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Investigation on the Performance of U-Slot and Truncated Corner Patch Microstrip Antenna

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ABSTRACT

In this study, the performance of a U-Slot (U-S) microstrip patch antenna and a Truncated Corner Patch (TCP) microstrip patch antenna was investigated at a frequency of 10GHz, utilizing Roggers 5880 as the substrate material. The simulation results indicated that U-S and TCP have: impedance of 284Ω and 50Ω, return loss 2.5 dB and 11dB, reflection coefficient of -7dB and 0.3 dB and Voltage Standing Wave Ratio (VSWR) of 9 dB and 3 dB. Based on these results, it can be observed that that TCP microstrip patch antenna outperform the U-S microstrip patch antenna in term of impedance, return loss and reflection coefficient. The TCP antenna exhibits a lower impedance of 50Ω compared to 284Ω for U-S antenna. Additionally, the TCP demonstrates a higher return loss of 11dB and a lower reflection coefficient of 0.3 dB indicating better matching and reduced signal reflection compared to the U-S antenna.

KEYWORDS: Impedance, Reflection Coefficient, Return Loss, Rogger 5880, Truncated Corner Patch Microstrip Patch Antenna, U-Slot Microstrip Patch Antenna, and Voltage Standing Wave Ratio

1.0 Introduction

Microstrip patch Antenna (MPA) is a small and cost effective antenna configuration that offers various advantages. These advantages includes compact size, low fabrication cost, slim profile, lightweight nature, easy installation and compatibility with different feeds. However, it also has limitaions such as low gain, lower efficiency, and potential issues with polarization purity (shukla *et al.*, 2015 and Aravindraj *et al.*, 2017).

Despite these limitations, the MPA is gaining significant in the next generation of communication systems, where multiple wireless application are prevalents. Its small form factor makes it suitable for space-constrained environments, and its affordability and ease of integration contribute to its popularity. Although compared to larger antenna, ongoing research aim to address these challenges and enhance their performance for specific applications (Sagar *et al.*, 2016).

As wieless technologies contiue to advance, MPAs find application in various domains, including IoT devices, smart homes and wireless sensor network. Their compact size cost effectiveness and versatility make them a compelling option for modern communication needs. Researchers and Engineer are actively working on optimizing MPA design and mitigating limitations to further enhance their performance and usability.

A MPA comprises a dielectric substrate with a conducting medium on both sides. The substrate plays a pivotal role in the microstrip anntena by determning the antenna's radiating range and size. On the upper side of the substrate, there is radiating patch, which serves as the main element responsible for signal radiation. The lower side features a ground plane made of a conducting material that matches the substrate's geometry. The size of the patch in the MPA is influenced by the dielectric constant of the substrate (Saraswat *et al*., 2016).

Different patch shapes have been developed, including Circular, Rectangular, U-Slot, Truncated Corner Patch etc. the overall electrcal and physical dimensions of the antenna primarily depends on the substrate thickness and its dielectric constant.

U slot (US)MPA: This antenna is charaterized by a slot in the shape of the letter "U" on the radiating patch. This slot enhances the performance of the antenna by introducing additional resonant modes and modifying the radiation pattern(Astuti & Rahardjo, 2018, and Al-Fadhali, 2020).

Some of advantages of U-slot MPA are improved bandwidth, reduced cross polarization and enhanced radiation characteristics. It can also be used in wireless communication, radar system, staellite communication among others (Ahmad *et al*., 2021).

The diagram for U-slot MPA is shown in figure 1.

