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Design and Simulation of Wideband E-Shaped Microstrip Patch Antenna

N. Krishna jyothi[1], *Dr.G.Srivalli*[2]
[1, 2] *Assisistant professor, ECE Department, GNITS, JNTUH Hyderabad*

Abstract: This paper covers the analysis and design of E-shaped Microstrip patch antenna using Rogers RT/ Duroid substrate with a dielectric constant 2.2 and a thickness of 3.2mm and FR4_epoxy substrate having a dielectric constant of 4.4 and thickness of 3.2mm.The simulation process has been done through HFSS(HIGH FREQUENCY STRUCTURAL SIMULATOR). The radiation characteristics of the simulated antennas are obtained and compared with that of designed microstrip patch antenna operating at 5.25 GHz and 5.8 GHz in terms of return loss, VSWR, Gain, Directivity, E-plane and H-plane radiation patterns, Bandwidth and terminal impedance. The performance characteristics of E-shaped Microstrip patch antenna using FR4_epoxy substrate are much improved compared to Rogers RT/ Duroid substrate antenna.
Keywords: Rectangular microstrip antenna, E-Shaped microstrip patch antenna, HFSS, Bandwidth, Return loss, VSWR.

I. INTRODUCTION

The microstrip patch antenna offers the advantages of low profile, ease of fabrication, lighter in weight, low volume, low cost, smaller dimension, conformity and compatibility with integrated circuits. Microstrip patch antenna can provide dual frequency operations, frequency agility, Omni directional patterning and broad band width .These antennas are used in different hand held communication devices [1].

For feeding the microstrip patch antenna, there are different methods like, line feeding method, coaxial feeding method etc. This paper uses coaxial feeding method. In this type of feeding technique the inner conductor of the coaxial connector extends through a dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane as shown in Figure 1.

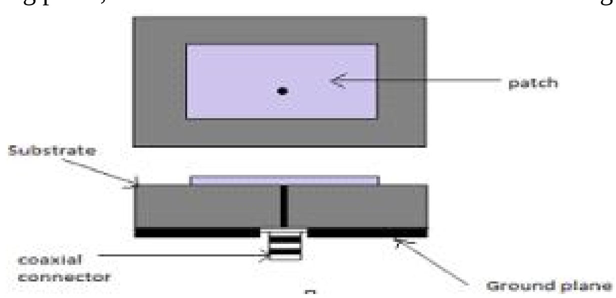

Fig.1 Coaxial Feed or Probe Feed

This type of feed arrangement has the advantage that the feed can be placed at any desired location inside the patch in order to match with its input impedance and is easy to fabricate and has low spurious radiation.

II. ANTENNA CONFIGURATION AND DESIGN

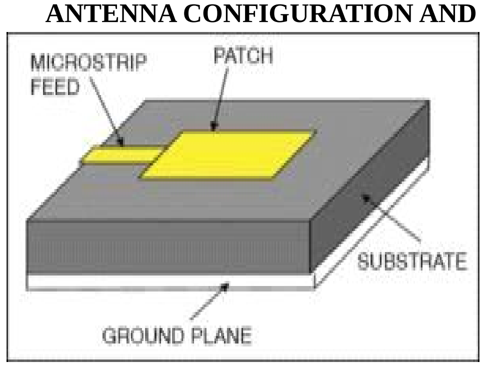

Fig.2 Microstrip patch Antenna

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For designing of a microstrip patch antenna as shown in Figure 2, the essential parameters required are resonant frequency, dielectric medium and substrate thickness for which antenna to be designed.
The parameters to be calculated are as under:
Width (W) of the radiating patch is given by the equation:

$$W = \frac{c}{2f_o\sqrt{\left(\frac{\varepsilon_r+1}{2}\right)}} \quad ----- (1)$$

Where, fo is the resonant frequency, ε_r is the dielectric constant or relative permittivity and c is the velocity of light in free space. Effective permittivity or effective dielectric constant of the dielectric substrate when W/h > 1, is given by the equation:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{-\frac{1}{2}} \quad ------ (2)$$

