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# Design and Analysis of a Micro strip Antenna for Terahertz Frequency Applications

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**Abstract:** This project's objective is to use CST software to construct a micro strip antenna for the terahertz (THz) frequency at 300 GHz. When designing a terahertz antenna at this frequency, a number of crucial elements need to be taken into account. Micro strip technology, a popular technology for high-frequency antennas, will be used to construct the antenna. A number of design elements, such as the shape of the antenna radiating elements and the proper feeding mechanism, will be emphasized. CST software will be used to simulate the antenna in order to assess and examine its performance. To assess its performance, antenna properties like gain, reflective frequency, and return loss will be examined. An analysis of the antenna's parameters revealed that its gain was 9.508, its voltage standing wave ratio was 1.107, and its return efficiency was -1.523 dB. The proposed THz antenna may be utilized as an antenna element in Massive MIMO antenna array designs since it has good radiation properties, making it appropriate for terahertz applications.

**Keywords:** Micro strip, gain, Return loss.

## 1- Introduction:

Terahertz (THz) frequencies are being investigated because of the increasing need for high-speed wireless communication systems. These frequencies have the potential to provide much larger bandwidth and data rates. The development of antennas that can function at THz frequencies, such 300 GHz, is essential to this investigation. For effective signal transmission and reception in the THz range, these antennas are necessary. Because of the peculiarities of this frequency range, designing a THz antenna at 300 GHz poses special difficulties. With a wavelength of about 1 mm, the antenna elements' small size and exact manufacturing requirements must be taken into account in the design. Furthermore, attaining the intended radiation properties and effective power transfer are essential for dependable and high-performance wireless communication. The goal of this project is to use CST software to construct a micro strip antenna that can operate at 300 GHz. Because of their planar form and small size, micro strip antennas are perfect for high-frequency applications, including THz frequencies. The performance of the antenna can be examined and improved by means of meticulous design and simulation using CST software. For THz antennas, the study investigates a number of design factors, such as substrate material selection, feeding method, radiating element design, and antenna type. The study also intends to assess the antenna's performance in terms of polarization, gain, radiation pattern, and integration capabilities. [1]

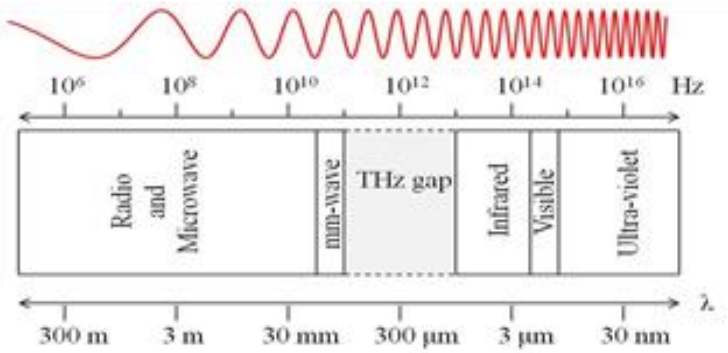



**Figure 1 An electromagnetic spectrum showing the location of the THz frequency band between the infrared and radio spectrums.**

There are several factors to consider when building an antenna for the 300 GHz band in the terahertz (THz) frequency range:

1. *Frequency and wavelength*: At 300 GHz, the wavelength is approximately 1 mm. The short wavelength necessitates small antenna elements and exact manufacturing processes.
2. *Antenna type*: A number of antenna types, including aperture, slot, micro strip, and horn antennas, can be considered for THz frequencies. The choice is determined by a number of factors, including as the intended radiation pattern, gain, polarization, and the necessary degree of integration.
3. *Radiating element*: The radiating element of the antenna must be constructed to operate effectively at 300 GHz. Due to their small size and flat shape, micro strip patch antennas are commonly used at THz frequencies. Other options include dipole antennas, slot antennas, or specially designed metamaterial structures.
4. *Feeding technique*: THz antennas can be challenging to feed because to their narrow wavelength. Techniques like proximity coupling, aperture coupling, and waveguide feeding are available. Waveguide configurations such as rectangular waveguides are commonly used for efficient power transfer at THz frequencies.
5. *Substrate material*: The choice of substrate material is essential for THz antennas. In order to minimize losses and enhance radiation efficiency, high permittivity, low-loss dielectric materials are preferred. Examples of suitable substrate materials include gallium arsenide (GaAs), indium phosphide (InP), and high-resistivity silicon (Si). [2].

