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Design of T-Shaped Microstrip Patch Antenna for Wireless Communication

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Abstract – In this paper, we have designed a T-Shaped ridged Rectangular Microstrip patch wideband. antenna for wireless communication applications. This project designed a planar T-Slotted Microstrip patch antenna for millimeter wave wireless communication at 55GHz.CST SOFTWARE was used to analyze the antenna's performance, which showed a low return loss of -19.13dB, a VSWR of 1.248, and a gain of 6.821dB. The antenna's compact size and compatibility with wireless technology make it a promising choice for modern communication systems.

Keywords - Slotted Microstrip Antenna, Wireless Communication, Millimeter Wave, WLAN, CST SOFTWARE,

1. INTRODUCTION

Microstrip patch antenna is a type of antenna commonly used in wireless communication systems due to their many advantages. One of the most significant benefits of these antennas is its compact size and low profile, which makes it an attractive option for contemporary wireless communication systems that require small and lightweight components.

Microstrip patch antennas are typically made from a flat metal patch that is placed over a ground plane and separated by a dielectric substrate. This planar configuration allows for easy fabrication and conformal mounting on the host surface, making them well-suited for use in applications where space is limited. Additionally, these antennas are capable of operating at multiple frequencies, including dual and triple frequency operations, which makes them versatile and flexible for use in a variety of wireless communication systems.

Another advantage of microstrip patch antenna's is their low fabrication cost, which is due to their planar structure and the ease with which they can be integrated with microwave integrated circuits (MICs). When mounted on a solid surface, these antennas are mechanically robust and can withstand harsh environmental conditions, making them well-suited for outdoor applications. When compared to traditional non-printed antennas, microstrip patch antennas have a variety of drawbacks. Their main limitations include surface wave excitation, poor gain, and narrow bandwidth, which all lower radiation efficiency. There are various methods that can be used to get around one of their more severe limitations, limited bandwidth.

One of the crucial components of any wireless communication systems is the antennas, responsible for transmitting and receiving signals. In recent years, microstrip patch antennas have become popular due to their compact size, low profile, and easy integration with wireless devices. These antennas use a flat, rectangular metal patch on the ground plane to radiate electromagnetic waves. Due to their low profile, microstrip patch antennas can be easily integrated with modern electronic devices like smartphones and other portable devices.

2. PHYSICAL DESCRIPTION

Antennas are mechanical devices that send or receive electromagnetic waves like radio or microwave signals and have numerous applications such as remote sensing, navigation, broadcasting, and telecommunication. The designed planar ridged T slot microstrip patch antenna is a lightweight, portable device that provides exceptional gain, efficiency, and bandwidth. It consists of a thin metallic patch that covers the ground plane, and an associated feedline. The ridged T slot antenna design enables the inclusion of a slot into the patch, as shown in **Fig.1**, which enhances the bandwidth or polarization diversity.

