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Design and Performance Analysis of 4×1Corporate Feed Circular Polarized Rectangular Micro Strip PatchAntenna using HFSS

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***Abstract*-The modern communication systems require high gain, high bandwidth and small size antennas that are capable of providing better performance. This leads to the design of micro strip antenna. My project proposes the design of a circularly polarized micro strip patch antenna. Before that as a first step I designed single element, a double element and four element micro strip patch antenna and compare their performances. FR4 is used as the dielectric subtract because it is easily available in the market. The patch antenna design is simulated by using Ansoft High Frequency Structure Simulator (HFSS) software. The antenna parameters like Return Loss, gain and impedance are calculated using HFSS software. The antenna is designed for 2.4 GHz frequency which is suitable for S-band applications.**

Keywords—rectangular micro strip patch antenna; patch parameters; corporate feeding; HFSS

I. INTRODUCTION

An antenna converts the desired signal from a source into electromagnetic radiations and is then radiate into free space. A good antenna transmits the energy in some desired directions and suppresses it in the undesired directions at some desired resonant frequencies. A perfect antenna design improves overall performance of the system which is depending on the physical size of the antenna.

Micro strip Antenna is used in many wireless communication applications, due to less weight, low cost, and the easiness in the fabrication into arrays. The main drawback of micro strip antennas is their inefficiency, narrow frequency bandwidth and low gain. To overcome the bandwidth and gain limitations, number of antenna elements or feeding matching networks may be employed.

II. MICROSTRIP PATCH ANTENNA

A patch antenna is fabricated by etching the desired pattern in metal trace attached to a dielectric substrate. There is a continuous layer of metal is attached to the opposite side of the dielectric substrate. It is known as ground plane. Commonly used patch shapes are square, rectangular, circular and elliptical. Micro strip patch antennas consist of very thin metallic structure (patch) placed on ground plane. The basic structure of a single patch micro strip antenna is shown in Fig.1.

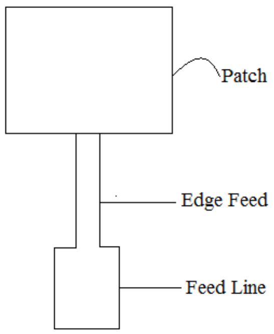

Fig.1. *Single Element Patch Antenna*

III. MICROSTRIP ANTENNA ARRAY AND FEEDING NETWORKS

Antenna arrays are used to enhance various antenna parameters which would be difficult with single patch antenna. There are a variety of methods to feed the signal in to Micro strip patch antennas. The main categories are

- Contacting: Radio frequency signal is directly fed to the patch element using metallic feed line.
  Eg: Edge feed and pin feed

- Non-Contacting:The phenomenon EM field coupling is used to transfer RF power between the micro strip line and antenna patch element.

Eg: aperture coupling and proximity coupling

Different Feeding Methods

A. Micro strip line feed

In this case a metallic strip (feed line),which has smaller width as compared to the patch is directly connected tothe Micro strip patch. This is shown in Fig.2. The advantage of this type of feeding technique is that, the feed line can be etched on the same substrate plane and it provides a planar structure.

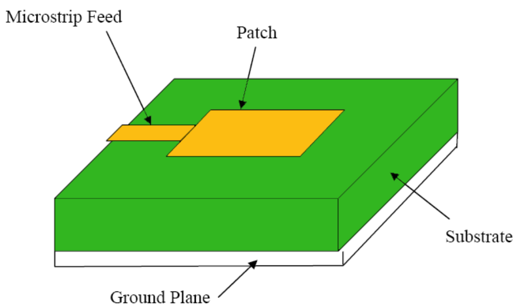

Fig.2.*Micro strip Line Feed*

B. *Micro strip Pin Feed*

In this case the coaxial connector is used to feed the RF power to the patch element. The coaxial connector consists of an inner conductor and an outer conductor. The inner conductor is drilled through the substrate plate and is soldered to themetallic patch element.The outer conductor is connected to the metallic ground plane. The advantage of this feeding technique is that the feed can be placed at any desired location. It is shown in Fig. 3.

