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# Design of high gain dual T-shaped stub antenna for satellite communication

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**ABSTRACT**

The ultra wide band (UWB) antennas play a vital role in supporting different wireless standards and are suitable for wide variety of applications. This paper is aimed to present a novel UWB dual notch microstrip antenna with modified ground plane. The antenna is designed to operate in UWB ranging from 2 GHz to 12 GHz with multi band operation. This will help in operating the antenna for different operations independently. The proposed structure will operate in two notch bands 3.3-4 GHz (Wi-MAX), 5.05-5.9 GHz (WLAN) and the structure is suitable for long distance communications because of its increased directivity. The structure can also be used for X-Band applications for various applications of traffic control, weather forecasting and vehicle speed detection systems. It is observed that, the proposed structure is offering a gain of 5.2 dBi with improved directivity with a beam width of $42.23^0$. This makes the antenna structure suitable for long distance satellite communications. The antenna is supporting the circular polarization at higher the frequencies and can be useful for the upcoming 5G mobile applications. Moreover, the proposed structure offers the less interference at the receiver. The structure is found to be smaller in dimensions, easily fabricated at low costs and can be integrated into any compact wireless devices. The structure is simulated using a commercially available software Ansys-HFSS and is analyzed.



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## 1. INTRODUCTION

The effective usage of electromagnetic spectrum by using multi band antennas have gain much attention in the ultra wide band (UWB) systems so as to support higher data rates and reduction of the multi path interference and they find many applications for 5G communications and Satellite applications. A T shaped radiation patch with U shaped parasitic strip beside of the feed line is designed with a frequency of 5.90 GHz for WLAN applications [1]. These antennas provide the advantages of broad band operation and immune to multi path interference. The recent literature finds various antennas with notched band properties with different configurations like H-Shaped, E-Shaped and U-Shaped slots [2-4] or by using the parasitic elements nearer to the radiating elements and in the ground plane. Different types of structures were presented in the literature with parasitic strips [5, 6] by etching the slots on the patch to achieve the desired notch band characteristics [7-9]. The slot will however improve the bandwidth performance with improved input impedance and radiation pattern characteristics. Similarly, the insertion of the slits in the interior of part of the antennas along with ground plane, nthe dual band operation is possible. But most of these designs could not give the required voltage standing wave ration (VSWR) and lower values of gain and directivity and poor performance in the radiation characteristics at different bands. Wen Jiang and Wenquan Che [10] have proposed a dual band UWB antenna with dual notch characteristics for WiMAX and WLAN applications. The structure consists of rectangular patch with modified ground plane and dual bands were reported by the introduction of T-stub and parasitic elements. But the structure reported a lower value of VSWR, gain and directivity.Kourosh Javadi and Nader Komjani [11] have presented antenna structure with low values of SAR U-slot Antenna using Frequency Selective Surface concept. The antenna is designed using PIFA structure suitable for cell phones and Wearable Applications. It is found to be compact structure with suitable values SAR as well, but could not provide the gain and directivity. Arash Omidi et al. [12] have presented a paper on low noise amplifier circuit in L Band and the proposed design could able to increase the gain, noise figure and stability but within the limited bandwidth. In another design, reported by Mohammad Javad Tavakoli and Ali Reza Mallahzadeh [13] on Wideband Directional Coupler for Millimeter Wave Application based on Substrate Integrated Waveguide. The proposed structure could able to justify the bandwidth requirements, but produces losses due to SIW based design. Monopole antenna for cognitive radio applications using band pass filter sections using PIN diode switching. The structure could able to report good values of gain and bandwidth [14], but the interference at the receiver is to be further reduced. A twin symmetrical U-slot [15] patch antenna covers the range 2.17 to 4.05 GHz. Similarly C and Beetle shaped slot patch [16, 17] antennas are used for LTE applications. To minimize the higher harmonics, to get desired gain with the aid of stubs [18, 19] in the rectangular patch, while the radiation pattern is unidirectional and elliptical polarization [20]. In general the most common drawback in the microstrip antenna s narrow band width to mitigate this drawback various methods are done by researchers [21], these types of microstrip antenna are supported for wireless applications such as WLAN, LTE, WiMAX [22-26] Therefore, this paper aims to presents a novel UWB dual notch microstrip antenna with modified ground plane with enhanced gain, directivity, bandwidth and to reduce the interference at the receiver. At the same time, the antenna must offer UWB in order to support upcoming 5G communications wireless standards. The antenna structure is designed with monopole operation with the modified ground plane so as to improve the gain and bandwidth. Moreover, the antenna is introducing the interference at these frequencies at the receiver. The structure consists of two T shaped stubs introduced in the middle of the slot on a rectangular patch antenna with edge cuts at the top and bottom of the structure. This makes the structure to operate in dual band. The tapered ground plane was implemented in order to enhance the bandwidth characteristics. The structure also is expected to lower the interference levels at the receiver because of the independent operation of frequencies because of the usage of two T-Shaped stubs in the design. The proposed design was simulated by using the Ansys-HFSS software and the results were analyzed to study the performance of the antenna structure and are presented. The parametric analysis of the antenna structure is performed so as to improve the operational characteristics of the proposed structure.

