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Design and Simulation of High Performance Rectangular Microstrip Patch Antenna Using CST Microwave Studio

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***Abstract*—The Microstrip patch antenna has become very famous and has attracted much attention towards the research because of its light weight, compact, inexpensive and are capable of maintaining high performance over a wide range of frequencies are preferred. In this paper, the rectangular patch is designed with different parameters like return loss, VSWR, directivity along two directions, radiation pattern in 2-D and 3-D, smith chart , impedance matching are simulated using CST Microwave Studio simulation software. The microstrip patch antenna is designed to increase the bandwidth and return loss. FR-4 with dielectric constant of 4.3 is used as a substrate for the proposed antenna. The designed rectangular microstrip patch antenna with inset feed technique is very useful for various applications in Industrial, Scientific and Medical sectors which operates at 3GHz range. It shows the return loss of -37.08dB and 6.652 dBi gain at the resonating frequency of 2.946 GHz. The inset feed and slot improve the impedance matching and return loss of the antenna.**

***Index Terms*—Patch antenna,Return loss,Gain, Directivity,CST MWS**

I. INTRODUCTION

The microstripe patch antenna consists of a small Metallic patch over a large metallic ground layer.A dielectric sheet known as substratesupports the patch.Using printed circuit board technology, the patch is usually etched on the dielectric substrate. That's why a microstrip patch is also referred to as Printed Antennas .The performance of patch depends on its size and shape. A microstrip patch can be fed either by a microstrip transmission line or co-axial transmission line. The microstrip line can be etched in a single process, together with the patch.A recess in the patch is generated to reach the correct Impedance point on the patch.The recess depth is calibrated to match the impedance. A patch antenna fed with a coaxial transmission line has an input bandwidth of around 2 to 4 percent. A single patch antenna provides 6-9db for the maximum directive gain. An inherent advantage of patch antenna is its ability to have diversity of polarization. Using multiple feed points or a single feed point with asymmetric patch configurations, patch antennas can be ideally built to have vertical, longitudinal, right hand circular polarization RHCP or left hand circular (LHCP) polarization.The patch normally fed to symmetry around the middle line, thus reducing the excitation of undesirable modes. For improved performance feeding line will have the impedance equal to patch impedance characteristics.A microstrip line was fed to the patch antenna Linked to the point inside of the patch where the impedance to the input is 50Ω. The patch may be square, rectangular, circular, triangle and elliptical but the most commonly used microstrip patch antenna is the rectangular microstrip patch antenna [1]. The basic outline of the antenna is depicted in Figure 1, where W is the width, and L is the length (relative to the feed point)[7]. In the simplest structure, $L = W = \lambda_{eff}/2$,

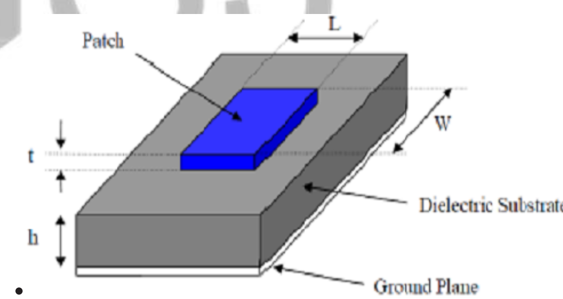

Fig. 1. Basic structure of a microstrip patch antenna.

which means an constant (ϵ_r) of the substance between the patch and the conductive surface (substrate) below which causes the shortening effect. The patch of antenna is a thin metal strip mounted on the ground plane under which the thickness of the metal strip is limited by $t << \lambda_0$ and the height is restricted by $0.00330 < h < 0.0530$ to reduce the fringing effect and analyzed the range of dielectric constants are usually high i.e. in the range of $2.2 < \epsilon_r < 12$ [2-3].

II. DESIGN PARAMETERS FOR PATCH ANTENNA

The most important three parameters considered for constructing a Microstrip patch antenna are given below [4]:

- Frequency of operation (f_0): The antenna has been designed between the range of 2-4 GHz and 3.0 GHz is the default resonant frequency exclusive for this research arrangement.