C. *Micro strip Series Feed*

In this technique the individual patch elements are connected in series using a transmission line from which the desired proportion of RF energy iscoupled into the individual element propagated along the line. This is shown in Fig. 4. Here the input power is feed at the first element. Quarter wavelength transformer method is used in this method.

D. *Corporate Feed*

A corporate feed is most widely used feeding techniques to fabricate the antenna arrays. In this case the incident power is equally splitting and distributing to the individual antenna elements. The corporate feeding technique can provide power splits of 2k (where k = 2; 4; 8; 16…..). Here, in the Fig. 5, the patch elements are connected by using the quarter wavelength impedance transformers.

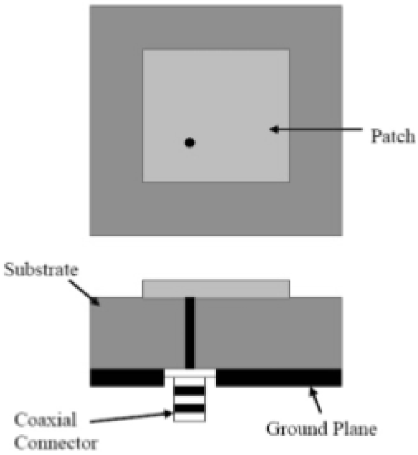

Fig.3.Micro strip Pin feed

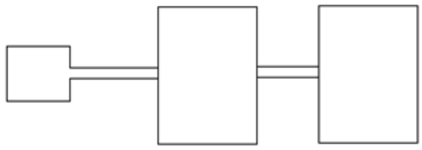

Fig.4.Micro strip Series Feed

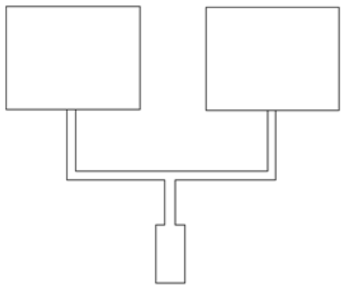

Fig.5. *Micro strip Corporate Feed*

IV. RECTANGULAR PATCH ANTENNA DESIGN

Micro strip patch is a rectangular metallic stripof width 'W', and length 'L' fabricated on a thin insulated dielectric substrate. The thickness of the substrate is denoted as 'h' and relative permittivity as 'ε_r'.

A. *Design Considerations of Patch Antenna*

The parameters considered for the design of a rectangular micro strip patch antennae are

- Resonant Frequency of antenna (f_0): The antenna has been designed for S-band applications. The resonant frequency of the proposed antenna is 2.4GHz.
- Relative Permittivity of the substrate (ε_r): The substrate material used for the design of the antenna is FR4. It has a dielectric constant of 4.4.
- Thickness of dielectric substrate (h): The thickness of the dielectric substrate is chosen as 1.6 mm which is a standard value.

The values chosen for the antenna design are $C = 3\times10^8$ m/s, $\varepsilon_r = 4.4$ and $f_0 = 2.4$ GHz.

B. *Design Procedure*

1. Calculation of Patch Width (W)

The width of the patch element (W) is calculated using the equation,

$$W = \frac{C}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}} \qquad (1)$$

Substitute $C = 3\times10^8$ m/s, $\varepsilon_r = 4.4$ and $f_0 = 2.4$ GHz, then we get W=38mm

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

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

Substitute ε_r = 4.4, h=1.6mm and W=38mm, then we get ε_{reff}=4.785

3. *Calculation of the Effective length* (L_{eff})

$$L_{eff} = \frac{C}{2f_0\sqrt{\varepsilon_{reff}}} \quad (3)$$

By substituting C = 3×10^8 m/s, ε_{reff}=4.785and f_0 = 2.4 GHz we get L_{eff}=28.57mm

4. *Calculation of the length extension* (ΔL)

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(W/_h+0.264\right)}{(\varepsilon_{reff}-0.258)\left(W/_h+0.8\right)} \quad (4)$$

By substituting ε_{reff}=4.785, h=1.6mm and W=38mm weget ΔL=0.724mm

5. *The length extension* (ΔL)*of patch*

$$L = L_{eff} - 2\Delta L \quad (5)$$

By substituting L_{eff}=28.57mm and ΔL=0.724mm we get L=27.122mm.

