



Design, Simulation and Analysis of a Square Shaped S-band Microstrip Patch Antenna

Ankan Bhattacharya

Assistant Professor

Department of Electronics and Communication Engg.
Mallabhum Institute of Technology, West Bengal, India

Abstract—In this paper a square shaped Microstrip Patch Antenna has been designed, simulated and analyzed in Zealand IE3D environment. The antenna is fabricated on a 60 mil RO4003 substrate from Rogers - Corp with a dielectric constant of 3.4 and loss tangent of 0.002. The basic design procedure of the antenna is discussed stepwise with appropriate diagrams. Sequential snapshots of the values of various parameters involved in the process of simulation set up are also presented. The surface current distribution is analyzed with appropriate simulations along with the discussion on the S-parameters of the simulated structure. The Elevation Pattern Directivity Display of the antenna is examined in this context. The basic antenna parameters such as Total Field gain, Directivity, Efficiency, Axial Ratio and VSWR are discussed along with the obtained simulation results.

Keywords—Microstrip, Patch, Antenna, IE3D, Gain, Efficiency, Directivity, Axial ratio, VSWR

I. Introduction

A **Patch Antenna** (also known as a rectangular microstrip antenna) is a type of radio antenna with a low profile, which can be mounted on a flat surface. It consists of a flat rectangular sheet or "patch" of metal, mounted over a larger sheet of metal called a ground plane. The assembly is usually contained inside a plastic radome, which protects the antenna structure from damage. Patch antennas are simple to fabricate and easy to modify and customize. They are the original type of microstrip antenna described by Howell; the two metal sheets together form a resonant piece of microstrip transmission line with a length of approximately one-half wavelength of the radio waves. The radiation mechanism arises from discontinuities at each truncated edge of the microstrip transmission line. The radiation at the edges causes the antenna to act slightly larger electrically than its physical dimensions, so in order for the antenna to be resonant, a length of microstrip transmission line slightly shorter than one-half a wavelength at the frequency is used. A patch antenna is usually constructed on a dielectric substrate, using the same materials and lithography processes used to make printed circuit boards. Fig. 1 shows a Probe Feed Patch Antenna. [1]-[3]

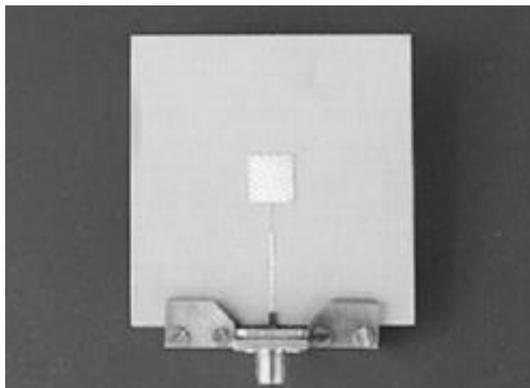


Fig.1 A microstrip patch antenna [4]

II. Basic Structure

Fig. 2 shows the basic structure of the square shaped microstrip patch. The antenna is fabricated on a 60 mil RO4003 substrate from Rogers - Corp with a dielectric constant of 3.4 and loss tangent of 0.002. The designed patch is 30mm in length and 30mm in width. In this case a rectangular patch is used, fed with a simple microstrip line. The feeding microstrip line is a 50 Ω line and the impedance of the antenna is matched to 50 Ω by using an inset feed.

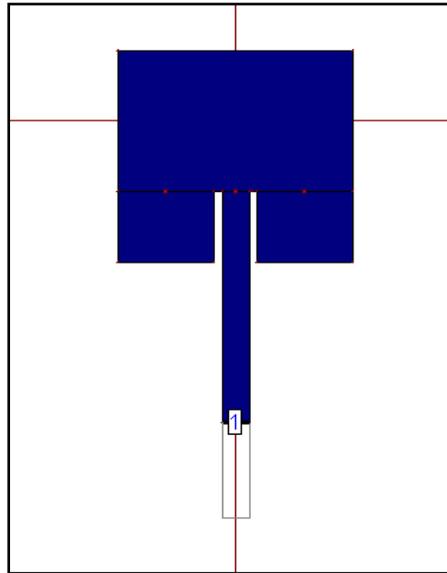


Fig. 2 Square shaped patch

III. METHOD OF MOMENT(MoM)

MoM analysis is a very well known technique for accurate calculations of antenna parameters. It can be used to calculate all the necessary antenna parameters under consideration. [5]

The basic Automatic Meshing Parameters specified are

- Highest frequency(GHz): 3
- Cells per wavelength: 30
- Meshing scheme: Classical
- Rectanglizations: 3 times

Fig. 3 shows a snapshot of the various Automatic Meshing Parameters and Fig. 4 shows a Statistics of the Meshed Structure.