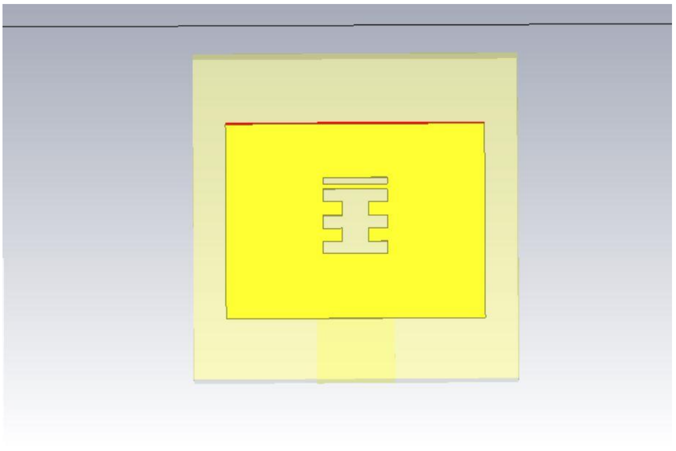

Fig.1. Top View of Design

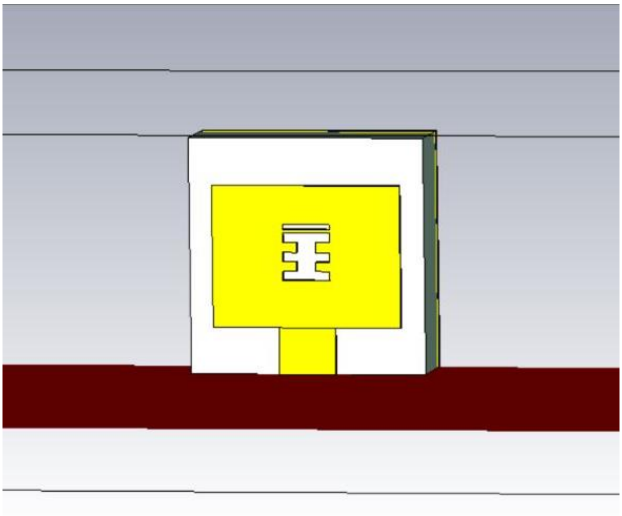

Fig.2. Front View of the designed antenna

The bottom part of the ridged T shaped slotted patch is shown in **Fig.2** and the front view is shown in **Fig.3** As the antenna's primary radiating component, a rectangular patch is intended. Copper(annealed) plate is supplied into the patch through a line. The port is used to supply the necessary electricity. The antenna is just 5 x 5 x 1.57mm^3 in size overall. The antenna is made on a RogerRT5880 substrate with a 1.57mm thickness, a loss tangent of 0.0009, and a relative permittivity of 2.2.

Table 1. Dimensions of patch antenna

Description	Value
Substrate Length	5mm
Substrate Width	5mm
Substrate Thickness	1.57mm
Length of Patch	4mm
Width of Patch	3mm
T-Shape vertical Slot width	0.4mm
T-Shape vertical Slot length	1mm
Horizontal Slot Width	0.2mm
Horizontal Slot Length	1mm
Upper Horizontal Slot Width	0.1mm
Vertical Slot Length	1mm
Feed Length	1mm
Feed Width	1mm
Each Ridge Length	0.2mm

The ground plane is a copper plate, with dimension of 5mm x 5mm and a thickness of 0.1mm. The patch is 4mm long and 3mm wide. This antenna has been examined to work at 55GHz frequency band. The values of substrate length, substrate width, substrate thickness, length of patch, width of patch, t-shaped vertical slot width, vertical slot length, horizontal slot width, horizontal slot length, upper horizontal slot width, slot length and line feed length and width are given in **Table 1.**

3. OPERATIONAL MECHANISM

The T-slot microstrip patch antenna with a line feed in CST is designed through a multi-step process. The first step involves creating a substrate and metal object that will be used to construct the antenna. Then, the antenna geometry is defined, and the antenna's performance is simulated. To further enhance the performance of the T-slot microstrip patch antenna, a horizontal slot is added above the T-slot. The placement and size of the horizontal slot can be modified to adjust the antenna's resonant frequency and impedance bandwidth to meet specific design requirements. The horizontal slot improves the antenna's impedance bandwidth and radiation efficiency, which is particularly useful for applications that require a wide frequency range.

Optimizing the performance of the T-slot microstrip patch antenna requires consideration of various parameters such as substrate thickness, patch size, and line feed position. The simulation and optimization process in CST accurately models the antenna's performance and allows designers to make informed decisions about the design. By using the simulation results, designers can quickly and efficiently modify the design of the antenna, leading to a higher probability of success in the final product.

Moreover, the simulation process can be used to predict the antenna's behaviour in different environments, allowing for a better understanding of how the antenna will perform in the real world. The simulation settings and boundary conditions must be carefully selected to ensure accurate results. Once the antenna has been designed and simulated, its performance is analysed to determine if it meets the required specifications.

In conclusion, the operational mechanism for the T-slot microstrip patch antenna involves several steps, including the definition of the antenna geometry, the connection of the line feed to the patch, the simulation of the antenna's performance, and the optimization of the design to meet the required specifications. The use of a horizontal slot further improves the antenna's performance by enhancing its impedance bandwidth and radiation efficiency. Through the simulation and optimization process, designers can modify the antenna design to achieve the desired performance.