The dielectric substrate material used is FR4. FR stands for Flame Retardant. It is easily available in the market. It is very cheap also.

The ground plate all other conducting surfaces are fabricated using PEC (Perfect Electric Conductor). It is an idealized material exhibiting infinite electrical conductivity and zero resistivity. The main advantage is that it will not generate heat.

TABLE I : MICROSTRIP PATCH DIMENSIONS

Patch Parameters	**Dimensions**
Patch Width (W)	38 mm
Effective dielectric constant (ε_{reff})	4.785
Effective length (L_{eff})	28.57 mm
length extension (ΔL)	0.724 mm
length extension (ΔL)	27.122 mm

V. SIMULATION RESULTS

The simulation software used to design and simulate the performance of the rectangular patch antenna is HFSS software. Single and double patch corporate feed antennas are designed and their parameters are measured and compared.

A. *Single Patch Antenna*

Fig. 6 shows single element patch antenna model designed using HFSS software.

Return Loss, radiation pattern and VSWR measured using the simulator software is shown below.

a) Return Loss

The return loss plot for a single element patch antenna is shown in Fig. 7. In the figure the return loss obtained at 2.4 GHzis -15.94dB.

b) Radiation pattern

3D radiation pattern can be obtained using the simulator software. Fig. 8 shows that the maximum gain obtained is 2.855 dB.

c) VSWR

The plot for VSWR is shown in the fig 9. The figure shows that the VSWR is 1.37.

