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Effect Of Element Spacing on The Parameters of Linear Array of Microstrip Patch Antenna

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Abstract: The performance and advantages of microstrip patch antennas such as low weight, low profile, and low cost made them the perfect choice for communication systems engineers. They have the capability to integrate with microwave circuits and therefore they are very well suited for applications such as cell devices, WLAN, navigation systems and many others.

Antenna arrays are widely used in various applications due to their ability to enhance system performance by providing increased gain, directivity, and beam shaping capabilities. This study specifically examines a variety of microstrip patch antenna arrays that resonate at 3.1GHz, utilizing an FR-4 Epoxy substrate with a dielectric constant of 4.4 and a height of 1.6mm.
Generally, the spacing between antenna elements is kept lambda/2, in this project we analyzed that effect of increasing the number of elements maintaining array size same, on the parameters of array, like radiation pattern, gain, return loss and directivity. The design and analysis of the array are carried out using numerical electromagnetic simulation tool HFSS.

Keywords: Microstrip Patch, Radiation Pattern, VSWR, Gain.

I. INTRODUCTION

Microstrip patch antenna consists of a metallic radiating patch on upper side of dielectric substrate, which is comparably thick and conducting ground plane on the lower side of it.[1] High dielectric constants of the substrate are helpful in miniaturizing dimensions of antenna. Required Gain and directivity cannot achieve with a single patch antenna so 4x1, 6x1 and 7x1, patch antennas array has been designed to achieve high gain and directivity.[2]

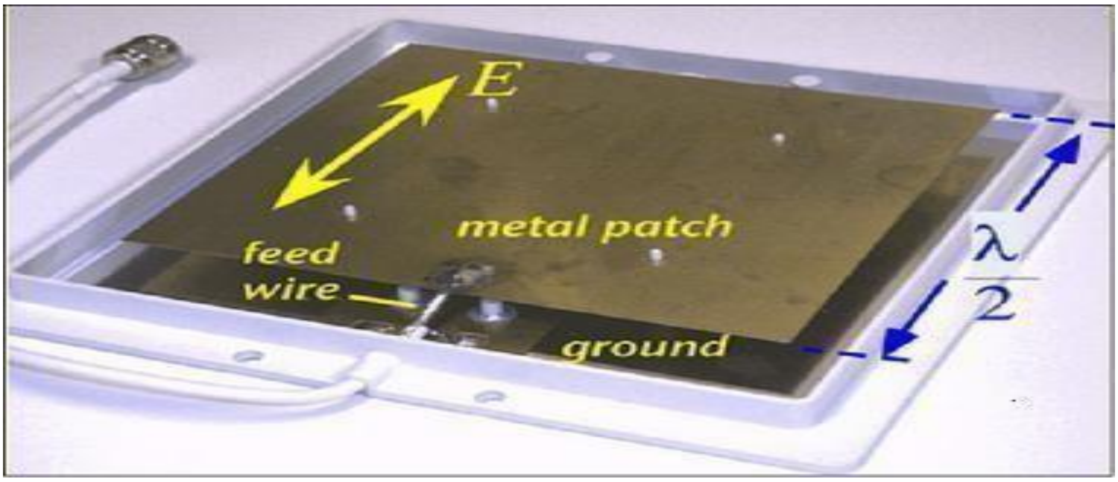

Fig 1. Microstrip Patch Antenna.

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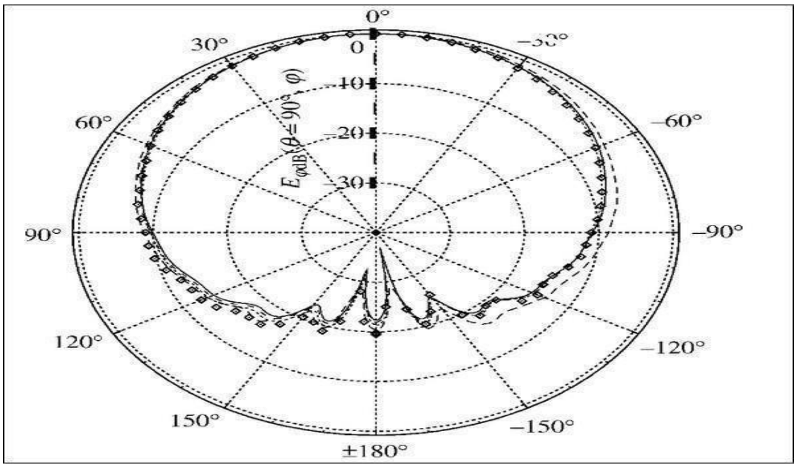