Length of the active patch (L), which is more responsible for better antenna performance generally lies between $\lambda o/3$ and $\lambda o/2$. However, it is given by the equation

$$L = L_{eff} - 2\Delta L \quad ------ (3)$$

Extended line length ΔL on both sides of the active patch due to the effect of fringing fields [7] is given by the equation:

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

Effective length is calculated by the formula

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \quad ----- (5)$$

The transmission line model is applicable to infinite ground planes only. However, for practical considerations it is essential to have a finite ground plane. It has been proved that similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately the six times the substrate thickness all around the peripheral. Hence, for this design, the ground plane dimensions would be given as:

$$L_g = 6h + L \quad ----- (6)$$
$$W_g = 6h + W \quad ----- (7)$$

In this design, desired input feed point Y_f along y-axis will be zero and only desired input feed point axis X_f along x-axis will be varied to locate the optimum feed point. The optimum feed point is given by the following equation [7].

$$Xf = L/2\sqrt{\varepsilon_{reff}} \quad - ---- (8)$$
$$Yf = W/2 \quad ----- (9)$$

III. DESIGN OF RECTANGULAR MICROSTRIP PATCH ANTENNA

A. Configuration 1

The essential parameters for the design are

Resonant frequency (f_0) = 5.25GHz
Dielectric constant (ε_r) = 4.4
Substrate thickness (h) = 3.2mm

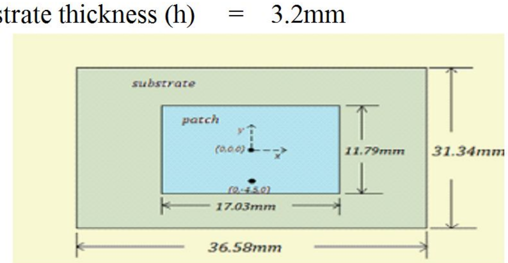

Fig.3 Design of Rectangular microstrip patch antenna for f_0=5.25 GHz, ε_r=4.4 and h=3.2 mm

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The Design parameters are optimized and the optimized design is shown in Figure 3 with the optimized values given in Table I

Table I optimized design parameters of antenna

L	W	Feed point location
11.79 mm	11.79 mm	(0,-4.5,0)

The simulated result of S_{11} scattering parameters (return loss) of rectangular micro strip patch antenna operating at 5.25GHz is presented in Figure 4.From the figure the antenna has almost 5.213 GHz resonant frequency and it has -33.4217db return loss. The value of VSWR at 5.25 GHz is 1.14 is shown in Figure 5.The simulated results for Gain (db) is shown in Figure 6. The measured gain is 4.2768db.This patch antenna is simulated by HFSS.

