

# DESIGN OF MICROSTRIP PATCH ANTENNA FOR GAIN ENHANCEMENT

Lilly Kumari<sup>1</sup>, Upendra Prasad<sup>2</sup>

<sup>1,2</sup>Department of Electrical Engineering B.I.T Sindri, Dhanbad (India)

## ABSTRACT

*This paper presents the design and analysis of rectangular microstrip patch antenna with coaxial probe feed and microstrip line feed. The design has been extended to a two-element array and then to a four-element array of rectangular patches to assess the pros and cons of using an array of elements instead of a single element. Further a quarter-wave transformer has been employed as a return loss minimization tool. All the designs have been simulated using Zeland IE3D v14.10.*

**Keywords:** Gain, Microstrip patch, Return Loss, Radiation Pattern, VSWR.

## I. INTRODUCTION<sup>[1,2]</sup>

A microstrip patch antenna is characterized by its length, width, input impedance, and gain and radiation patterns. The length of the antenna is nearly half wavelength in the dielectric; it governs the resonant frequency of the antenna. A microstrip patch antenna (MPA) consists of a conducting patch of any planar or non-planar geometry on one side of a dielectric substrate with a ground plane on other side.

Microstrip antennas are attractive due to their low profile, simplicity in fabrication, light weight, conformability and low cost. These antennas can be integrated with printed strip-line feed networks and active devices. These advantages of microstrip antennas make them popular in many wireless communication applications. The disadvantages of microstrip patch antennas are: narrow frequency band with low efficiency, low gain. These disadvantages can be overcome by constructing many patch antennas in array configuration.

In this paper, first design of single patch rectangular microstrip antenna by using microstrip line feed and coaxial Probe feed. The design has been extended to a two-element array and then to a four-element array of rectangular patches by using microstrip line feed. Further a quarter-wave transformer used for return loss minimization and after this all design results compare in terms of return loss, VSWR, Gain, Beamwidth.

## II. DESIGN

**Rectangular Patches** are one of the most commonly used because of ease of analysis and fabrication and their attractive radiation characteristics. For a rectangular patch, the length  $L$  of the patch is usually  $0.3333\lambda_0 < L < 0.5\lambda_0$ , where  $\lambda_0$  is the free-space wavelength. The patch is selected to be very thin such that  $t \ll \lambda_0$  (where  $t$  is the patch thickness). The height  $h$  of the dielectric substrate is usually  $0.003\lambda_0 \leq h \leq 0.05\lambda_0$ . The dielectric constant of the substrate ( $\epsilon_r$ ) is typically in the range  $2.2 \leq \epsilon_r \leq 12$ .

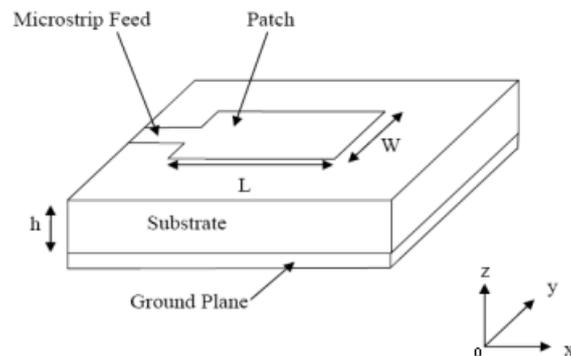


Fig1. rectangular microstrip patch with rectangular coordinate system

### A. design of single rectangular patch<sup>[3,5]</sup>:

Design Specifications:

- Frequency of operation ( $f_0$ ): 5.2 GHz.
- Dielectric constant of the substrate ( $\epsilon_r$ ): 4.4 .
- Height of dielectric substrate (h): 1.6 mm.

Step 1: Calculation of the Width (W):

$$W = \left( \frac{c}{2 \times f_0} \right) \times \left( \frac{\epsilon_r + 1}{2} \right)^{-1/2} \text{ mm} \quad \dots (1)$$

Substituting  $c = 3 \times 10^8$  m/s,  $\epsilon_r = 4.4$  and  $f_0 = 5.2$  GHz, we get:  $W = 17.5$  mm

Step 2: Calculation of Effective dielectric constant ( $\epsilon_{\text{reff}}$ ):

$$\epsilon_{\text{reff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \times \left( 1 + \left( \frac{12 \times h}{W} \right)^2 \right)^{-1/2} \quad \dots (2)$$

Substituting  $\epsilon_r = 4.4$ ,  $W = 17.5$  mm and  $h = 1.6$  mm we get:  $\epsilon_{\text{reff}} = 3.81$

Step 3: Calculation of the Length (L):

$$L = \frac{c}{2 \times f_0 \times \sqrt{\epsilon_{\text{reff}}}} - 2\Delta l \text{ mm} \quad \dots (3)$$

Where,

$$\Delta l = 0.412 \times h \times \left[ \frac{(\epsilon_{\text{reff}} + 0.03) \times (W + 0.264h)}{(\epsilon_{\text{reff}} - 0.258) \times (W + 0.8h)} \right] \text{ mm} \quad \dots (4)$$

Substituting  $\epsilon_{\text{reff}} = 3.81$ ,  $c = 3 \times 10^8$  m/s and  $f_0 = 5.2$  GHz we get:  $L = 14.6$  mm