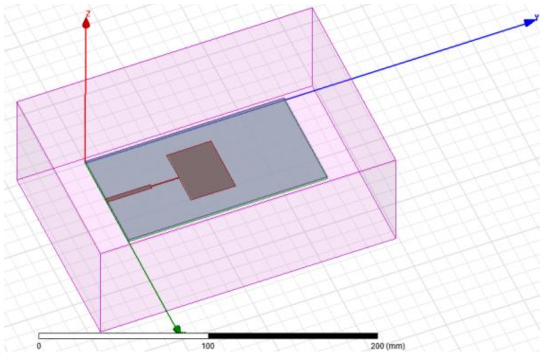

Fig.6.*One Element Micro strip Patch Antenna Model*

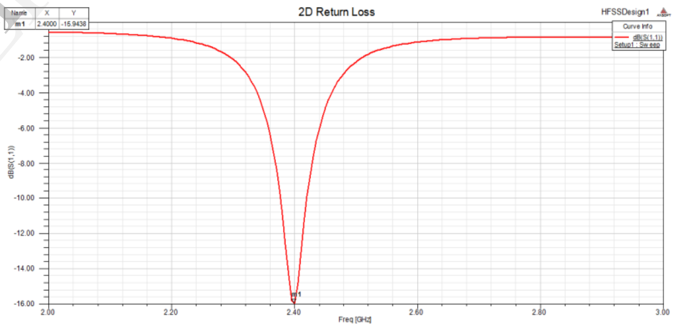

Fig.7.Return Loss of Single Element Patch Antenna

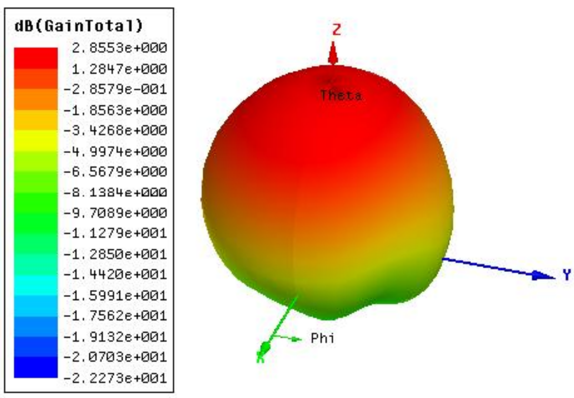

Fig.8. 3D Radiation Pattern for Single Element Patch Antenna

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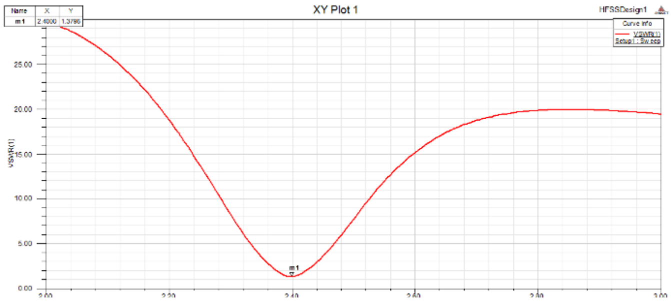

Fig.9. VSWR Plot for Single Element Patch Antenna

B. Double Patch Antenna

Fig.10 shows double element patch antenna model designed using HFSS software.

Return Loss, radiation pattern and VSWR measured using the simulator software is shown below.

a) Return Loss

The return loss plot for a single element patch antenna is shown in Fig.11. In the figure the return loss obtained at 2.4 GHz is -17.49dB.

b) Radiation pattern

3D radiation pattern can be obtained using the simulator software. Fig. 12 shows that the maximum gain obtained is 5.772 dB.

c) VSWR

The plot for VSWR is shown in the Fig. 13. The figure shows that the VSWR is 1.53 at 2.4 GHz.

