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DESIGN OF MICROSTRIP PATCH ANTENNA FOR GAIN ENHANCEMENT

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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 [1, 2]

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 $0.3333\lambda o < L < 0.5\ \lambda o$, where λo is the free-space wavelength. The patch is selected to be very thin such that $t << \lambda o$ (where t is the patch thickness). The height h of the dielectric substrate is usually $0.003\lambda o \leq h \leq 0.05\lambda o$. The dielectric constant of the substrate (ε_r) is typically in the range $2.2 \leq \varepsilon r \leq 12$.

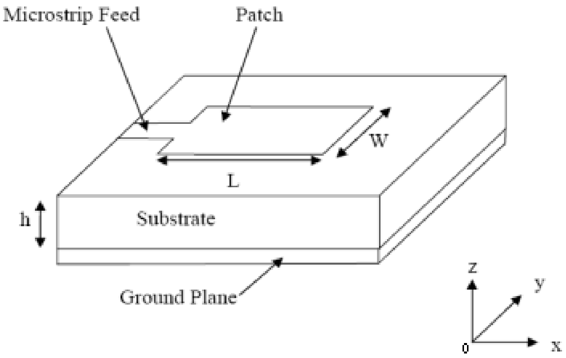


Fig1. rectangular microstrip patch with rectangular coordinate system

A. *design of single rectangular patch*[3,5]*:*

Design Specifications:

- *Frequency of operation* (f_o): 5.2 GHz.
- *Dielectric constant* of the substrate (ε_r): 4.4 .
- *Height of dielectric substrate* (h): 1.6 mm.

Step 1: Calculation of the Width (W):

$$W=\left(\frac{c}{2\times f_o}\right)\times\left(\frac{\varepsilon_r+1}{2}\right)^{\frac{-1}{2}}\ \text{mm} \qquad \ldots(1)$$

Substituting $c = 3\text{x}10^8$ m/s, ε_r =4.4 and f_o = 5.2 GHz, we get: *W* **= 17.5 mm**

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

$$\varepsilon_{reff}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\times\left(1+\left(\frac{12\times h}{W}\right)\right)^{\frac{-1}{2}} \qquad \ldots(2)$$

Substituting ε_r = 4.4, *W* = 17.5 mm and *h* = 1.6 mm we get: ε_{reff} **= 3.81**

Step 3: Calculation of the Length (L):

$$L=\frac{c}{2\times f_o\times\sqrt{\varepsilon_{reff}}}-2\Delta l\ \text{mm} \qquad \ldots(3)$$

Where,

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

Substituting ε_{reff} = 3.81, $c = 3\text{x}10^8$ m/s and f_o =5.2 GHz we get: *L*= **14.6 mm**