The proposed antenna design is simulated with the aid of High Frequency Structure Simulator (HFSS). The paper is arranged in the following manner. The section 2 explains the basic antenna geometry and the design methodology. The section 3 discusses the result analysis obtained from the simulation. Section 4 concludes the paper with the improvements, applications of the proposed structure.

## 2. ANTENNA DESIGN GEOMETRY

The microstrip antenna structures are proved to be better substitute over the traditional antennas owing to their advantages of low cost, less weight and ease of fabrication. But the performance of the gain and bandwidth are proved to be less and hence are to be improved by proper designing techniques. At the same time, the multi band operation of the antennas is preferable for many applications to replace the number of antennas for different applications. A compact dual-T shaped stub antenna was proposed for the use of satellite applications suitable for upcoming 5G communications. The proposed structure was designed by using a slotted rectangular patch with edge cuts at the top and bottom and two T shaped stuns are introduced at the corners of the slot. The structure was designed on to a Rogers substrate with a dielectric constant of $\varepsilon_r = 4.4$ and loss tangent of 0.0009 with a height of 1.6 mm.The dimensions of the structure are calculated by using the basic microstrip antenna design and transmission line theory and are optimized carefully and to operate the antenna to meet the specifications. The edge cuts were introduced in the design so as to resonate the structure with dual band operation. The stubs in the slot will improve the gain of the antenna. A tapered ground plane is introduced at the back side of the structure to enhance the band width and a feed line with proper impedance matching will make the structure to resonate with the improved performance of the design parameters. The antenna structure along with the optimized dimensions is shown in the Figure 1.

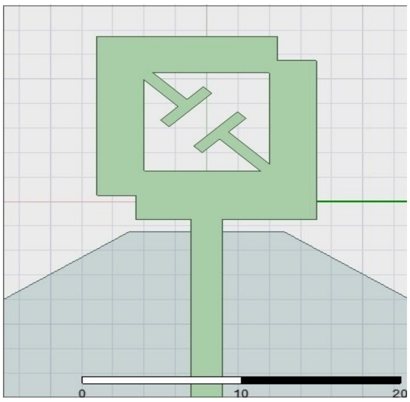


Figure 1. Dual T-shaped stub antenna structure

### 2.1. Dimensions

The slot on the patch will suppress the band notch characteristics of the wide band frequency operation and they will improve the impedance matching which in turn increases the bandwidth performance of the antenna. A parasitic patch is introduced in the antenna closer to the radiating structure so as to improve the notch band characteristics. The designed structure is analyzed by using commercially available simulating software, Ansys-HFSS for the performance verification of the antenna and the same is shown in the Figure 2. Similarly, the proposed design parameters are represented in Table 1. It is observed that the antenna is resonating at 3.5 GHz and 9.1 GHz with a return loss of -42.79 dB and -41.4 dB. The corresponding VSWR of the structure is found be too nearly to the value of unity giving rise to the values of 1.015 with a reflection coefficient of 0.007 and 1.017 with a reflection coefficient of 0.009. The following Figures 3 (a) and (b) shows the simulated return loss and VSWR of the structure. The impedance band width of 62.50% is observed at 3.5 GHz and 61.53% at 9.1 GHz.

