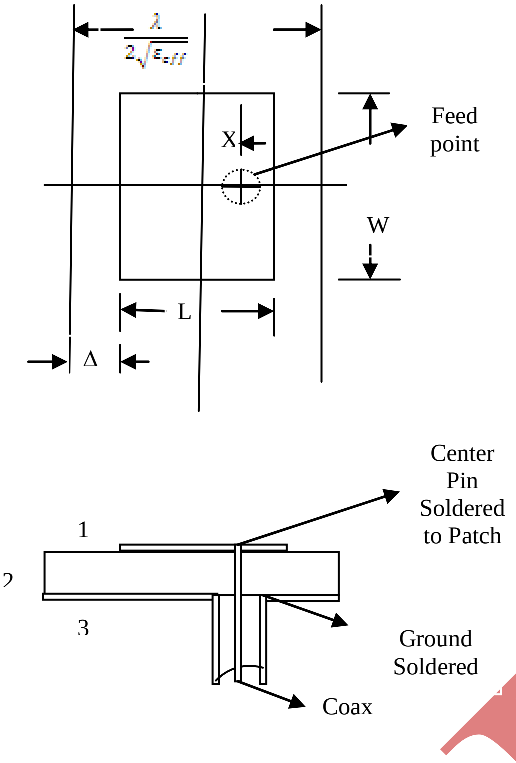
Equation (12) enables one to plot the radiation pattern for every mode of the rectangular microstrip patch antenna.

A combination of parallel-plate radiation conductance and capacitive susceptance loads both radiating edges of the patch.

$$G_1 = \frac{W}{120\lambda_0}\left[1-\frac{(k_0 h)^2}{24}\right], \frac{h}{\lambda_0} < \frac{1}{10} \tag{17}$$

Where λ_0 is the free-space wavelength and wave number $k_0 = \frac{2\pi f_r}{c}$. The input conductance of the patch fed on the edge will be twice the conductance of one of the edge slots

$$R_{in} = \frac{1}{2G_1} \tag{18}$$



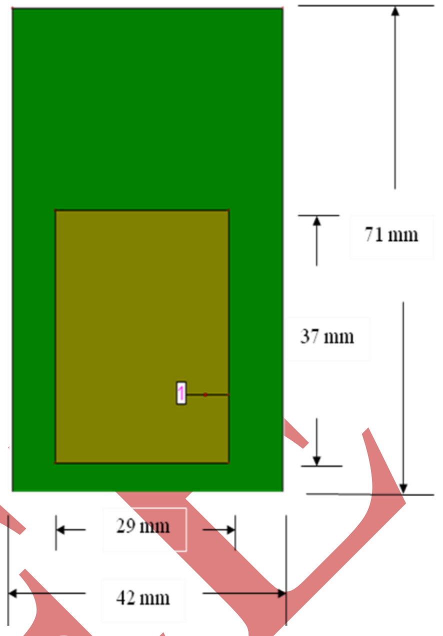


Figure1: Coax feed microstrip patch antenna

Figure 2.Simulation setup of feed point from IE3D

The patch can be fed by a coax line from underneath "Fig.1". The impedance varies from zero in the center to the edge resistance approximately as

$$R_{in} = \frac{1}{2G_1}\cos^2\frac{\pi}{L}x_0 \qquad 0\leq x_0 \leq L/2 \qquad (19)$$

Where R_i is the input resistance, R_e the input resistance at the edge, and x_0 the distance from the patch center.

III ANTENNA DESIGN

In common use, a rectangular microstrip antenna mainly includes a ground plate, a radiation unit and a power unit. The design of substrate L_0 x W_0 x h, the size of radiation sticks slab L x W. The antenna structure dimensions can be calculated by making use of microstrip theory[9].Based on 4G standard, the up-converter work band of the microstrip antenna should be 2400-2500MHz. Simply taking the work frequency of the microstrip antenna as f=2.5GHz,dielectric constant ε_r = 4.2 which is glass epoxy and thickness of patch h=1.6 mm, we get the antenna length L=29mm, the antenna width W=37mm, by using Eq. (1-4) and conceder the substrate length L_0= 42 mm, the substrate width W_0=72 mm.