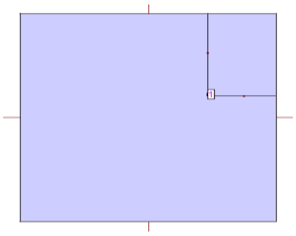


Fig2a. Design using coaxial probe feed

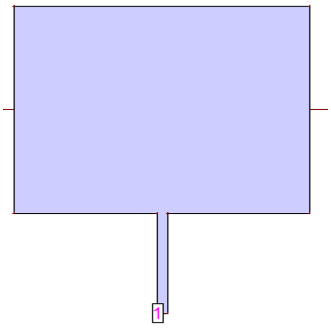


Fig2b. Design using microstrip line feed

B. Design of 2- element microstrip antenna array[3]:

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

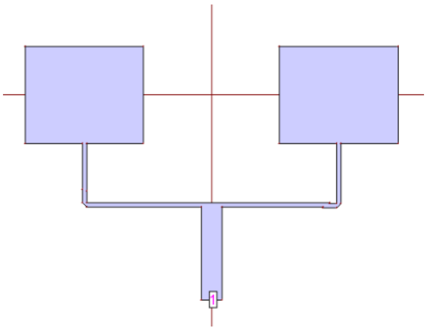


Fig 2c. Design of 2-element microstrip antenna array

C. Design of 4- element microstrip antenna array[2,3]:

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

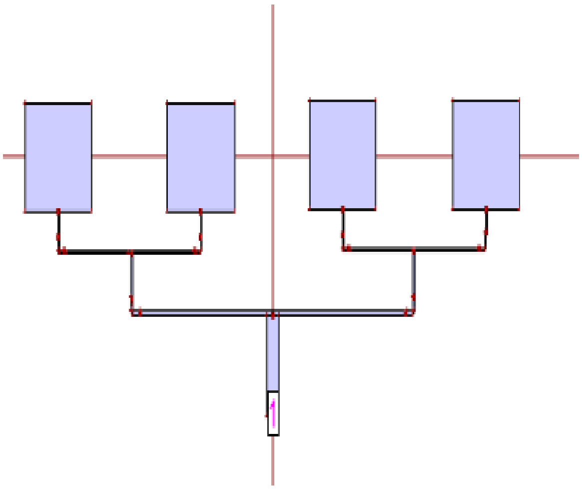


Fig2d. Design of 4- element microstrip antenna array

D. Design using quarter-wave transformer for 4-element microstrip array [4, 7]:

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

$$Z_{\text{transformer}} = [Z_{in} \text{ X } Z_{out}]^{1/2} \qquad \ldots (5)$$

$$= [100 \text{ X } 50]^{1/2}$$

$$= \; 70\ \Omega \text{ (approx.)}$$

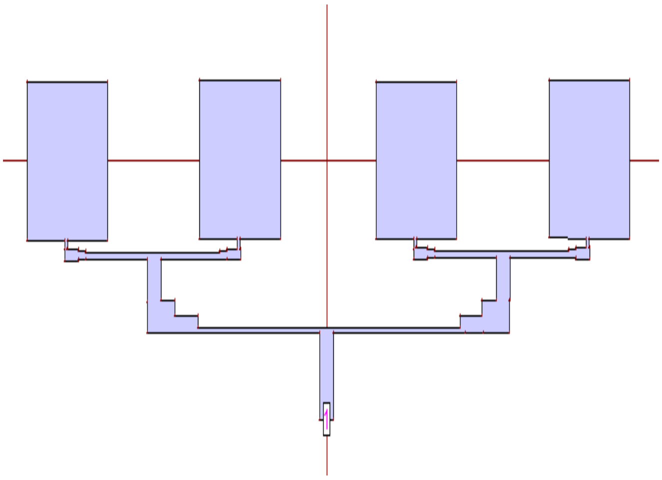


Fig2e. Design using quarter-wave transformer for 4 element microstrip array

III. RESULTS

A. Rectangular Patch with coaxial probe feed

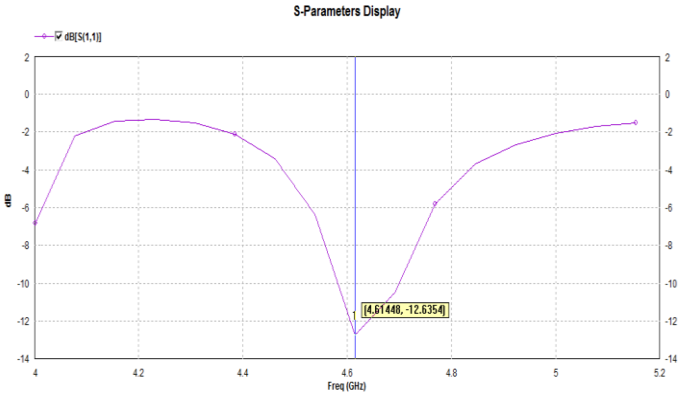


Fig3a. Return Loss Vs frequency

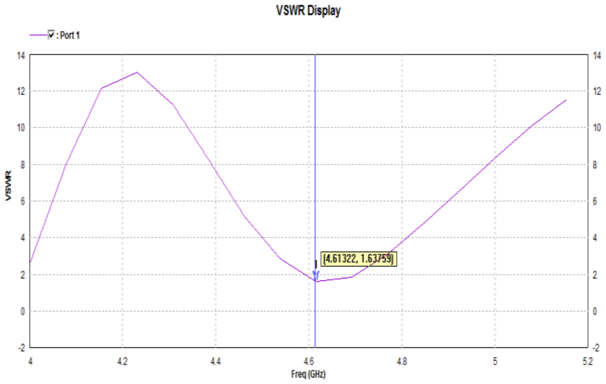


Fig3b. VSWR Vs Frequency

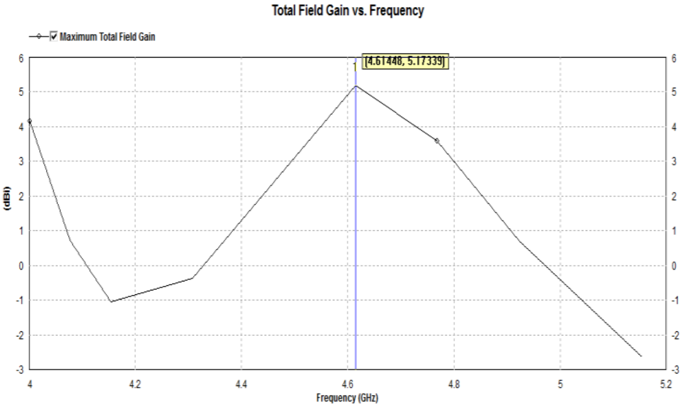


Fig3c. Gain Vs Frequency

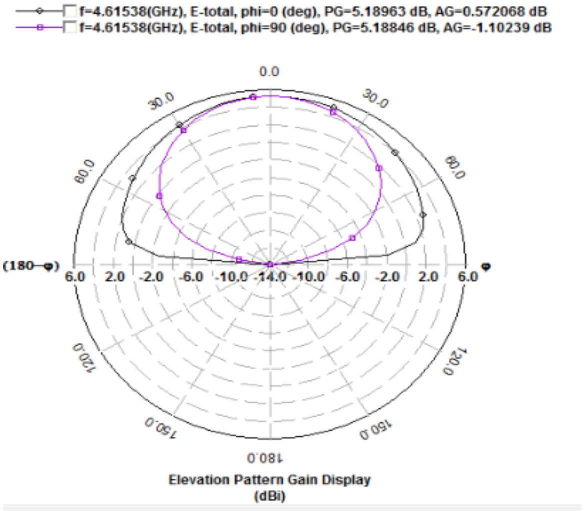
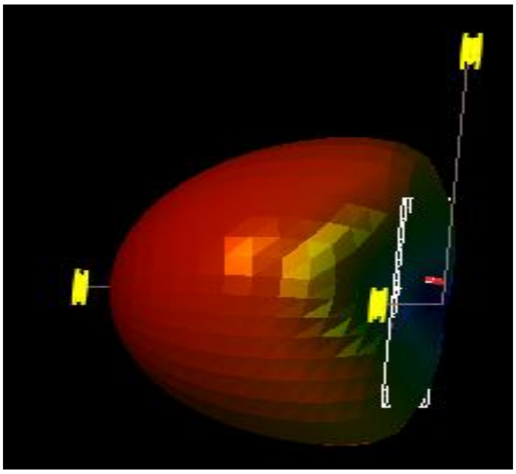