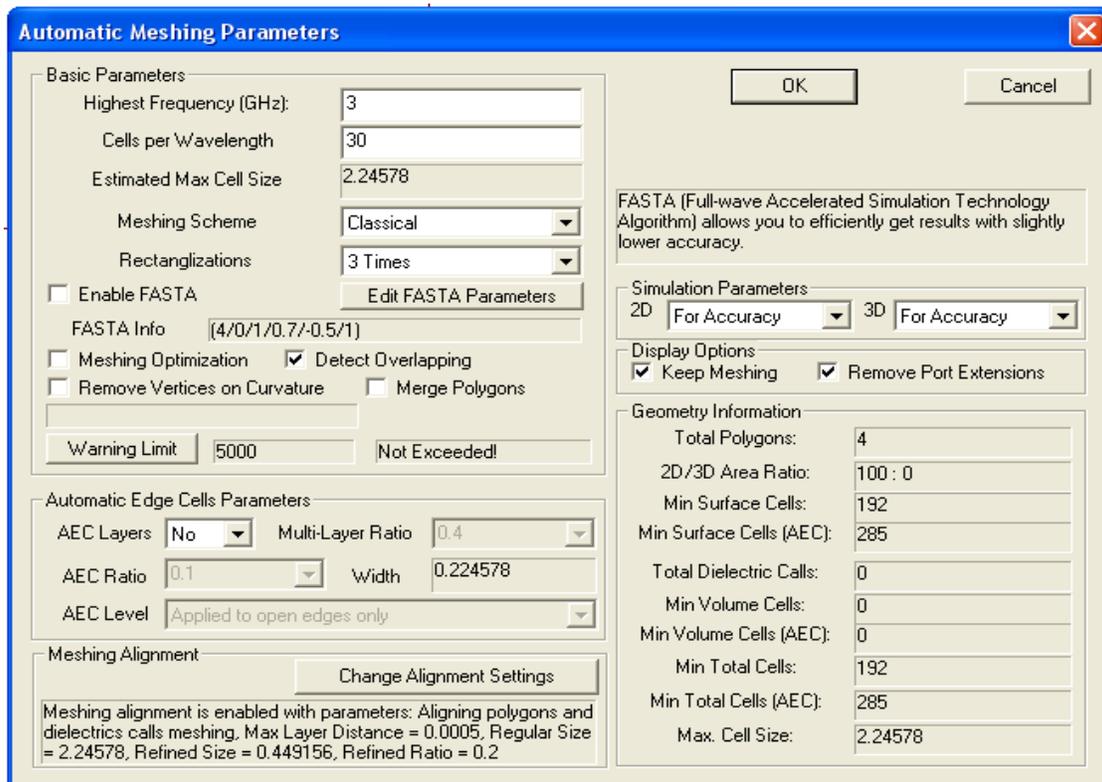


Fig. 3 Automatic Meshing Parameters

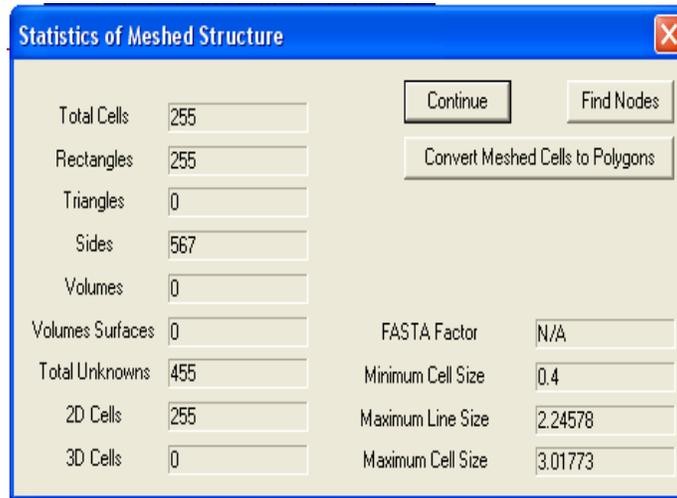


Fig. 4 Statistics of Meshed Structure

IV. SIMULATION SET UP

The Highest frequency specified is 3GHz. The number of cells per wavelength specified is 30. The number of cells/wavelength determines the density of the mesh. In method of moment simulations, one should not use fewer than 10 cells per wavelength. The greater is the number of cells per wavelength, greater is the accuracy of the simulation. However, increasing the number of cells increases the total simulation time and the memory required for simulating the structure. In many simulations using 20 to 30 cells per wavelength should provide enough accuracy. However, this cannot usually be generalized and is different for each problem. As seen in Fig. 3, in the “Automatic Edge Cell Parameters” fields, the “AEC Layers” field shows “NO”. One can define edge cells to increase the accuracy of the simulations. In coupled structures or in structures where multiple trace lines are located in close proximity to each other, it is important to use edge cells. In this case, edge cells will not be used for this simulation. In the ‘Enter Frequency Range’ window the values of the parameters entered are:

- Start Freq.(GHz): 1
- End Freq.(GHz): 3
- No. of Freq: 201

The “Frequency Parameters” field is now filled with 201 evenly spaced frequency points between 1GHz and 3GHz range.

