Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 44 No. 4 (2023)

Design of a T- Shaped Wideband Patch Antenna for Satellite Applications

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Abstract— The aim of this research work is to propose an electrically small sized antenna, which has a wideband at ku and k band frequencies. This paper accentuates on the design and analysis of rectangular shaped multi slot optimized antenna which can be suitable for Ku and K-band broadcasting fixed satellites, mobile satellite and RADAR applications. The propounded antenna has been designed using FR-4 as substrate fed by microstrip transmission line

Keywords— Microstrip patch, Ku/K Band, Satellite applications, Wideband patch**.**

1. Introduction

In the current era, satellite and radar communication systems are massively increasing and to use them further more efficiently, a very compact and multitasking antennas are required. So, the use of microstrip antennas in this field is increasing. But, unfortunately there are some limitations for microstrip antenna such as narrow bandwidth, which would not be appropriate for contemporary mobile communication systems and low gain, poor polarization purity, limited power handling capabilities and spurious feed radiation [1-3]. To overcome these limitations and complications associated with the microstrip antennas, many researchers have recommended and explored many techniques such as by selecting the proper substrate using different feeding techniques, and by incorporating different shapes and sizes for antennas and with the use of several resonators [4-8].

For the current trend of communication technologies and satellite applications, every individual antenna accomplishes its functions on a particular frequency, and for diverse operations, a number of antennas may require and that will effect a constrained place and dimension problems. So, many researchers are coming up with the wideband antennas at different frequencies and bands which will have a wider bandwidth and high gain with a good impedance matching and with better feeding techniques. Extensive research work has gone in to the design of the wideband antennas [9-13], over the past few years and there is still scope to investigate the small antennas with improved antenna parameters to suit the latest communication requirements.

In this paper, a conventional rectangle patch antenna with optimized size and with integrating slots has been designed with FR-4 as substrate. The paper is organized into Three sections. In section II Antenna Modelling and Design is discussed. In III Results and discussion has been discussed. Finally, in section IV conclusion of the paper has been presented.

2. Antenna Modelling and Design

Elementary formula referred from literature [3] is used to compute the measurements of the patch antenna and after calculating, the best appropriate values of each parameter are selected to design a rectangular patch antenna. The most important parameters to be determined before formulating the patch antenna are Operating frequency(f), Dielectric constant and height of substrate (h). The performance of the patch antenna is mainly dependent on the selection of the substrate and the above mentioned parameters. The length and width of the patch can be considered using the formula provided [3],

The Width (W) of the patch antenna is given as,

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

Length (L) of the patch is given as,

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L$$

The length extension L is given as:

$$\Delta L = 0.421h\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)}$$

By using the formula above mentioned, the parameters of the patch antenna are calculated and further to enhance the performance as per the requirements, Optimization is done by considering various conditions to obtain the best dimensions for patch antenna and feed. The dimensions of the T shaped patch (before optimization) are provided in the table I. The different results obtained for this antenna are discussed in the next session.

Table I: Dimensions of the patch

Parameter	**Dimensions**
Design frequency (f)	13 GHz
Patch Width (W)	7.017 mm
Patch Length (L)	4.714 mm
Inset length	2.08 mm
Width of feed( )	2.91 mm
Length of the substrate	14.314 mm
Width of the substrate	16.617 mm
Dielectric constant	4.4
Effective relative permittivity	3.332
Thickness of the substrate	1.6 mm
Wavelength (lambda)	23.07 mm

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\sqrt{[1+12\frac{h}{W}]}$$

Inset feed microstrip line is used to feed the proposed patch antenna, the length and width of the feed line is also designed. By choosing the proper position of the feeding point, the antenna input impedance is matched to the feed line. To accomplish additional bands, one need to incorporate different slots and slits on the patch. So, the patch antenna in this paper is of rectangular shape having three slots. The position and area of the three slots are accountable for changing resonance frequency. Because of the introduction of the slots on the patch, current lines are changed. So the actual length of the current lines turns out to be longer and the antenna dimensions and size remains miniature.

In this paper the substrate used for the proposed antenna is FR-4 having a dielectric constant of 4.4 with a thickness of 1.6mm and loss tangent of 0.002. This patch antenna has a very compact configuration with a measurements of 7.017x4.714x1.6 mm^3. The feeding method used for this patch is microstrip inset feed by properly selecting the width and length of the feed line. The width of feed is taken as 2.91 mm. and the length of the inset is 2.08mm.