Fig3d. 2-D radiation pattern



Back view

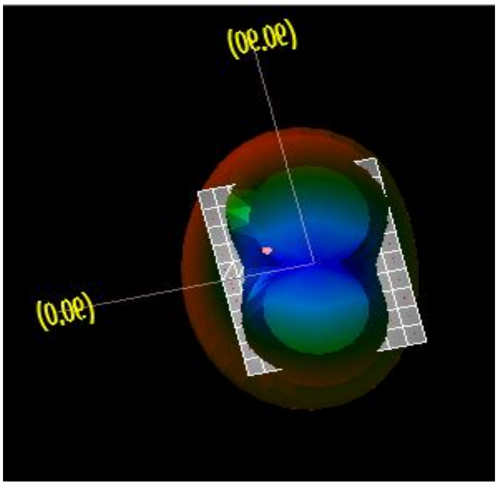


Fig3e. 3-D radiation patterns

B. *Rectangular Patch with microstrip line feed*

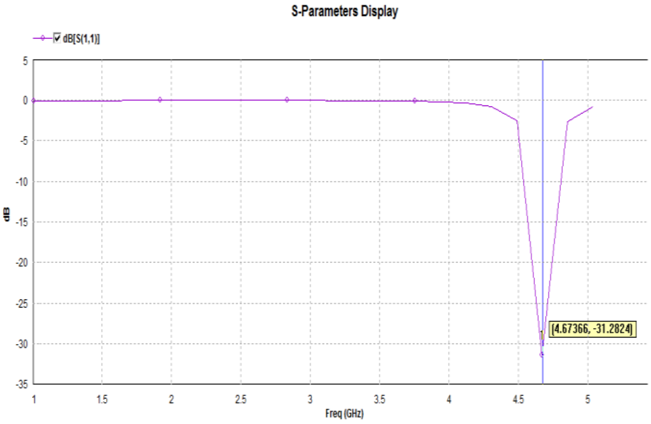


Fig4a. Return Loss Vs Frequency

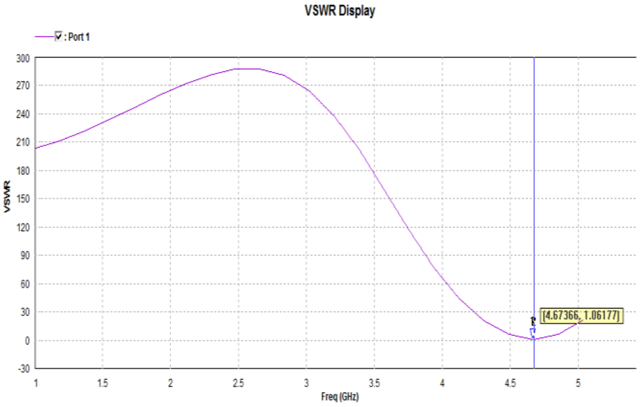


Fig4b. VSWR Vs Frequency

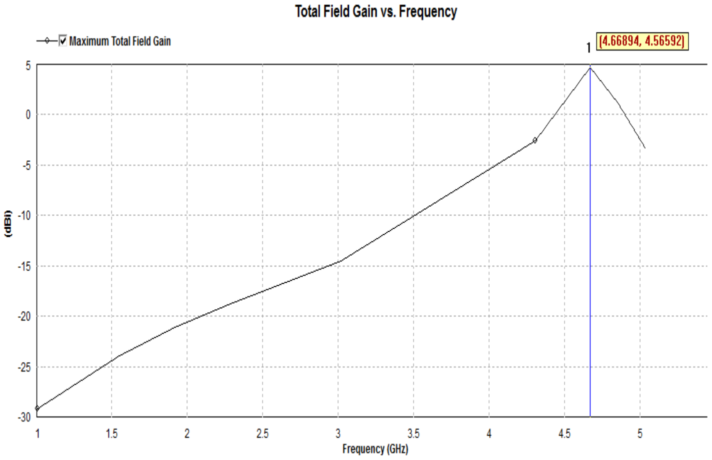


Fig4c. Gain Vs Frequency

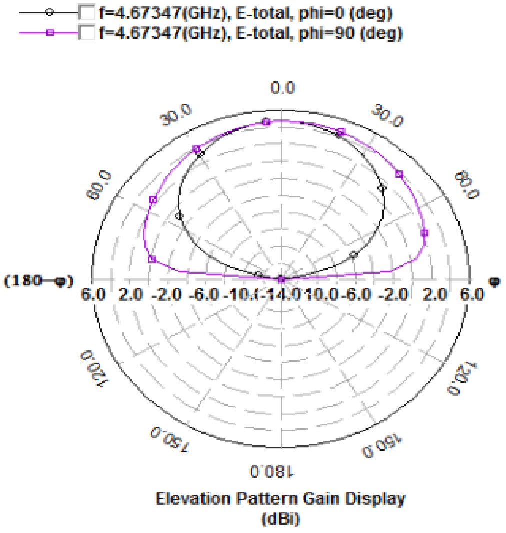
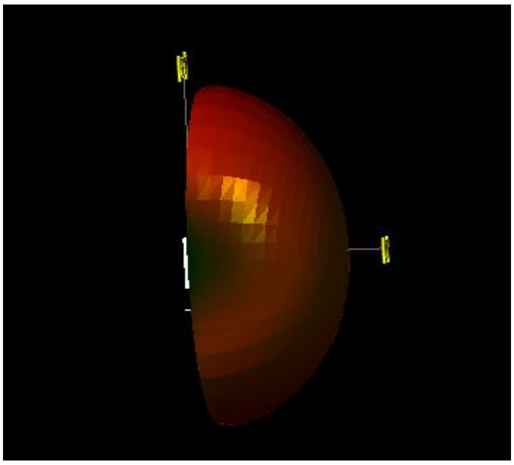


