Scientific Journal of Impact Factor(SJIF): 3.134

e-ISSN(O): 2348-4470
p-ISSN(P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 2, Issue 6, June -2015

Design, Simulation and Fabrication of Patch array antenna for Indian Regional Navigation Satellite System

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Abstract— *The modern mobile communication systems requires high gain, large bandwidth and minimal size antenna's that are capable of providing better performance over a wide range of frequency spectrum.This paper presents the design of microstrip rectangular patch antenna with center frequency at 1.176GHz for IRNSS application. The array of four by one (1x4) patch array microstrip rectangular antenna with microstrip line feeding based on quarter wave impedance matching technique was designed and simulated using Advance design system(ADS) tool. The performance of the designed antenna was than compared with the single patch rectangle antenna in term of return loss, Voltage Standing Wave Ratio (VSWR), bandwidth, directivity, radiation pattern and gain. The array antenna on the substrate type FR-4 with dielectric constant of 4.6 and thickness of 1.6mm respectively.*

Keywords— *Patch array antenna, ADS Software, Return loss, Antenna gain, Bandwidth*

I. INTRODUCTION

Communication between humans was first by sound through voice. It has been only very recent in human history that the electromagnetic spectrum, outside the visible region has been employed for communication, through the use of radio. One of humankind's greatest natural resources is the EM spectrum and the antenna has been instrumental in harnessing this resource.

Microstrip patch antennas (also just called patch antennas) are among the most common antenna types in use today, particularly in the popular frequency range of 1 to 6GHz. This type of antenna had its first intense development in the 1970s,as communication systems became common at frequencies where its size and performance were very useful. At the same time, its flat profile and and other antenna options, made it attractive for airborne and spacecraft applications. More recently, those same properties, with additional size reduction using high dielectric constant materials, have made patch antennas common in handsets, GPS receivers and other mass-produced wireless products.[1]

In this paper, the design of single and four by one (1x4) patch array microstrip rectangular antennas with microstrip line as feeding method is presented. Quarter-wave transformer is used to match the feeding line to the antennas. The center frequency is determined to operate at 1.176 GHz which is suitable for IRNSS application. The 4x1 patch array antenna on the substrate type FR-4 with dielectric constant of 4.6 and thickness of 1.6mm. This antenna offers a return loss of -24.56 dB, Gain is 8.28dB,VSWR at 1.007.More significantly, as per the rigorous simulation study using Advance design system(ADS) tool.

II. ANTENNA DESIGN

In designing a microstrip antenna, numerous substrates can be used to achieve good response and their dielectric constants are usually in the range of $2.2 \leq \varepsilon_r \leq 12$.

Table 1: Design specification for rectangle patch antenna

Center Frequency, f_0	1.176 GHz
Substrate	FR-4
Dielectric Constant	4.6
Substrate Height	1.6 mm
Loss Tangent	0.009
Copper Thickness	0.035 µm

The most desirable substrate for good antenna performance are normally thick substrate whereby the dielectric constant is at the lower end This is due to the fact that the this range provide better performance compared to thin substrate.FR-4 was originally chosen as the substrate as it has a low loss tangent which will not reduce the antenna efficiency, and has a relatively low dielectric constant.[2]

A.Single Microstrip Patch Antenna Design

The objective of this part is to design a single microstrip patch antenna which consists of patch, quarter-wave transformer and feedline. [2]

1. Calculation of Width (W)

$$W = \frac{1}{2fr\sqrt{\varepsilon_o \mu_o}} \sqrt{\frac{2}{\varepsilon r + 1}} \qquad (1)$$

2. Calculation of Effective dielectric constant (ε_{reff})

$$\varepsilon_{reff} = \frac{\varepsilon_r}{2} + \frac{\varepsilon_r - 1}{2\sqrt{1 + \frac{12h}{W}}} \qquad (2)$$

3. Calculation of the Effective length

$$L_{eff} = \frac{C}{2f_o\sqrt{\varepsilon_{reff}}} \qquad (3)$$

4. Calculation of the length extension

$$\frac{\Delta L_{eff}}{h} = 0.412 \frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \qquad (4)$$

