

# **A Novel Tri-band Microstrip Antenna Design with T-shaped Slots for C, X and Ku-band Applications**

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**ABSTRACT:** In this research, with the purpose of designing Multiband antenna and to enhanced the bandwidth and gain of Microstrip antenna. The design is proposed in which Microstrip antenna patch is loading with two partially T-slot shaped, the shape of patch is rectangular and partial ground plane is used in design. Feeding is done by using Microstrip feed line. After designing antenna the simulations results shows the improvement multiband which has resonant frequency 4.4GHz, 8GHz, 9.6GHz, and 13GHz is achieved in low cost substrate FR4 Epoxy with highest bandwidth. The partially T-slot shaped patch antenna will operate at frequency above 9 GHz which will make it suitable for Ku band applications.

**KEYWORDS:** Microstrip antenna, partial ground plane, Tri-band, Microstrip feed line.

## **I. INTRODUCTION**

Antennas are very important component in wireless communication system. There are different types of antennas exist practically which we used for transmit and receive EM waves. Out of these Microstrip antenna is one of the most important antenna nowadays due to their attractive features such as low profile, light weight, low cost and ease in fabrication. Due to increase demand of communication engineering, in respect of maximum data transmission at higher range it is necessary to have size reduction and improved bandwidth with slotted patch radiator to meet the requirement for practical applications. From many years or decades the use of Microstrip antennas have been intensively increased in electronic circuits and communication systems like satellite communication, radar, etc., due to its low profile, low-weight, small size, low cost [1]. Nevertheless, Microstrip antennas typically suffer from low gain, poor polarization purity, and limited power capacity, by selecting suitable substrate, changing the antenna shape or size, using a variety of feeding techniques and impedance matching methods, the problems can be solved[2],[3].The Microstrip line is used for feeding because of its ease in fabrication and simple to match by controlling inset positions. A  $VSWR < 2$  and  $S_{11} < -10$  dB is achieved for a frequency range 4.0-16 GHz in T-stair slot with stable E-plane radiation patterns. In order to resolve the weakness of Microstrip antennas and increase the bandwidth, a sequence of small slots of T-shaped were applied in both sides of rectangular elementary patch. Gain of patch element has been developed by using feed point and ground plane [5]. After getting suitable gain and bandwidth, highly directive slotted patches were substituted in array by using wide band feeding circuit in the other side of ground plane. In this paper, based on the theory of Microstrip array antenna, numerical calculation and simulation are realized. An efficient and new compact layered coaxial feed rectangular slotted Microstrip patch antenna is proposed for Ku-band satellite applications with reduced size. The novel shape of patch antenna is shown in Fig.1. The design and optimization have done to operate suitably at Ku-band by introducing different slits in radiating patch.

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## II. RELATED WORK

Microstrip antenna has many advantages like low profile to conformal easily, easy to fabricate in PCB, etc. With advantages it also have disadvantages like narrow bandwidth and low gain, to overcome these problems many researchers adopt many techniques due to these the problems can be resolve to a great extent.

Microstrip antenna invented by Bob Munson in 1972 (but earlier work by Dechamps goes back to 1953). This became popular after 1970. The revolution in large-scale integration and circuit miniaturization led to the development with this concept due to which wireless communication makes boom in market by its demand. These antennas widely used in mobile market and as it designed for above than 1GHz frequency this is used as microwave communication antenna. For high frequency this antenna will be best selection.

A Microstrip antenna also called patch antenna. A rectangular shaped Microstrip antenna consists of metal patch, ground plane, dielectric substrate, and feed line. Antenna patch, ground plane, feed line made up of high conductive material usually copper is selected. Substrate which has dielectric constant value between 1-9 can be selected by antenna engineer depends on its application.

Various Mathematical model and software were developed for simulation and modelling of this antenna which makes calculations very easy and less time consume for analysis. Many researchers publish there working antenna in many journals and conferences on this antenna which shows importance gained in research area. The analysis of this antenna can be done by Transmission line model and Cavity Model methods, these two methods or approaches are easy to implement in computer program within short computation time. According to P. Bhartia, 1980 with these two approaches the antenna characteristics are not very accurate which are limited to narrow band Microstrip antennas. But later a full wave analysis method, FDTD and MPIE have been proposed in which antenna characteristics is very accurate solved integral equations by Method of Moment (MoM). This MoM method applied for both single element and array of Microstrip antenna and also applied for single layer and multilayer configuration.