Fig4d. 2-D radiation pattern



Side view

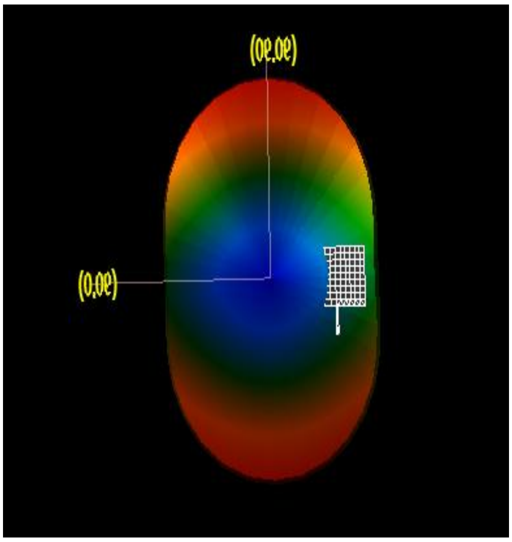


Fig4e. 3-D radiation patterns

C. Two-element array with microstrip line feed

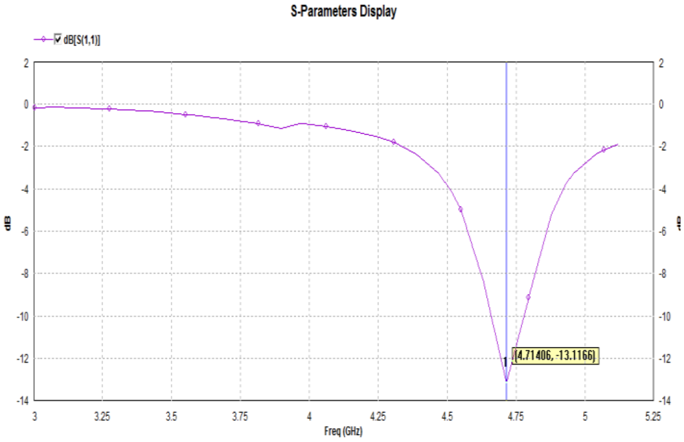


Fig5a. Return Loss Vs Frequency

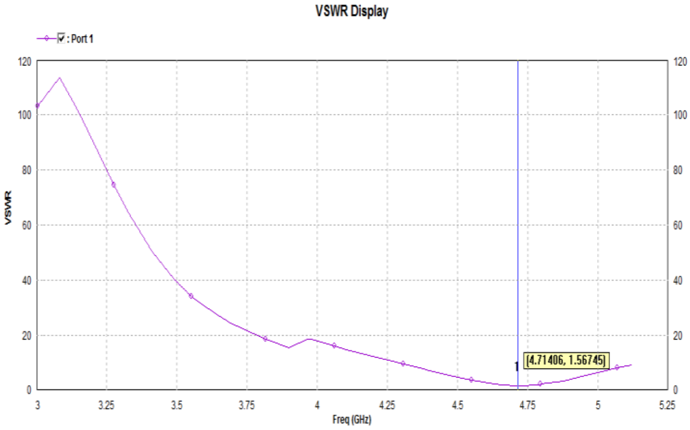


Fig5b. VSWR Vs Frequency

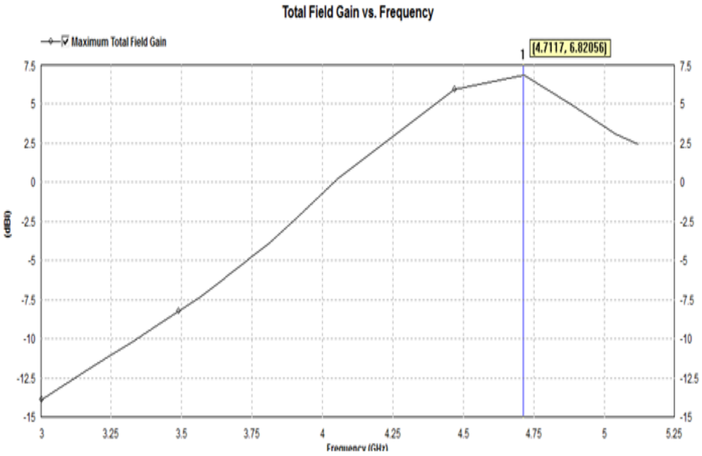


Fig5c. Gain Vs Frequency

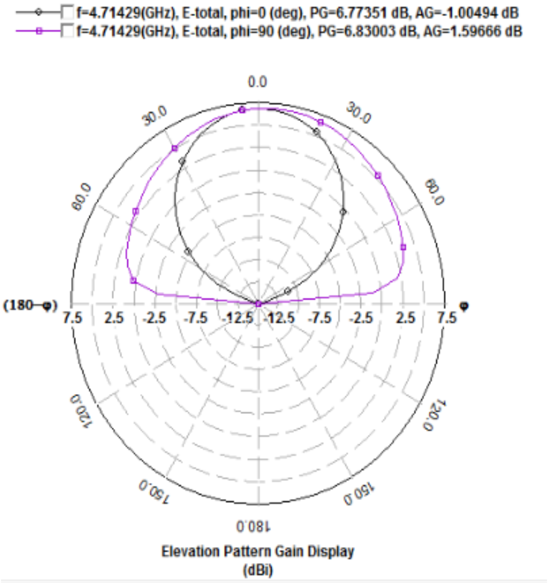
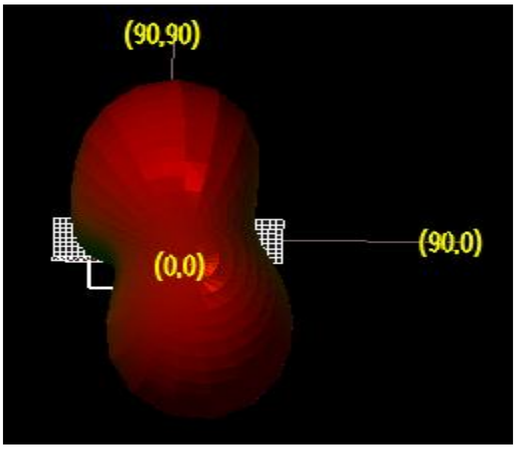