V. Simulation Results

Fig. 5 shows the S-parameters of the simulated structure. From analysis of the figure the exact frequency determined at which S11 is minimized is 2.71904GHz. The antenna is well matched to 50 Ω at this particular frequency.

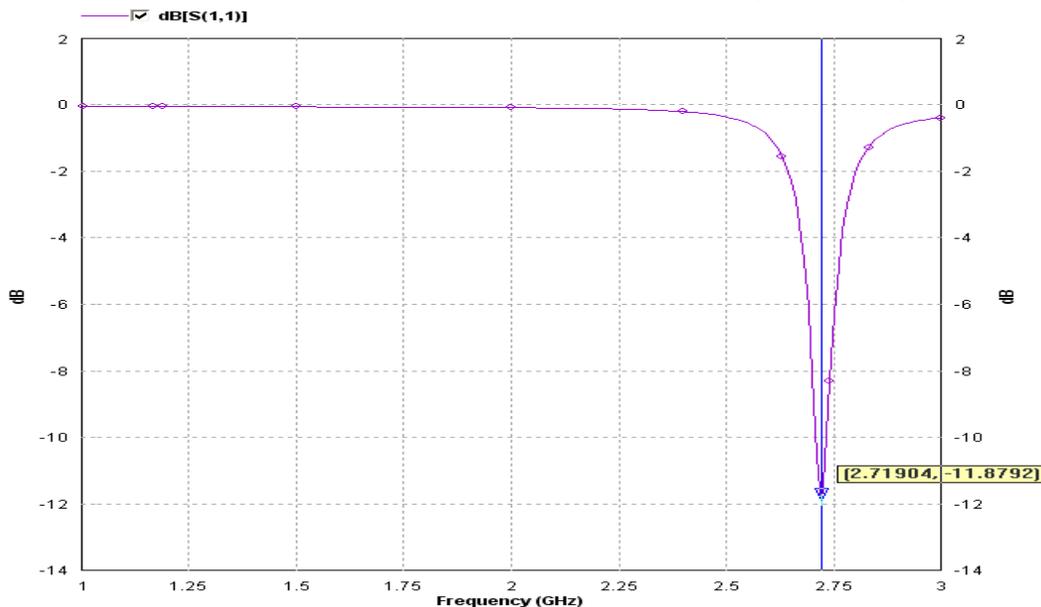


Fig. 5 S parameters

VI. Radiation Parameters

In this context, the current distribution on the surface of the antenna is simulated to obtain the radiation pattern at the frequency of operation. This time, instead of simulating the structure from 1 GHz to 3 GHz, it will only be simulated at 2.71904GHz, which is the frequency of operation of the antenna. Also, the number of cells per wavelength is increased to 70 from 30.

After the simulation is complete, IE3D invokes MODUA to display the S-parameters of the structure. Since there is only one frequency point, so no curve is depicted in MODUA. In this case, IE3D also invokes a secondary MGRID view window, in which the meshed antenna structure is shown as a 3D view window in which a three dimensional version of the structure is shown. In these two windows, the current distribution of the structure can be examined - Fig. 6.