Fig 2. Radiation pattern of Microstrip patch antenna.

In general terminology, Microstrip patch antenna consists of the patch which is mounted on the material which is known as substrate having the dielectric constant and loss tangent.[3] The Microstrip patch antenna performance is depending on and determined by its operating frequency, resonant frequency, gain, directivity, and radiation efficiency.[4] A slot cut on the radiating patch also affects the performance of the antenna as it introduced a capacitive effect. A combination of slot and notch also influences the antenna parameter.

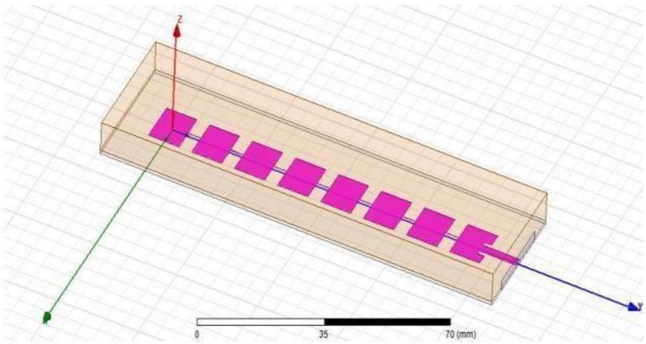

Fig 3. Rectangular 8x1 patch array antenna with series feed.

II. SOFTWARE REQUIREMNTS

Ansys HFSS:
Best-In-Class 3D High Frequency Structure Simulation Software Multipurpose, full wave 3D electromagnetic (EM) simulation software for designing and simulating high-frequency electronic products such as antennas, components, interconnects, connectors, ICs and PCBs.

3D Electromagnetic Field Simulator for RF and Wireless Design Ansys HFSS is a 3D electromagnetic (EM) simulation software for designing and simulating high-frequency electronic products such as antennas, antenna arrays, RF or microwave components, high- speed interconnects, filters, connectors, IC packages and printed circuit boards. Engineers worldwide use Ansys HFSS software to design high-frequency, high-speed electronics found in communications systems, advanced driver assistance systems (ADAS), satellites, and internet-of-things (IoT) products.

Few of the areas of application are in:
- Electromagnetics Component-to-System EM Workflow
- Electromagnetics Coupled EM System Solver
- Electromagnetics3D Design Share
- Electromagnetics Automatic Adaptive Meshing
- Smarter Antenna Design and Placement Simulation.

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Fig 4. Ansys HFSS Logo.

III. METHODOLOGY

DESIGN SPECIFICATIONS OF PATCH ANTENNA:

Both the antennas can be designed by using the following equations. By using these equations, we can easily find out the values for dimensions of inset fed patch.

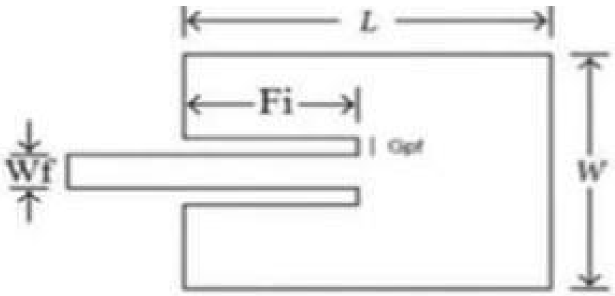

Fig 5. Specifications.

a. Calculation of Width:

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}}$$

on substituting, $C=3*10^8$ m/sec, f_o= 3.1 GHz, we get W= 29.4mm.