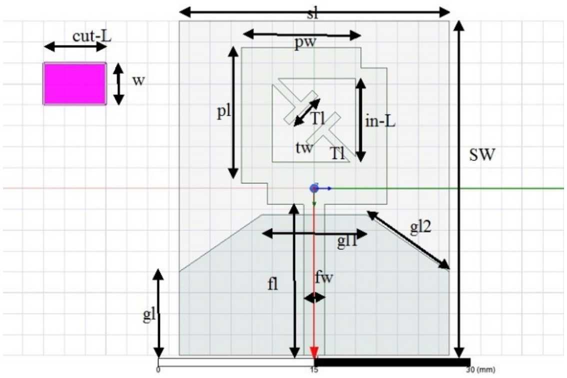
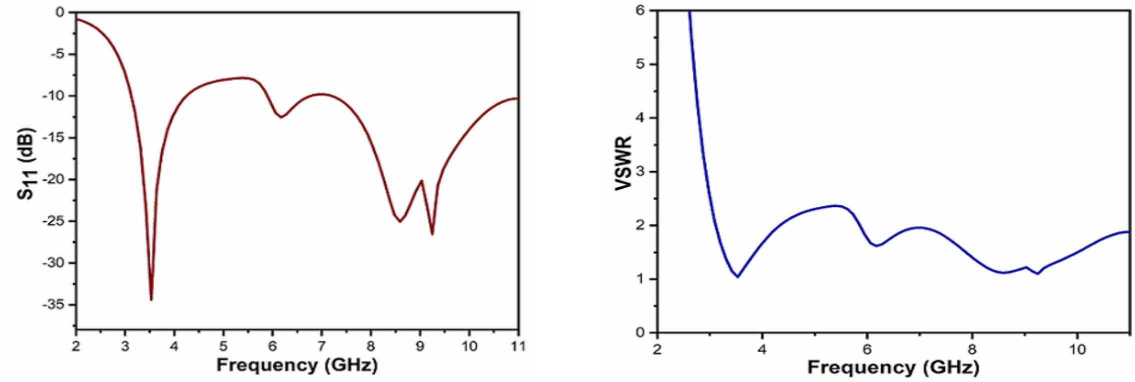



Figure 2. The Simulated schematic of the proposed antenna

Table 1. Simulation parameter

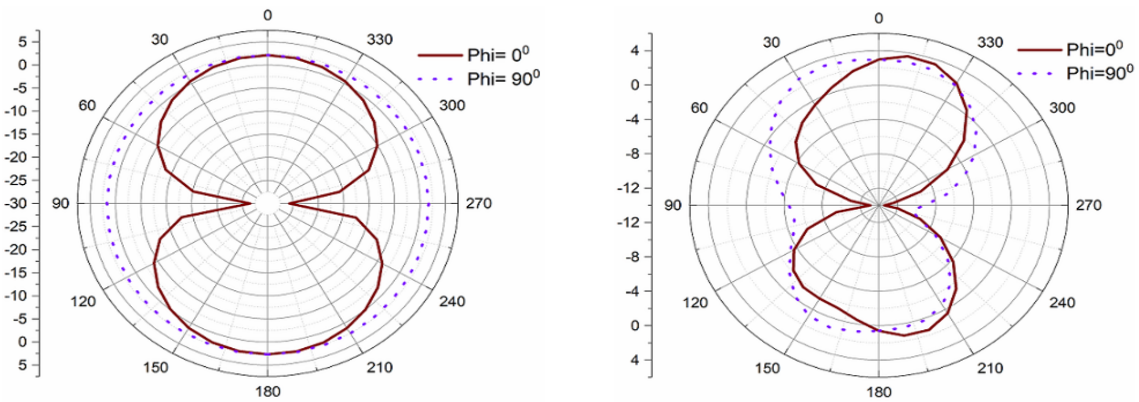
| Parameter | Value (mm) | Parameter | Value (mm) |
|---|---|---|---|
| Sl | 26 | Ground-L | 8 |
| Sw | 32 | Gl1 | 9.7 |
| Pl | 13 | Gl2 | 10 |
| Pw | 11.5 | Fl | 14.5 |
| Square Cut-L* W | 2*2.5 | Fw | 2 |
| In-L | 8 | T1 | 2.8 |
| Tw | 0.77 | Tl | 3.6 |