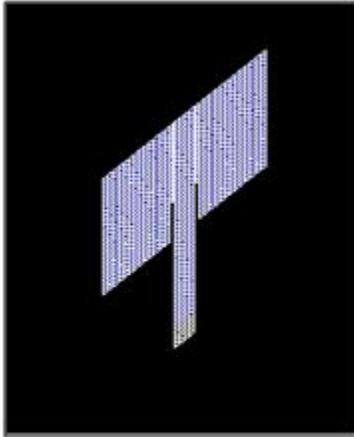


Fig. 6 3D view of the antenna

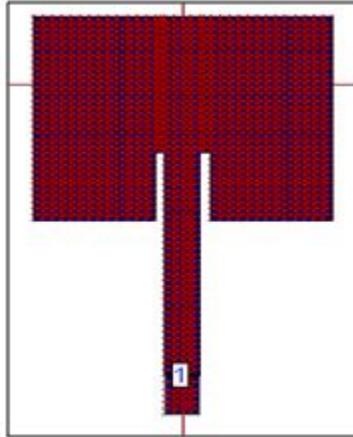


Fig. 7 Densely meshed antenna

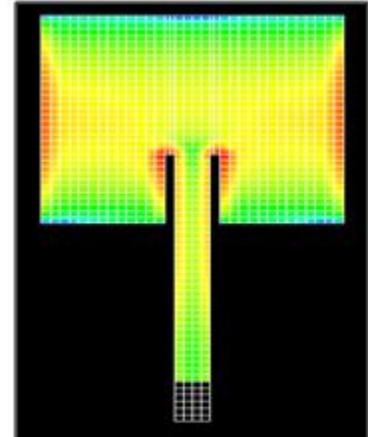


Fig. 8 Antenna surface current distribution

The average current density on the surface of the antenna is shown in different colors. This average current distribution is shown in Fig. 8. The half-sinusoidal current distribution on the surface of the antenna is to be noted here. On the top edge, the current is zero, at the center it is maximum, and on the bottom edge, it is zero again. This indicates a resonance condition. It is also noted that generally the current density is much higher closer to the edges of the structure compared to other areas. This is why it is important to use edge cells in certain problems. The strong edge current densities can significantly affect the response of structures with strong edge couplings (such as edge coupled bandpass microstrip filters).

