DESIGN & SIMULATION OF DUAL BAND T-SHAPED SLOT MICRO STRIP ANTENNA FOR C-BAND APPLICATIONS

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Abstract

Microstrip patches radiate from the currents induced on the surface of the patch because of the electromagnetic cavity with significant resonant frequencies formed between patch and ground plane according to the frequencies applied with different feeding techniques. This paper presents the design and simulation of a T-shaped Dual band Microstrip patch antenna with operating frequencies 5.40GHz, and 6.60GHz for C-Band applications. The T-shape provides Dual band characteristics with good bandwidth which is required in wireless devices with significant design characteristics and can be easily mounted on air craft, space craft, satellites, missiles etc., An Edge-Fed microstrip with substrate FR4epoxy having dielectric constant 4.4 and substrate heights of 6.5mm, 4.56 mm, 3.048mm, and 1.524mm are designed and analyzed with different parameters like VSWR, Gain, Peak directivity, Return losses, Bandwidth, Radiation efficiency, FBR etc,. This antenna design is an improvement from previous research and it is simulated using HFSS (High Frequency Structure Simulator) version 13.0 software.

Keywords :T-shaped slot microstrip,Dual Band, C-Band, Edge-Fed, HFSS Software 13.0

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1. INTRODUCTION

Microstrip patch antenna consists of a metallic patch with different configurations and shapes on a grounded substrate. These antennas are more popular because of their design, ease of analysis and fabrication. The feasible Design and Radiation characteristics highlight its significance in the wireless communication industry. The design characteristics include low profile, simple and inexpensive to fabricate using different methods of printed circuit technologies especially compatible to MMIC designs and comfortable to planer, non planer and rigid surfaces with robust structures [5]. The radiation characteristics include good resonant frequencies, Efficiency, Gain, Polarization, Radiation Pattern and Impedance.

The C-Band is a widely used microwave frequency band in wireless communication systems including Radars, Satellites, Aircrafts, Spacecrafts, missiles and in several space borne applications. The IEEE C-Band (4 to 8 GHz) and its sub band frequencies are feasible also for modern wireless communication systems include Wi-Fi, WLAN, Wi-MAX, Bluetooth etc,[10]. The C-Band performs better under adverse weather conditions compared to other microwave bands used in other applications.

In this paper, a Dual band microstrip patch antenna has been designed, simulated, and analyzed the performance using Finite Element Method based tool, HFSS (High Frequency Structure Simulator) software version 13.0. A T-shaped microstrip patch antenna with substrate of FR4epoxy material and fed with Edge-feed system is developed on Ansys HFSS platform and analyzed to observe the different antenna performance parameters at different frequencies of operations. This paper is structured as follows. Section II describes methodology followed for design of microstrip patch, design parameters and geometry. Section III shows the results explaining antenna parameters like Radiation pattern, Return loss, VSWR, Gain with specifications tabulated and finally Section IV is conclusion.

2. METHODOLOGY

2.1 Design of T-shaped Microstrip Slot

In this section there is presented a design with the use of Microwave HFSS simulation software. First of all we have to choose a dielectric constant and substrate height to design an antenna as these are the basics for the designing[9][8]. They were chosen according to the design frequency. There was chosen substrate material is FR4epoxy with dielectric constant 4.4.

The width of the patch is 0.3mm which is copper (annealed) material having the relative permeability, electrical conductivity (σ) and relative density (ρ) of 1.0, 5.8×10^7 (S/m) and 8900 (kg/m2) respectively[1]. The antenna is fed with 50 Ω microstrip transmission line. Figure 1 shows the geometry of the proposed antenna. The lengths and widths of patch is represented in Table1.

2.2 Designing parameters:

- Calculation of the Width (W)
- Calculation of Effective dielectric constant (ε_{reff})
- Calculation of the Effective length (L_{reff})
- Calculation of the length extension (ΔL)
- Calculation of actual length of patch (L).