b. Calculation of Effective Dielectric Constant:

The calculation of effective dielectric constant of micro strip patch antenna is given by the equation:

$$\varepsilon_{reff} = \frac{\varepsilon_{r+1}}{2} + \frac{\varepsilon_{r-1}}{2}\left[1+12\,\frac{h}{W}\right]^{-1/2}$$

on substituting h=1.6mm, w=29.4mm, Er=4.4, we get Ereff=4.08.

c. Calculation of Effective Length:

The calculation of effective length of the micro strip antenna is given by the equation:

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$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}}$$

On substituting c=3*108, f0=3.1 GHz, Ereff=4.08mm, we get Leff=24.12mm.

d. Calculation of Length extension:

The calculation of effective length of the micro strip antenna is given by the equation:

$$\Delta L = \frac{0.412h(\varepsilon_{reff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{w}{h}+0.8)}$$

On substituting h=1.6mm, w= 29.4 mm, εreff = 4.08, we get ΔL = 7.35X10-4 mm.

e. Calculation of length:

The length of the micro strip patch antenna is given by the equation:

$$L = L_{eff} - 2 * \Delta L$$

On substituting Leff = 24.12 and ΔL= 7.35X10-4 mm, we get L= 22.65mm.

f. Calculation of length of feedline:

$$f_i = \frac{6h}{2} = 3h$$

The length of feedline is given by the equation is fi = 4 .8mm.

g. Calculation of length of substrate:

Ls=6h+L

On substituting h=1.6mm, L=22.65mm, we get Ls=32.65mm.

h. Calculation of width of substrate:

Ws=6h+W

On substituting h=1.6mm, W=29.4mm, we get Ws=39.04mm.

III. SIMULATION

A. 4x1 MICROSTRIP PATCH ARRAY:

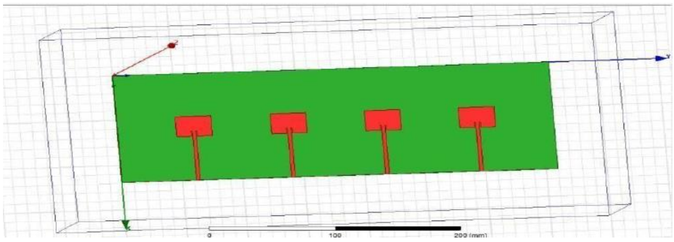

Fig 5. 4x1 Microstrip Patch Array.

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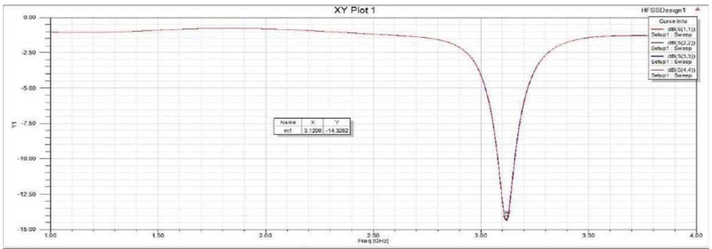

Fig 6. S-Parameter Plot of 4x1 Microstrip Patch Array.

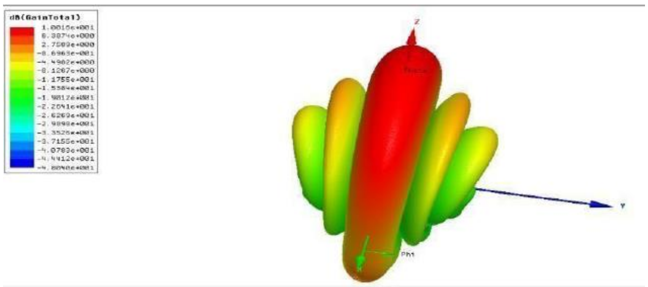

Fig 7. Radiation Pattern (3D) of 4x1 Microstrip Patch Array.