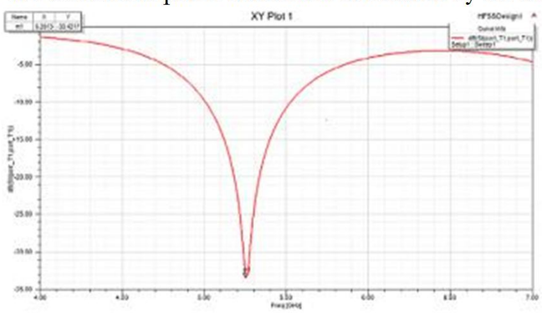

Fig.4 Return loss versus Frequency plot

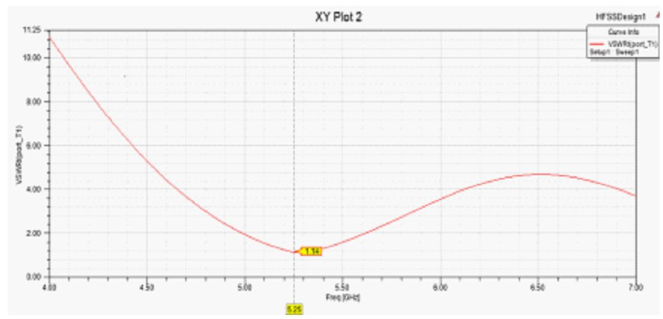

Fig.5 VSWR versus Frequency plot

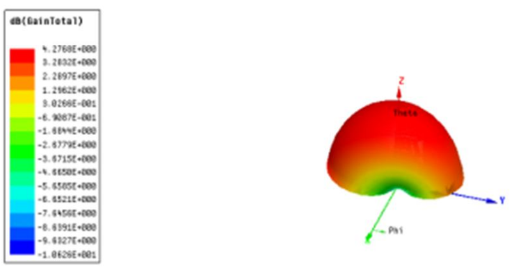

Fig.6 3D polar plot of Gain for f_0=5.25 GHz, ε_r=4.4 and h=3.2 mm

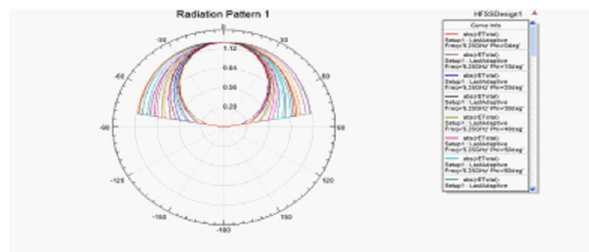

Fig.7 3D polar plot of Radiation pattern for f_0=5.25 GHz, ε_r=4.4 and h=3.2 mm

B. Configuration 2

The essential parameters for the design are

Resonant frequency (f_0) = 5.8GHz,
Dielectric constant (ε_r) = 4.4
Substrate thickness (h) = 3.2mm

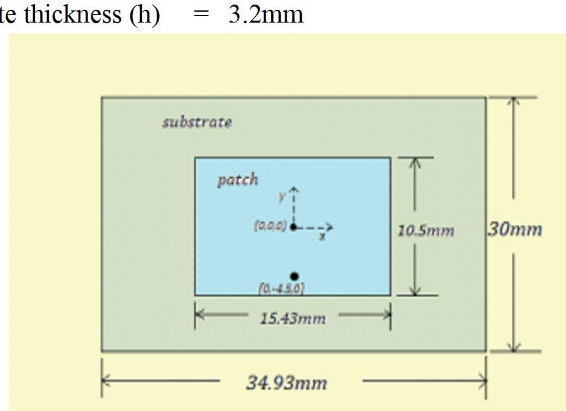

Fig.8 Design of Rectangular microstrip patch antenna for f_0=5.8 GHz, ε_r=4.4 and h=3.2 mm

The Design parameters are optimized and the optimized design is shown in Figure 8 with the optimized values given in Table II

Table II optimized design parameters of antenna

L	W	Feed point location
10.5 mm	15.43 mm	(0,-4.5,0)

The simulated result of S_{11} scattering parameters (return loss) of rectangular microstrip patch antenna operating at 5.8GHz is presented in Figure 9.From the figure the antenna has almost 5.8090 GHz resonant frequency and it has -38.7444 db return loss.