## 2- Problem Statement:

The following are the primary problems and challenges associated with the development of Nano antennas:

1) *Antenna size*: small antennas are required to achieve effective performance at terahertz frequencies, but this is challenging to accomplish using traditional methods due to the difficulty of shrinking antennas to Nano scale dimensions;
2) *Signal loss*: At high frequencies, like terahertz frequencies, signal loss between antennas and the environment increases; therefore, advanced materials and designs that maximize antenna efficiency and minimize signal loss are required;
3) *Low kinetic effects*: utilizing ordinary metals in Nano antennas may result in electrons having low kinetic effects, which lowers the antennas' ability to transmit signals at terahertz frequencies. To get around this problem, advanced materials, such as plasmatic materials, are required.

## 3- Paper Objectives:

The project's primary goals are to:

1) Use CST software to design a microstrip antenna for the terahertz (THz) frequency at 300 GHz.
2) When designing an antenna, take into account significant terahertz-specific characteristics.
3) When developing the antenna, make use of microstrip technology, a popular method for high-frequency antennas.

4) To maximize antenna performance, concentrate on optimizing the geometry of the radiating element.

5) Choose the best feeding method for the microstrip antenna.

6) To examine and assess the antenna's performance, simulate it using CST software.

7) Examine the antenna's performance by looking at parameters including gain, VSWR, and return loss.

**4- Literature Review:**

Table 1 presents a comparative overview of various wireless technologies with respect to their operational frequency, transmission range, and peak data rate:

**Table 1 Comparison between THz and other wireless technologies [3].**

| Technology | Frequency Ranges | Transmission Range | Peak Data Rate |
|---|---|---|---|
| Bluetooth Low Energy (BLE) [26] | 2.4 GHz | 100 m | 1 Mbps |
| Low Power Wide Area Network (LoRaWAN) [27] | 868 MHz, 0.9 Ghz, Sub 1 GHz | 10 Km | 50 Kbps |
| Narrowband -Internet of Things (NB-IoT) [300] | 0.7 to 0.9 GHz | 10 Km | 200 Kbps |
| Millimeter Wave (mmWave) Communication [29] | ~ 24 to 100 GHz | 100 meters | 10 Gbps |
| THz Communication [30] | 0.1 THz -10 THz | 10 meters | 10 Gbps to 160 Gbps |

**Fig. 2** illustrates the multi-disciplinary importance of THz technology. It emphasizes how non-ionizing, high-frequency THz waves offer powerful tools for safe imaging, high-speed data transfer, and precise material analysis. As THz devices become more compact and affordable, their integration into everyday technologies (e.g., portable THz cameras and sensors) is expected to increase significantly [4].

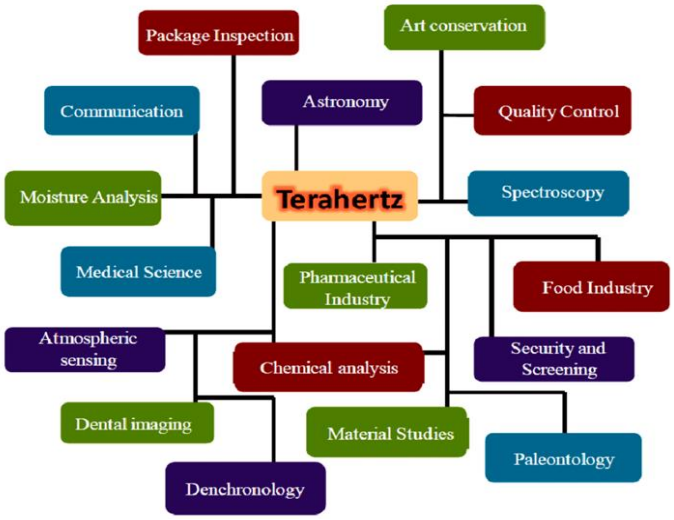



**Figure 2. Various applications of THz radiation [5].**

The design parameters can be performed mathematically based on given frequency 300GHz, and determining the other physical dimensions accordingly by using equations (1) to (7) to determine the length, and width of patch and substrate taking into account that c=3x108 m/s. After parametric study is performed the final design of the antennas is simulated based on the dimensions Shown in table-2 [6].

$$\varepsilon_{reff} = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2}\left(1 + \frac{12}{\frac{h}{w}}\right)^{-1/2} \quad for \quad \frac{h}{w} < 1 \tag{1}$$

$$l_{eff} = L + 2\Delta l \tag{2}$$

$$f_r = \frac{c}{2l_{eff}\sqrt{\varepsilon_{eff}}} \tag{3}$$

$$\mathrm{W} = \frac{\boldsymbol{c}}{\boldsymbol{2 * fr * \sqrt{\frac{\varepsilon r + 1}{2}}}} \tag{4}$$