## III. FORMULATION METHOD OF ANTENNA DESIGNING

In the process of design we needs to calculate some parameters for subtract and the ground and which will be easily calculated by formulas discussed below. To calculate width of the dielectric subtract

$$w = \frac{1}{f_r \sqrt{\mu_0 \epsilon_0}} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (1)$$

Where  $f_r$  is the resonance frequency,  $\epsilon_r$  dielectric constant of the subtract &  $\mu_0, \epsilon_0$  are the permeability and permittivity of free space respectively.

$$w = \frac{v_0}{f_r} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (2)$$

Where  $v_0$  show the velocity of wave in free space. Now after calculating width of dielectric next is dielectric constant which we have to calculate and the formulas used to calculate dielectric constant is given by,

$$\epsilon_r = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2 \sqrt{1 + \frac{12h}{w}}} \quad (3)$$

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Here we consider effective length instead of original length because the Microstrip antenna looks longer as only because of fringing effect and the effective length of the antenna is differ by  $\Delta L$  from the physical length. This extension in length is simply the ratio of width to the height and  $\epsilon_{eff}$  which is given by below formula

$$\frac{\Delta L_{eff}}{h} = 0.412 \frac{(\epsilon_{eff} + 0.3) \left( \frac{w}{h} + 0.264 \right)}{(\epsilon_{eff} - 0.258) + \left( \frac{w}{h} + 0.8 \right)} \quad (4)$$

Now the original length is given by

$$L = \frac{1}{2fr\sqrt{\epsilon_{eff}\mu_0}} - 2\Delta L \quad (5)$$

After calculating all these we have to calculate the dimension of the ground plane which will be varied for same antenna in some amount and this relation is given by

$$Lg \geq \left( \frac{\lambda_{eff}}{4} \right) * 2 + L \quad (6)$$

$$Wg \geq \left( \frac{\lambda_{eff}}{4} \right) * 2 + W \quad (7)$$

## IV. ANTENNA DESIGN

In this paper, antenna is designed by using ANSOFT HFSS (High Frequency Structural Simulator). A schematic diagram of the proposed frequency antenna is shown in Figure 1. The configuration comprises of Partial T shape patch antenna on a substrate of a thickness  $h$  and dielectric constant  $\epsilon_r$ .