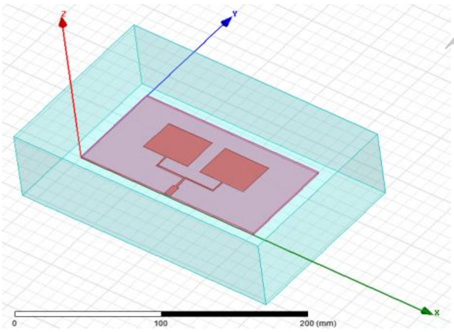

Fig.10.Two Element Micro strip Patch Antenna Model

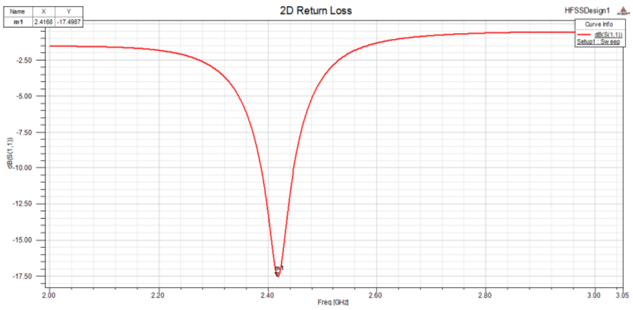

Fig.11.Return Loss of Double Element Patch Antenna

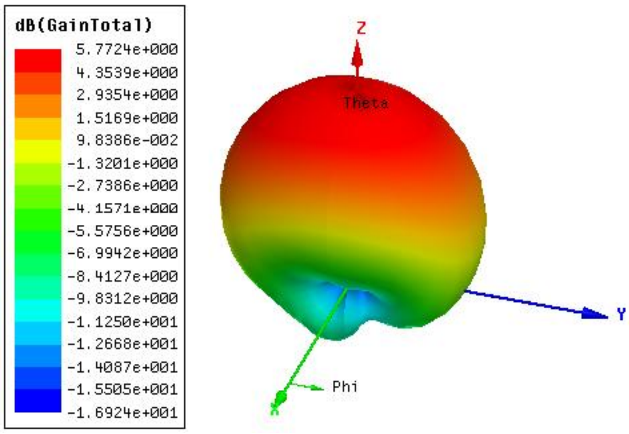

Fig.12. 3D Radiation Pattern for Double Element Patch Antenna

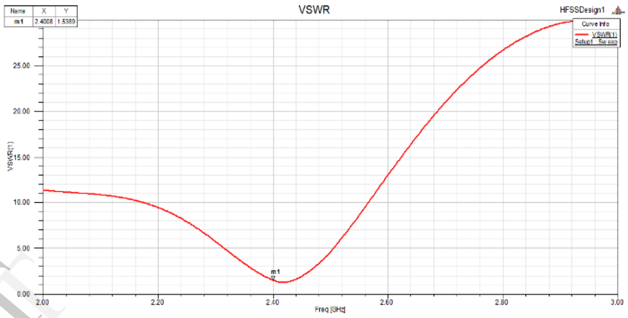

Fig.13. VSWR Plot for Double Patch Antenna

C. Four Patch Antenna

Fig.14 shows double element patch antenna model designed using HFSS software.

Return Loss, radiation pattern and VSWR measured using the simulator software is shown below.

a) Return Loss

The return loss plot for a single element patch antenna is shown in Fig.15. In the figure the return loss obtained at 2.4 GHz is -28.325dB.

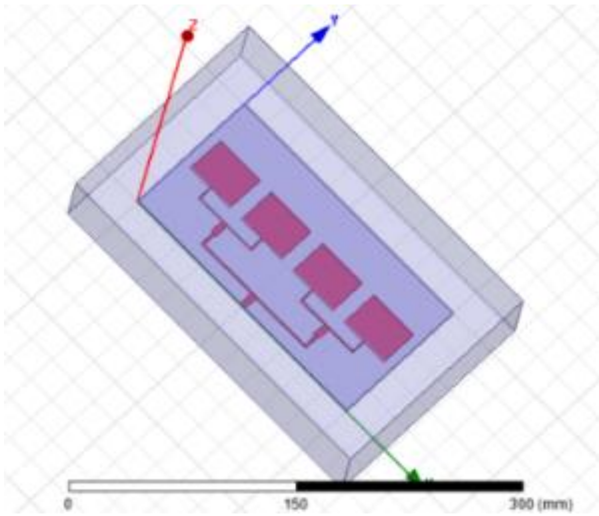

Fig.14.Four Element Micro strip Patch Antenna Model

b) Radiation pattern

3D radiation pattern can be obtained using the simulator software. Fig. 16 shows that the maximum gain obtained is 8.35 dB.

c) VSWR

The plot for VSWR is shown in the Fig. 17. The figure shows that the VSWR is 1.07 at 2.4 GHz.