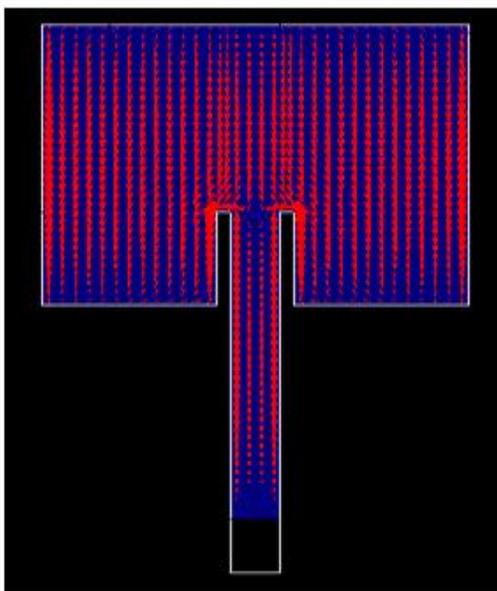


Fig. 9 Vector Electric Current distribution

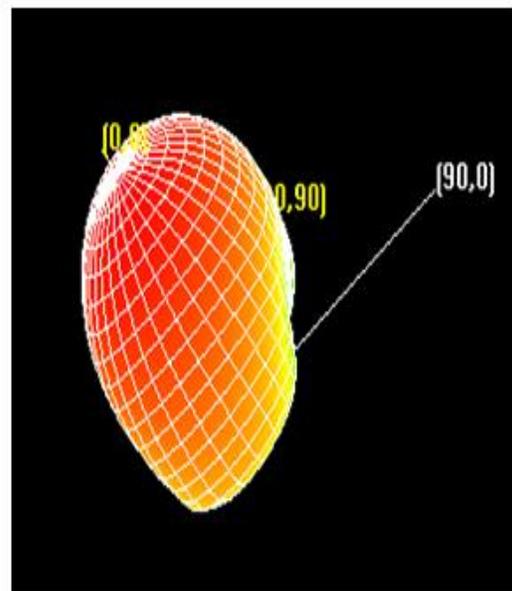


Fig. 10 3D Radiation Pattern

VII. GRAPH ANALYSIS

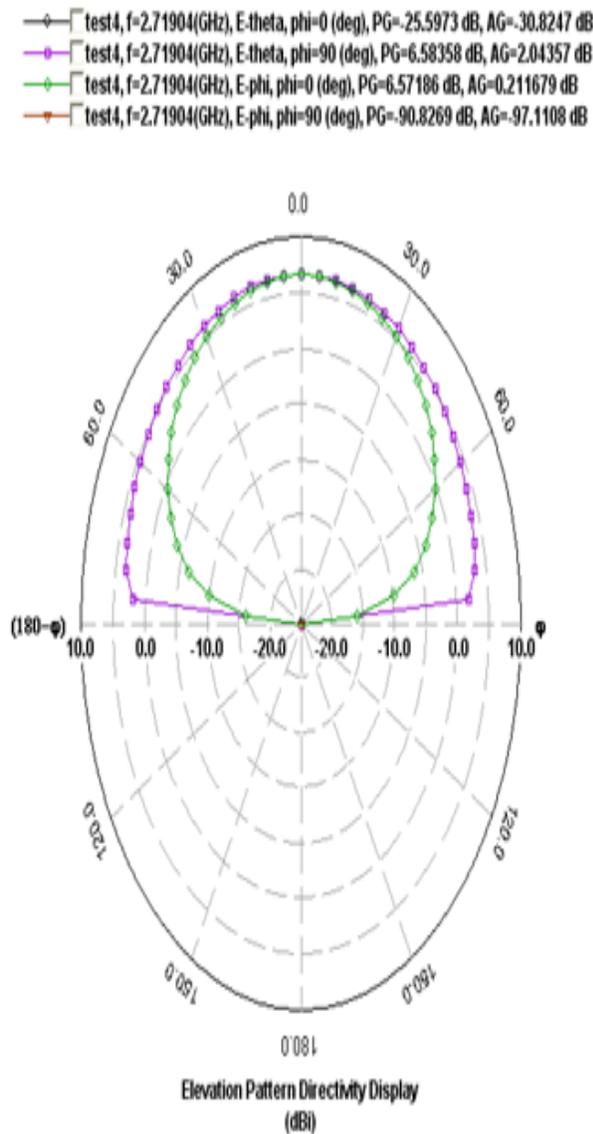


Fig. 11 Elevation Pattern Directivity Display

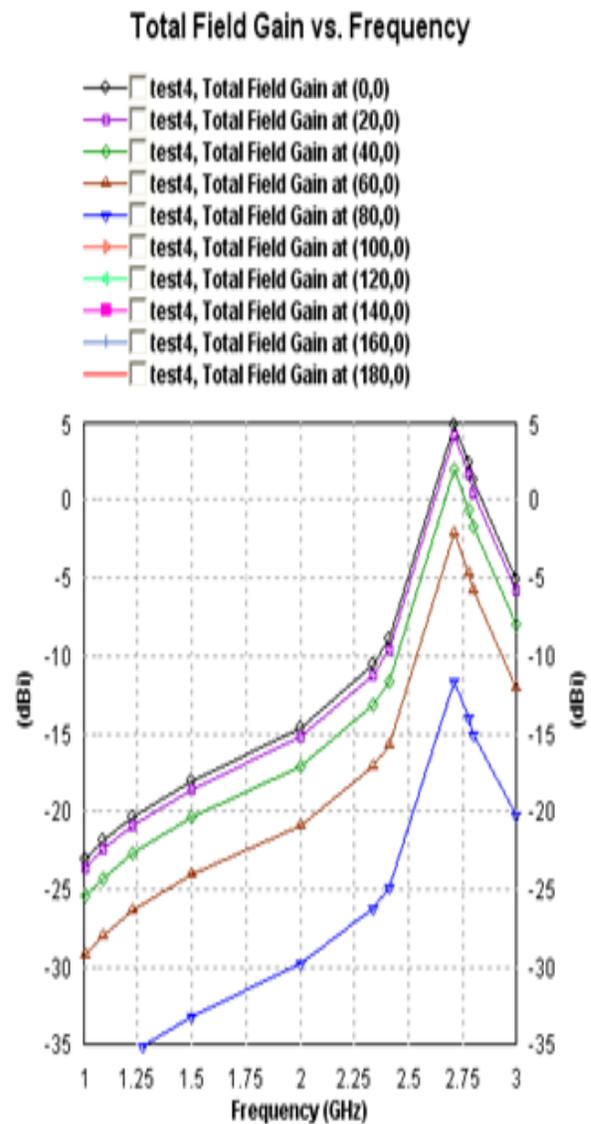


Fig. 12 Total Field Gain vs Frequency

Fig. 11 shows the Elevation pattern directivity display at the operating frequency of 2.71904GHz at phi = 0deg. And phi = 90 deg. respectively.

- E-theta, phi=0 deg., PG=-25.5973 dB, AG=-30.8247 dB
- E-theta, phi=90 deg., PG=6.58358 dB, AG=2.04357 dB
- E-phi, phi=0 deg., PG=6.57186 dB, AG=0.211679 dB
- E-phi, phi=90 deg., PG=-90.8269 dB, AG=-97.1108 dB

In electromagnetics, an antenna's **power gain** or simply **gain** is a key performance figure which combines the antenna's directivity and electrical efficiency. Antenna gain is usually defined as the ratio of the power produced by the antenna from a far-field source on the antenna's beam axis to the power produced by a hypothetical lossless *isotropic antenna*, which is equally sensitive to signals from all directions. Usually this ratio is expressed in decibels, and these units are referred to as "*decibels-isotropic*" (dBi).

Fig. 12 shows the *Total Field Gain vs Frequency* curve at phi = 0 deg. From the figure it can be observed that the Total Field Gain is maximum at the operating frequency of 2.71904GHz.