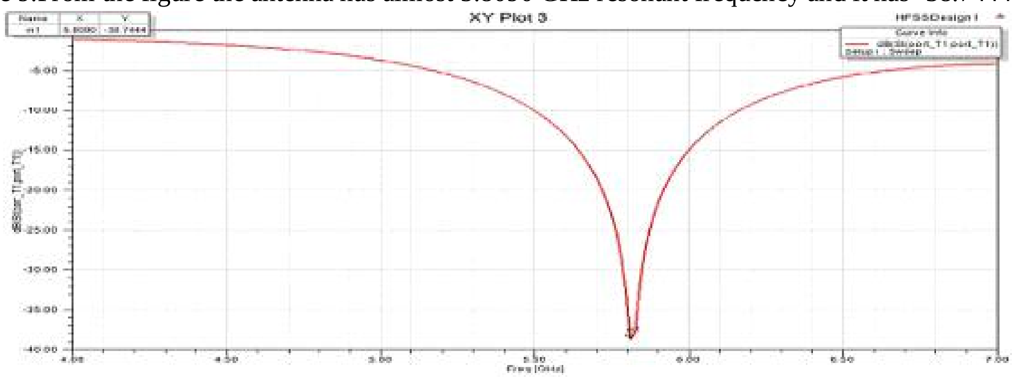

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Fig.9 Return loss versus Frequency plot for f_0=5.8 GHz, ε_r=4.4 and h=3.2 mm

IV. E-SHAPED MICROSTRIP PATCH ANTENNA DESIGN USING ROGERS RT/ DUROID SUBSTRATE

The E-shaped microstrip patch antenna consists of an E-shaped patch, supported on a grounded dielectric sheet of thickness h and dielectric constant εr. An E-shaped microstrip patch antenna is shown in Figure 10.

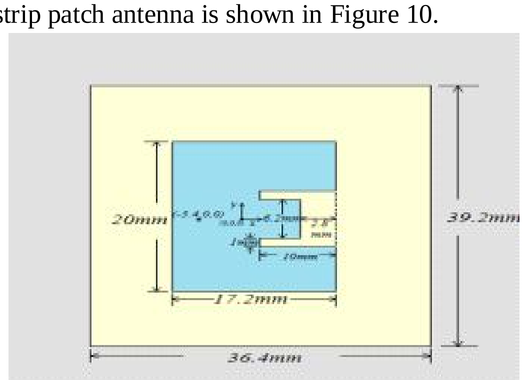

Fig.10 The E-Shaped Micro Strip Patch Antenna using Rogers RT/ Duroid substrate

The E-Shaped Micro Strip Patch Antenna the parameters are
Resonant frequency = 5.25 GHz
Dielectric constant = 2.2
Substrate thickness = 3.2 mm
Width of the patch = 20 mm
Length of the patch = 17.2 mm
Length of Ground = 36.4 mm
Width of Ground = 39.2 mm
Feed position: (-3.4, 0, 0)
Simulation Results Using Rogers/Duroid Substrate:

E-shaped microstrip patch antenna using Rogers/Duroid substrate resonates at frequencies of 5.25 GHz and 5.8GHz.The simulated results of designed antenna gives return loss of -25.3 db and -33.32 db presented in Figure 11 and VSWR of 1.12 and 1.05 at 5.23 GHz frequency and 5.799 GHz frequency respectively is shown in Figure 12. The E-plane and H-plane radiation patterns are shown in the Figures 13a, 13b, 14a and 14b. Terminal impedance of 54.50 ohms and 58.65 ohms are obtained at two resonating frequencies 5.25 GHz and 5.8 GHz respectively is shown in Figure 15. It has band width of 780 MHz and gain of 7.358db.