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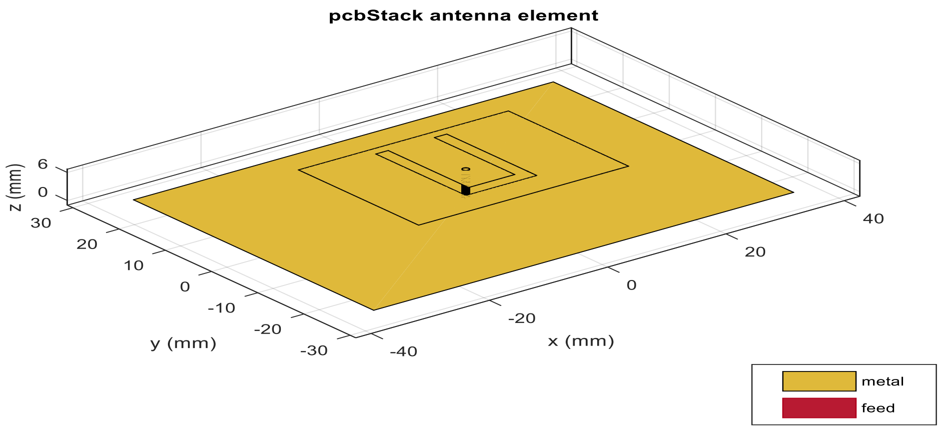

Fig 1: U-Slot MPA (Plotted from Matlab 2021a)

Truncated Corner Patch (TCP) MPA are commonly used in wireless communication system, satellite communication wireless sensing and other application where improved radiation characteristics and bandwidth. Both U-slot and TCP MPA are examples of innovative designs that aim to enhance the performance and capabilities of MPA (Karpart and Imamoglu, 2023). The diagram for TCP MPA is shown in figure 2.

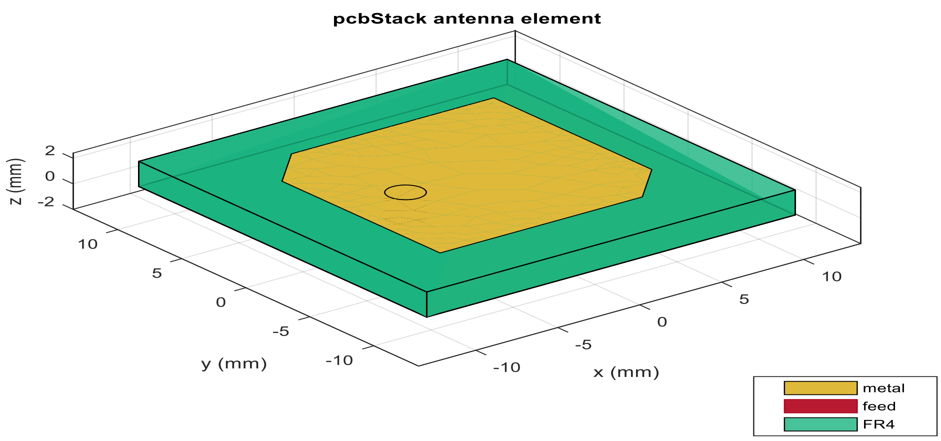

Fig 2 : Truncated Corner Patch MPA (Plotted from Matlab 2021a)

1.1 Aim and Objectives

The aim is to design and investigate the Performance of U-Slot and Truncated Corner Patch Microstrip Patch Antenna.

The objectives are

To study the design of U-slot and TCP micro strip patch antenna

To develop method on how micro strip parameters can be improved

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To simulate micro strip antenna using Matlab Software

To analyse micro strip patch antenna parameters such as return loss, Voltage standing wave ratio and reflection coefficient.

1.2 Scope and Limitation

The scope is to investigate performance between U-slot and TCP MPA and the work is limited to check for return loss, reflection coefficient and VSWR.

2.0 Literature Review

Comparison for truncated corner patch uaing two different substrates: Taconic TLC and FR4 were carried out. The result shows that trunated conrner patch antenna with substrate FR4 show better performance with frequency of 1.576 GHz. The application is good for GPS application (Verma, and Sirvastava, 2021). However the work only centered on substrate.

