Improving Performance of Circularly Polarized Patch Antenna by Varying Stub Positions

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Abstract - *In this paper, we analysed the stacked microstrip planar antenna and improved its performance by implementing circular polarization through change in stub position. Circular polarization is necessary to have constant receiving power levels. In order to create circularly polarized radiation, it is required to excite two orthogonal patch modes on the antenna with 90° phase difference. The extent of improvement is measured through some parameters like return loss, axial ratio and radiation efficiency of antenna using IE3D software.*

Key Words: **Axial ratio, Circular polarization, Return Loss, Radiation efficiency, Stub, Bandwidth**

1. INTRODUCTION

A three layer stacked microstrip planner antenna with air sandwiched in them is used. The outer layers are equally thick and have the same dielectric constant. Circular polarization [1] can be obtained by a number of methods [2] such as:

1. 3-dB hybrid
2. Truncated corner
3. Stub on radiating edge
4. Corner fed
5. Slot centre

(Refer to Figure 1). An antenna mostly radiates an elliptical polarization defined by parameters such as axial ratio, tilt angle and sense of rotation. In our experiment we have used the Stub position method in order to generate unity axial ratio i.e.0 dB for a perfect circular polarization.

2. PROPOSED ANTENNA DESIGN

The simple structure of single-feed circularly polarized microstrip antennas [3] does not require an external polarizer. Although this offer some advantages but the main weakness of an ordinary microstrip antenna is its narrow bandwidth. There are several techniques [4] to overcome this problem. We have used the method of stacked microstrip patch as shown below (Figure 2):

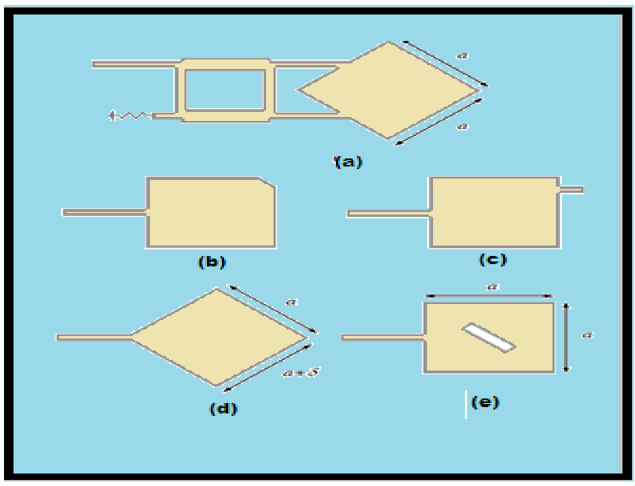

Fig-1: (a) 3-db hybrid (b) Truncated corner (c) Stub on radiating edge (d) corner fed (e) Slot centre

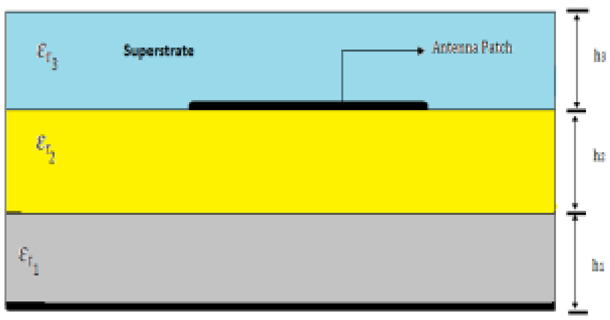

Fig-2: A patch antenna in a three layers dielectric

The stacked microstrip patch method for the multilayer (three Layers) microstrip antenna structure involves addition of a superstrate layer [5] over the patch. With the addition of superstrate, effective permittivity of all the substrate reduces. Hence, the length of the patch is decreased than the original length required for the resonance at 2.4 GHz. We will use the following quasi-static equation [6] for the multilayer dielectric structure shown in Fig 2. Equation (1) can still be used provided that the proper effective permittivity is determined.

$$f_{mn} = \frac{c}{2\sqrt{\varepsilon_{eff}}}\left[\left(\frac{m}{2W}\right)^2 + \left(\frac{n}{2L}\right)^2\right]^{1/2} \quad (1)$$

The expression for ε_{eff} [7] is:

$$\varepsilon_{eff} = \varepsilon_{r1}\varepsilon_{r2}\frac{(q_1+q_2)^2}{\varepsilon_{r1}q_2+\varepsilon_{r2}q_1} + \varepsilon_{r3}\frac{(1-q_1-q_2)^2}{(1-q_1-q_2-q_3)+q_3} \quad (2)$$

Where, ε_{eff} = Effective dielectric constant

ε_{r1}, ε_{r2}, ε_{r3} = Dielectric constant of substrate 1 and substrate 2, substrate 3 respectively,

q_1, q_2 and q_3 = filler constants.