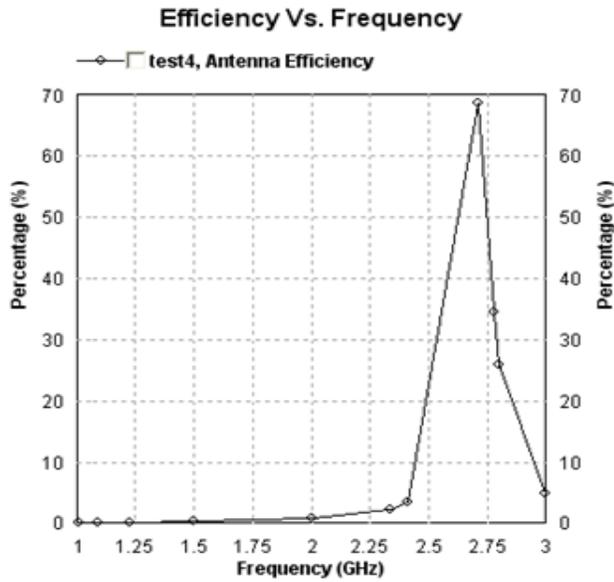


Fig. 13 Efficiency vs Frequency

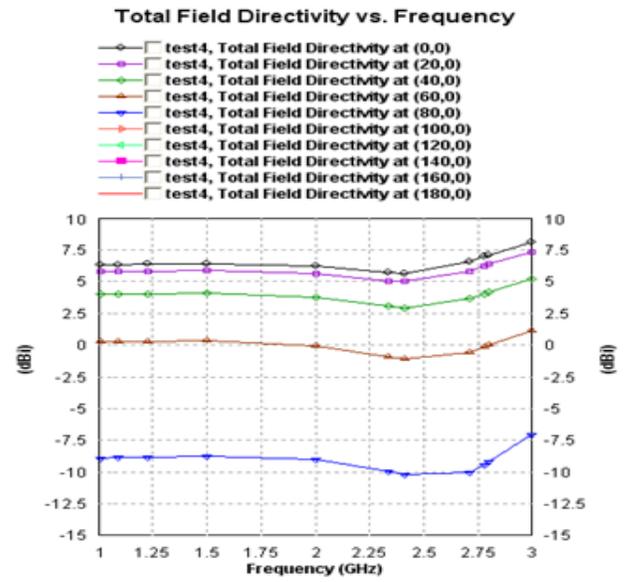


Fig. 14 Total Field Directivity vs Frequency

Radiation efficiency is defined as "The ratio of the total power radiated by an antenna to the net power accepted by the antenna from the connected transmitter." It is sometimes expressed as a percentage (less than 100), and is frequency dependent. It can also be described in decibels.

Efficiency is one of the most important antenna parameters. It can be very close to 100% (or 0 dB) for dish, horn antennas, or half-wavelength dipoles with no lossy materials around them.

Fig. 13 shows the *Efficiency vs Frequency* curve. From the figure it can be observed that the Efficiency is maximum at the operating frequency of 2.71904GHz.

Directivity is a figure of merit for an antenna. It measures the power density the antenna radiates in the direction of its strongest emission, versus the power density radiated by an ideal isotropic radiator (which emits uniformly in all directions) radiating the same total power.

Fig. 14 shows the *Total Field Directivity vs Frequency* plot of the concerned antenna.

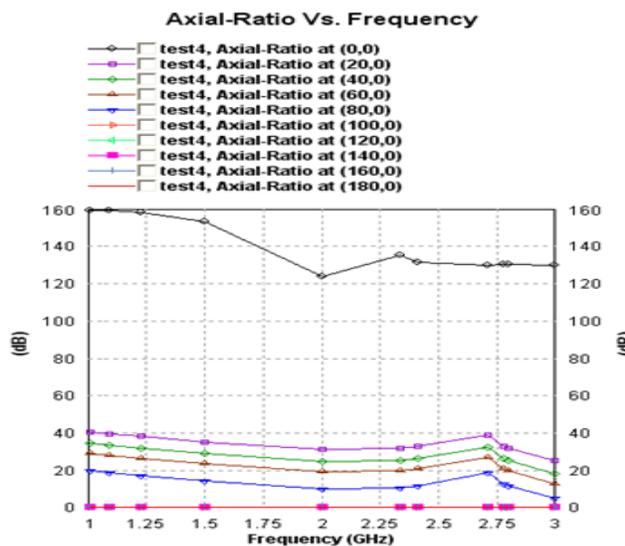


Fig. 15 Axial Ratio vs Frequency

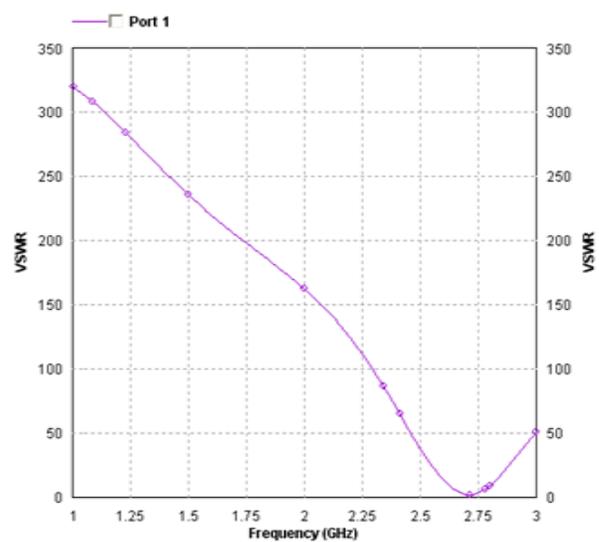


Fig. 16 VSWR vs Frequency

Fig. 15 shows the *Axial Ratio vs Frequency* plot of the patch antenna.