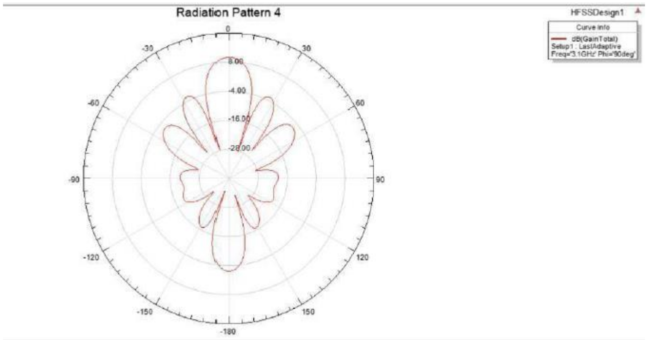

Fig 8. Radiation Pattern (2D) of 4x1 Microstrip Patch Array.

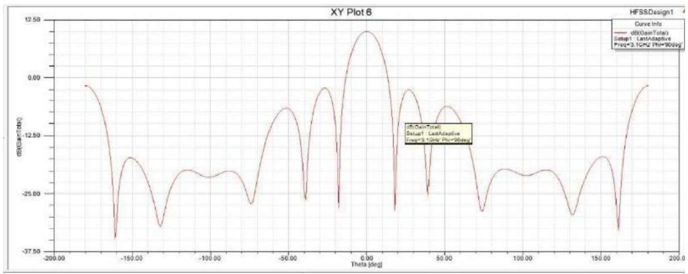

Fig 9. Gain plot of 4x1 Microstrip Patch Array.

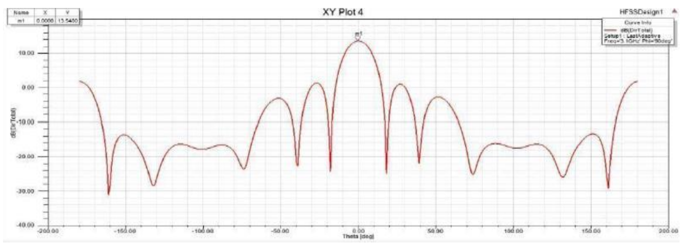

Fig 10. Directivity plot of 4x1 Microstrip Patch Array.

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B. 7x1 MICROSTRIP PATCH ARRAY:

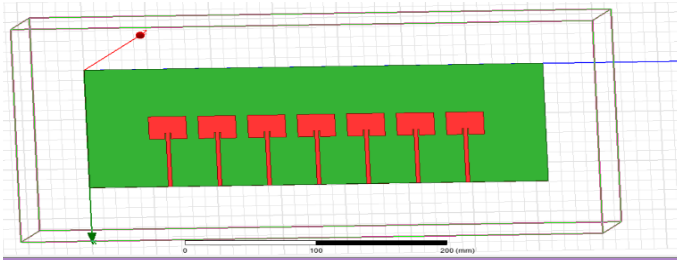

Fig 11. 7x1 Microstrip Patch Array.

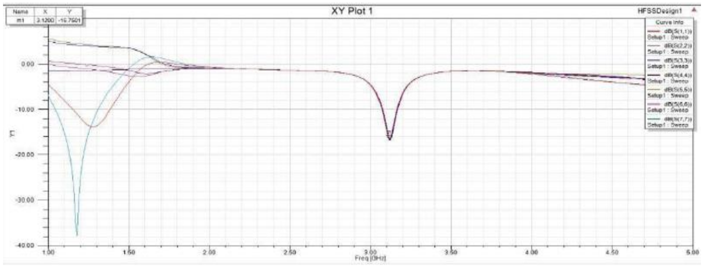

Fig 12. S-Parameter Plot of 7x1 Microstrip Patch Array.

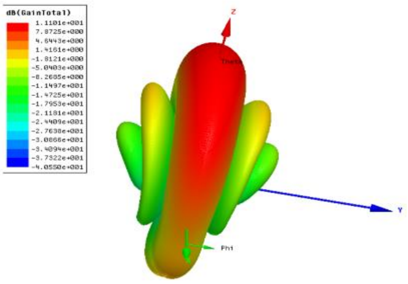

Fig 13. Radiation Pattern (3D) of 7x1 Microstrip Patch Array.

