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# TRIPLE BAND THZ MIMO ANTENNA FOR SHORT-RANGE COMMUNICATIONS

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## ABSTRACT

For wireless applications, a single-patch antenna having a shape slot is suggested along with a 1×8 Multiple Input Multiple Output (MIMO) antenna array. The substrate is made of polyimide material, which has a 0.04 mm thickness and a dielectric constant of 3.5. The proposed MIMO antenna array uses a remarkably small rectangular microstrip patch antenna with dimensions of 0.075mm by 0.111mm by 0.04mm. Performance measures such as return loss, bandwidth, antenna gain, antenna efficiency, and VSWR ECC are computed for resonating frequency. The designed MIMO antenna array resonates for three different frequencies of 0.7487 THz, 0.8015 THz, and 1.1558THz and has a return loss of less than -10 dB. The designed array has an antenna efficiency of 96% and a maximum achievable antenna gain of 16.5 dB for resonating frequency. Due to its improved properties, the designed antenna array might be suitable for a range of THz applications.
**Keywords:** HFSS, patch antenna, MIMO antenna, THz band.

## INTRODUCTION

The importance of wireless communication is expanding as technology is evolving rapidly. Due to the dramatic rise in internet traffic caused by this circumstance, bandwidth and related resources are in short supply. By taking into account the data rate which is reaching Gbps or may even reach Tbps with the current traffic demand. The most modern THz communication that is being used today has a data rate of up to Gbps (Zhi Chen et al. 2019). The THz electromagnetic frequency spectrum, which is a blank space between microwave frequency and infrared light, may therefore be the most viable approach to boosting the transmission data rate. The frequency band above microwave radiation offers many benefits for wireless communication networks, including wide bandwidth for higher data rate, dramatically enhance directivity, low percentage of interference, and system design compactness because the antenna size gets very small at the THz frequency band (Aditi Sharma and Ghanshyam Singh 2009). This section of the electromagnetic spectrum comes within the frequency range of 0.1 to 10 THz and a wavelength range of 0.03 to 0.3mm. The THz band's enormous bandwidth which is greater than 10 GHz, made it possible for a number of applications that require rapid data rates (Mohamed Moussaoui and Mohamed El Jbari 2022).

Following are some benefits of the THz wave:

1. Low toxicity: THz waves are generally employed in biomedical applications, such as body scanning for cancer therapy, and they don't damage body organs. The usage of single photon energy is to blame for this.

2. Better spectral resolution: THz band can be used to find explosives, poisons, and viruses that are harmful.

3. Visualization: THz waves have a relatively short wavelength, allowing for quick and easy penetration. THz frequency is therefore commonly employed in airports.

4. larger Bandwidth: Because the band of the THz spectrum is the highest in electronics, THz frequency has a very high-speed data rate.

The properties of both millimeter wave frequency and light waves are present in the THz frequency band. As opposed to millimeter-wave frequency, the THz frequency band has a broad bandwidth, a highly directional beam, and is more efficient and penetrates than light waves. THz antennas have a lot of benefits, but there are also a lot of design obstacles. High frequency causes the antenna's size to be drastically reduced. For THz antennas, there is a packaging restriction. The efficient radiation of THz antennas is another design challenge (PR Pandya, M Sarada Devi and N Langhnoja2022). As THz transmission can offer tens of GHz of bandw idth and can support extremely high data rates, it is regarded as one of the k ey technologies for future 6G wireless netwo rks (Tan, Jingbo, and Linglong Dai 2021).

However, because of the high-frequency band, THz communications have substantial path loss (Chong Han, A. Ozan Bicen and Ian F. Akyildiz 2015). Future THz communications could potentially incorporate MIMO technology, which can produce high directional beams with tremendous array gains, to make up for the substantial path loss. Furthermore, a research study has shown that MIMO technology can increase spectrum efficiency to greater levels while lowering energy usage in wireless applications by 10–20 times (Cen Lin and Geoffrey Ye Li 2016).