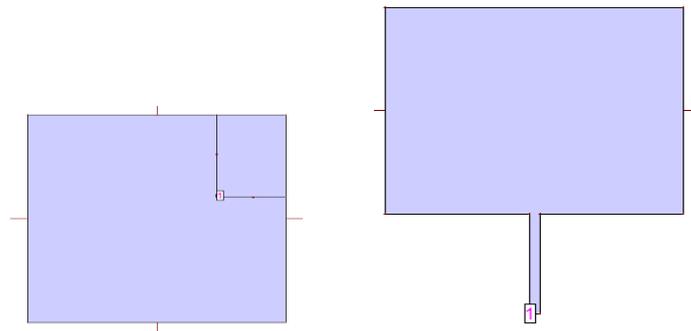


Fig2a. Design using coaxial probe feed

Fig2b. Design using microstrip line feed

### B. Design of 2- element microstrip antenna array<sup>[3]</sup>:

In order that the impedance of line feed matches the patch impedance width of the line feed has been accordingly designed:  $100\Omega$  for direct feed to patches and  $50\Omega$  for main coaxial probe feed.

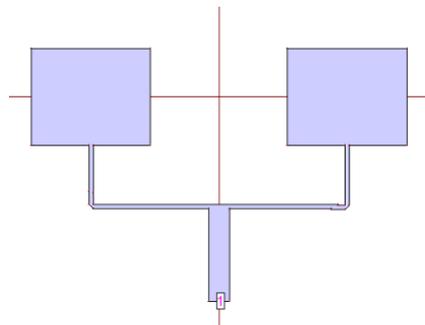


Fig 2c. Design of 2-element microstrip antenna array

### C. Design of 4- element microstrip antenna array<sup>[2,3]</sup>:

The microstrip feed lines have been designed according to impedance requirements of the design:  $200\Omega$  for direct feed to the patches,  $100\Omega$  for the intermediate feed line and  $50\Omega$  for the main coaxial probe feed.

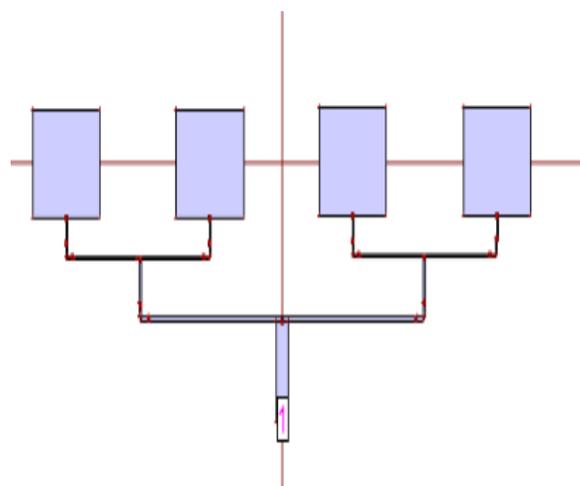


Fig2d. Design of 4- element microstrip antenna array

### D. Design using quarter-wave transformer for 4-element microstrip array<sup>[4, 7]</sup>:

In this design it has been used to transfer  $50\Omega$  impedance to  $100\Omega$  impedance Its impedance is given by

$$\begin{aligned}
 Z_{\text{transformer}} &= [Z_{\text{in}} \times Z_{\text{out}}]^{1/2} \quad \dots (5) \\
 &= [100 \times 50]^{1/2} \\
 &= 70 \Omega \text{ (approx.)}
 \end{aligned}$$