5. The actual length (L) of patch

$$L = L_{eff} - 2\Delta L_{eff} \qquad (4(a))$$

The feedline will be fed to the patch through a quarter-wave transformer matching network. Fig. 1 below shows a single microstrip patch antenna which consists of patch, quarterwave transformer and feedline. [2]

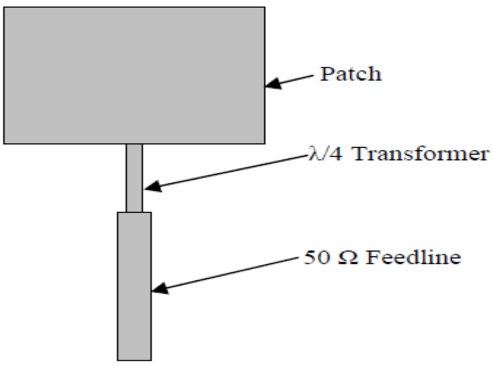


Figure 1:Patch antenna with quarter-wave transformer[2]

The impedance of the quarter-wave transformer is given by :

$$Z_1 = \sqrt{Z_o R_{in}} \qquad (5)$$

Where Z1 is the transformer characteristic impedance and Z_o is the characteristic impedance (real) of the input transmission line (50 Ω). Rin is the edge resistance at resonance, G_e represents the edge conductance.

$$R_{in} = \frac{1}{2 * G_e} \qquad (6)$$

$$G_e = 0.00836 \frac{W}{\lambda_o} \qquad (7)$$

B.Microstrip Patch Array Antenna Design

The corporate feed network is chosen for designing four elements array networks. The array antenna consists of a branching network of two-way power dividers. Quarterwave transformers (70 Ω) are used to match the 100 Ω lines to the 50 Ω lines. Fig. 2 below shows the impedance for individual lines in the four element rectangular array antenna.[2]

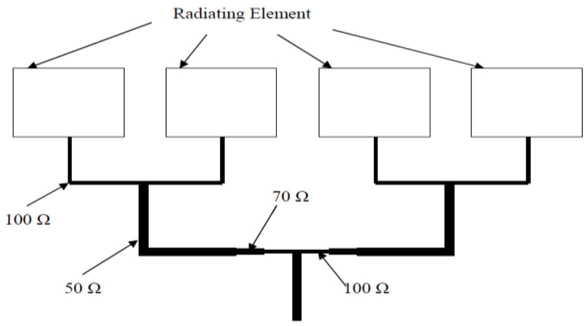


Figure 2: Four elements array line impedance design layout[2]

The patch dimensions are obtained using (1) and (2). However to match the 100 Ω to 50 Ω transmission lines, the calculation step is shown below.

$$Z_1 = \sqrt{50 * 100} = 70\Omega$$

Table 2: Microstrip line impedance dimension

Impedance	Width(mm)	Length(mm)
50 Ω	2.95	34.44
70 Ω	1.58	35.58
100 Ω	0.66	36.16

C. ADS Simulations

Table 2 shows the optimization of the designs and comparisons were made in order to choose the best design, thus the simulations for single antenna were not very extensive.

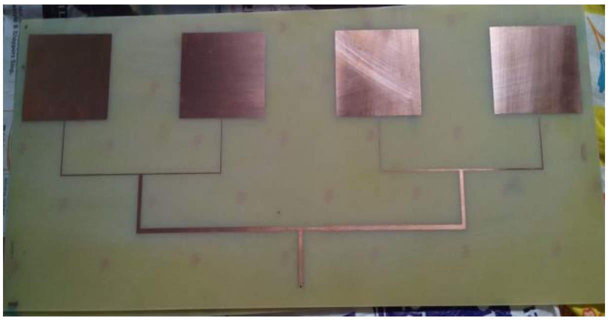


Figure 3: Fabricated 4 elements microstrip rectangular patch array antenna

The single patch antenna design is needed for performance comparison with the patch array antenna. Thus, the extent of effectiveness of array configuration can be observed when comparing both types of configuration. Besides that, it will be necessary to vary the patch width, length and other parameter such as length of microstrip line of 100 Ω in order to optimize the performance of antenna.