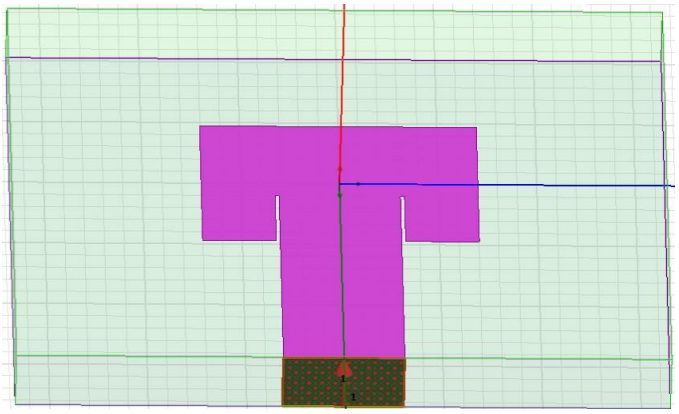

Fig 1: T- shaped patch antenna

The dimensions of the antenna are optimized for obtaining the better results, for antenna to be resonating in different frequencies slots are also introduced at different positions on the patch by carefully optimizing it for better results. Several shapes and sizes of the slots at various positions are studied and finally achieved three rectangular slots for having a wideband antenna resonating across Ku and K band. The modified dimensions of the patch are given below in table II. The location of the slots is also optimized for better results.

Table II: Optimized Dimensions of Patch

Parameter	**Dimensions**
Patch Width (W)	7.1 mm
Patch Length (L)	4.82 mm
Inset length	1.85 mm
Width of feed(W_f)	3.08 mm
Length of slot 1	5 mm
Width of slot 1	0.5 mm
Length of Slot 2	1.5 mm
Width of slot 2	1 mm

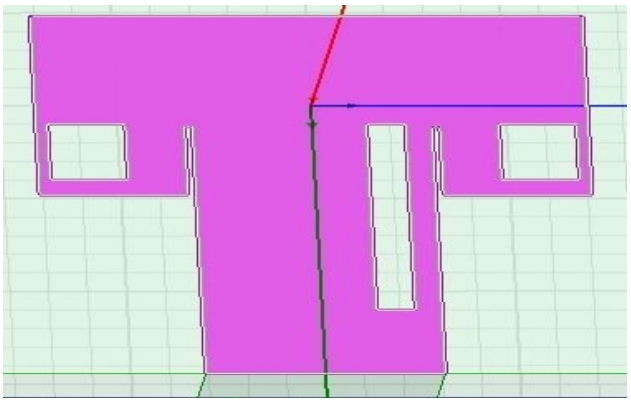

Fig 2: optimized shape of the patch antenna

3. Results and Discussion

The Patch antenna presented in this paper is designed and parameterized with help of commercially accessible finite element method based software HFSS (High Frequency Structured based Simulator). Return loss for the Optimized patch antenna is shown in the fig 3 and it is observed that patch antenna has wide band with a significant gain. The amount of power reflected from the antenna gets mathematically expressed using return loss. A less than -10 dB is always anticipated.

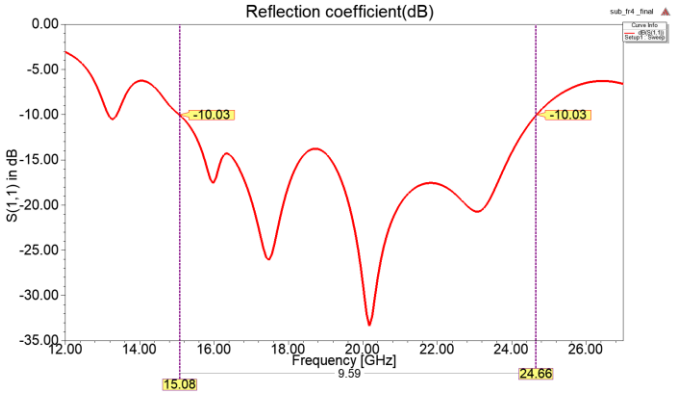

Fig 3: S_{11} of proposed patch antenna

S_{11} of the patch antenna at 20.19 GHz is at -33.86 dB and after introducing slots in to patch antenna with the optimized dimensions. Figure 4 shows the VSWR vs Frequency plot. This figure indicates that at the resonance frequencies of the patch antenna are in good matching condition as all frequencies are below VSWR 2. The variation of input impedance with respect to frequency is shown in the Figure 5, where real values are around 50 and Imaginary values are at 0 at center frequency of 20.19 GHz.