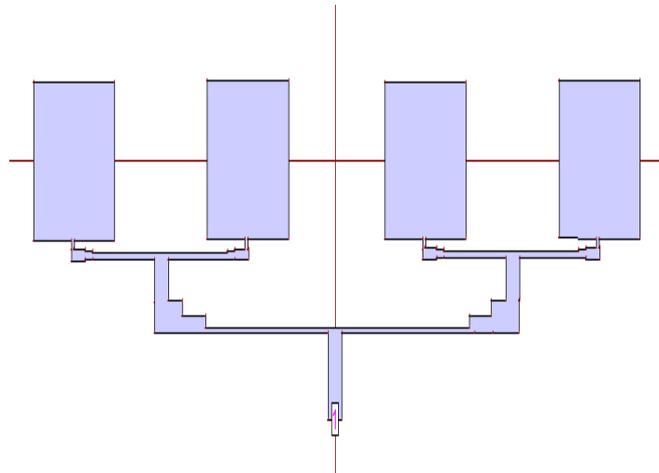


Fig2e. Design using quarter-wave transformer for 4 element microstrip array

### III. RESULTS

#### A. Rectangular Patch with coaxial probe feed

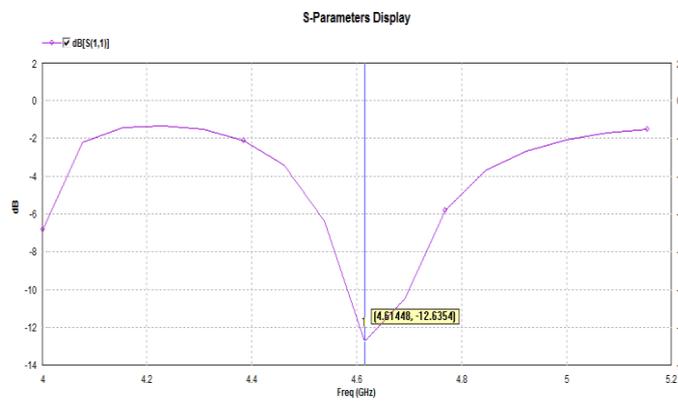


Fig3a. Return Loss Vs frequency

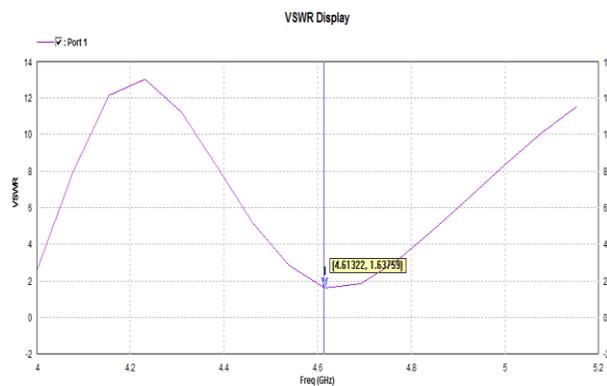


Fig3b. VSWR Vs Frequency

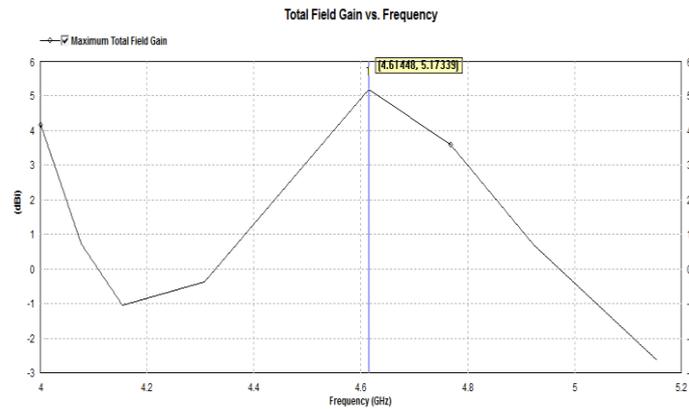


Fig3c. Gain Vs Frequency

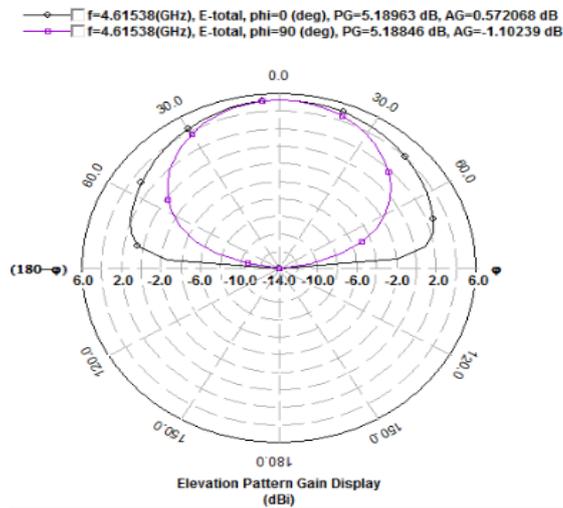
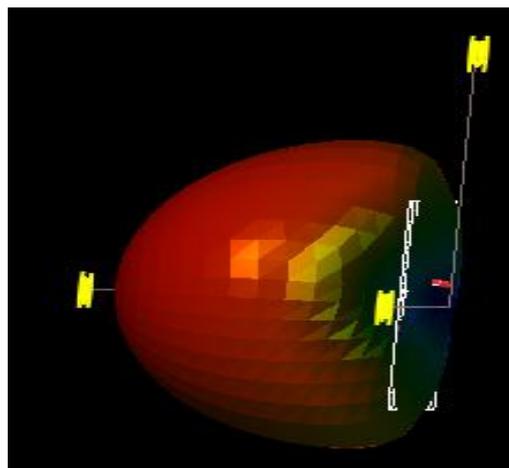