2.3 Designing Equations

The below equations are used to find out the length and width of patch [3][4].The width of the patch is found by

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

Where the v_0 is the free-space of velocity of light
The effective dielectric constant can then found by

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{t}{W}\right]^{-0.5} \qquad (2)$$

The extension length has been adapted into the form

$$\Delta L = 0.412\, t\,\frac{(\varepsilon_{eff}+0.3)(\frac{W}{t}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{W}{t}+0.8)} \qquad (3)$$

The actual length of patch(L) can be determined as

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} - 2\Delta L \qquad (4)$$

2.4 Geometry of Antenna

The geometry of the designed antenna is shown in the Figure 1.The antenna is made of a single patch on top, one layers of dielectric and a edge feed slot connected to the upper patch. The shape of the patch T enables with two small arms radiate a particular range of resonance frequencies, the copper material adds the radiation efficiency in the required direction with good front-to-back ratio [1]. The construction and structure with the combination of epoxy substrate enables the antenna to radiate with low VSWR to avoid the reflections. All the dimensions are optimum for effective radiation pattern with good directivity in the given operating frequencies. The specification of dimensions of the patch is represented with widths(**w**) and heights(**h**).

Dimension	**W1**	**W2**	**W3**	**h1**	**h2**	**h3**	**h4**
Specification(mm)	**28**	**4**	**20**	**45**	**8**	**17**	**1.5**

Table.1: Antenna specifications

The design of the proposed antenna is done with the tools available in the HFSS 13.0 software platform and represented in Figure 2. The edge feeding technique is used to assign the excitation to the patch directly at the edges of the patch and substrate.

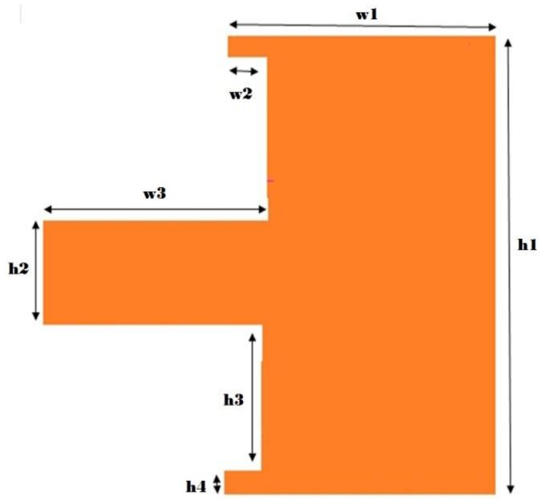

Figure1: Design geometry of proposed micro strip patch.

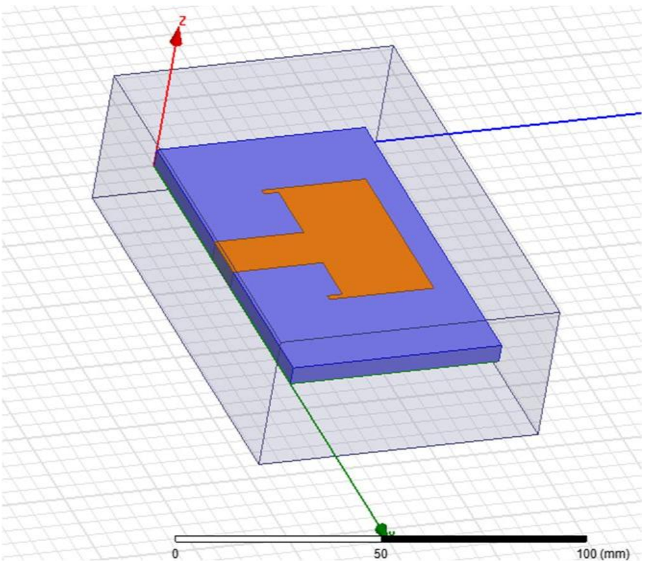

Figure 2: Design of Dual Band micro strip patch in HFSS software

3. RESULTS AND EXPLANATIONS

3.1 Return Losses

Figure 3 illustrates both the simulated and experimental results of the antenna return loss. Here, Return loss is defined as

$$R = 20\log10\,|K| \qquad (5)$$

where K is the reflection coefficient. The Return loss is related with the VSWR and operating frequencies. As shown in this figure 3, simulated values of the first and second resonant frequencies are 5.4 GHz and 6.6 GHz, respectively. Current paths of the 1st and2nd modes are shown. The resonant frequencies can be calculated approximately as follows:

$$f_1 = \frac{c}{2\sqrt{\varepsilon_{eff}}L1} \qquad (6)$$

$$f_2 = \frac{c}{2\sqrt{\varepsilon_{eff}}\,L2} \tag{7}$$

Where $L1$ and $L2$ are the average lengths for current paths of the 1st and 2nd resonant modes and c is the velocity of EM wave in free space. The effective dielectric constant is given by

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{10t}{W}\right)^{-0.555} \tag{8}$$

Where t and W are thickness of the substrate and width of the metallic patch. The return losses are shown in the below Figure 3.