Fig5d. 2-D radiation pattern



Back view

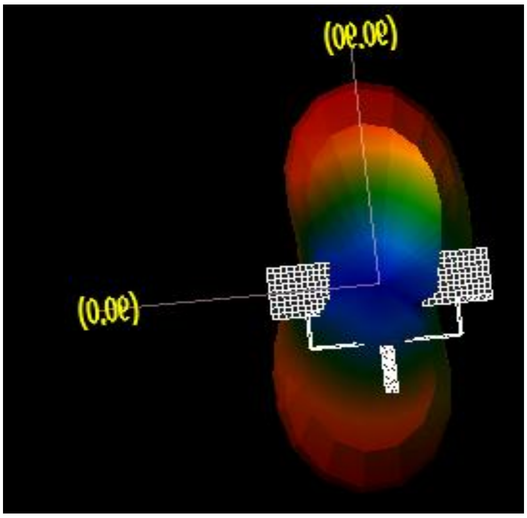


Fig5e. 3-D radiation patterns

D. *Four-element array using microstrip line feed*

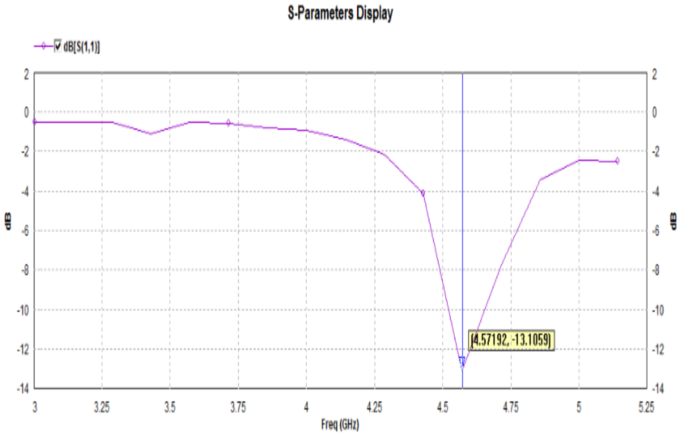


Fig6a. Return Loss Vs Frequency

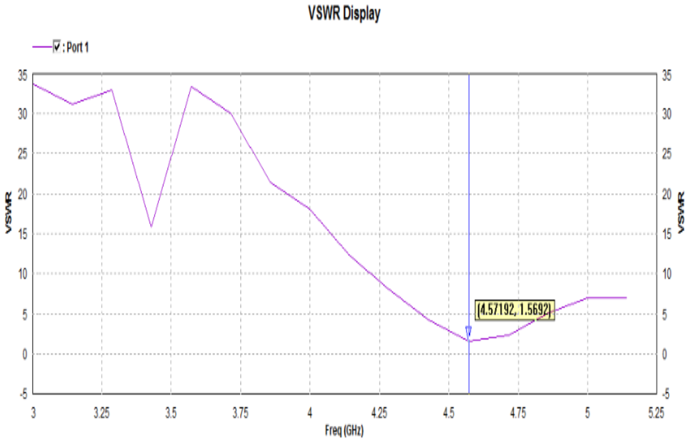


Fig6b. VSWR Vs Frequency

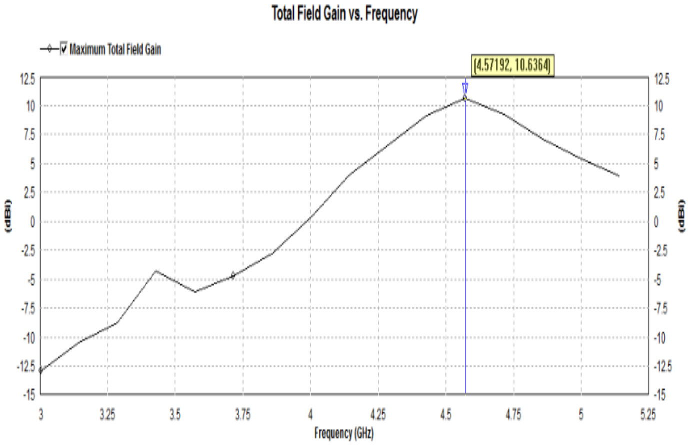


Fig6c. Gain Vs Frequency

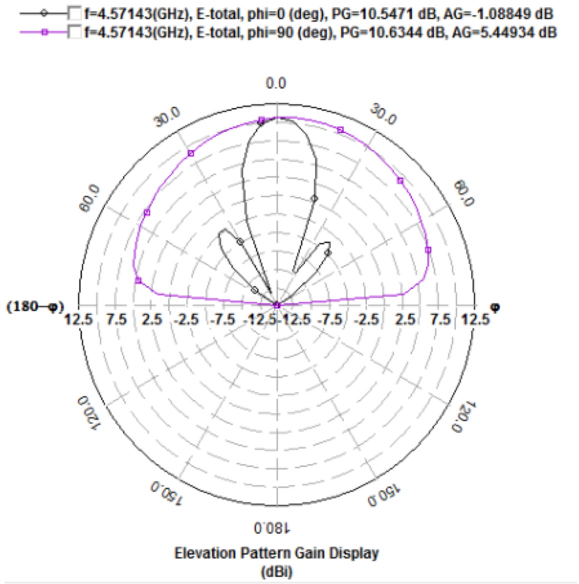
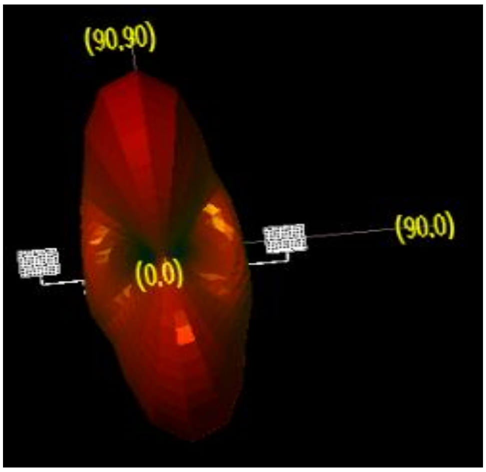