Fig3d. 2-D radiation pattern



Back view

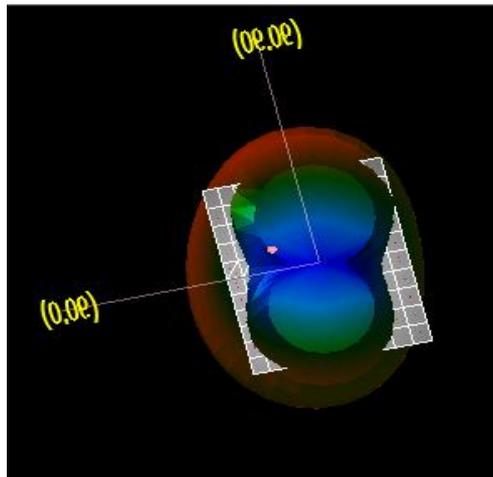


Fig3e. 3-D radiation patterns

B. Rectangular Patch with microstrip line feed

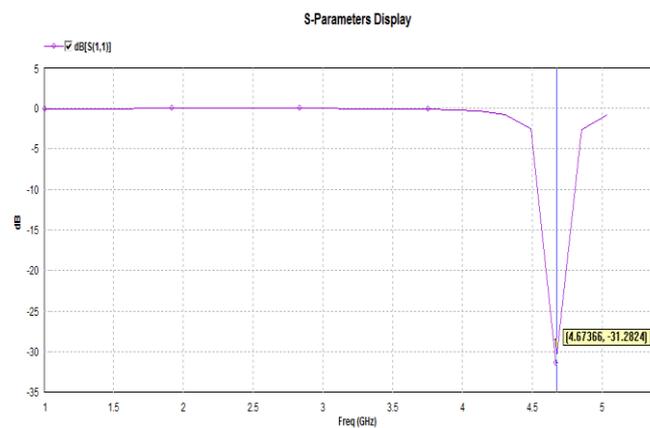


Fig4a. Return Loss Vs Frequency

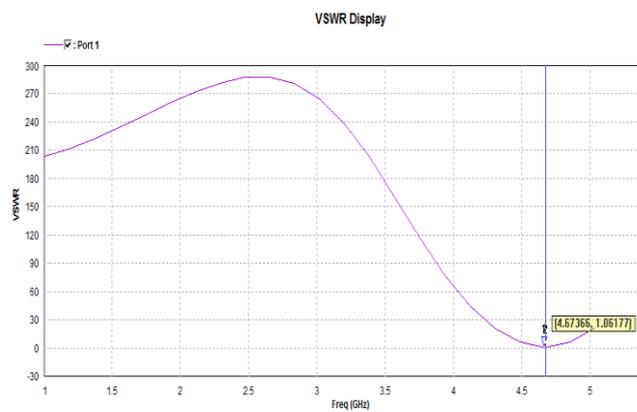


Fig4b. VSWR Vs Frequency

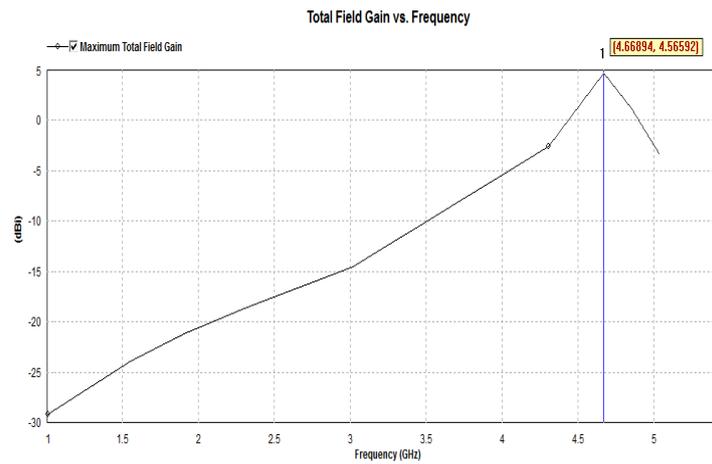


Fig4c. Gain Vs Frequency

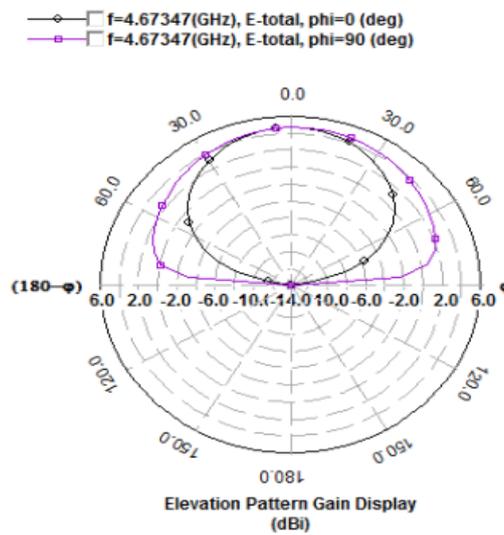
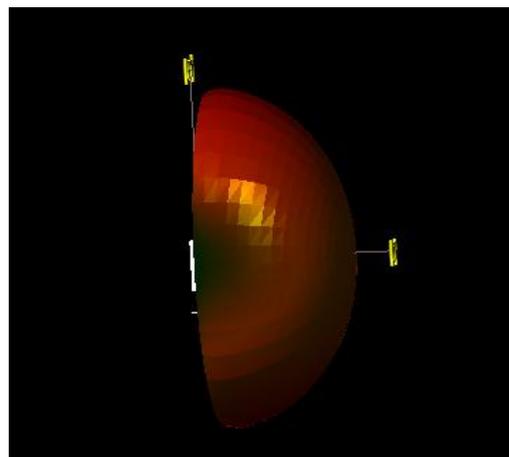