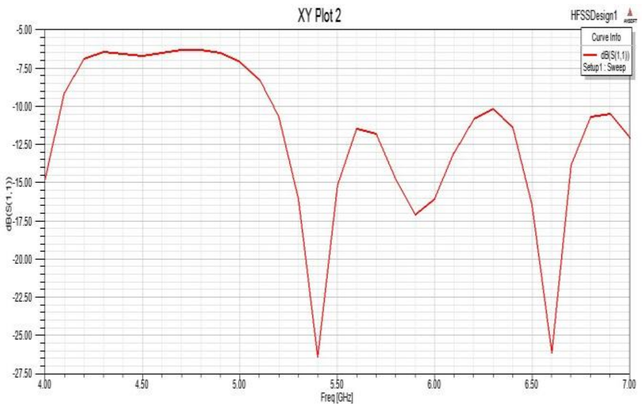

Figure 3: Return losses

3.2 Radiation Pattern

The two dimensional radiation pattern can be plotted by taking the variation of the absolute value of field strength or power as a function of θ. This curve gives the necessary Directional characteristics of the antenna include HPBW, FNBW, Direction of Propagation, FBR etc., Significant changes in the values of thickness of the substrate, dielectric constant of the substrate, shape of the patch, effective length, Feed position, W/L Ratio effect the Directional characteristics of the Proposed microstip antenna. The radiation pattern visualizes the propagation characteristics of the antenna for optimization.

The radiation Pattern of the proposed antenna is shown in below figures 4

E

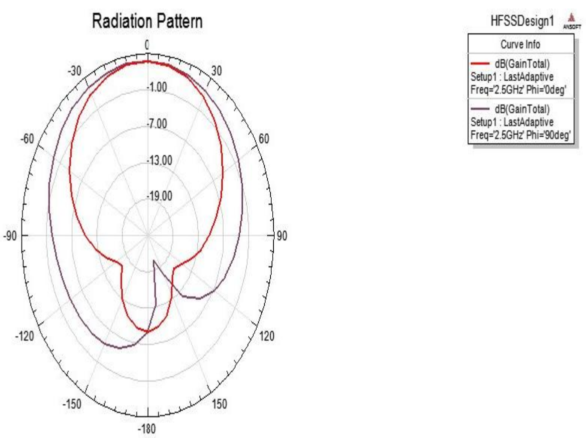

Figure 4: Radiation pattern

3.3 3-D Radiation Pattern

The radiation pattern is the variation of the power radiated or electric field intensity or absolute Gain as a function of three dimensional space coordinates[5][6]. It is main concentration for the wide band applications.

The Figure 4 and 5 show the radiation pattern for the antenna at 5.4GHz. HPBW is the angular separation between half power points of the radiation. HPBW (angle) is observed 60˚ for Optimum Frequency of 5.4 GHz.