It is necessary to calculate filler constants q_1, q_2 for calculating effective dielectric constant for given stack of dielectric layer as given by equation (2). Hence filler constants can be calculated as follows -

$$q_1 = \frac{h_1}{2h_{12}\left\{1+\frac{\pi}{4}-\frac{h_{12}}{w_e}\ln\left[\frac{2w_e}{h_1}\sin\left(\frac{\pi h_1}{2h_{12}}\right)+\cos\left(\frac{\pi h_1}{2h_{12}}\right)\right]\right\}} \quad (3)$$

$$q_2 = 1 - q_1 - \frac{h_{12}}{2w_e}\ln\left(\frac{\pi w_e}{h_{12}} - 1\right) \quad (4)$$

$$q_3 = 1 - q_1 - q_2 - \frac{h_{12}-v_e}{2w_e}\ln\left[\frac{2w_e}{2h_{12}-h_{12}+v_e}\cos\left(\frac{\pi v_e}{2h_{12}}\right) + \sin\left(\frac{\pi v_e}{2h_{12}}\right)\right] \quad (5)$$

With

$$w_e = w + \frac{2h_{12}}{\pi}\log_e\left[17.08\left(\frac{w}{2h_{12}} + 0.92\right)\right] \quad (6)$$

Where,

$h_{12} = h_1 + h_2$, and $h_{13} = h_1 + h_2 + h_3$.

Dielectric constant is calculated according to the values given in table 1 below. The stacked multilayer antenna can be treated as a single substrate patch antenna having effective dielectric constant as calculated above. The effective dielectric constant using above formula is ε_{eff} =1.03.

Table 1: Substrate specification for Fabrication

LAYER	Substrate	Dielectric constant (ε_r)	Height (h) mm
layer 1	DSWT	1.07	1.6
layer 2	Air	1	5
layer 3	DSWT	1.07	1.6

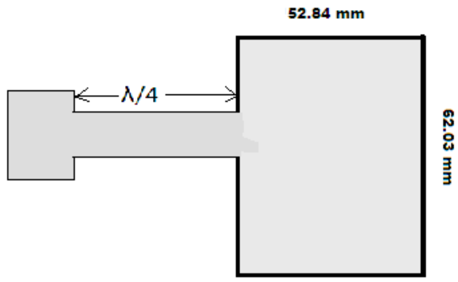

Fig-3: Patch of three layered Reference antenna

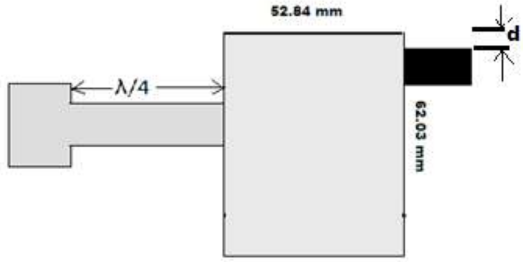

Fig-4: Circular Polarization using Stub at radiating edge of patch of three layered antenna

3. RESULT AND DISCUSSION

Initially in our research, we simulated the three layered antenna without stub. The simulation was designed using IE3D software and results were analysed. The results were unsatisfactory as antenna seemed to be randomly polarized showing poor return loss and axial ratio. The return loss of reference antenna was obtained around -9 dB, as shown in figure 5 and 6, indicating poor matching with antenna impedance. The axial ratio was also found to be outside the 3dB in three layers reference antenna as per figure 7. Then stub was introduced in the antenna system to improve parameters such as axial ratio, bandwidth, antenna efficiency etc. Using the stub at different position, the performance of antenna improved as discussed next.