Fig4d. 2-D radiation pattern



Side view

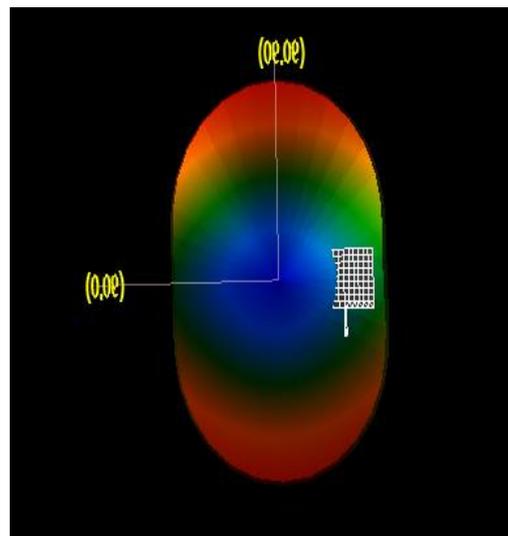


Fig4e. 3-D radiation patterns

### C. Two-element array with microstrip line feed

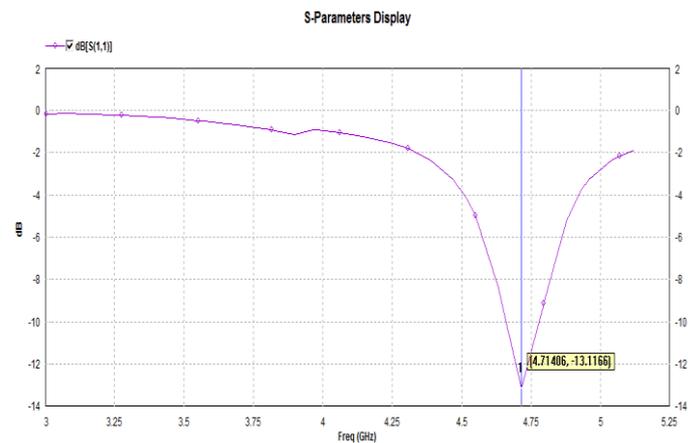


Fig5a. Return Loss Vs Frequency

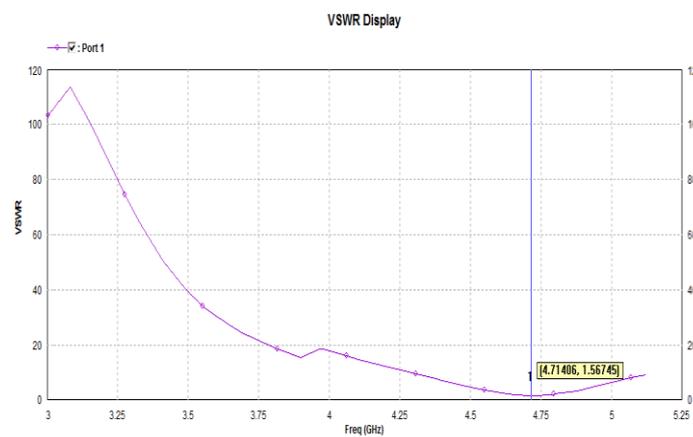


Fig5b. VSWR Vs Frequency

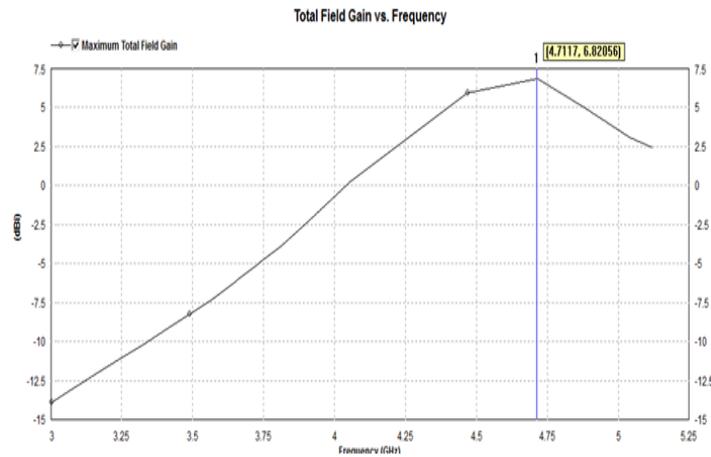


Fig5c. Gain Vs Frequency

—○— f=4.71429(GHz), E-total, phi=0 (deg), PG=6.77351 dB, AG=-1.00494 dB  
—□— f=4.71429(GHz), E-total, phi=90 (deg), PG=6.83003 dB, AG=1.59666 dB

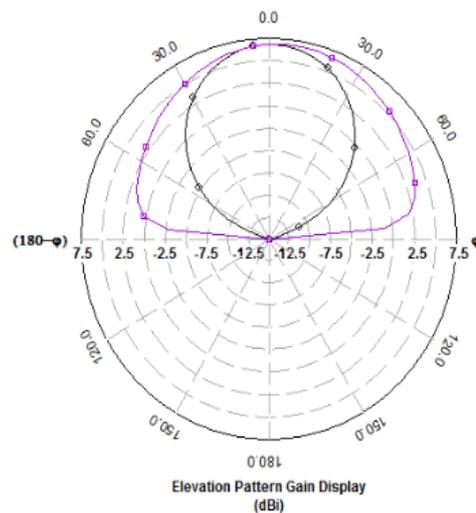
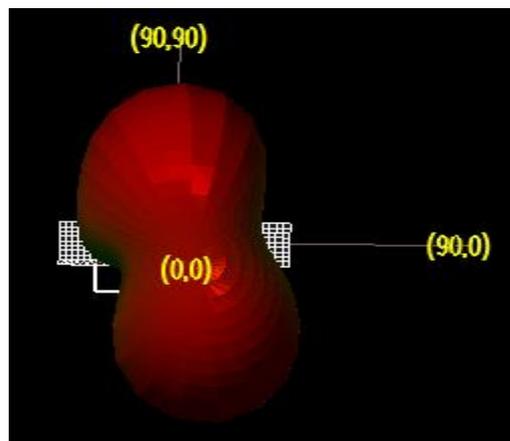