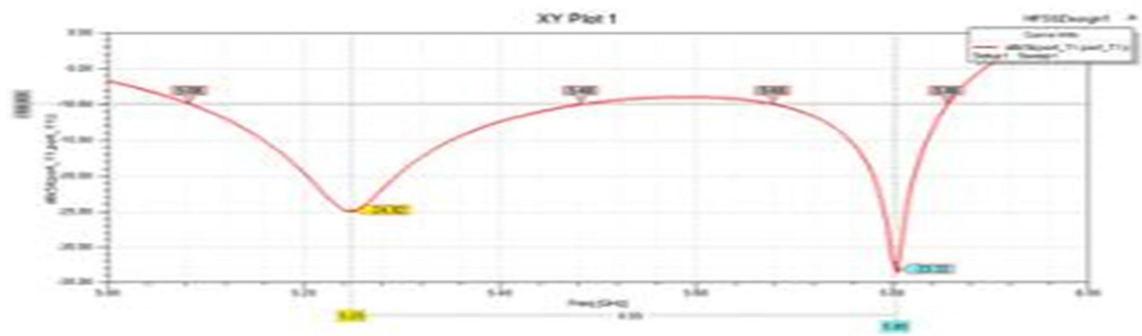

Fig.11 Return loss versus Frequency

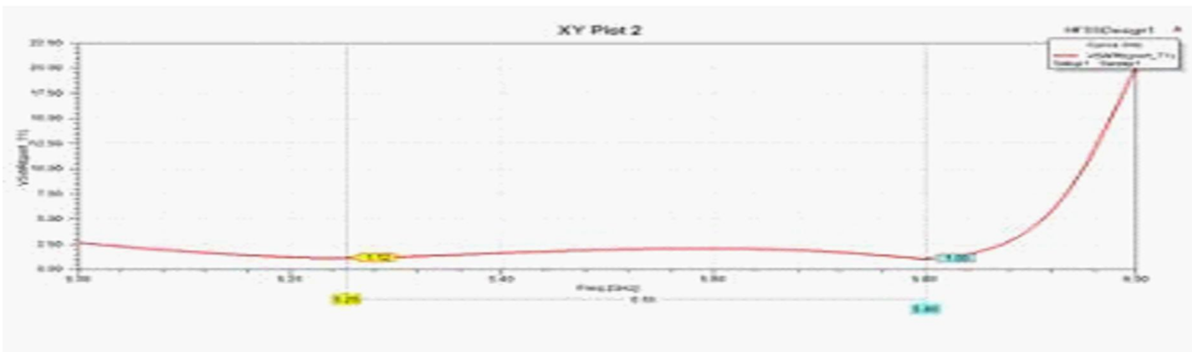

Fig.12 VSWR versus Frequency plot

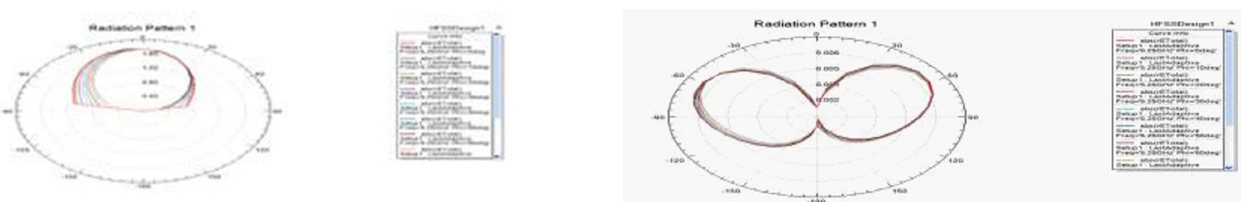

Fig.13a & b E-Plane and H-Plane Radiation pattern at 5.25GHz

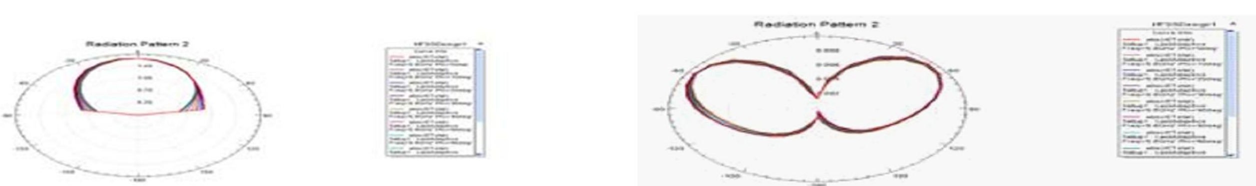

Fig.14a & b E-Plane and H-Plane Radiation pattern at 5.8GHz

Fig. 15 Terminal Impedance versus Frequency plot for f_0=5.25 GHz, ε_r=2.2 and h=3.2mm

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V. E-SHAPED MICROSTRIP PATCH ANTENNA DESIGN USING FR_4 EPOXY SUBSTRATE