(a) (b)

Figure 3. (a) Return loss ($S_{11}$) Parameter plot, (b) VSWR plot

The radiation characteristics at 3.5 GHz and 9.1 GHz of the proposed structure are as shown in the Figures 4 (a) and (b) respectively. It is observed that the normal dipole operation i.e. Figure of eight is observed from the E-plane characteristics and the Omni-directional pattern observed from the H-plane characteristics. The beam width so obtained is $42.53^0$ at 3.5 GHz and $42.53^0$ at 9.1 GHz and can be observed from the following plots. The structure is providing the good impedance match at these frequencies and can be observed from the following Smith Chart as shown in Figure 5.




(a) (b)

Figure 4. Radiation pattern characteristics for both Phi = 0 and 90 deg at (a) 3.5 GHz and (b) 9.1 GHz

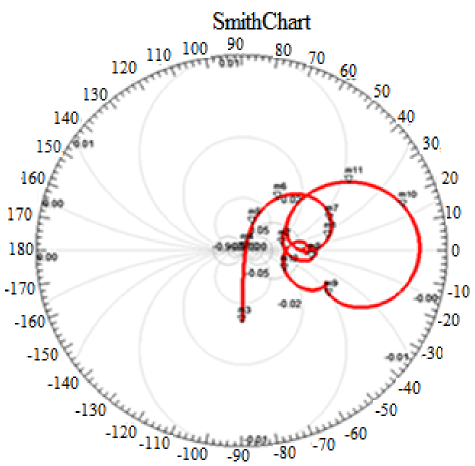



Figure 5. Smith chart characteristics

The structure is offering a gain of 5.2 dBi at 3.5 GHz and 2.5 dBi ar 9.1 GHz and can be observed from the following Figure 6 and the 3 dimensional gain of the proposed structure is shown in Figure 7. It can be seen that the proposed structure is offering linear polarization at 3.5 GHz and as the frequency increases it is showing the circular polarization. The same can be observed from the return loss plot and the axial ratio at 9.1 GHz is shown in Figure 8.