Fig5d. 2-D radiation pattern



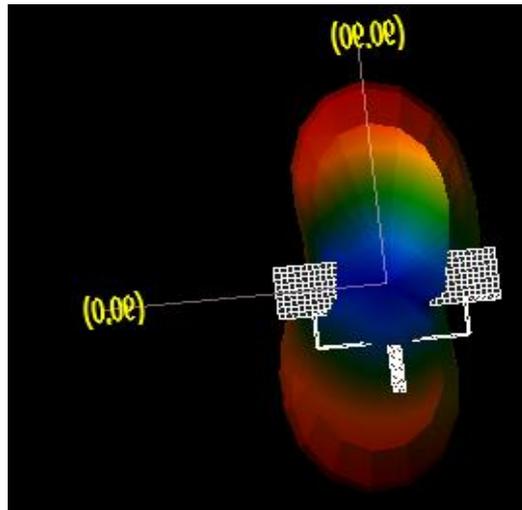


Fig5e. 3-D radiation patterns

D. Four-element array using microstrip line feed

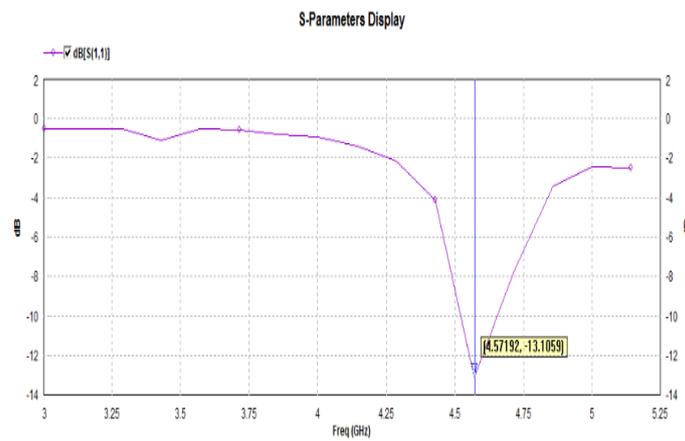


Fig6a. Return Loss Vs Frequency

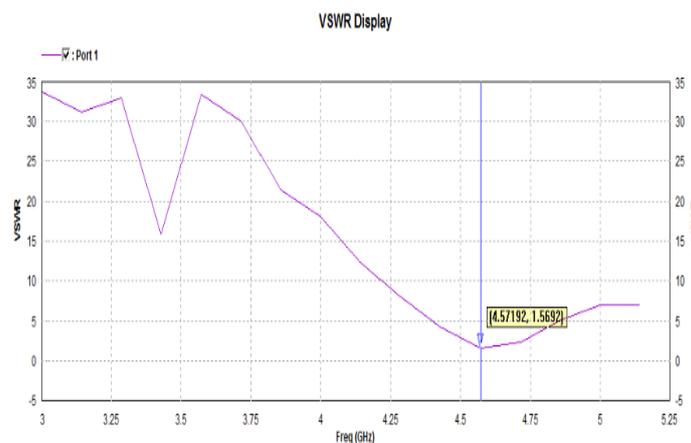


Fig6b. VSWR Vs Frequency

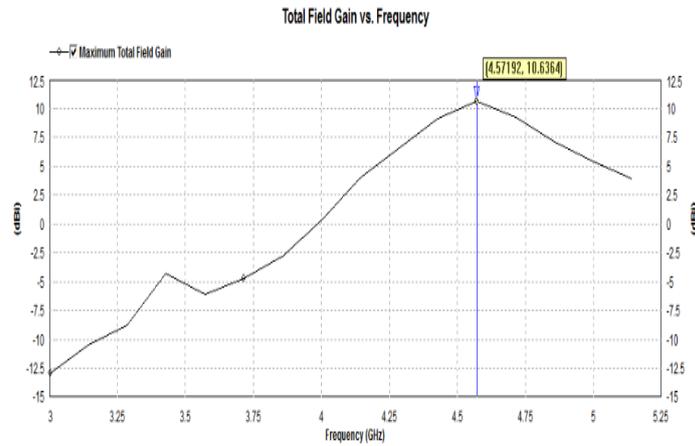


Fig6c. Gain Vs Frequency

—○—□— f=4.57143(GHz), E-total, phi=0 (deg), PG=10.5471 dB, AG=-1.08849 dB  
—○—□— f=4.57143(GHz), E-total, phi=90 (deg), PG=10.6344 dB, AG=5.44934 dB

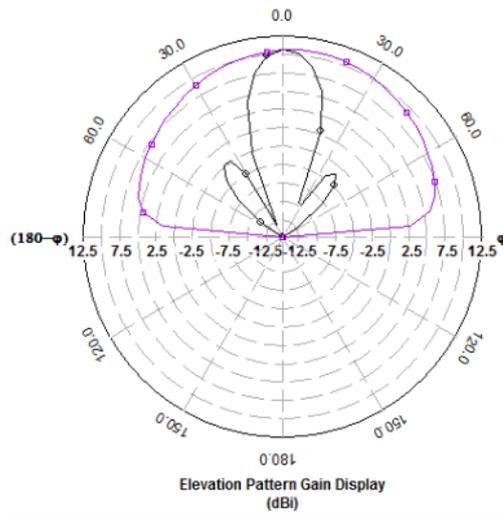
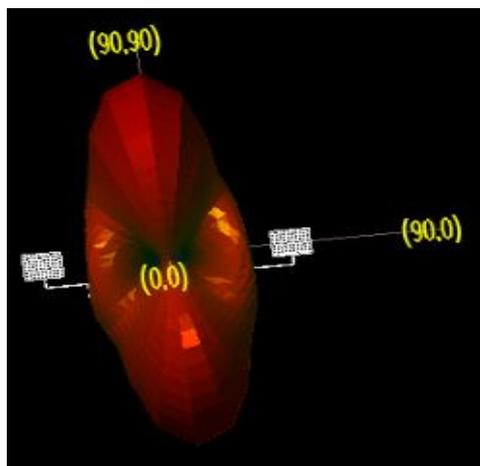