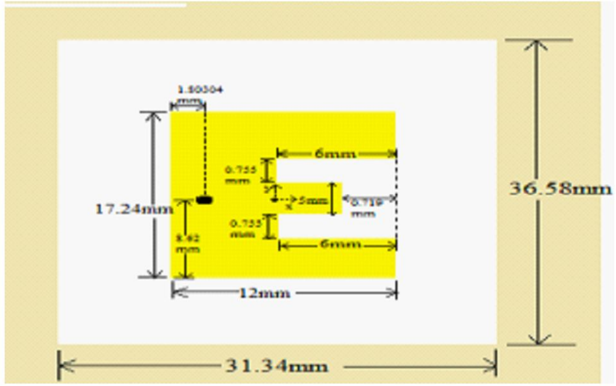

Fig.16 Design of E-Shaped Microstrip Patch Antenna using FR4_epoxy substrate

The E-Shaped Micro Strip Patch Antenna as shown in Figure 16, the parameters are
Resonant frequency = 5.25 GHz
Dielectric constant = 4.4
Substrate thickness = 3.2 mm
Width of the patch = 17.24 mm
Length of the patch = 12 mm
Length of Ground = 31.34 mm
Width of ground = 36.58 mm
Feed position: (-4.19, 0, 0)

A. Simulation Results Using FR_4 Substrate

The simulated results of radiation characteristics plots for above design are given below. The Return loss versus frequency plot has the peak values of -28.46 dB and -17.08 dB at two resonating frequencies 5.25 GHz and 5.8 GHz respectively is shown in Figure 17. A 10 dB Bandwidth of 920 MHz is obtained and VSWR of 1.08 and 1.33 are obtained at two resonating frequencies 5.25 GHz and 5.8 GHz respectively is presented in Figure 18. Terminal impedance of 52.63 ohms and 38.86 ohms are obtained at two resonating frequencies 5.25 GHz and 5.8 GHz respectively is shown in Figure 19. It has a Gain of 4.31 dB and 4.02 dB and directivity of4.31 dB and 4.02 dB is shown in Figures 20 and 21. The E-plane and H-plane radiation patterns are shown in the Figures 22a, 22b, 23a and 23b.