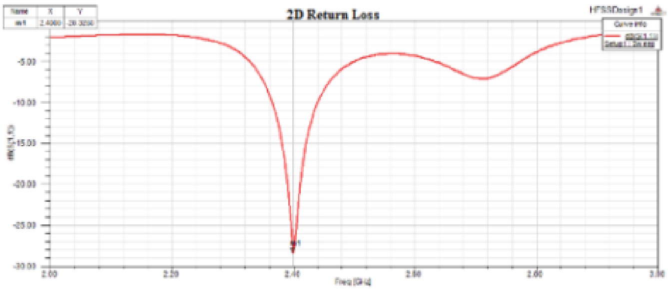

Fig.15.*Return Loss of Four Element Patch Antenna*

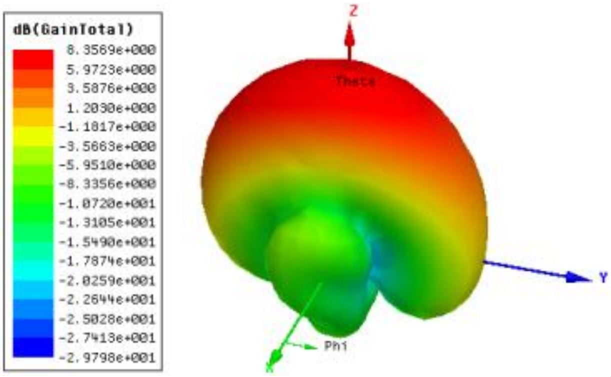

Fig.16. 3D Radiation Pattern for Four Element Patch Antenna

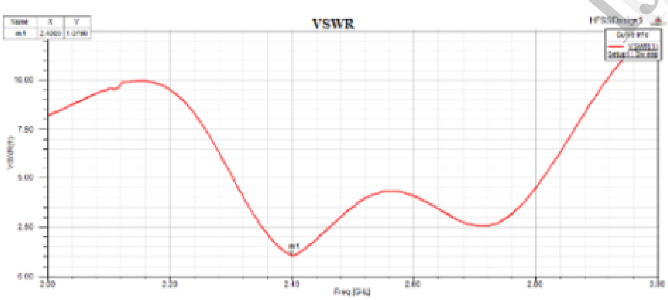

Fig.17. VSWR Plot for Four Patch Antenna

TABLE II: COMPARISON STUDY

Antenna Type	Return Loss(dB)	Gain(dB)	VSWR
Single Patch	-15.98	2.855	1.37
Double Patch	-17.49	5.774	1.5
FOUR Patch	-28.325	8.35	1.07

D. Circularly Polarized Patch antenna

The circularly polarized four element patch antenna is designed by making slots at the corners of each patch.

The designed model is shown in fig. 18.

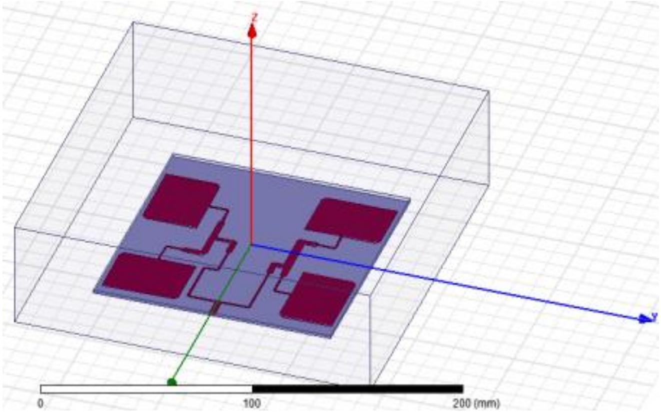

Fig.18.Four Element Circularly polarized Patch Antenna Model

The 3D and 2D radiation pattern of the circularly polarized antenna is shown in fig. 19 and fig. 20.

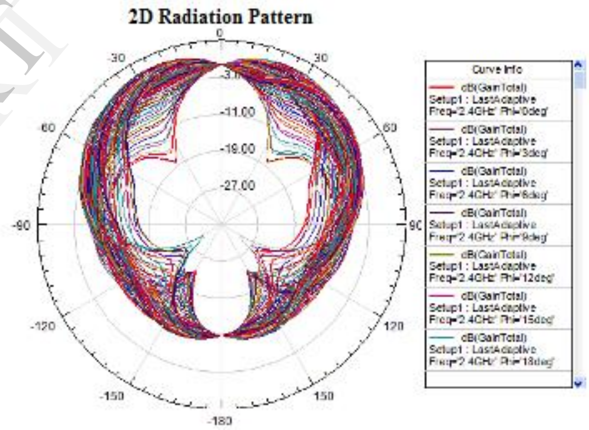

Fig.19.2D Radiation Patternof Circularly polarized Patch Antenna

VI. CONCLUSION

A single patch, double patch and four patch (corporate feed) micro strip antennas are designed for S band applications and their characteristics are investigated using the High Frequency Structure Simulator (HFSS) software. The parametric outcomes such as Return Loss, VSWR, and Gain for both antennas are tabulated in Table II. From the comparison study, it is concluded that, the four patch micro strip antenna with corporate feeding is more efficient which gives higher gain and best return loss at the desired frequency range centered at 2.4 GHz. That is as the number of patches increases the performance of the antenna improves. The circularly polarized antenna is also designed by making slots in each patch. The radiation pattern of such an antenna is also included in the paper.

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