Fig6d. 2-D radiation pattern



Back view

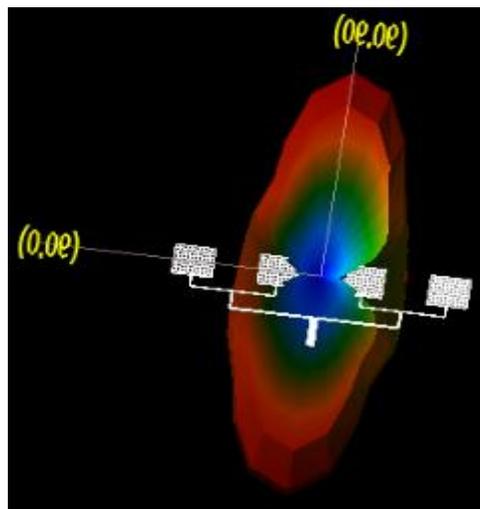


Fig6e. 3-D radiation patterns

E. Four-element array using quarter wave transformer

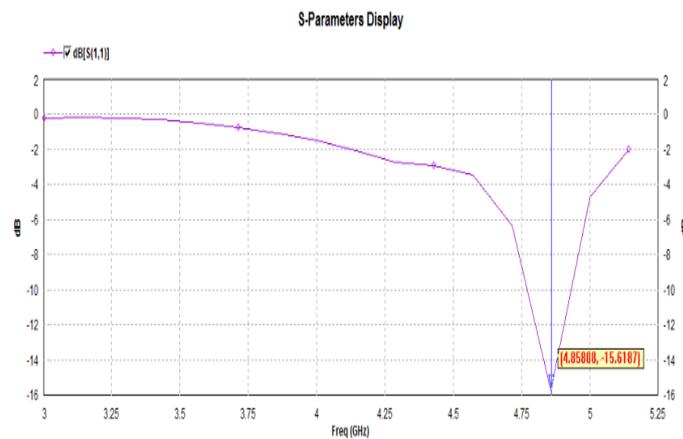


Fig7a. Return Loss Vs Frequency

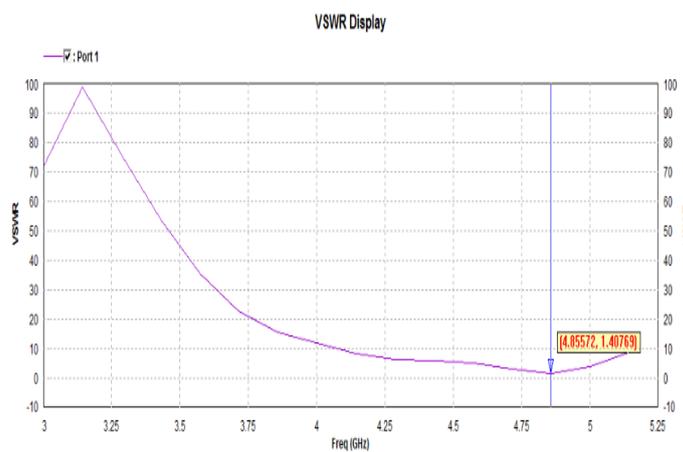


Fig7b. VSWR Vs Frequency

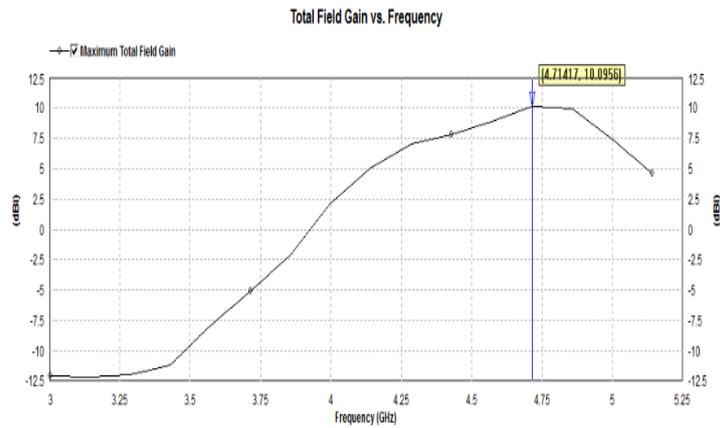


Fig7c. Gain Vs Frequency

—◇—□— f=4.57143(GHz), E-total, phi=0 (deg), PG=8.86415 dB, AG=-2.74085 dB  
—◇—□— f=4.57143(GHz), E-total, phi=90 (deg), PG=8.86415 dB, AG=3.47663 dB