Fig6d. 2-D radiation pattern



Back view

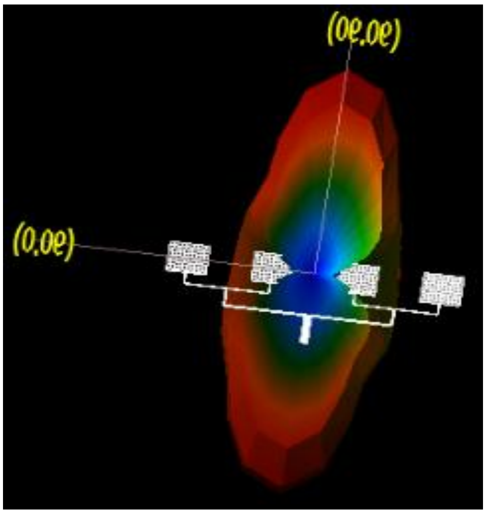


Fig6e. 3-D radiation patterns

E. *Four-element array using quarter wave transformer*

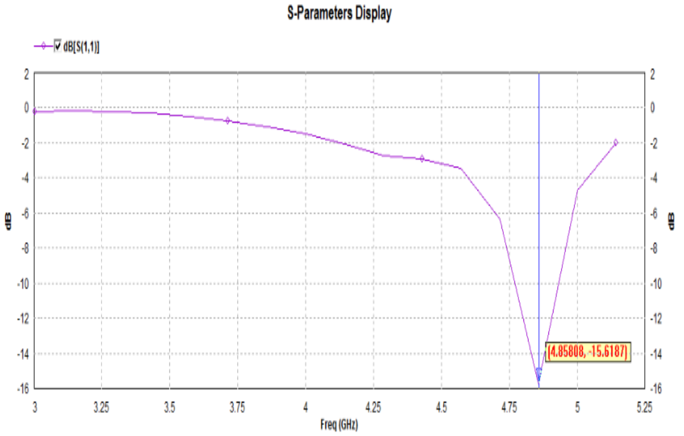


Fig7a. Return Loss Vs Frequency

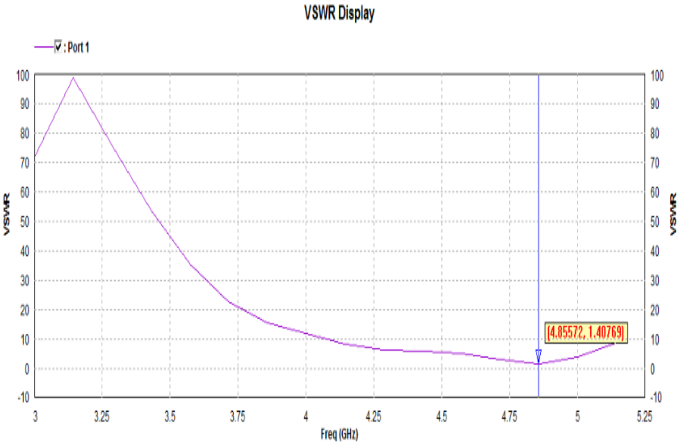


Fig7b. VSWR Vs Frequency

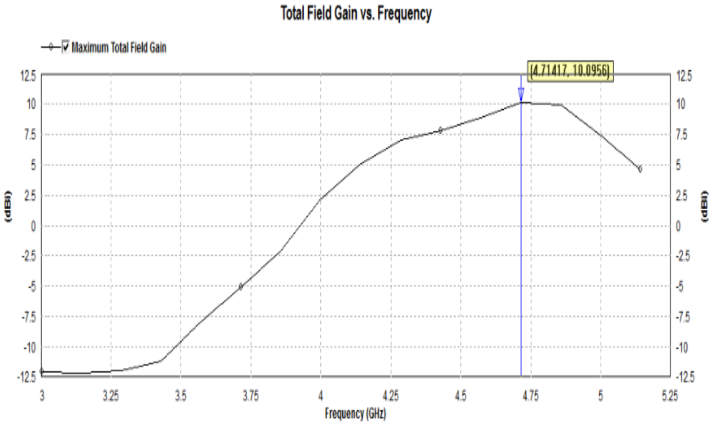


Fig7c. Gain Vs Frequency