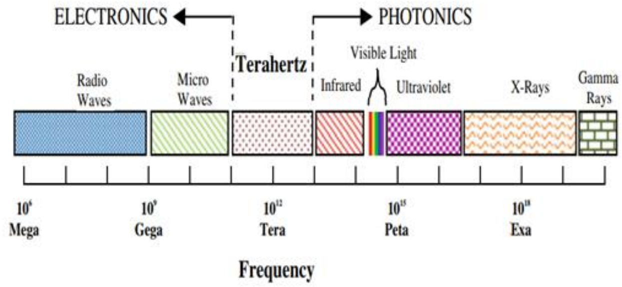



**Figure 1: Electromagnetic Frequency Band [3]**

In recent years, a lot of researchers have been focusing on the new frequency band spectrum, employing a significantly larger amount of bandwidth for THz communication systems for both industrial and civilian applications. THz antennas of various modest sizes have recently been developed and simulated. (Amarveer S. Dhillon et al. 2017) designed a planar antenna of the polyimide substrate material at 0.67 THz resonance frequency with 5.22dB antenna gain and 5.08 dBi directivity and 40.16 GHz bandwidth for defence purposes. (M Singh. et al. 2021) proposed an ultra-wideband MIMO patch antenna array by utilizing polyimide substrate material. the designed MIMO antenna array is of very compact size and resonates at 0.660 and 0.83 THz frequencies. The achieved antenna parameters are an antenna gain of 8.28 dB, an antenna efficiency of 72.85%, and a bandwidth of 57.96 GHz. (Kushwaha et al. 2018) presented a special dual-band antenna with a polyimide substrate that has a high antenna gain of 7.94 dB and a frequency bandwidth of 10.1%, primarily for defence applications. (Abdesselam H. et al. 2019) analyzed and proposed five patch antennas for THz frequency ranging between 0.5 and 0.8 THz using a modified photonic bandgap substrate and achieved 9.19 dB antenna gain and 90.84% radiation efficiency. It is evident from the explanation above that the designed MIMO array outperforms the previously mentioned THz antenna. A MIMO antenna array has a greater throughput and very high efficiency over the resonant frequency. Also, a majority of researchers have only developed a single antenna for THz bands and haven't specified the ideal configuration for a MIMO antenna array. The divisions between the segments of this research article are described below. Section 2 carries the analysis and simulation results of star shape single patch antenna. Section 3 carries the simulation designing of a 1×8 MIMO array for the THz frequency band spectrum. Furthermore, the final section summarizes the work's overall details.

## SINGLE PATCH ANTENNA DESIGN CONFIGURATION AND RESULTS

Before developing a system as a real-world application, it is now standard procedure to simulate the system's performance. To check the gain, return loss, bandwidth, radiation efficiency, and VSWR, a simulator called "ansoft HFSS" is employed. The expense of fabrication is reduced thanks to this simulator.

A frequency range of 0.8 THz was chosen for the design and study of the proposed MIMO antenna radiated surfaces on both sides of the microstrip patch antenna make it more favorable than other designs. The graphic below depicts the simulated single-patch antenna in three dimensions shown in fig. 1.

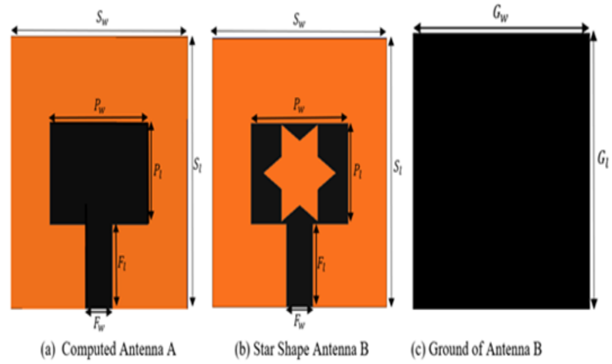



**Figure 2: Design of Single Patch Antenna**

**Table 1. Dimensions for designed antenna**

| Antenna Parameters | Dimensions |
|---|---|
| $P_w$ (Patch's Width) | 0.111 mm |
| $P_l$ (Patch's Length) | 0.076 mm |
| $S_w$ (Substrate's Width) | 0.2 mm |
| $S_l$ (substrate's Length) | 0.2 mm |
| $F_w$ (Feedline's Width) | 0.03 mm |
| $F_l$ (Feedline's Length) | 0.062 mm |
| h (Substrate's Height) | 0.04 mm |

In this section, a patch antenna of a rectangular shape is transformed into a slotted star patch antenna. First, a single patch antenna of a rectangular shape is modeled on a polyimide substrate having a dielectric constant of 3.5. In order to improve the antenna's performance even further, as shown in fig. 2, the simulated rectangular patch antenna is changed into a slotted star-shaped patch antenna in the process stage (b). The patch antenna's dimensions are modified for improvement in order to achieve the best possible antenna characteristics. The dimensions of the patch antenna are 0.076 ×0.111×0.04 mm. Table 1 lists the precise dimensions of each component of the final constructed antenna.