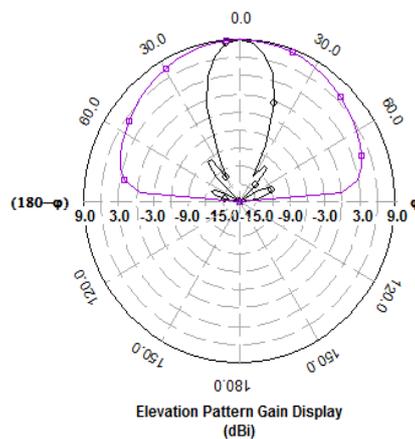
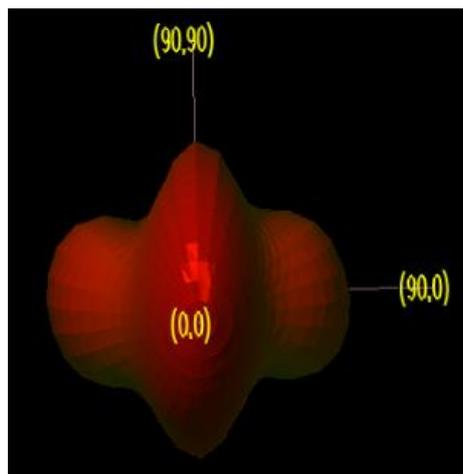


Fig7d. 2-D radiation pattern



Back view

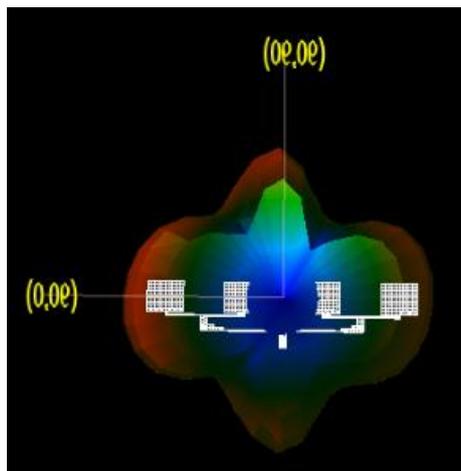


Fig7e. 3-D radiation patterns

**F. Comparison of Results**

Type of Antenna	S <sub>11</sub> (dB)	Min VSWR	Max gain (dBi)	Beamwidth (°)
Rectangular patch with coaxial probe	-12.6	1.63	5.17	135.048
Rectangular patch with microstrip line feed	-31.28	1.06	4.56	81.723
Two-element array with microstrip line feed	-13.12	1.57	6.82	54.99
Four-element array with microstrip line feed	-13.11	1.57	10.64	28.01
Four-element array with quarter wave transformer	-15.62	1.40	10.10	27.20

TABLE1. COMPARISON OF RESULTS

## IV. CONCLUSION

The simulation results for various designs have been tabulated here for comparison.

A major contributing factor for recent advances of microstrip antennas is the current revolution in electronic circuit miniaturization brought about by developments in large scale integration (LSI). But a major drawback is their low gain characteristic.

However this can be overcome using a number of techniques, one of which is using an array configuration, as we have observed in the above simulated results. From Table 1 we observe that microstrip line feed is a better feed technique than coaxial probe feed because reflections are minimized which implies that a better impedance matching is obtained.  $VSWR < 2$  has been observed which is desirable.

Further we observe that using an array configuration has improved the directivity of the antenna as the main lobe has become narrower (lower beamwidth compared to that of single patch). Gain of array antenna has improved significantly with respect to a single element antenna gain. A further enhancement of gain is achieved if array size is increased. The use of quarter wave transformer has minimized the return loss resulting in considerable reduction in the side lobe level as shown in fig 7d.

## REFERENCES

- *Textbooks:*

- [1] C.A. Balanis, Antenna Theory: Analysis and Design, 2/e, John Wiley & Son, Inc., 1997.
- [2] John D Kraus, R.J. Marhefka, Ahmad S Khan, Antennas & Wave Propagation, 4/e, TMH Education Private limited, 2006.
- [3] Ramesh Garg, Microstrip Antenna Design Handbook, Artech House Inc. Norwood, 2001.

- *Journals:*

- [4] R.E. Munson, "Conformal Microstrip Antennas And Microstrip Phase Arrays", IEEE Trans. Antennas Propagation, Vol. AP-22, no. 1, Jan 1974.
- [5] G. Guru Prasad, G. Madhavi Latha, V. Charishma, "Design and Analysis of 8x1 Array Microstrip Patch Antenna using IE3D", International Journal of Engineering and innovative technology, vol.1, Issue 3, March 2012.
- [6] George Casu, Catalin Moraru and Anderi Kovacs (2014), Design and implementation of microstrip patch antenna array, IEEE Communications (COMM) 2014 10th conference, Acc. No. 14484740, page 1-4.
- [7] Norfishah Ab Wahab and Z .B. Maslam, W. Muhammad and Norhayati Hamzah (2010), Microstrip rectangular 4x1 array antenna at 2.5GHz for WiMax application, IEEE 2nd International Conference on Computational Intelligence, Communication Systems and Network
- [8] IE3D User's Manual Release 14.1 (Zeland Software, Inc.), May 2008.

- *Websites:*

- [9] [www.ieeexplore.org](http://www.ieeexplore.org)
- [10] [www.wikipedia.org](http://www.wikipedia.org)