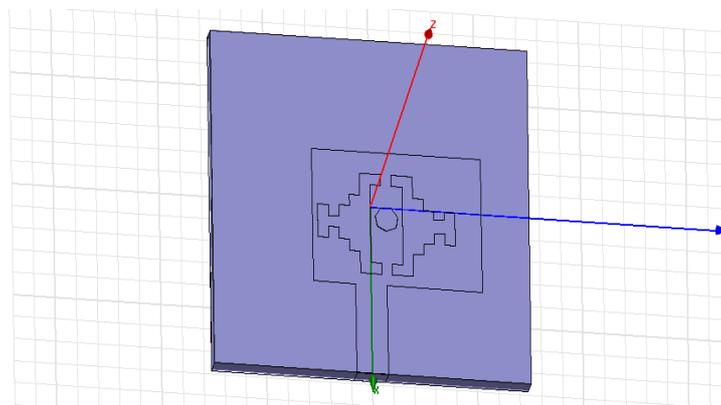


Figure 1: Design of Partial slot T-shape Patch Microstrip Antenna

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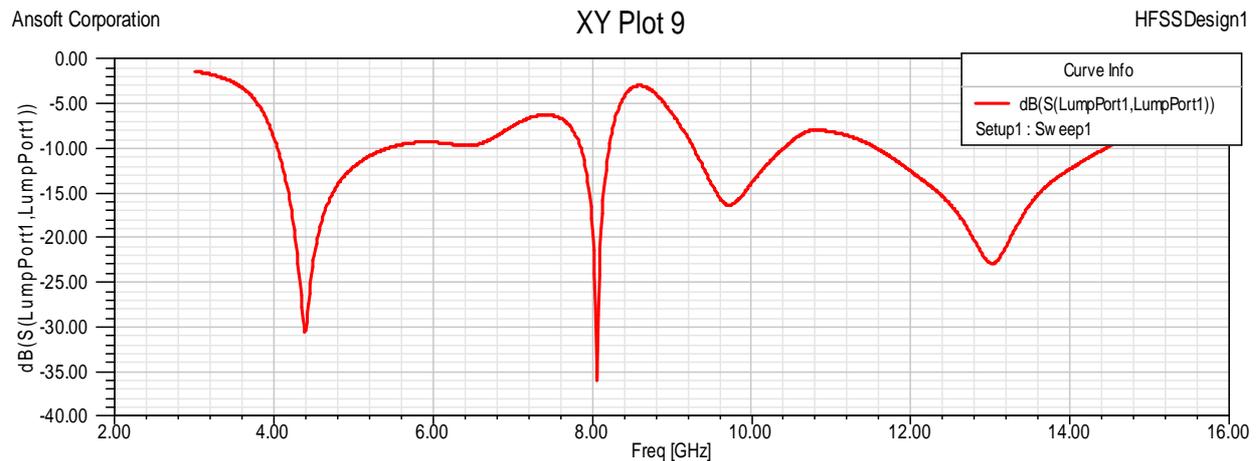
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S.No	Parameters	Dimensions	Material
1	Substrate	$W_{sub}=30$ mm $L_{sub}=30$ mm $H_{sub}= 1.6$ mm	FR4 EPOXY
2	Rectangular patch	$L_p= 11.64$ mm $W_p= 16$ mm	Copper
3	Ground Plane	$W_g= 30$ mm $L_g= 16$ mm	Copper
4	Tap-Slot	$L_{Hs}=$ Varying $W_s=$ Varying	-
5	Feed line	$W_f= 3$ mm $L_f= 8$ mm	Copper

**Table 1:** Shows the dimension of various parameters of antenna.

## V. EXPERIMENTAL RESULTS

The results shown here are simulated on HFSS software. In HFSS, rectangular patch and partial ground plane are made up of PEC (Perfect Electrical Conductor) and air or vacuum can be used for the radiation box. Figure 2 shows the variation of return loss with frequency. Return loss is the loss of power in the signal returned/reflected by the discontinuity in a transmission line which occurs due to mismatch with terminating load. The gain of the antenna has been studied using a Microstrip patch antenna fabricated on the same substrate.



**Fig 2:** Return loss v/s frequency curve for varying length of ground plane

From the Figure 2, it is clear that optimum bandwidth is achieved when length of ground plane is 8mm and at resonating frequency 4.4GHz, 8GHz, 9.6GHz and 13GHz. Figure 3 shows VSWR v/s frequency curve at a particular width of ground plane. VSWR is simply the rate of peak amplitude of standing wave to the minimum amplitude of standing wave. VSWR below 2 is considered well for an antenna. For this design, VSWR is less than 2 from 4GHz-16GHz in figure 3.

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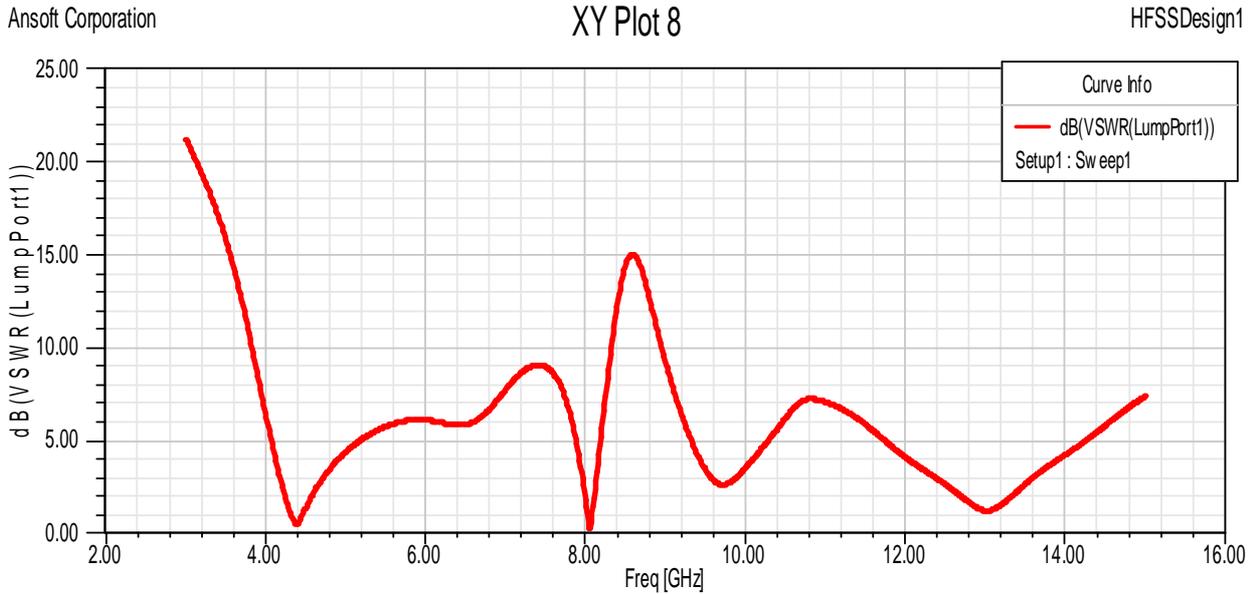