Design and Fabrication of disconnected reqular ring and inverted U shaped slot with Rogger 5880 as a substrate in frequency range of 2.45 GHz (Wifi) and 3.3 GHz (5G). The result show that fabricated antenna has better reflection coefficient for WiFi and have same value for reflection coeffcient for 5G (Mokhis *et al.*, 2019 and Astuti *et al*.,2022).

Furthermore, studies on multiple resonant frequency, radiation and impedance properties for U- Slot microstrip was conducted by (Weigand *et al*., 2003). Simulation of result were obtained using method of mement.

U-slot patch antenna using Characteristics Mode Analysis(CMA) was carried out for impedance function. The CMA shows that U- slot demostrated a wideband size (Borchardt & Laponite, 2019, and Lu *et al*., 2019).

3.0 Methodolgy

The methodology employed in this work is the use of Matlab software to design U-slot and TCP antennas, thereafter, they were simulated for impedance, reflection coefficient and return loss and Voltage Standing Wave Ratio (VSWR).

According to (Yogeeswaran & Ramesh, 2020), the mathematical expression is given in equation 1-7:

The width of micro strip patch antenna is expressed as

$$W = \frac{c}{2fr\sqrt{(er+1)/2}} \quad (1)$$

Effective dielectric constant calculation **(** ε_{reff}): The effective dielectric constant is:

$$ereff \frac{er+1}{2} - \frac{er-2}{2}\left[1 + \overset{=}{1}2\frac{h}{W}\right]^{--} \left(\frac{1}{2}\right) \quad (2)$$

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Effective length calculation (**L_{eff}**): The effective length is:

$$Leff = \frac{c}{2fr\sqrt{ereff}} \quad (3)$$

Length extension calculation (**ΔL**): The length extension is given by:

$$\Delta L = 0.412h\frac{(ereff+0.3)(\frac{W}{h}+0.264)}{(ereff-0.258)(\frac{W}{h}+0.8)} \quad (4)$$

Actual length of patch calculation (**L**):

The actual length is obtained by:

$$L = Leff - 2\Delta L \quad (5)$$

Ground plane dimensions' calculation (**L_g and W_g**):

$$Lg = 6h + L \quad (6)$$

$$Wg = 6h + W \quad (7)$$

Where $ereff$ is effective dielectric constant, $Leff$ is effective length, ΔL is length extension, and L is actual length.

4.0 Simulation

The simulation for U-slot and TCP for impedance, Reflection coefficient, VSWR and return loss were given in fig 4.1 to fig 4.4 below.