- Dielectric constant of the substrate ϵ_r: Dielectric constant is one of the most important parameters in the Microstrip antenna and substrate is used. One of the most used materials is FR4, but it only supports the 2-4 GHz range. FR4 PCB is also not capable of handling high power at microwave frequencies. Its permittivity is 4.3.
- Height of dielectric substrate (h): Antennas used in phones are expected to be light in weight and small in size, which restricts their height. By substituting $c = 310^8 m/s, \epsilon_r = 4.3$ and $f_0 = 3$GHz, the values of antenna dimensions can easily be determined. The following equations are used in designing the patch antennas [4-5]:

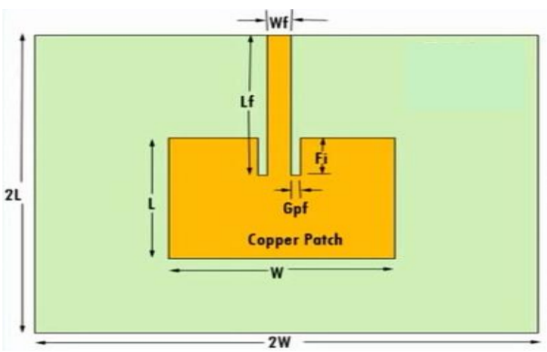

Fig. 2. Inset feed microstrip patch antenna.

- Calculation of the width(W): $W = \frac{c}{2\times f_0 \sqrt{\frac{(\epsilon_r+1)}{2}}}$
- Calculation of effective dielectric constant(ϵ_{reff}): $\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2} \times [\frac{1+12h}{W}]^{\frac{1}{2}}$
- Calculation of extension length (ΔL: ΔL=$\frac{0.412(\frac{W}{h}+0.264)(\epsilon_{reff}+0.03)}{(\epsilon_{reff}-0.258)\times(\frac{W}{h}+0.8)}$
- Calculation of effective length (L_{eff}):L_{eff})=$\frac{c}{2f_0\sqrt{\epsilon_{reff}}}$
- Calculation of actual length of patch (L): $L = L_{eff} - 2\Delta L$
- Calculation of ground plane dimensions (L_g and W_g): $L_g = 2L, W_g = 2W$
- Calculation of Length of the Microstrip transmission line [5]: $TL = \frac{\lambda}{4} = \frac{\lambda_0}{4\sqrt{\epsilon_r}}$

The dimensions of the antenna design used in this work are shown in Table-1:

TABLE I
DESIGN PARAMETERS OF THE ANTENNA

Parameter	Value	Unit
Resonant Frequency (fr)	2.946	GHz
Substrate Width (W_g)	61.38	mm
Substrate Length (L_g)	47.36	mm
Patch Width (W)	30.69	mm
Patch Length (L)	23.68	mm
Length of the inset(Fi)	7.53	mm
Length of the Microstrip transmission line	12.056	mm
Dielectric constant of substrate (ϵ_r)	4.3	mm
The height of the dielectric substrate (h)	1.6	mm
The height of the conductor (t)	0.035	mm
The width of Microstrip feed line (Wf)	3.137	mm
The gap between the patch and the inset-fed (Gpf)	0.512	mm

III. RESULT AND DISCUSSIONS

The Microstrip patch antenna is designed and simulated using CST. This program analyzes the 3D and multilayer configurations in general forms.It have been commonly used for the design of different antenna types.It may be used to calculate and plot the return loss, standing wave ratio from Smith charts, Real power Vs Frequency, VSWR, E-field and H-field distribution, gain as well as radiation patterns.

A. Return Loss and Real Power:

Fig.-3 shows that the antenna is resonating at 2.946 GHz. Return loss is the simplest way to describe the input and output of the signal sources or when the load is not matched or not all the available generated power is delivered to the load [8]. The parameter S_{11} has been calculated for the proposed antenna and the results of the simulated return loss are shown in Fig.3.The value of return loss has been found as -37.08dB which is very good. In figure 4 describes the different real

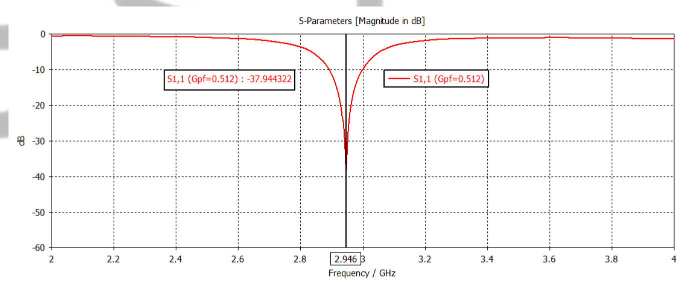

Fig. 3. Simulated return loss curve

power for this proposed antenna.The power losses in the metals is 0.00835..W and accepted power is 0.499...W. Fig.5 shows the efficiency of the designed antenna in dB.