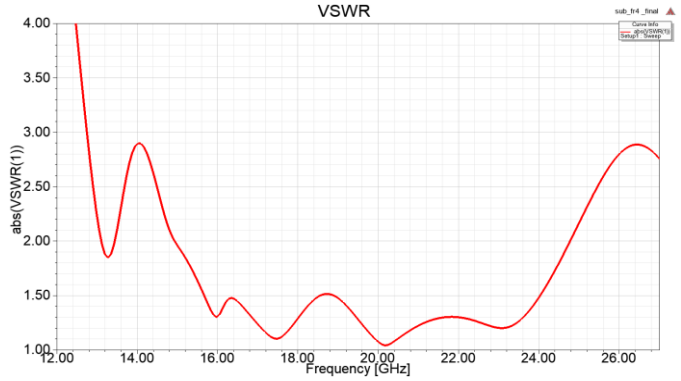

Fig 4: VSWR vs Frequency of modified patch antenna

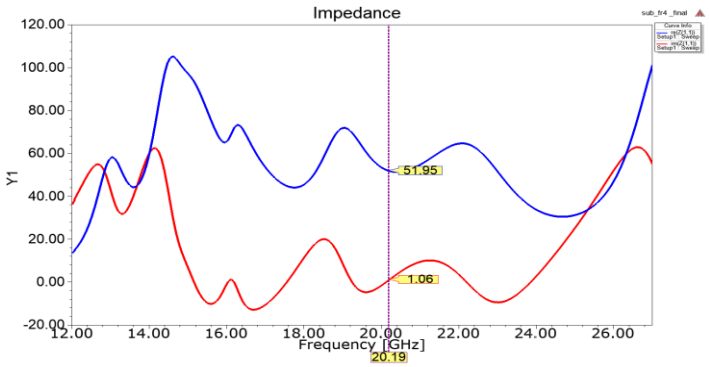

Fig 5: Impedance vs Frequency of modified patch antenna

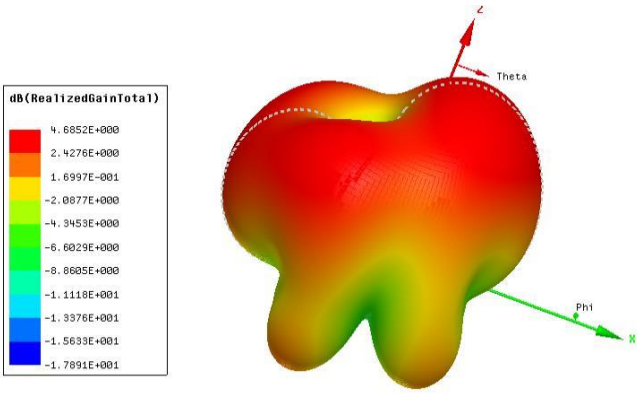

Fig 6: 3-D polar plot of modified patch antenna At 20.19 GHz

The 3-d gain of patch antenna is shown in Fig 6. The gain of the antenna at center frequency of 20.19 GHz is at 4.68 db. The radiation patterns of the wideband antenna are calculated in the two principal planes (XZ and YZ-plane) at frequency 20.19 GHz are depicted in the Figure 7.

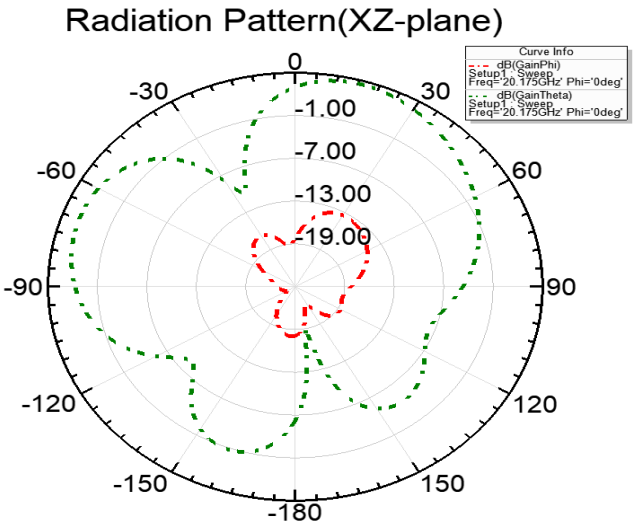

Fig 7 (a): Simulated Radiation pattern at 20.19 GHz in XZ-Plane

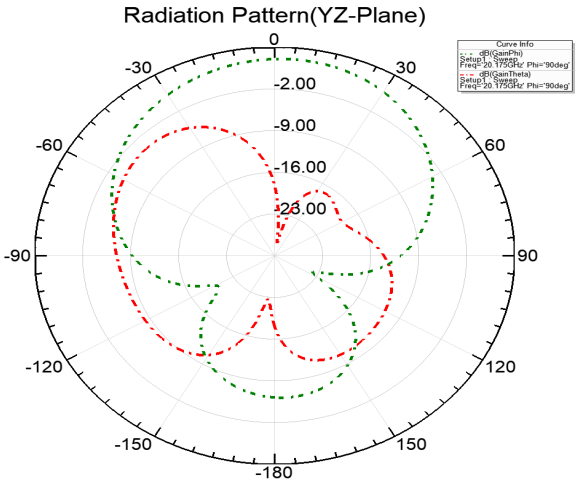

Fig 7 (b): Simulated Radiation pattern at 20.19 GHz in YZ-Plane

6. Conclusion

A rectangular shaped microstrip line feed patch with three slots incorporated on the patch has been designed and simulated using HFSS software in this work. The conventional patch antenna is optimized with various slots to obtain the wideband frequencies with a significant gain with better impedance matching. The antenna is designed using the FR-4 as substrate. This work shows that a simple rectangle slots with proper size and at a proper distance can result in a wideband antenna with reasonable gain. The simulated antenna has an impedance bandwidth of about 9.59 GHz from 15.08 GHz to 24.66 GHz considering 20.52 GHz as center frequency. The designed antenna is properly matched around 50 ohms and observed directivity of 5.4 dB. The designed antennas can be suitably used for broadcasting fixed Satellite, Mobile Satellite and RADAR applications.

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