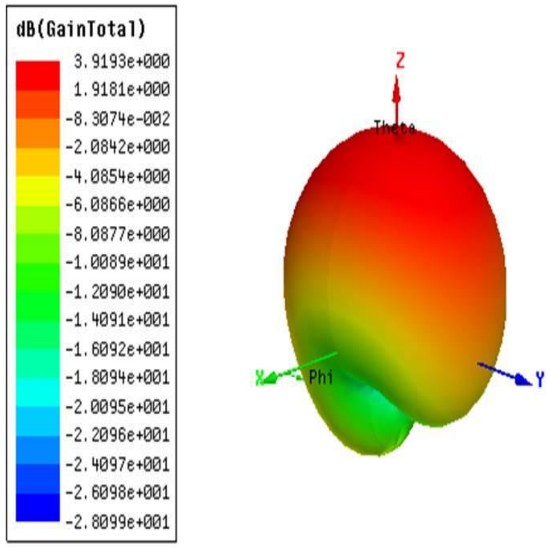

Figure5: 3D-view of radiation pattern

3.4 Field Distribution

The E-field distribution and H-Field distribution for this design is

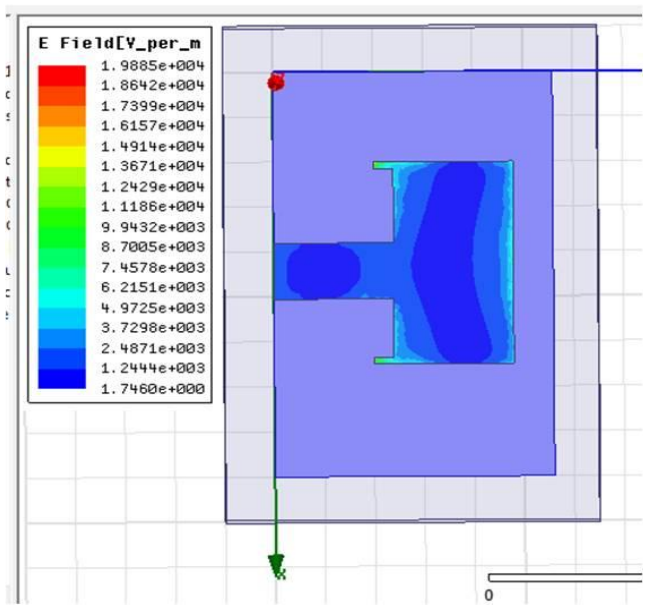

Figure 6: E-field distribution for T-shape micro strip patch antenna

Significant variations in the E and H fields can be observed in the figure 6 and 7 respectively.

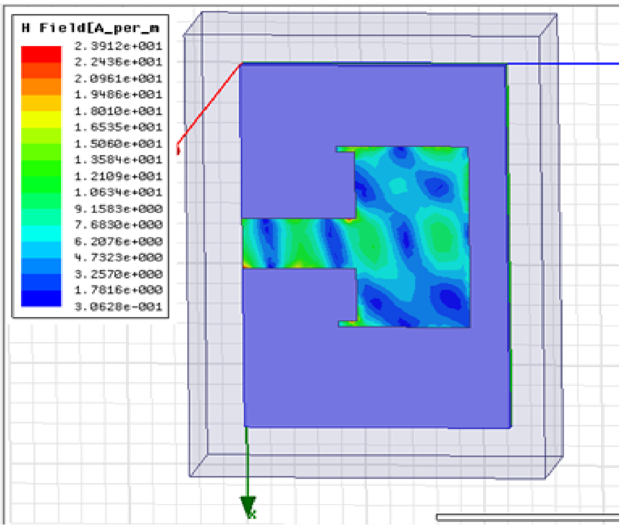

Figure 7: H-field distribution for T-shape micro strip patch antenna

3.5 VSWR

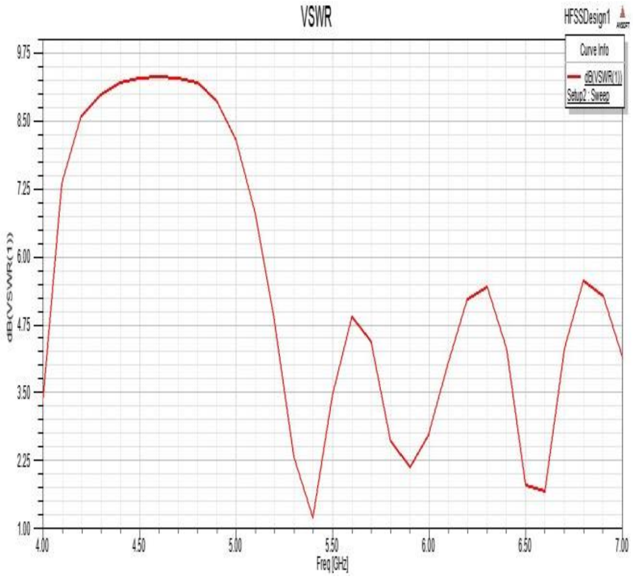

Figure 8: VSWR for E-shape patch antenna

3.6 Gain

Another useful measure describing the performance of an antenna is the Gain. It is the measure of the effectiveness of the antenna radiation in the desired direction with less antenna losses. Its value can be obtained by taking the intensity of radiation with reference to the total input power to the antenna for entire solid angle covering radiation. The similar parameter directivity is a theoretical measure that describes only the directional properties of the antenna without considering the losses [5][6]. And therefore Gain of an antenna (in a given direction) is defined as "The ratio of 4π times radiation intensity to the total input power". Radiation from the Isotropic radiator is the reference to define Gain. And it is given by

$$Gain = 4\pi \frac{radiation \ \ intensity}{total \ \ input \ \ power} = 4\pi \frac{U(\theta,\varphi)}{p_{in}} \qquad (9)$$