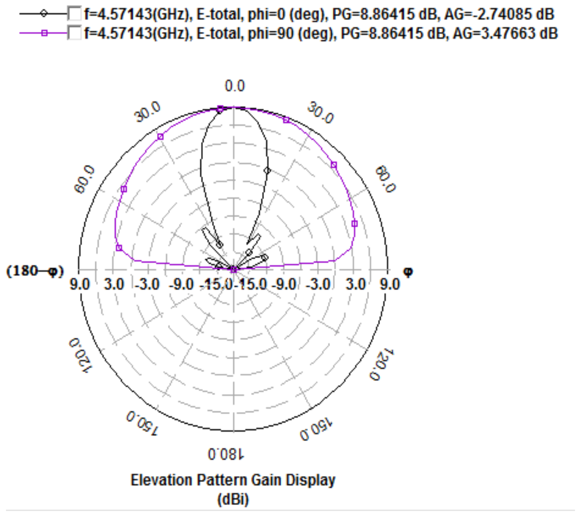
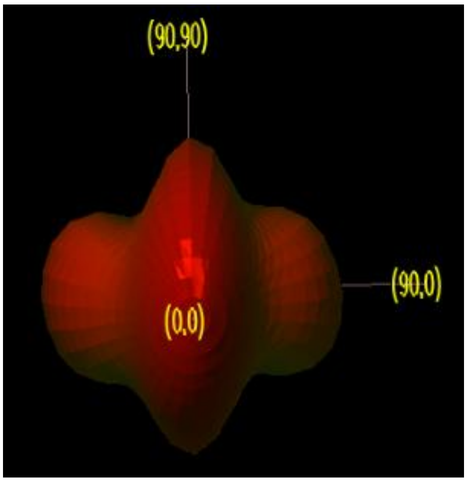


Fig7d. 2-D radiation pattern



Back view

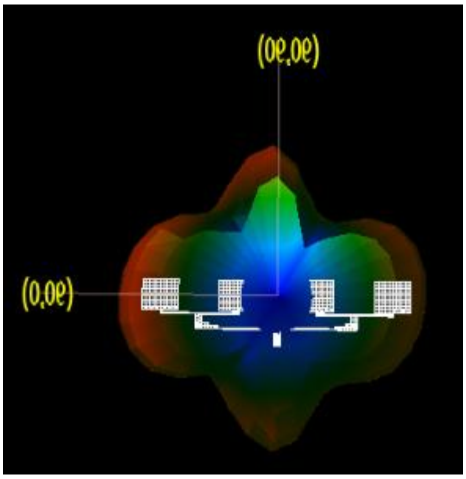


Fig7e. 3-D radiation patterns

F. Comparison of Results

Type of Antenna	**S_{11} (dB)**	**Min VSWR**	**Max gain (dBi)**	**Beamwidth (^{o})**
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.

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