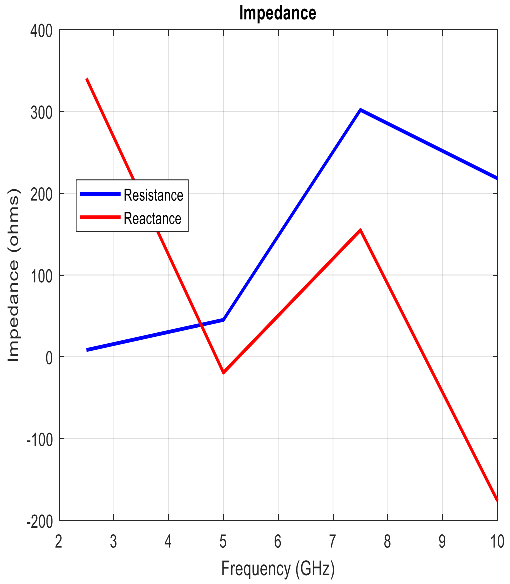

Fig 4.1 (a) U-Slot Impedance

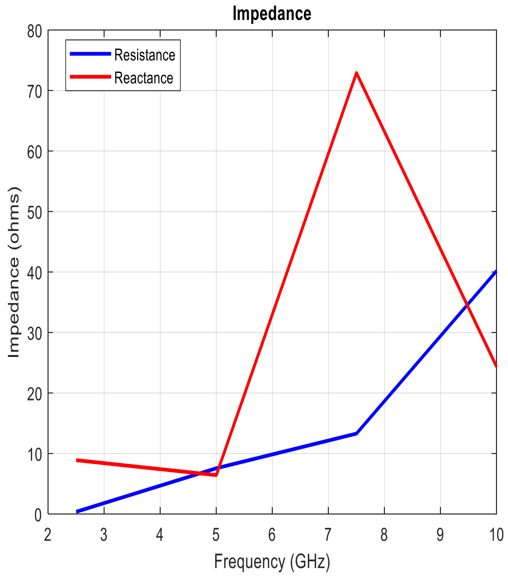

fig 4.1(b) TCP Impedance

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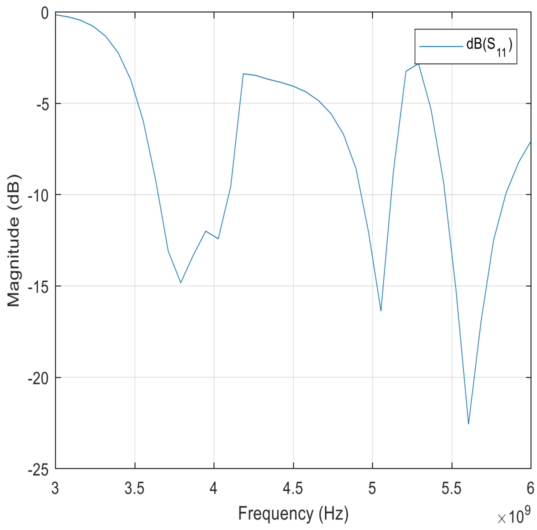