The **Axial ratio** is the ratio of orthogonal components of an E-field. A circularly polarized field is made up of two orthogonal E-field components of equal amplitude (and 90 degrees out of phase). Because the components are equal magnitude, the axial ratio is 1 (or 0 dB).

The **VSWR** is always a real and positive number for antennas. The smaller the VSWR is, the better the antenna is matched to the transmission line and the more power is delivered to the antenna.

The minimum VSWR is 1.0. In this case, no power is reflected from the antenna, which is ideal. Often antennas must satisfy a bandwidth requirement that is given in terms of VSWR. For instance, an antenna might claim to operate from 100-200 MHz with $VSWR < 3$. This implies that the VSWR is less than 3.0 over the specified frequency range. This VSWR specifications also implies that the reflection coefficient is less than 0.5 over the quoted frequency range.

For a radio (transmitter or receiver) to deliver power to an antenna, the impedance of the radio and transmission line must be well matched to the antenna's impedance. The parameter VSWR is a measure that numerically describes how well the antenna is impedance matched to the radio or transmission line it is connected to. The min. VSWR is obtained at the operating frequency i.e. 2.71904 GHz.

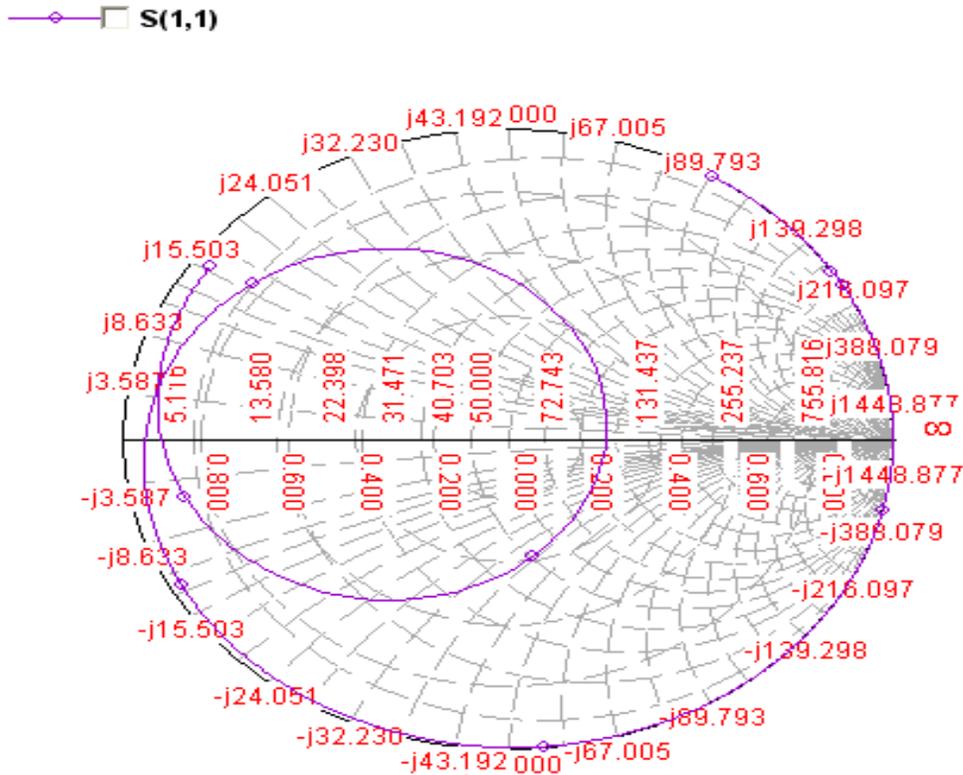


Fig. 17 Smith Chart

The **Smith Chart** is a fantastic tool for visualizing the impedance of a transmission line and antenna system as a function of frequency. Smith Charts can be used to increase understanding of transmission lines and how they behave from an impedance viewpoint. Smith Charts are also extremely helpful for impedance matching. Fig. 17 shows the Smith Chart for the simulated structure.

VIII. Conclusion

A microstrip or patch antenna is a low profile antenna that has a number of advantages over other antennas it is lightweight, inexpensive, and easy to integrate with accompanying electronics. The properties of Probe Feed Square Shaped Patch Antenna have been analyzed thoroughly with the help of appropriate simulation results. A detailed knowledge of Gain and Directivity is necessary in order to design a Probe Feed Patch Antenna. Choosing a substrate for antenna design also plays an important role. Selecting a suitable substrate, may fulfil the antenna requirements. Among all other substrates, RO4003 is a standard substrate from Rogers - Corp with a dielectric constant of 3.4 and loss tangent of 0.002 is capable of providing optimum simulation results. In near future, various other substrate materials will be considered and the antenna characteristics will be analyzed with generalized and quantized results and simulations.