II. SIMULATION RESULTS

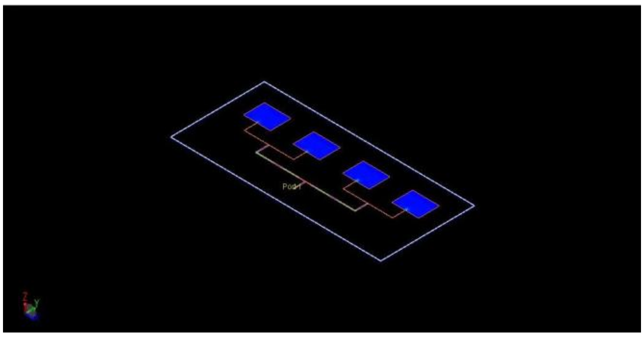


Figure 4: 3D view of patch array antenna

Here in figure 4 we can see the 3D view of patch array antenna, figure 5 shows that the return loss for four element patch array antenna is -24.560 at frequency 1.176 GHz at L-band.

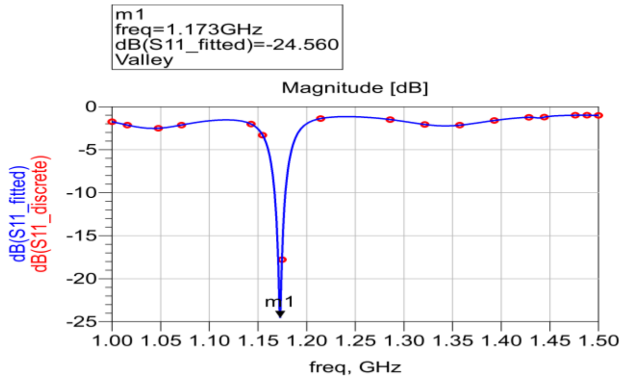


Figure 5: Return loss of patch array antenna

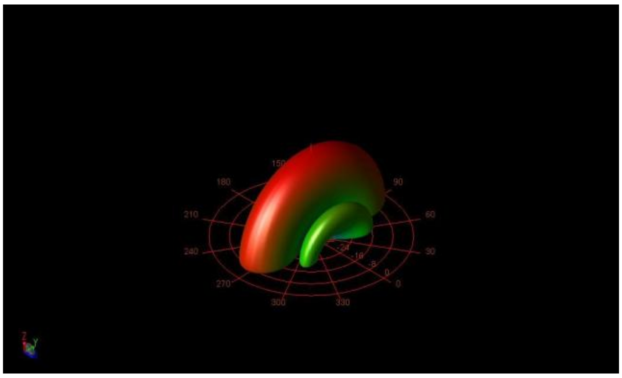


Figure 6: Radiation pattern of patch array antenna

Figure 6 shows the 3D radiation pattern of patch array antenna, In which the red part shows the main lobe and green part shows the side lobe radiation.

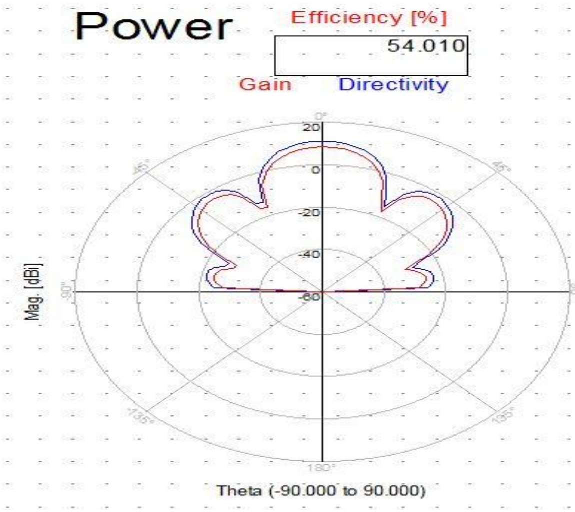


Figure 7: The Simulated radiation pattern of patch array antenna

Figure 7 shows the radiation pattern in 2D and also shows the gain in red line and directivity in blue line.Gain is 8.2805 dBi and Directivity is 10.9557 dBi at frequency 1.176 GHz.Antenna efficiency is 54.010 %.