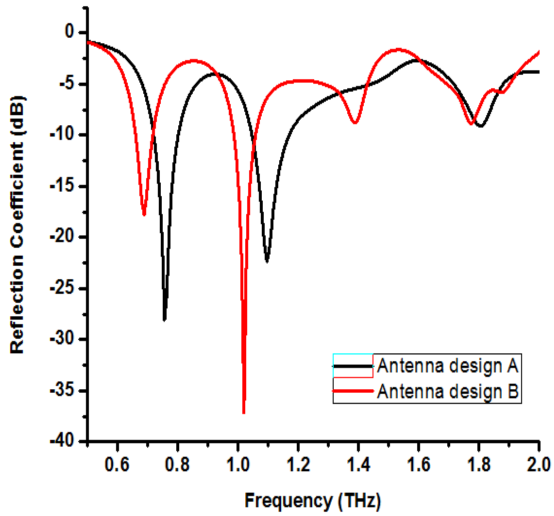
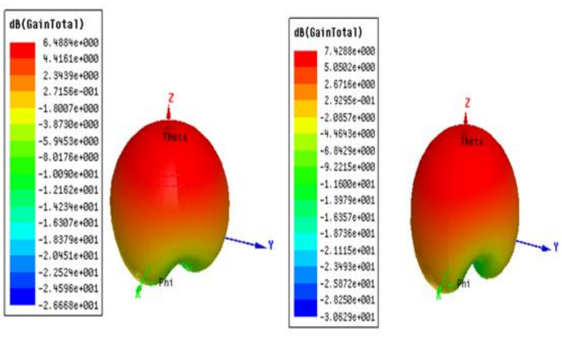



**Figure 3: Return loss of Patch Antennas A and B**




(a) Antenna A (b) Antenna B

**Figure 4: 3D view of Gain of Patch Antennas A and B**

The parameters of the intended antenna's radiation efficiency are also evaluated, along with other factors like antenna gain, bandwidth, and VSWR. Our investigation of the performance of the respective antennas shows that the reflection coefficient for the simulated Antennas A and B which indicates the degree to which the antenna matches impedances is shown in fig.3 for designed antennas A and B. is lower than -10 dB.

The rectangular shape antenna operates at 0.7563 THz and 1.0955 THz frequency bands having return loss of -28.054 dB and -22.338 dB respectively. And, patch antenna having a star slot resonates at 0.6884 THz and 1.0201THz having a return loss of -17.759 dB and -37.155dB respectively. The maximum bandwidths of the designed antennas A and B are 124 GHz, and 71.7 GHz respectively. The gain of two simulated antennas, A and B, is shown in fig. 4. Their relative peak gains are 6.48 dB and 7.42 dB. Fig.6 shows that created antennas A and B have radiation efficiency values of 87%, and 95% respectively. Moreover, as shown in fig. 5, designed antennas A and B exhibit VSWRs within 0 and 2.