4. PARAMETER ANALYSIS

Microstrip patch antennas are popular for their low profile, easy integration, and affordability. To achieve an efficient and high-performance microstrip patch antenna, it is critical to optimize its design and dimensional parameters.

The design parameters include resonant frequency, bandwidth, radiation pattern, gain, and impedance matching. The resonant frequency determines the antenna's operating frequency range, and the bandwidth affects the amount of data transmitted or received. The radiation pattern determines the electromagnetic wave's direction and strength, impacting the antenna's coverage area and communication link quality. The gain measures the antenna's effectiveness in converting electrical power into radiation in a specific direction. Impedance matching is crucial for optimal power transfer, reducing signal loss and improving overall antenna performance.

In addition to the design parameters, the dimensional parameters of the antenna are critical for its performance. These parameters include length, width, thickness, and substrate dielectric constant of the patch. The patch's length and width determine the resonant frequency and bandwidth, while the thickness impacts its radiation efficiency and impedance matching. The substrate's dielectric constant plays a significant role in determining the antenna's impedance and radiation pattern. The feeding mechanism's shape and location, such as the microstrip line or coaxial probe, also affect the antenna's impedance matching and radiation pattern.

The following equations are the different patch equations that are used for findings and calculations of width (1), effective dielectric constant (2), extension of length (3), effective length (4), and calculation of actual length (5)

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r+1)}{2}}} \tag{1}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{\frac{-1}{2}} \tag{2}$$

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

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} \tag{4}$$

$$L = L_{eff} - 2\Delta L \tag{5}$$

The slot equations that are useful for finding and calculations of lengths and widths of slots are

$L \approxeq \lambda/2$ and $W \approxeq (0.05\text{-}0.1)\,\lambda$.

5. SIMULATION RESULTS

The following are the outputs for the desired antenna. CST software is used to simulate and examine the antenna. The following **Fig.3** shows the curve of S-Parameters of the simulated antenna. At the centre frequency of the curve represents the reflection coefficient as -19.13dB and frequency is 55GHz.

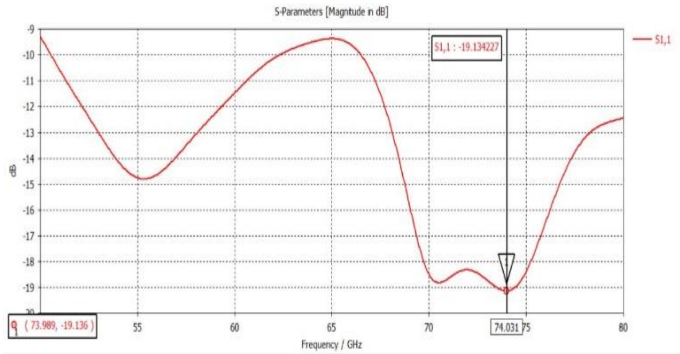

Fig.3: Reflection Coefficient

The below graph in **Fig.4** shows the plot VSWR which is almost nearer to 1. Voltage standing Wave Ratio (VSWR) being 1:1 indicated that signal power is transmitted from source to load through the transmission line without any deflections in power the transmitter or source.

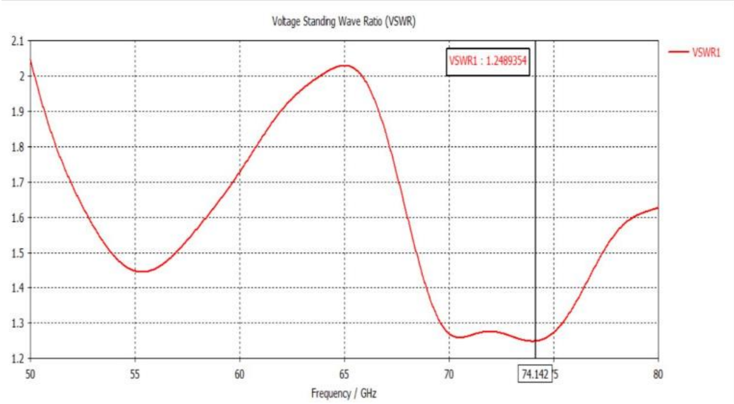

Fig.4: VSWR plot for Antenna

The 3D view of radiation pattern of the antenna is represented in **Fig.5**. The graphical representation of the far field of the antenna radiation pattern is also shown in **Fig.6** and **Fig.7**.