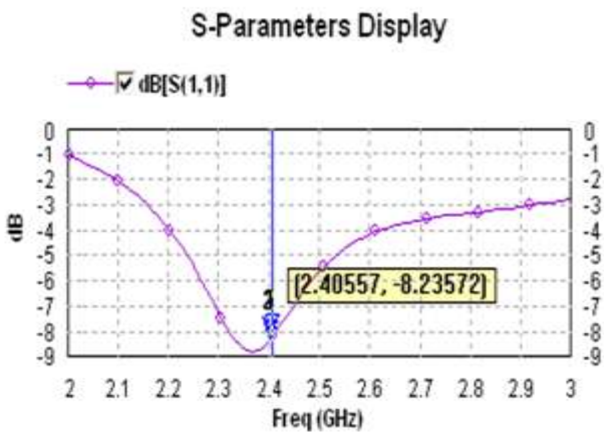

Fig-5: Return Loss of Multilayered reference Antenna

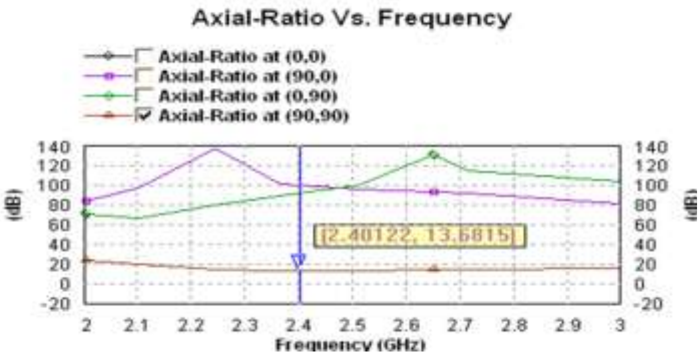

Fig-6: Axial Ratio of three layered reference Antenna

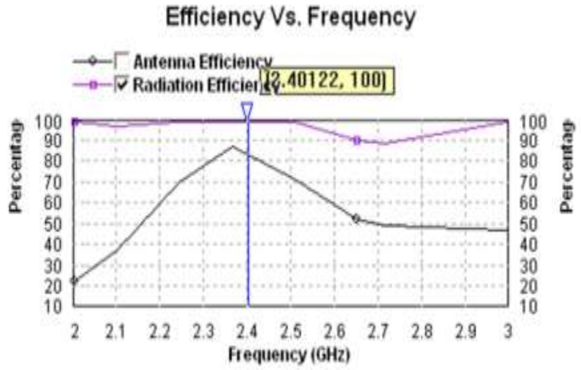

Fig-7: Efficiency of Multilayered reference Antenna

A stub is introduced at one of radiating edge to bring the result within the limit of all parameters. The dimension of stub is taken constant as 10 mm x 8 mm but position of stub is varied. The best result we obtained by varying the stub's position is given in figure 8,9,10 for axial ratio, return loss and efficiency. We observe that, with the introduction of stub, the input impedance has been changed remarkably which in turn changes the best return loss and gives the better result of axial ratio indicating polarization purity (introducing orthogonal component having 90^0 phase shift). The different results we obtained by varying the stub's position is given in table 2 for axial ratio, return loss and efficiency.

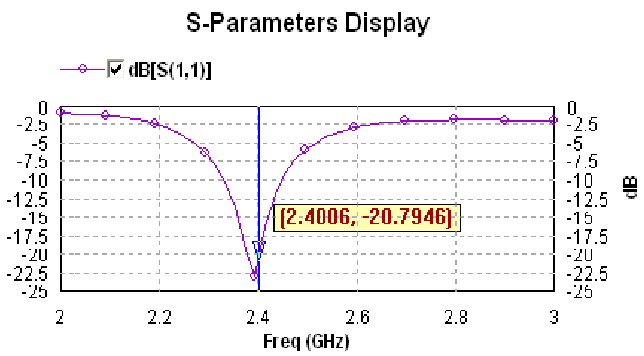

Fig-8: Return Loss of Antenna using Stub

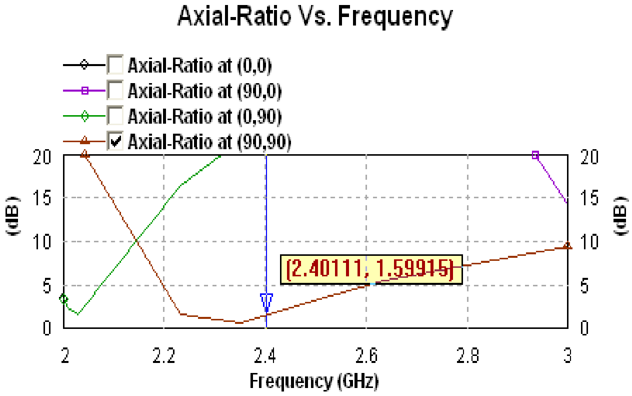

Fig-9: Axial Ratio of Multilayered Reference Antenna

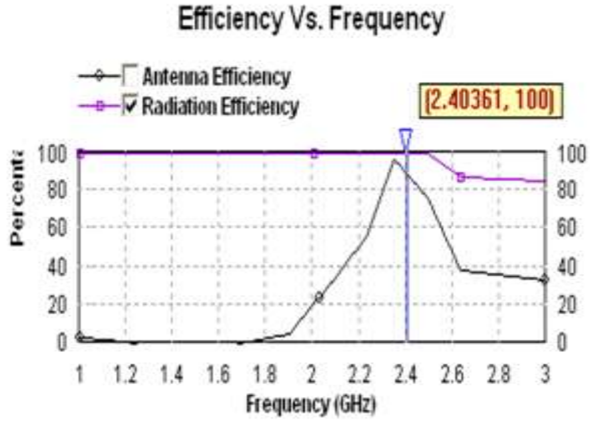

Fig-10: Efficiency of Antenna using Stub

4. CONCLUSIONS

In our paper, three layers microstrip planar antenna with dimensions 52.81x62.06 mm was taken as the base antenna. In order to obtain circular-polarization we tried to achieve 0 dB value of unity axial ratio for polarization purity. Polarization purity is the ratio of major axis to the minor axis in elliptical polarization. In our paper we have used the stub position method to achieve circular polarization in which the position of stub is varied and the parameters such as Return loss, axial ratio, antenna efficiency and radiation efficiency are measured. We were able to achieve the value of return loss as -21.091, axial ratio as 1.643 with 100% antenna efficiency which makes our antenna design perfect for circular polarization.

Table 2: Variation of all the parameters with the stub position

S No.	d (mm)	Resonant Frequency (GHz)	Return Loss	Band-width	Axial Ratio	Radiation Efficiency
1	5	2.4	-19.78	0.11	2.14	99.85
2	6	2.4	-21.09	0.11	2.19	100
3	7	2.4	-20.42	0.11	1.64	100
4	8	2.4	-20.28	0.11	1.64	100
5	9	2.4	-17.94	0.10	1.97	99.84

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