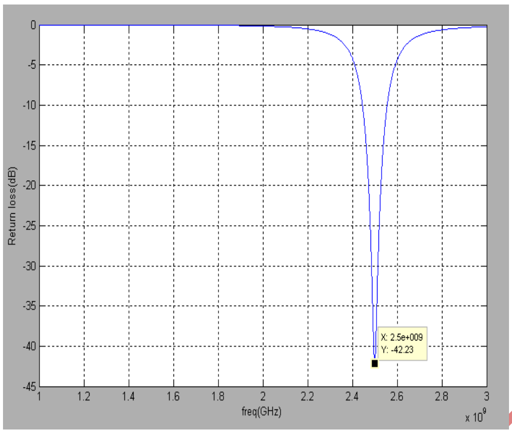
IV SIMULATION AND RESULT ANALYSIS

Making use of the MATLAB software directly [10], we first discuss the way of rectangular microstrip to improve the design of 4G antenna for application of circular polarization. As shown in "Fig.1", there are three layers for the antenna basic structure, in which two layers (1, 3) are air layers with relative dielectric constant as1, and the intermediate layer is a gloss epoxy dielectric layer with relative dielectric constant as 4.2. Now find the value of S_{11} on feeding point(x=19mm, y=23mm) by MATLAB and also simulate the proposed antenna with

IE3D 3D EM simulator [11]. The simulation setup from IE3D of proposed antenna shown in “Fig.2”.Finally compared output simulated and practical results in table1.

4.1 Simulation Result of Reflection Coficient from Matlab and IE3D

Firstly all formulas coded in MATLAB which taken by references then run on working frequency and evaluates reflection coefficient S_{11} with the variation on frequency and also find out the reflection coefficient with IE3D which are shown in“Fig.3-4”, the reflection coefficient represent in 10 dB below of the scale in the range of 2400-2500 MHz so from simulation results are satisfactory.



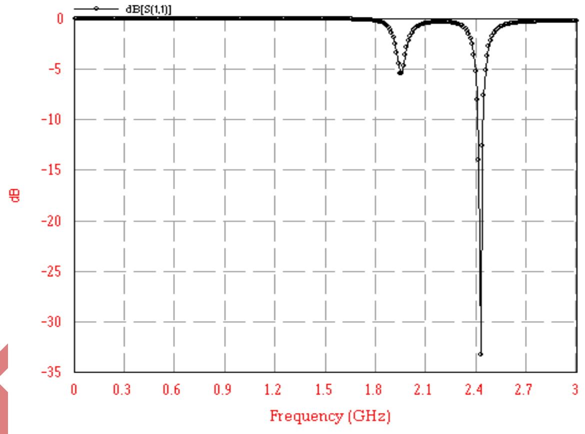
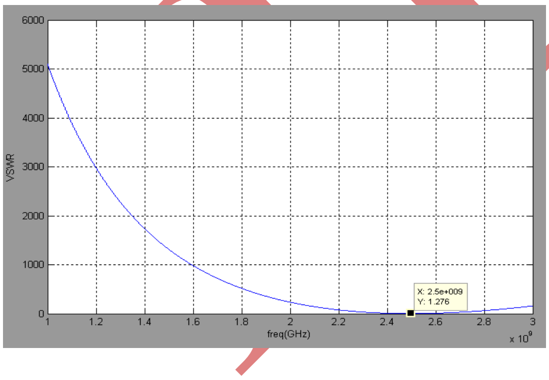


Figure: 3. Return loss Vs frequency plot from MATLAB **Figure: 4. Return loss Vs frequency plot from IE3D**

4.2 Simulation Result of VSWR from MATLAB and IE3D.

Now draw the VSWR plot with respect to frequency variation. The VSWR is less than 2 from some frequency band which is lies between our frequencies range 2400-2500 MHz from output of MATLAB and IE3D simulation, so this is the good agreement of microstrip antenna VSWR condition as shown in “Fig.5-6”.



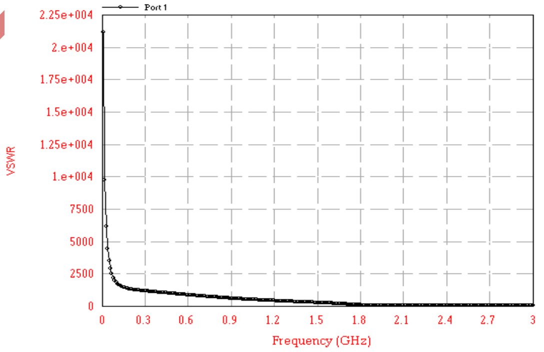
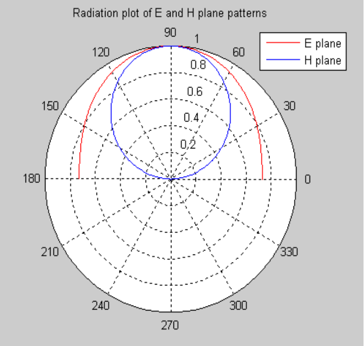


Figure: 5. VSWR Vs frequency plot from MATLAB **Figure 6: VSWR Vs frequency plot from IE3D**

4.3 Simulation Result of Radiation Pattern from MATLAB and IE3D

Now draw the Radiation pattern of simulated data from MATLAB and IE3D, we observe the Electric field and magnetic field is mutually 90^0 out of phase over range of 2400-2500 MHz and its elevation pattern gain display maximum 4 dBi, which are shown in “Fig.7-8”.