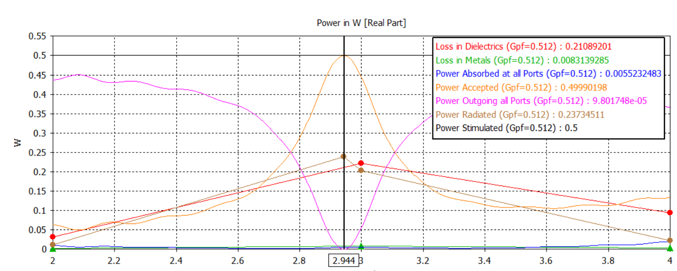

Fig. 4. Real power vs frequency

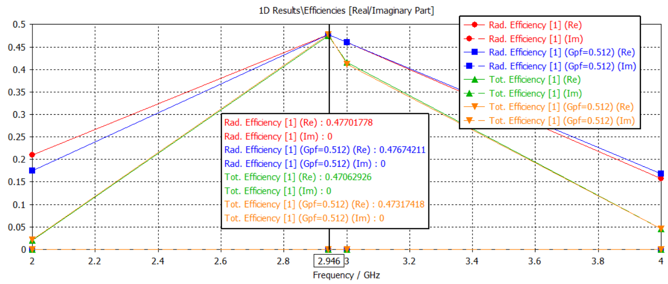

Fig. 5. Efficiency of the proposed antenna

B. Voltage Standing Wave Ratio (VSWR):

The calculation of impedance mismatch is Known as VSWR (Voltage Standing Wave Ratio)[9]. The VSWR ratio of proposed antenna is found as 1.028 as shown in Fig.6, which should lie in between 1 and 2.

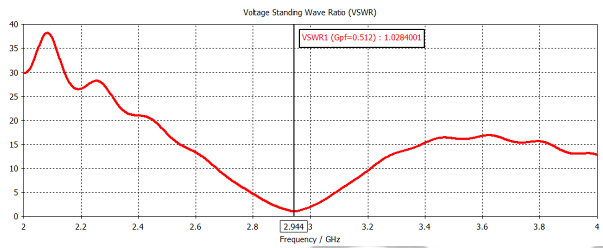

Fig. 6. VSWR at resonant frequency of 2.946 GHz

C. Bandwidth

From the figure- the antenna bandwidth was calculated by using this formula [5]:
Bandwidth:= $\frac{f_1 - f_2}{\sqrt{f_1 \times f_2}} \times 100\%$. The value of f_1 and f_2 are taken at -10dB and the bandwidth of the designed is obtained 3.68%.