Table 3: Parameters of patch array antenna

Power radiated (Watts)	0.0043
Effective angle (Steradians)	1.0084

Directivity(dBi)		10.9557
Gain (dBi)		8.2805
Maximim intensity (Watts/Steradian)		0.0043
E(theta)max(mag,phase)	1.8011	-5.2157
E(phi)max(mag,phase)	0.0940	-4.7941
E(x)max(mag,phase)	0.0012	-152.734
E(y)max(mag,phase)	1.7762	-5.214
E(z)max(mag,phase)	0.3127	174.784

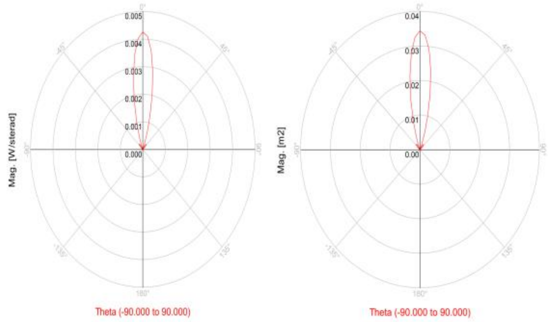
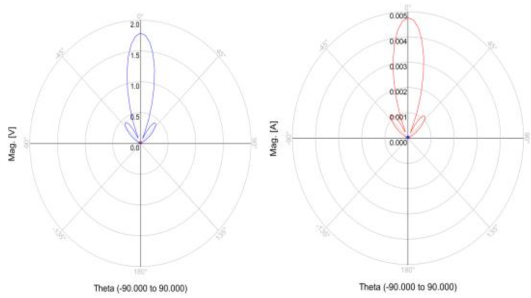


Figure 8: Radiated power and Effective area

Table 3 shows all antenna parameters from simulation result of four element patch array antenna in ADS tool at 1.176 GHz frequency for IRNSS application.