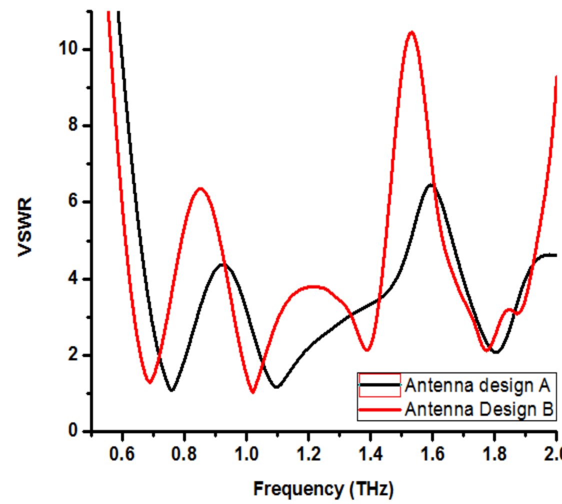



**Figure 5: VSWR of Patch Antennas A and B**

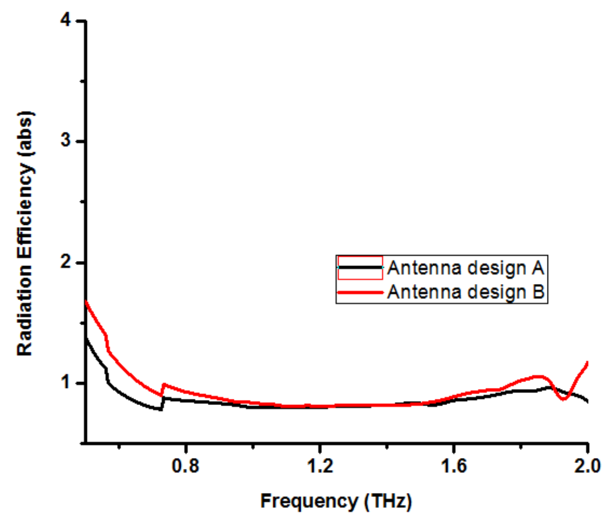



**Figure 6: Radiation Efficiency of Antennas A and B**

## MIMO ANTENNA ARRAY FOR THz APPLICATIONS

The 1×8 MIMO antenna is proposed for THz applications under this section. The MIMO array uses antenna design B to improve the antenna performance. As a result of the very high frequency, the proposed MIMO antenna for THZ is smaller in size. The key advantage of the THz frequency range is the availability of greater bandwidth. THz antennas' higher data rate and incredibly small size are other noteworthy features. Its greater bandwidth serves the demands of network users for simultaneous transmission and reception of multiple forms of data, including messages, videos, animations, and other content (Jha, Kumud Ranjan, and Ghanshyam Singh 2014).

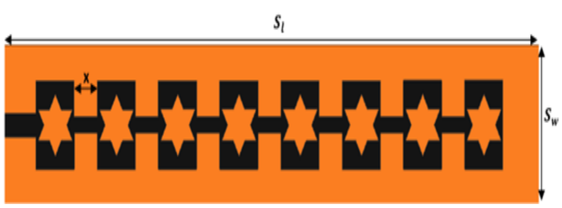



**Figure 7: 1×8 MIMO Antenna Array**

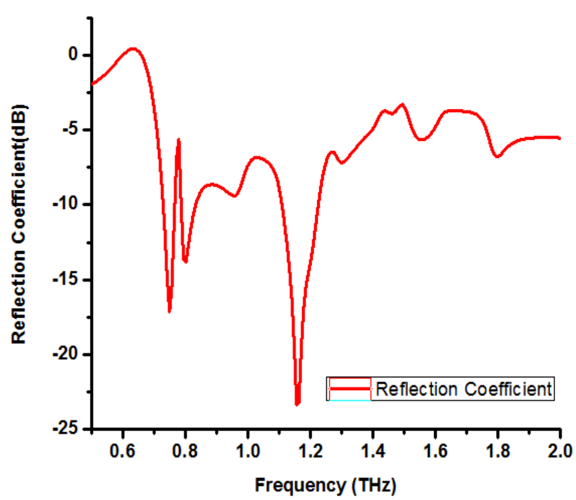



**Figure 8: Return loss of MIMO Patch Antennas**

The Following the development of a star shape-slotted single patch antenna, a 1×8 MIMO antenna is designed and simulated shown in fig. 7. In a 1×8 MIMO array, eight identically sized antenna elements are used to increase the antenna's performance. There is an x= 0.045 mm gap between each antenna element and the width of connected.