D. E-field, H-field,Power flow and surface current Distribution

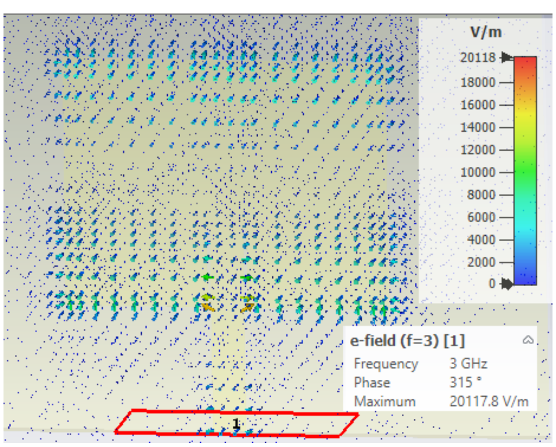

Fig. 7. E-field Distribution of the designed Antenna at 3GHz

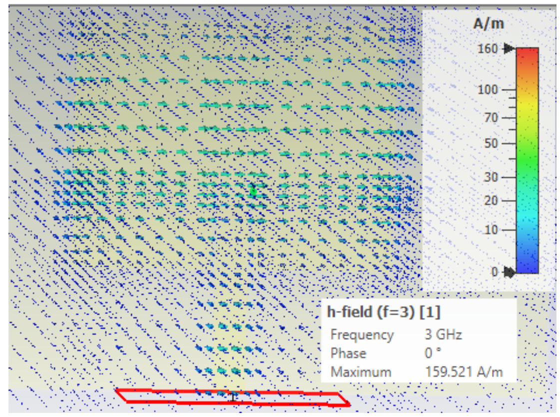

Fig. 8. H-field Distribution of the designed Antenna at 3GHz

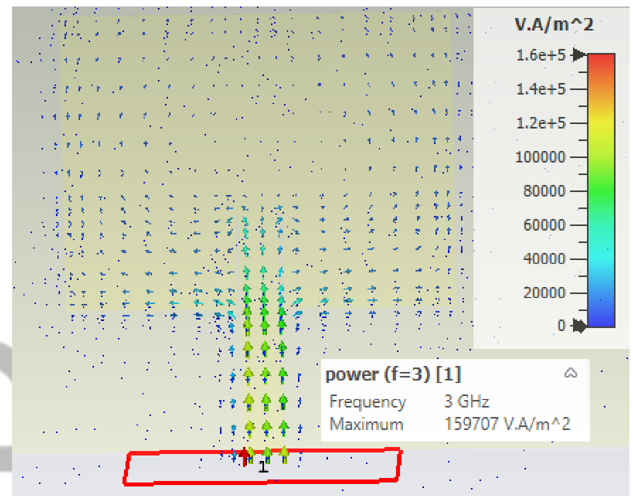

Fig. 9. Power flow of the antenna at of 3GHZ

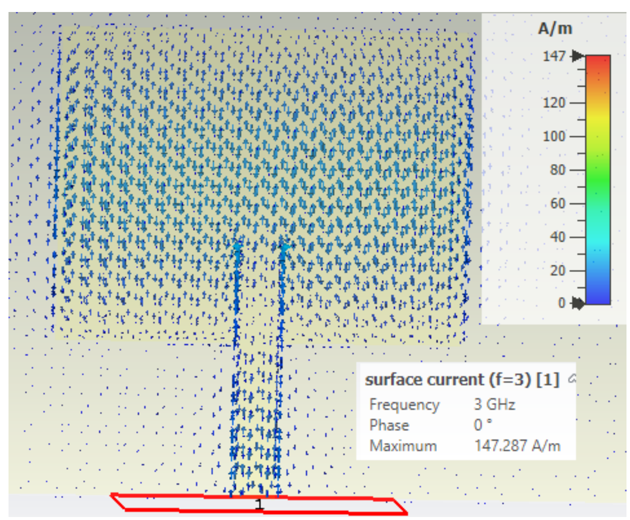

Fig. 10. Surface current distribution of the designed Antenna at 3GHz

E. 3-D Far-Field Radiation Pattern for Directivity and Output Gain

- Gain: Gain is a very important parameter of every antenna. Basically, the gain is the ratio of the radiated field intensity by est antenna to the radiated field intensity by the reference antenna. Antenna gain, usually expressed in dB, simply refers to the direction of maximum radiation. In this study, the gain of the proposed antenna at the frequency of 3GHz is 3.287dB as shown in Fig.11.

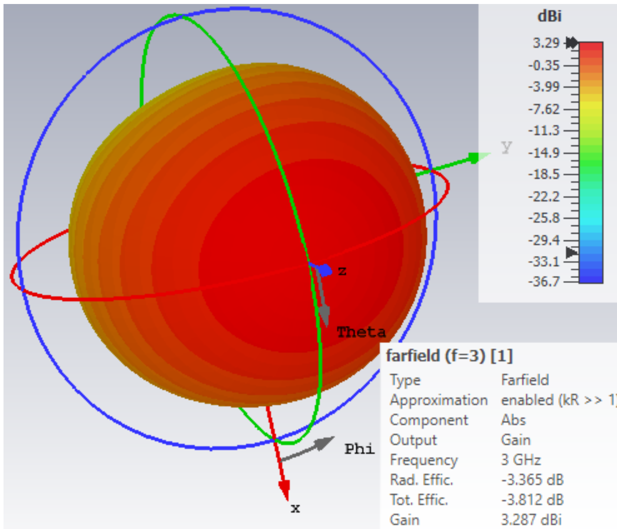

Fig. 11. Gain of the designed antenna at 3GHz

- Directivity: It is desirable to maximize the radiation pattern of the antenna response in a fixed direction in order to transmit or receive power. Likewise, the directivity is dependent only on the shape of the radiation pattern.The achieved directivity of designed antenna is 6.652dBi at 3GHz as shown in fig.12.