Fig 4.2 (a) U-Slot Reflection Coefficient

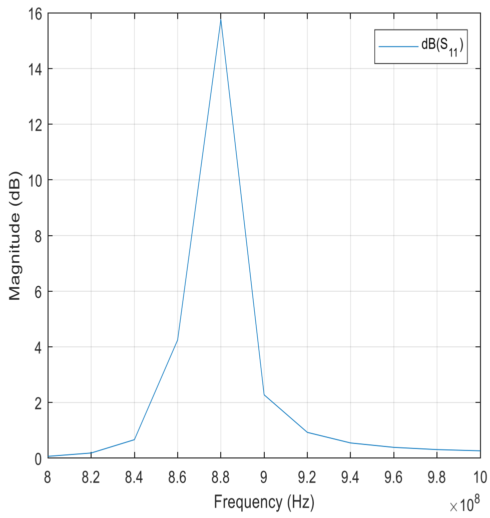

fig 4.2(b) TCP Reflection Coefficient

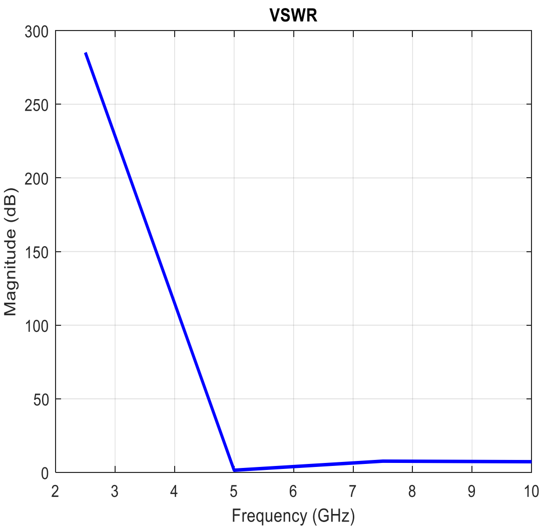

Fig 4.3(a) U-Slot VSWR

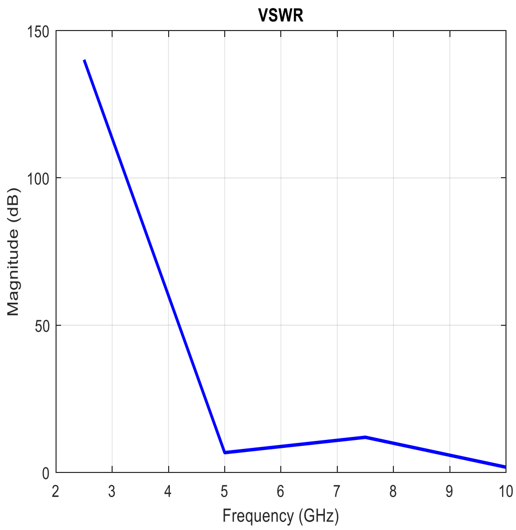

fig 4.3(b) TCP VSWR

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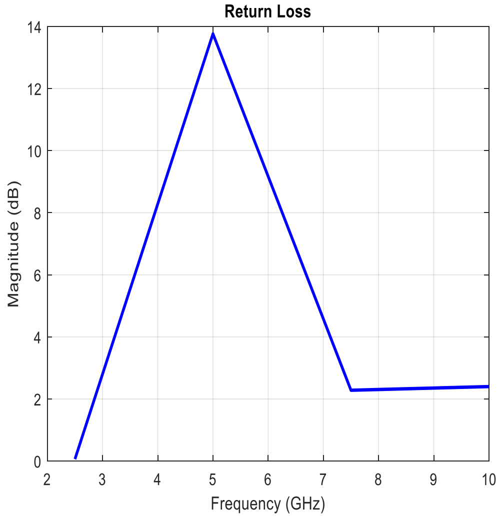

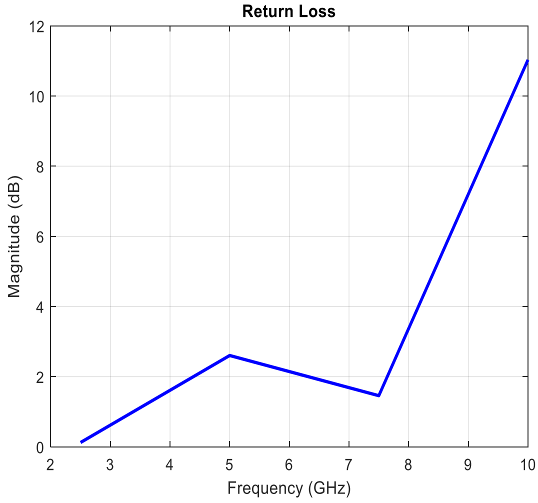

Fig 4.4 (a) U-slot Return loss fig 4.4(b) TCP return loss

Table 4.1: Result from Simulated graph

S/N	Type of Shapes	Impedance (Ω)	Retrun Loss (dB)	Reflection Coefficient (dB)	VSWR (dB)
1	U- Slot	284	2.5	-7	9
2	Truncated Corner Patch	50	11	0.3	3

5.0 Discussion of Result

From the simulation result in fig 4.1, the U-slot and TCP have impedance value of 284Ω and 50Ω respectively. Similarly, for fig 4.2, fig 4.3 and fig 4.4 the reflection coefficient, VSWR and return loss for U-slot and TCP are -7dB and 0.3dB, 9dB and 3dB, 2.5 dB and 11dB. It can be deduced that TCP MPA give better performance for impedance, return loss and reflection coefficient when compared to U-slot microstrip antenna of the same frequency range of 10 GHz.

Conclusion

Two types of MPA investigated are U-Slot MPA and TCP MPA in a frequency range of 10 GHz. The simulation results indicated that TCP antenna exhibits a lower impedance of 50Ω compared to 284Ω for U-Slot antenna. Additionally, the TCP MPA demonstrates a higher return loss of 11dB and a lower reflection coefficient of 0.3 dB indicating better matching and reduced signal reflection compared to the U-Slot antenna.

Recommendation

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It is recommended to use TCP MPA for frequency of 10 GHz.

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