Etheta Ephi

Figure 9:Absolute Field Htheta Hphi

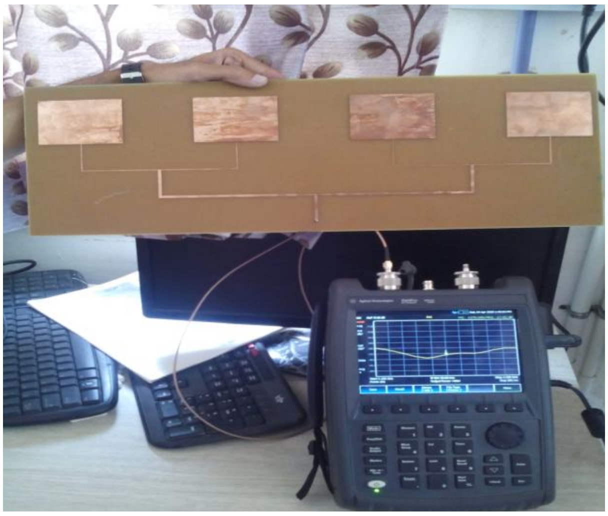


Figure 10:Measurement of return loss in Lab

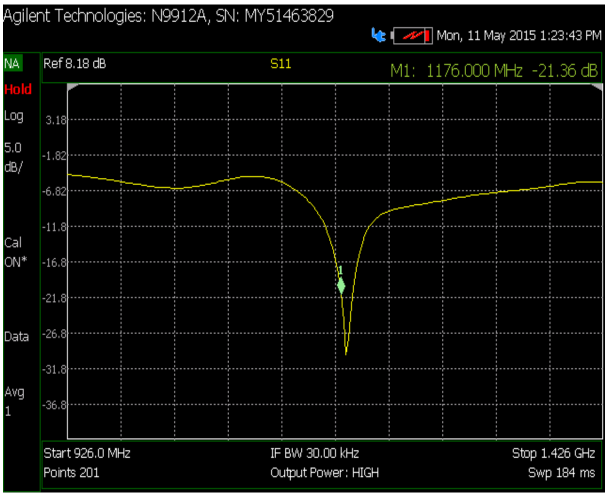


Figure 11: Return loss of patch array antenna

Return loss[practical]	-21.36dB

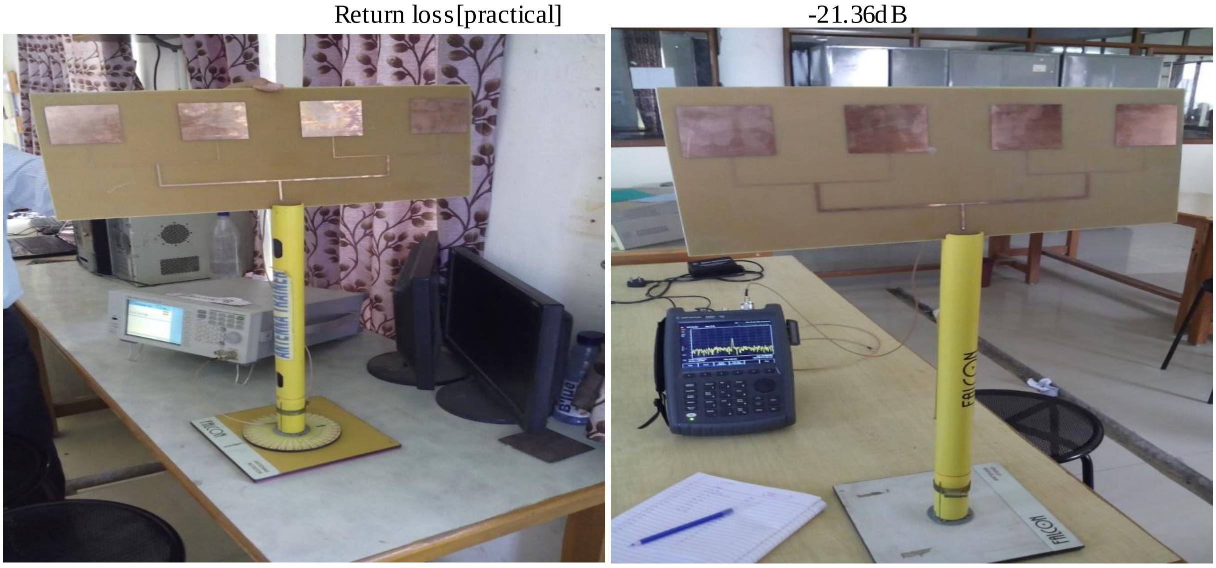


Figure 12: Measuring radiation pattern

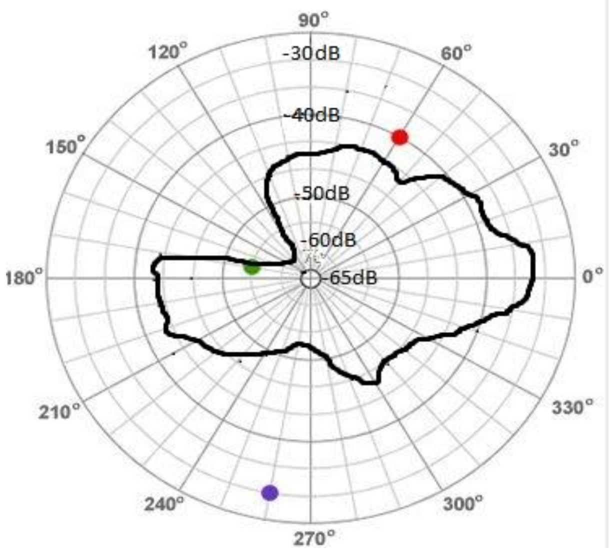


Figure 13:Radiation pattern drawn from result

Table 4 shows all the results of single element,1x2 array antenna,1x4 array antenna of gain,return loss and directivity.

Table 4: Simulation result comparisons table

No	Name	Gain[dBi]	Return loss[dB]	Directivity[dBi]
1	Single element antenna	3.76	-31.00	6.57
2	1x2 array antenna	6.02	-29.07	9.13
3	1x4 array antenna	8.28	-24.56	10.96

III.ACKNOWLEDGMENT

The authors would like to convey thanks to the Director, and experts for their continuous support and encouragement in LJIET, Ahmedabad. The authors would like to express thanks and appreciation to the Technical Evaluation Committee, LJIET for kind support.

IV. CONCLUSION

From the results, it is clear that the above designed antenna is much suitable for high gain, high bandwidth and high directivity for IRNSS. It is providing a lower gain and directivity in single patch antenna but if we make an array for same dimension element we get better results like higher gain and directivity and radiation pattern, so if I increase the elements in array I will get more gain and directivity so it is more suitable for IRNSS applications.

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