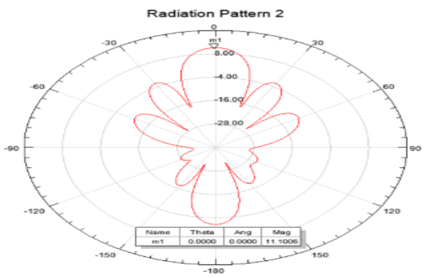

Fig 14. Radiation Pattern (2D) of 7x1 Microstrip Patch.

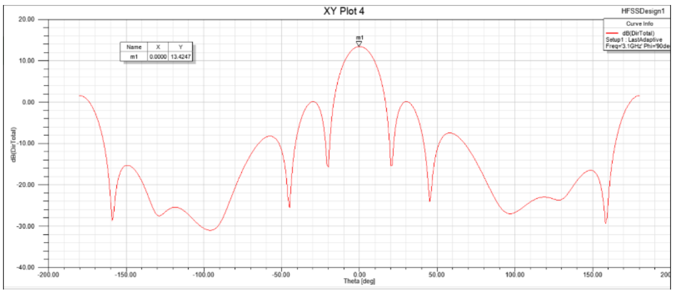

Fig 15. Directivity plot of 7x1 Microstrip Patch Array.

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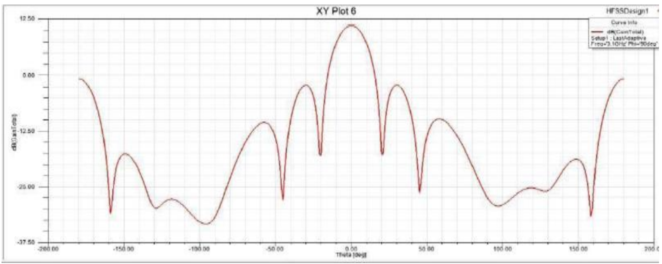
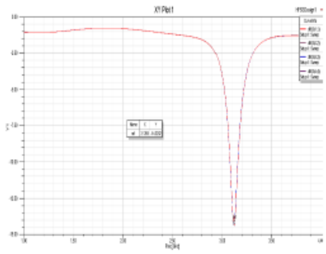
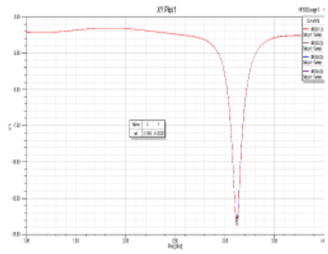
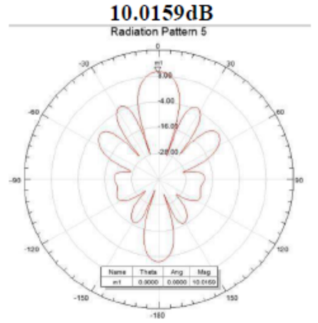
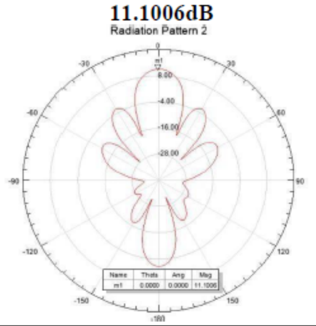
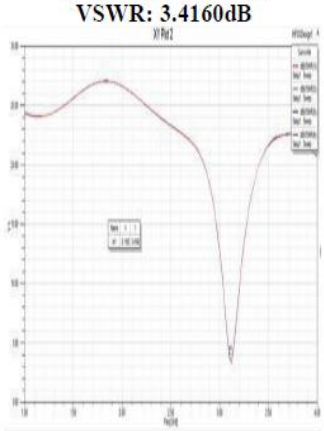
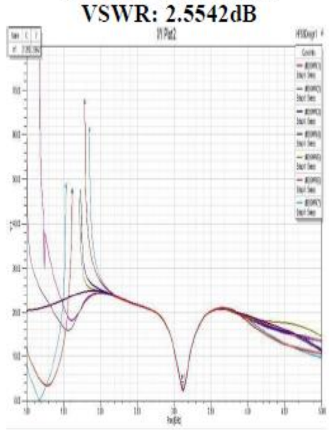


Fig 16. Gain plot of 7x1 Microstrip Patch Array.