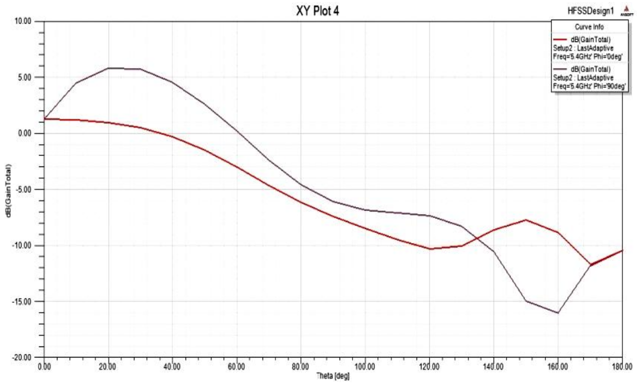

Figure 9: Two dimensional variation of gain

3.7 Antenna Radiation Parameters At Different Frequencies And Thickness

Frequency(GHz)	**2.5**	**5.4**	**6.6**
Gain (dB)	2.46562	3.89944	3.22377
Radiation Efficiency (%)	64.7632	64.6174	58.1091
Max U(W/Sr)	0.127889	0.308818	0.255279
Peak Directivity	3.80713	6.03466	5.54779
Radiated Power(W)	0.422141	0.643086	0.57825
Accepted Power(W)	0.651822	0.995221	0.995112
Incident Power(W)	1	1	1

Table 2: Values for radiation parameters for each frequency at substrate thickness **t=4.56mmFor t=6.5mm**

Frequency(GHz)	**5.4**	**6.6**
Gain (dB)	2.72829	3.83917
Radiation Efficiency (%)	71.0014	66.689
Max U(W/Sr)	0.203426	0.284859
Peak Directivity	3.84258	5.75682
Radiated Power(W)	0.66528	0.621822
Accepted Power(W)	0.936996	0.932422
Front-to-Back Ratio	84.1909	7.51838
Incident Power(W)	1	1

Table 3: Radiation parameters for each frequency at substrate thickness **t=6.5mm for t=3.048mm**

Frequency(GHz)	5.4	6.6
Gain (dB)	4.75636	1.73123
Radiation Efficiency (%)	56.1713	46.4233
Max U(W/Sr)	0.362876	0.124697
Peak Directivity	8.46759	3.72921
Radiated Power(W)	0.538541	0.420204
Accepted Power(W)	0.958747	0.905157
Front-to-Back Ratio	30.5743	19.9883
Incident Power(W)	1	1

Table 4: Radiation parameters for each frequency at substrate thickness **t=3.048mm for t=1.524mm**

Frequency(GHz)	5.4	6.6
Gain (dB)	3.23041	1.22299
Radiation Efficiency (%)	37.3072	28.8526
Max U(W/Sr)	0.116243	0.0552133
Peak Directivity	8.65894	4.23874
Radiated Power(W)	0.168703	0.163692
Accepted Power(W)	0.452198	0.567337
Front-to-Back Ratio	21.4827	44.6343
Incident Power(W)	1	1

Table 5: Radiation parameters for each frequency at substrate thickness **t=1.524mm**

It is observed that the proposed antenna has the return losses of -26.50 and -26.00 with the VSWR of 1.20 and 1.60 at 5.4GHz and 6.6GHz respectively. From the simulation results of Table 3, it is observed that at t=6.5mm the Radiation efficiency is significantly good, but with less Directivity and Gain. And a significant difference in the ranges of FBR is observed for the two interested frequencies.

From the simulation results of Table 4&5, it is observed that at t=3.048mm and 1.524mm the Directivity and gain are good but with poor Radiation Efficiency and FBR. The optimum results are observed at the substrate thickness of t=4.56mm for the interested band of frequencies.

4. CONCLUSION

In this paper, a T-shaped Dual band microstrip patch antenna using FR4epoxy substrate excited with edge feed, and analyzed the performance using Finite Element Method based tool, HFSS (High Frequency Structure Simulator) software version 13.0. The performance of the designed antenna was analyzed in term of bandwidth, gain, return loss, VSWR, and radiation pattern. The design was optimized to meet the best possible result. Substrate used was FR4epoxy which has a dielectric constant of 4.4 with different substrate thicknesses. The results show the multiband antenna is able to operate with 5.4GHz and 6.6GHz frequencies for substrate thickness 4.56mm. Due to the frequency of operation and compact area occupied, the proposed antenna is well suited for different devices used in WLAN, Wi-Fi, WiMAX and in different wireless and C-band applications.

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