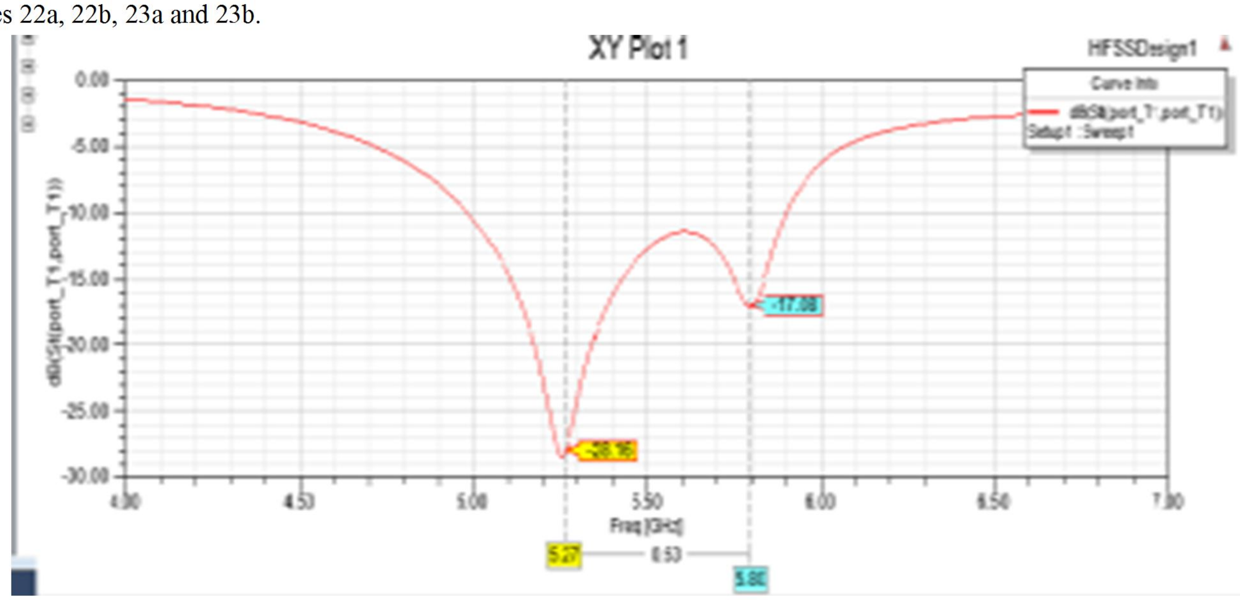

Fig.17 Return loss versus Frequency plot

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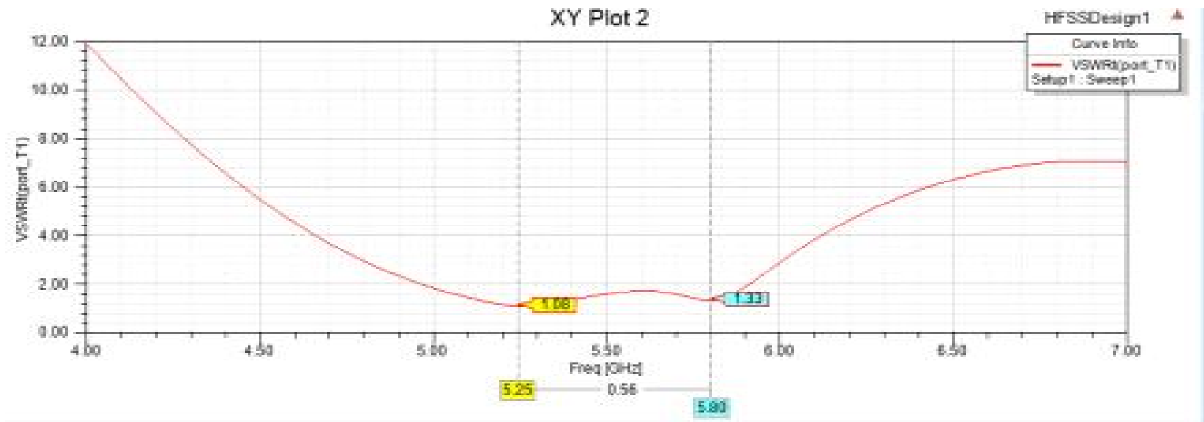

Fig.18 VSWR versus Frequency plot

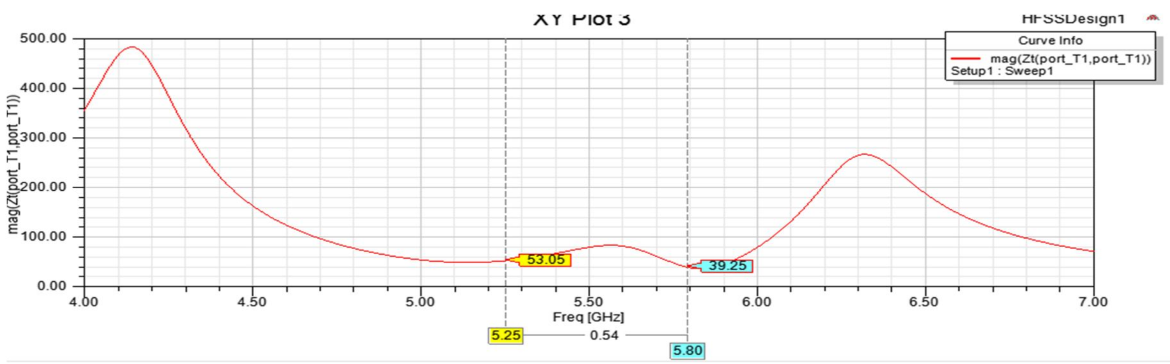

Fig.19 Terminal Impedance versus Frequency plot for f_0=5.25 GHz, ε_r=4.4 and h=3.2 mm