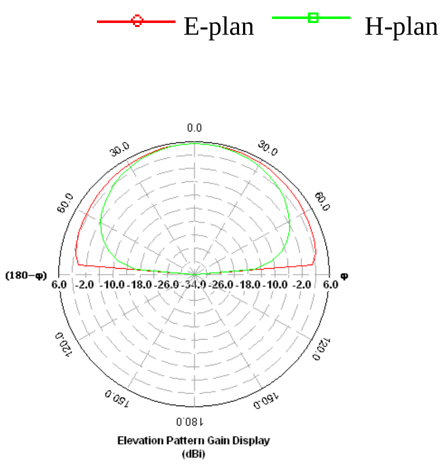
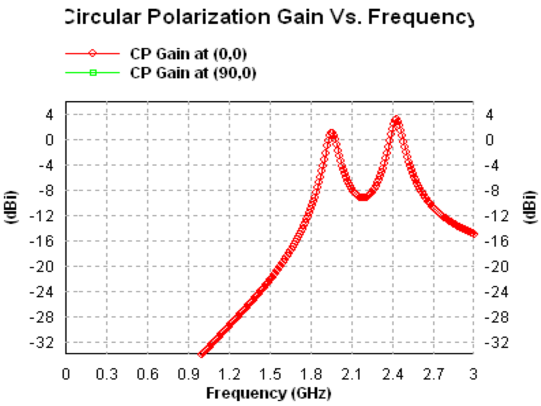


Figure 7: Radiation pattern E, H plane plot from MATLAB   Figure 8: Radiation pattern E, H plane plot from IE3D

4.4 Simulation Result of Circular Polarization Gain and Axial Ratio from IE3D

Now draw the Circular Polarization Gain and Axial Ratio from simulated data of IE3D, which are shown in "Fig.9-10" from the "Fig.9-10" observe the gain is 4 dBi and Axial Ratio is 65 dB at 90^0 out of phase at resonance frequency of proposed antenna.



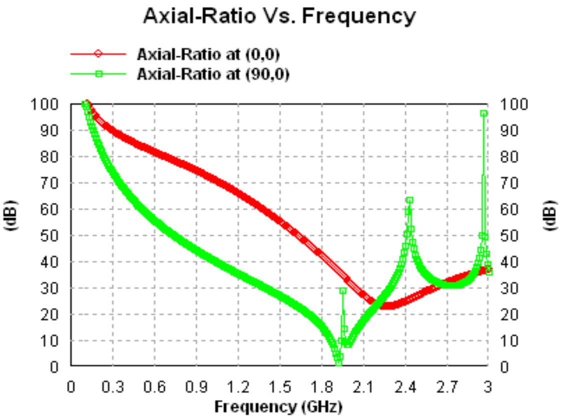


Figure 9.Circular Polarized Gain Vs Frequency Plot   Figure 10.Axial Ratio Vs Frequency Plot

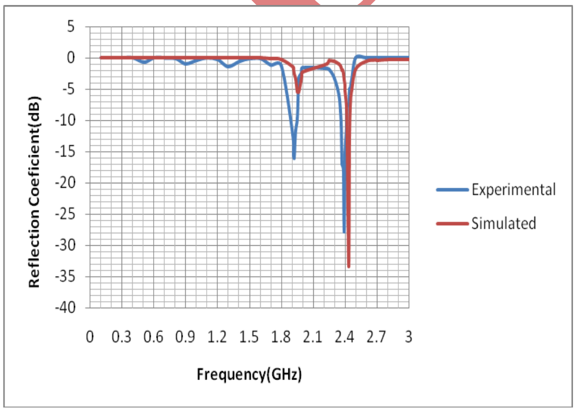


Figure: 11. Reflection Coefficient plot from Spectrum Analyzer and IE3D

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Table I

Comparison on different parameter of the antenna				
Parameter	***Working frequency (GHz)***	***Resonance frequency (GHz)***	***Cavity Model***	***MOM Model***
Return loss	2. 5	2.43	-33. 34(dB)	-42. 29(dB)
VSWR	2.5	2.43	1.276	1.047
Directivity	2.5	2.43	8.0475(dB)	8(dB)

V CONCLUSION

Based on the theoretic and practical analysis of the microstrip antenna, we have discussed the size structure design method. By giving the similar design formula, then we simulated the antenna which can run at 2.5GHz frequency and calculated its reflection coefficient S_{11} by using IE3D based on MOM. Through the simulation and practical analysis, we observed that the return loss shifted within our main frequency ranges 2400-2500 MHz, and from radiation pattern E- field radiates circularly with constant axial ratio. So we can say that the proposed antenna will works on 4G system with circular polarized.

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