The antenna gain can be determined by the formula.

Gain = Efficiency x Directivity

The antenna for 55GHz has a directivity of 8.060dBi with a total efficiency of -0.057. The gain of the antenna is founded to be equals to 6.821dBi which determines its performance to be much better than normal slotted patch antennas like the T-Slot, E-Slot, H-Slot. The additionally added horizontal slot has improved the gain of the antenna and increased bandwidth along with improving the radiation pattern and reducing the cross polarization. The bandwidth that is well below 10 dB is -14.80GHz with a return loss of -19.13dB.

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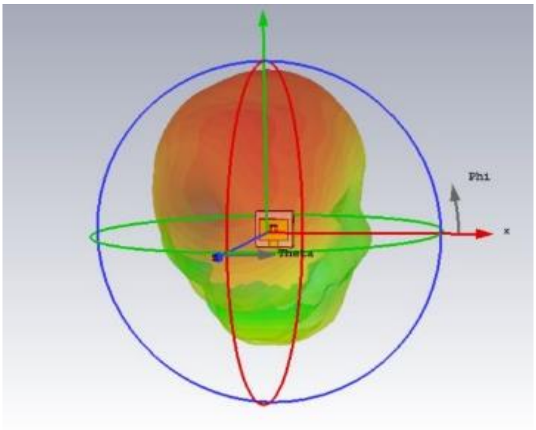

Fig.5: Far Field Radiation Pattern for 55GHz

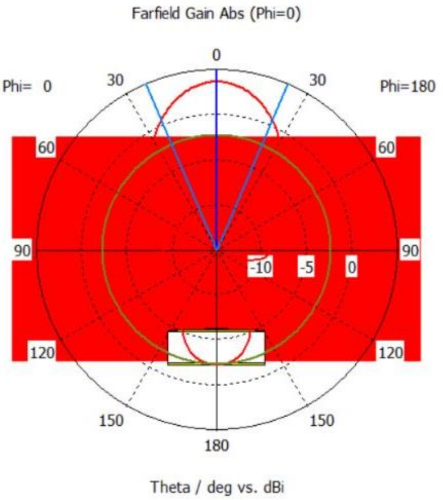

Fig.6: Far Field Pattern for 55GHz

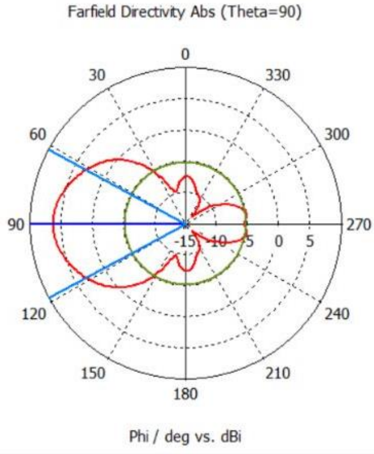

Fig.7 Farfield Directivity

6. RESULTS

As you can see in the above figures, the results of various parameters of antenna are shown. So, these are the results of T-shape ridged Rectangular Microstrip Patch Antenna. The values of antenna parameters are given below.

Table 2. The values of antenna parameters

Parameter	Values
Gain	6.21db
Return Loss	-19.13db
Resonant Frequency	55Ghz
Directivity	8.06db

7. CONCLUSION

In this paper, we have designed a wideband T-Shaped Rectangular Microstrip Patch Antenna. The Antenna has a high gain of 6.821dBi and a narrow bandwidth to provide precise directional coverage and improved detection of distant targets, and the low return loss of -19.13dB ensures minimal signal losses and high data rates. The feeding method for this antenna is microstrip feeding and T-Shaped ridges are provided in antenna for better performance. The designed T-Shaped Microstrip patch antenna can be used for wireless communication purposes effectively.

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