IV. RESULTS

The following table depicts the comparison of various parameters of microstrip array of 4 antenna elements and microstrip array of 7 antenna elements.

Sl. no	Antenna Parameters	Microstrip Array Of 4 Antenna Elements	Microstrip Array Of 7 Antenna Elements
1.	S-parameter or return loss	Frequency: 2.5GHz to 3.5GHz Return Loss: -14.3262dB 	Frequency: 2.5GHz to 3.5GHz Return Loss: -16.7101dB 
2.	Gain	10.0159dB 	11.1006dB 
3.	VSWR	Frequency: 3.12GHz VSWR: 3.4160dB 	Frequency: 3.12GHz VSWR: 2.5542dB 

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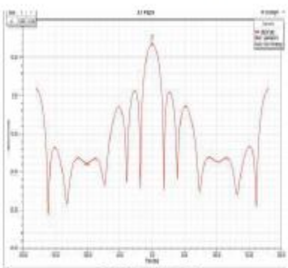
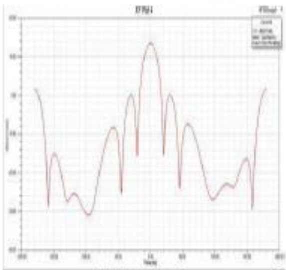
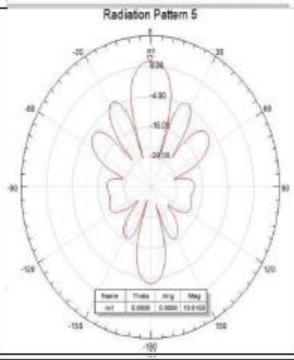
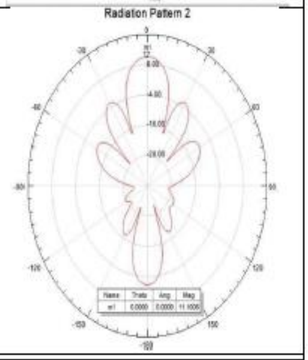
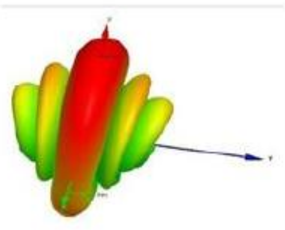
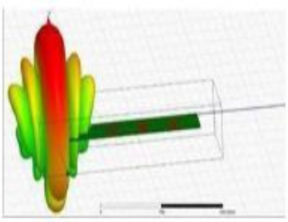
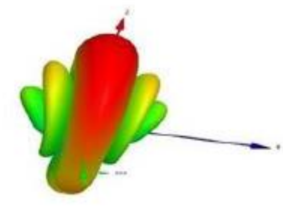
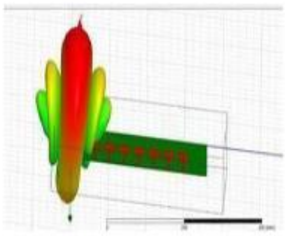
4.	Directivity	13.5480dB at 0 degree 	13.4247dB at 0 degree. 
5.	Radiation Pattern in 2D		
6.	Radiation Pattern in 3D	 	 

V. CONCLUSION

In conclusion, this project is not for replacing something, rather it is for the analysis of the effect of spacing between elements so that we can choose the antenna elements spacing judiciously to optimize the space.

Upon comparison of parameters between microstrip array of 4 antenna elements and 7 antenna elements, since there is very minute increase in the parameter values of microstrip array of 7 antenna elements, we conclude that microstrip array of 4 antenna elements is more effective than the later in terms of cost and time complexity factors.

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