Figure 3: Variation of VSWR v/s Frequency

The E-plane is defined as the plane containing the electric field vector and the directions of maximum radiation while the H-plane is the plane containing the magnetic field vector and the direction of maximum radiation. The x-z plane elevation plane with some particular azimuth angle  $\phi$  is the principle E-plane. While for the x-y plane azimuth plane with some particular elevation angle  $\theta$  is principle H-plane. Figure 4,5 and Figure 6 shows 2D E-plane radiation pattern at frequency 4.4GHz, 7.2 GHz, 13GHz frequency.

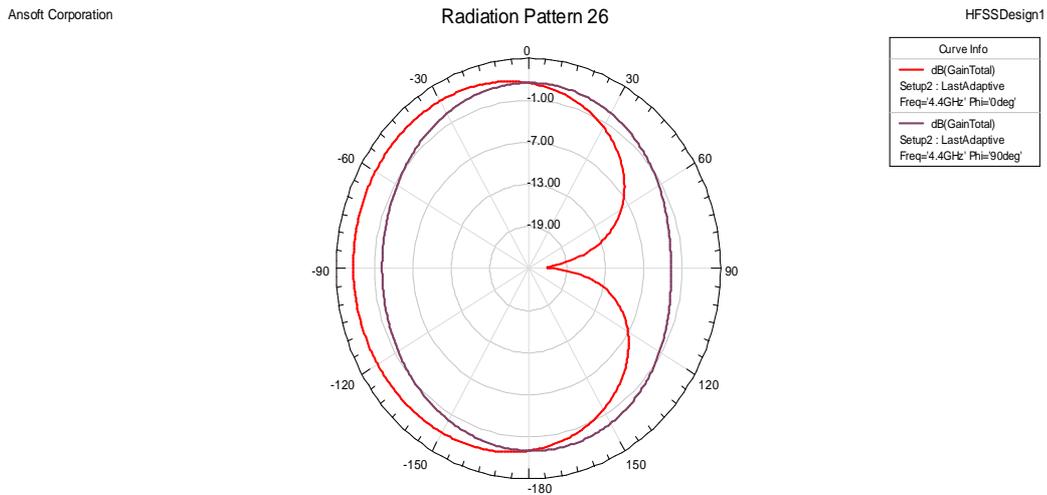


Figure 4: 2D E-plane Radiation Pattern at 4.4 GHz

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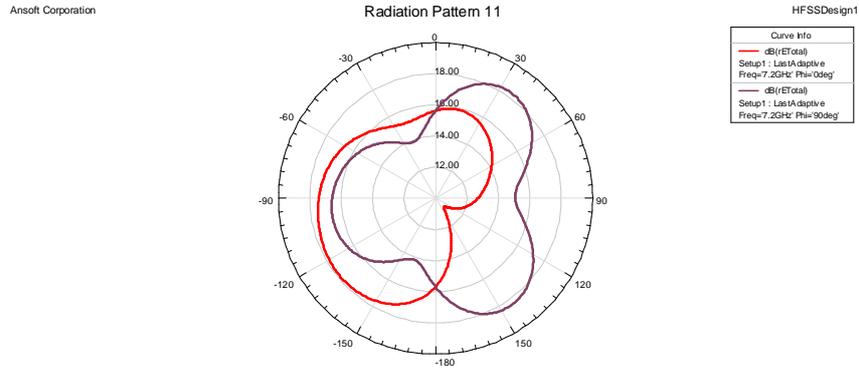