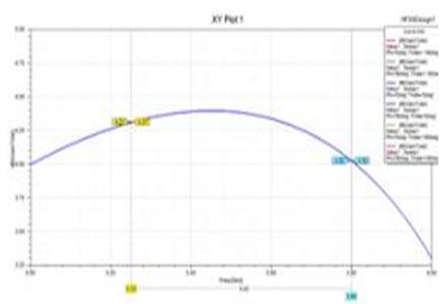

Fig.20 Directivity versus Frequency plot

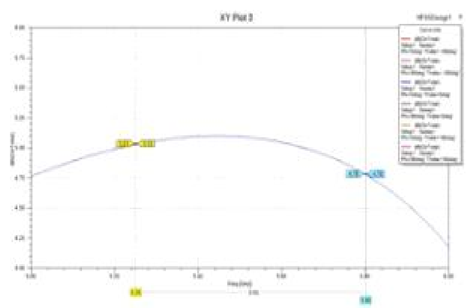

Fig.21 Gain versus Frequency plot

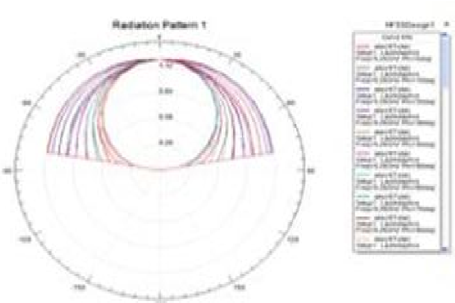

Fig.22a E-Plane Radiation pattern at 5.25 GHz

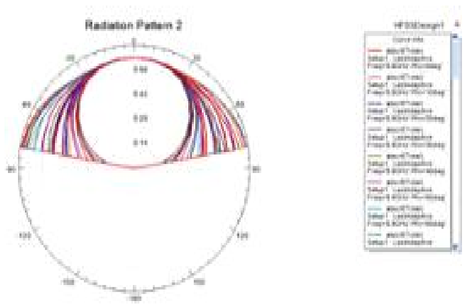

Fig.23a E-Plane Radiation pattern at 5.8 GHz

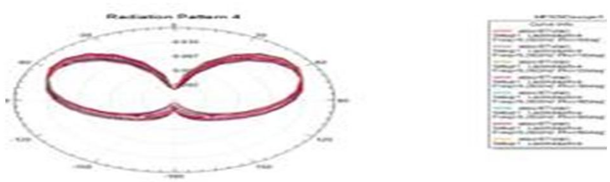

Fig.22b H-Plane Radiation pattern at 5.25 GHz

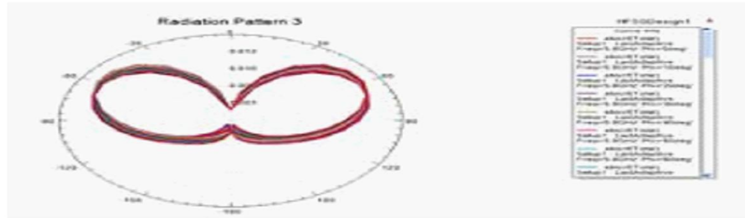

Fig.23b H-Plane Radiation pattern at 5.8 GHz

VI. CONCLUSIONS AND FUTURESCOPE

In this paper two rectangular microstrip patch antennas are designed to cover two different microwave frequency ranges with the same substrate dielectric permittivity. Instead of that a single E-Shaped Microstrip patch antenna is designed to cover dual frequencies. The E-Shaped Microstrip patch antenna using FR_4 substrate enhances bandwidth 920 MHz, Gain 4.129db and good return loss of -28.46 db and -17.08 db is achieved. We conclude that proposed geometry is applicable for wide band from 5-6 GHz. In future the radiation characteristics of the E-Shaped Microstrip patch antenna can be improved by using different feed techniques.

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