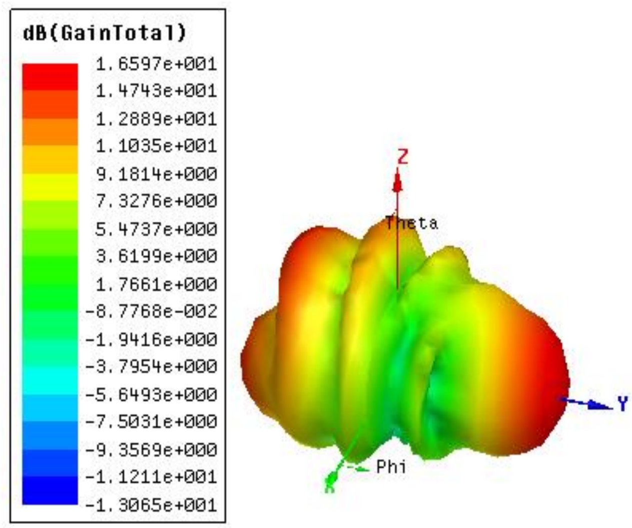



**Figure 9: Gain for 1×8 MIMO Antenna Array**

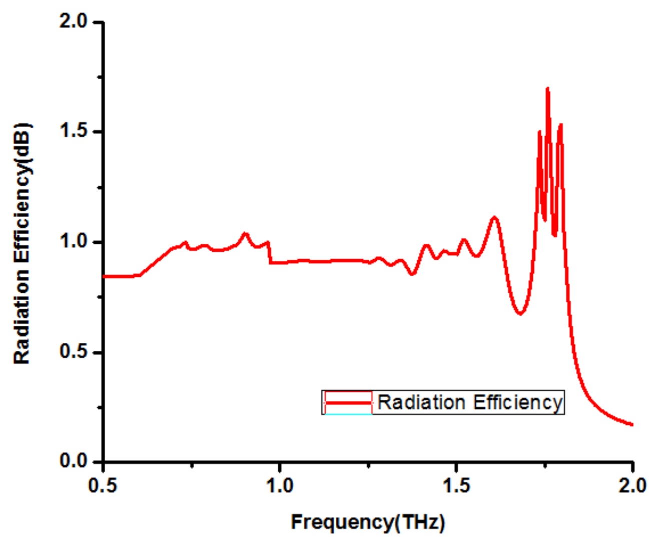



**Figure 10: Radiation efficiency for 1×8 MIMO Antenna**

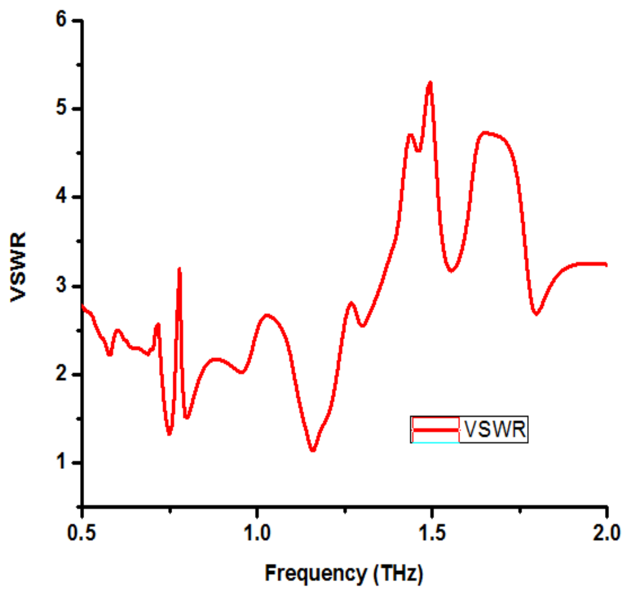



**Figure 11: VSWR for 1×8 MIMO Antenna Array**

Fig. 8 depicts that the proposed 1x8 MIMO array operates at 0.748 THz, 0.801 THz, and 1.115 THz frequency with the return loss of -17.142, -13.843 dB, and -23.323 dB respectively, and has a very broad bandwidth of 116.6 GHz. Comparing the proposed MIMO to the designed single antenna, the gain is enhanced. The peak gain is shown in fig. 9. and radiation efficiency shown in fig. 10 of the 1×8 MIMO for resonating frequencies are 16.59 dB and 96% respectively. Also, as depicted in figure 11, the simulated VSWR for this designed MIMO are 1.3228, 1.5099, and 1.1464. The designed single antenna A and B and the MIMO array's frequency specifications are listed in Table 2.

## CONCLUSION

A MIMO antenna array design for THz applications is the focus of this research paper. For THz wireless applications, we have introduced a triple-band MIMO patch antenna array with higher efficiency, higher gain, wideband and low profile in this paper. The proposed MIMO antenna resonates at 0.748 THz, 0.801 THz, and 1.155 THz frequencies and has a reflection coefficient of -17.142, -13.843 dB, and -23.323 dB respectively. Such a MIMO antenna achieved an antenna efficiency of 96, a peak gain of 16.5 dB, ad VSWR between 0 and 2. A 1×8 MIMO antenna is designed and studied because the MIMO antenna system must address the numerous losses in the THz environment. The designed MIMO array might be a strong candidate for on-chip components in the upcoming generation of short-range wireless communications.

**Table 2: Simulated results of proposed single and MIMO antenna**

| Antenna parameters | Return Loss (dB) | Maximum B.W. (GHz) | Gain (dB) | Radiation Efficiency (%) | VSWR |
|---|---|---|---|---|---|
| Antenna A | -28.0543, -22.3381 | 124.5 | 6.48 | 87% | 1.0824.1.1654 |
| Antenna B | -17.7597, -37.1551 | 71.7 | 7.42 | 95% | 1.2973,1.0281 |
| 1×8 MIMO Antenna | -17.1425, -13.8432, -1.1558 | 116.6 | 16.597 | 96% | 1.3228, 1.5099. 1.1464 |

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