Figure 5: 2D E-plane Radiation Pattern at 7.2 GHz

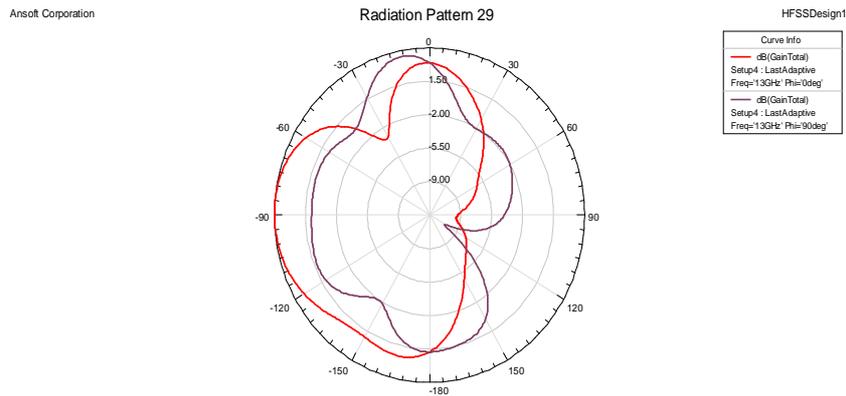


Figure 6: 2D E-plane Radiation Pattern at 13 GHz

Figure 7 and 8 shows 3D radiation pattern at 9GHz and 13GHz different frequencies within the band 8.1-13 GHz.

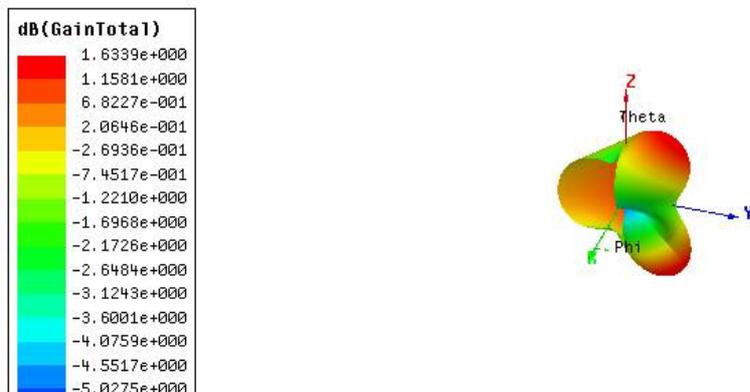


Figure 7: 3D Radiation Pattern at 9 GHz

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Figure 8: 3D Radiation Pattern at 13 GHz

The partial slot antenna is suitable for data transmission at a particular range with less bandwidth which can be improved by making modifications in its length and shape through which the bandwidth can be vary. Table 2 shows some parameters of an antenna.

Antenna Parameters	Proposed Results Partial T-shaped Slot, Frequency(GHz)
Return Loss(dB)	-30dB at 4.4 GHz -36dB at 8.0 GHz -23dB at 13GHz
Gain(dB)	15dB at 7.2 GHz
VSWR	0.5 at 4.4 GHz 0.5at 8.0 GHz 1 at 13 GHz

Table 2: Parameter of partial T Stair slot antenna

## VI. CONCLUSION

A novel design of triple band rectangular Microstrip antenna with Microstrip feed line is designed and simulated by using HFSS 11.1 software. An aspect of Microstrip antenna has been studied. The main aspect is the design of partial T slot antenna having ground plane length 8mm, width 1mm, feeding position 2.5 mm from symmetrical position, substrate material is FR-4 epoxy with tangent loss 0.002, then we get different bandwidth for  $S_{11} < -10$  dB at resonant frequency 4.4GHz, 8GHz, 9.6GHz, and 13GHz or  $VSWR < 2$ . The antenna is suitable for designing purpose as well as transmission in C, X and Ku band. However, since this antenna will be used for satellite

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television receiving only, the antenna can be used with possible degradation of the TV picture quality particularly during rain period.

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