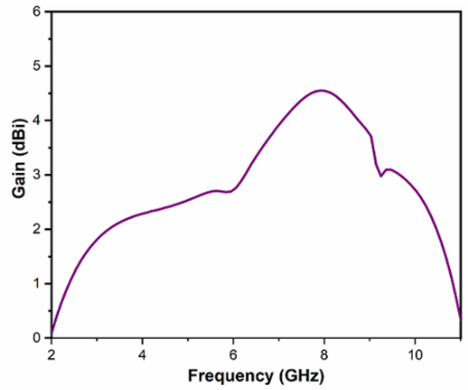



Figure 6. Gain Characteristics

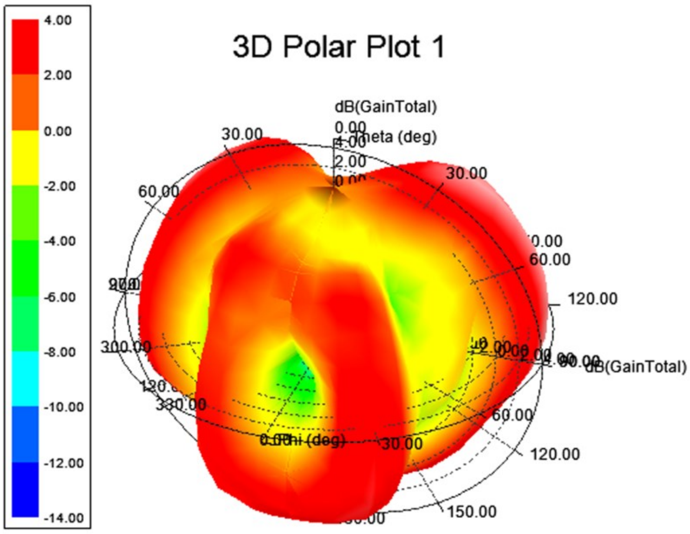



Figure 7. 3-D plot showing the gain characteristics

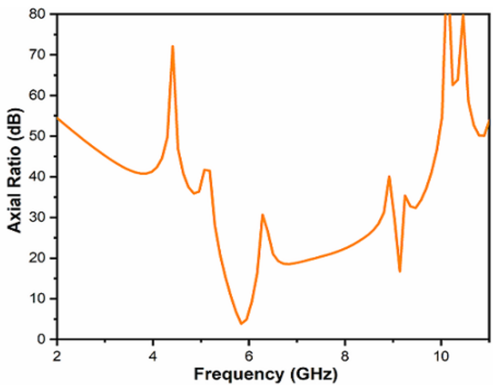



Figure 8. Axial ratio at 9.1 GHz

## 3. DISCUSSION OF THE SIMULATION RESULTS

It is observed from the above plots that the antenna is resonating at dual band i.e 3.5 GHz and 9.1 GHz with good return loss values more than -10 dB and with a VSWR equals nearly unity. This shows the antenna is showing improved performance in terms of VSWR. Highly directional characteristics can be seen from the radiation pattern and a beam width of $42.23^0$ is achieved. This makes the antenna suitable for long distance communications with improved directivity. It can also be visualized from the above figures that the antenna is providing less interference at those frequencies as they offer different polarizations at the operational frequencies and it is observed that the linear polarization at lower frequency band and circular polarization with the increase in frequency. The impedance band width performance is observed for the proposed structure which makes the antenna suitable for broad band applications. The antenna offers a gain of 5.2 dBi and 2.5 dBi along with the similar radiation band width can be observed from the radiation pattern characteristics. The antenna is offering the circular. Polarization at 9.1 GHz with improved performance. The antenna could provide the comparison results with existing works presented in the Table 2.

Table 2. Performance comparison

| Performance compare | Proposed work | [1] | [8] | [10] |
|---|---|---|---|---|
| Dielectric constant | 3.55 | 3.38 | 2.65 | 4.4 |
| Thickness(mm) | 0.8 | 0.8 | 1 | 1.6 |
| Size ($\lambda_0 * \lambda_0$) | 0.59*0.68 | 0.59*0.73 | 0.77*0.93 | 0.59*0.68 |
| Frequency | 9.15 GHz | 9 GHz | 8.5 GHz | 8.25 GHz |

## 4. CONCLUSION

The proposed structure presented in this paper can work for broad band operation with the dual band operation due to the introduction of the stubs in the slot provided in the radiating element. The structure offers the better impedance matching at different frequencies giving rise to the stable radiation characteristics at different frequencies. Therefore, interference offered at the receiver is low and can be operated independently at different frequencies. The improved performance in the gain as well as band width due to the proper designing and optimization of the feed line and the truncated ground plane structure. The two notch bands 3.3-4 GHz (Wi-MAX), 9.1-9.1. GHz (WLAN) and this type of structure is more suitable for long distance communications because of its increased directivity. The proposed antenna structure is designed with a Rogers material Substrate and is compact and easy to design. This improved characteristic of the proposed structure makes it suitable to use for different wireless applications such as in satellite communication systems. The structure can be further altered with introducing more number of stubs to offer multi band operation and can be used for even for upcoming 5G communication Systems.

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