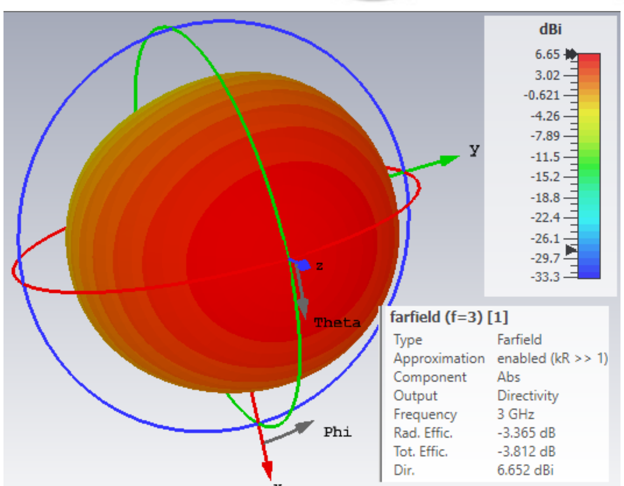

Fig. 12. Directivity of the designed antenna

- Smith Chart: Fig.15 shows the smith chart of the proposed antenna. It is the graphical representation of the normalized characteristic impedance. The Smith chart is used as the most useful graphical tools for high frequency circuit applications. The purpose of the Smith chart is to identify

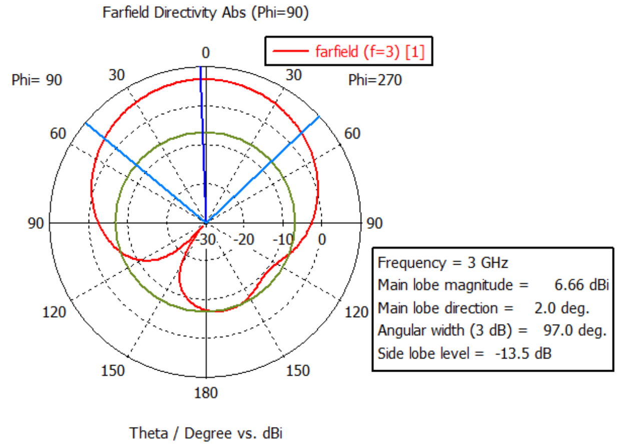

Fig. 13. Polar plot for the elevation angle of the designed antenna

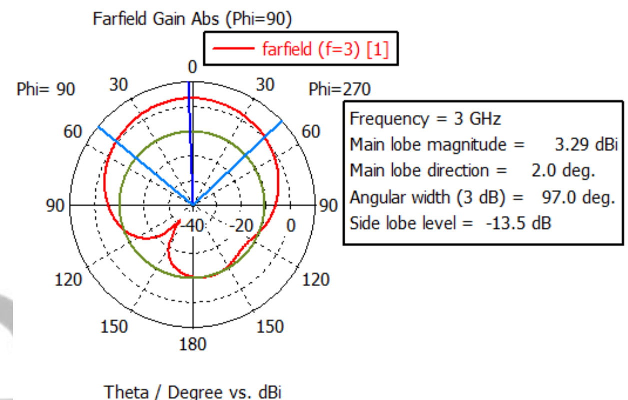

Fig. 14. Polar plot of the farfield gain of the designed antenna

every possible impedance in the reflection coefficient of the domain of existence.

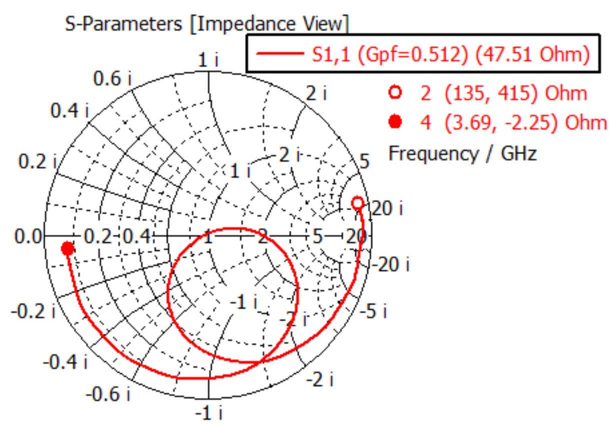

Fig. 15. Smith Chart

IV. Conclusion

In this paper, a simple rectangular microstrip patch antenna is designed and simulated at 3GHz using CST Microwave

TABLE II
SIMULATED RESULTS OF THE DESIGNED ANTENNA

Parameter	Value	Unit
Resonant Frequency (fr)	2.946	GHz
Directivity	6.652	dBi
Gain	3.287	dB
Return Loss	-37.08	dB
Accepted power	0.499	W
VSWR	1.028	–

Studio software for the application in weather radar, surface ship radar, and some communications satellites [6].The radiation pattern and other significant parameters such as gain, efficiency and loss of return has been studied. The return loss at resonant frequency of 2.946GHz is -30.08 at below -10 db which shows that there is good matching at frequency points.The bandwidth of the proposed antenna at -10dB is found 3.68% and the gain of our designed antenna at the frequency of 3GHz is 3.287dB.

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