References

1. "Microstrip Antennas," IEEE International Symposium on Antennas and Propagation, Williamsburg Virginia, 1972 pp. 177-180
2. "Radiation from Microstrip Radiators," IEEE Transactions on Microwave Theory and Techniques, April 1969, Vol. 17, No. 4 pp.235-236
3. "Microstrip and Printed Antenna Design" (2nd Edition) Randy Bancroft SciTech Publishing Inc. 2009 page 106
4. <http://www.indiamart.com/microwave-research-corporation/antennas.html>
5. <http://personal.ee.surrey.ac.uk/Personal/D.Jefferies/mmethod.html>
6. C. Balanis, Wiley, Antenna Theory (3rd edition) 2005, ISBN 0-471-66782-X
7. John de Kraus, Ronald J. Marhefka, Antenna for all applications (3rd edition), 2002, ISBN 0-07-232103-2
8. <http://www.antenna-theory.com/basics/directivity.php>
9. Asok De, N.S. Raghava, Sagar Malhotra, Pushkar Arora, Rishik Bazaz, "Effect of different substrates on Compactstacked square Microstrip Antenna"; JOURNAL OF TELECOMMUNICATIONS, VOLUME 1, ISSUE 1, FEBRUARY 2010
10. Md. Amirul Islam, Sohag Kumar Saha, Md. Masudur Rahman, "Dual U-Shape Microstrip Patch Antenna Design for WiMAX Applications"; ISSN: 2278 – 7798 International Journal of Science, Engineering and Technology Research (IJSETR) Volume 2, Issue 2, February 2013
11. Anamika Verma, Dr.Sarita Singh Bhadauria, Rectangular Patch Antenna Using "ARRAY OFHEXAGONAL RINGS" Structure in L-band; ISSN: 2278 – 7798; International Journal of Science, Engineering and Technology Research (IJSETR)Volume 1, Issue 5, November 2012
12. Ashwani Patel Singh, "A Leaf Shaped Microstrip Patch Antenna"; International Journal of Science, Engineering and Technology Research (IJSETR) Volume 2, Issue 4, April 2013
13. J. Doondi kumar, O.Ranga rao, P. Krishna reddy, S.Sarath, S.Bhuvan, "Analysis of Elliptical and Circular Patch Antennas In Presence of HIS ";International Journal of Science, Engineering and Technology Research (IJSETR) Volume 2, Issue 5, May 2013
14. D. Orban and G.J.K. Moernaut, The Basics of Patch Antennas; Orban Microwave Products
15. Rahul Tiwari, "Rectangular micro-strip patch antenna using metamaterial for wireless communication"; Journal of Research in Electrical and Electronics Engineering (ISTP-JREEE)
16. D. C. Nascimento and J. C. da S. Lacava, "Design of Low-Cost Probe-Fed Microstrip Antennas; Technological Institute of Aeronautics; Brazil
17. N.T. Markad, Dr. R.D. Kanphade, Dr. D. G. Wakade, International Journal of Scientific and Research Publications, Volume 2, Issue 5, May 2012 1 ISSN 2250-3153; www.ijsrp.org; Probe Feed Microstrip Patch AntennaComputer Aided Design Methodology;
18. Mehta, G.; Kotha, S. Recent chemistry of benzocyclobutenes. Tetrahedron Lett. 2001, 57.
19. <http://www.sigmaaldrich.com/catalog/product/aldrich/164410?lang=en®ion=>
20. <http://personal.ee.surrey.ac.uk/Personal/D.Jefferies/antennas.html>
21. Chandu DS, Ramesh Deshpande, "Computational analysis of 2.25GHz Rectangular patch antenna"; (IJERT)
22. http://www.soontai.com/cal_rtvsr.html
23. John T. Taylor and Qiuting Huang (1997). CRC Handbook of Electrical Filters. CRC Press. ISBN 0-8493-8951-8.
24. Julie K. Petersen (2003). Fiber Optics Illustrated Dictionary. CRC Press. ISBN 0-8493-1349-X.
25. <http://www.microwaves101.com/encyclopedia/vswr.cfm#vswr>
26. Trevor S. Bird, "Definition and Misuse of Return Loss", IEEE Antennas & Propagation Magazine, vol.51, iss.2, pp.166-167, April 2009.
27. Ankan Bhattacharya, "Design, simulation and analysis of a Probe Feed Patch Antenna with Benzocyclobutene as the substrate material", International Journal of Science, Engineering and Technology Research (IJSETR), ISSN: 2278 – 7798, Volume 2, Issue 7, July 2013