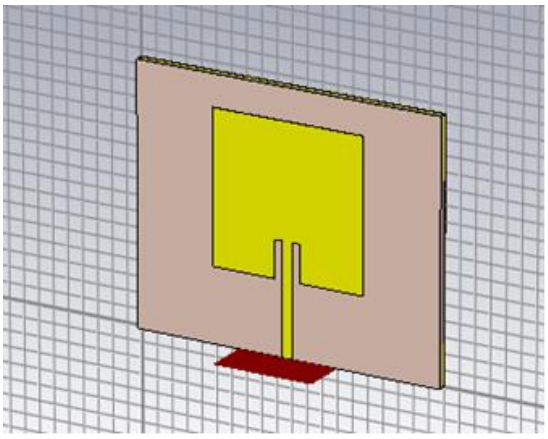
$$\mathrm{L} = \frac{c}{2 * fr * \sqrt{\varepsilon_{reff}}} - 2\Delta l \tag{5}$$

$$\frac{\Delta f}{f_0} = 3.77\,\frac{\boldsymbol{\varepsilon_r - 1}}{\boldsymbol{\varepsilon_r{}^2}}\,\left(\frac{Lh}{\lambda w}\right) \tag{6}$$

**Table 2: the first proposal for the dimensions of the antenna.**

| Symbol | Design parameters | Optimized values (um) |
|---|---|---|
| $S_H$ | Substrate Height | 88 |
| $P_W$ | Patch width | 240 |
| $P_L$ | Patch length | 163 |
| $S_W$ | Substrate width | 571 |
| $S_L$ | Substrate length | 353 |
| $G_W$ | Ground width | 571 |
| $G_L$ | Ground length | 353 |
| Lf | Feed line length | 84 |
| Wf | Feed line width | 40 |

For performance predictions and simplified analysis, a rectangular shaped Microstrip patch antenna operating at 300 GHz for application is proposed as shown in the Fig.3.



### A. *Simulation Results and Discussion (First design):*

The performance of the MSPA (Microstrip patch array) is evaluated using different metrics. Among these, the return loss, bandwidth, VSWR, beam gain, and radiation efficiency are often utilized. The return loss ($S11$) versus frequency plot of the proposed MSPA is given in Figure 4. From the plot, we observe that the antenna return loss is about $-40.689$ dB at the resonant frequency [7].

The bandwidth of the rectangular MSPA is determined between the regions where a return loss is less than $-40.689$ dB, i.e., between $0.2907$ THz and $0.31259$ THz. Therefore, the $-10$dB return loss of the proposed rectangular MSPA bandwidth is $21.89$ GHz [8].

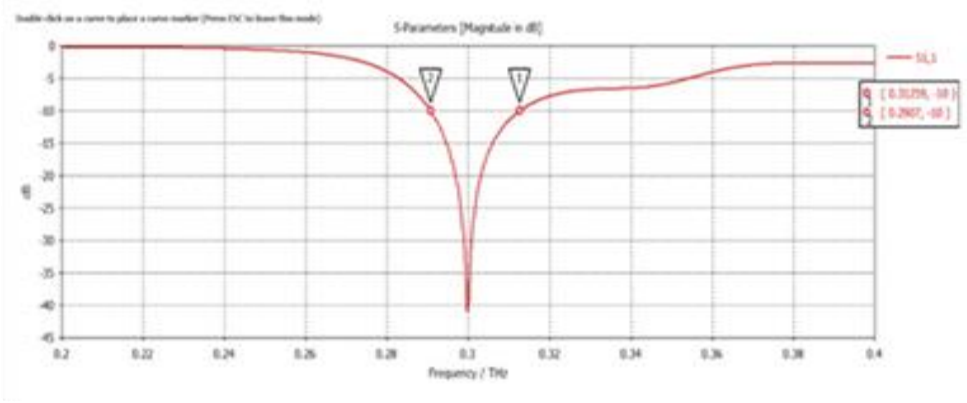



**Figure 4. An electromagnetic spectrum showing the location of the THz frequency band between the infrared and radio spectrums.**

The input power delivered from the source cannot be radiated without loss due to incorrect compensations. Some of this power is reflected at the antenna, and it is returned to the transmitter, which is quantified by VSWR. The VSWR is described as a function of reflection coefficient, which expresses the power reflected from the antenna. The smaller the VSWR, the better the MSPA is matched to the feeder line and power distributed to the patch. Hence, for an ideal transmission line, the magnitude of VSWR is one, and for the practical scenarios, a magnitude of less than two is satisfactory as long as return loss is less than $-20$ dB [9].

In fig.5, radiation pattern is presented, the radiation taking rectangular polarization geometry with gain of $5.242$ dBi.

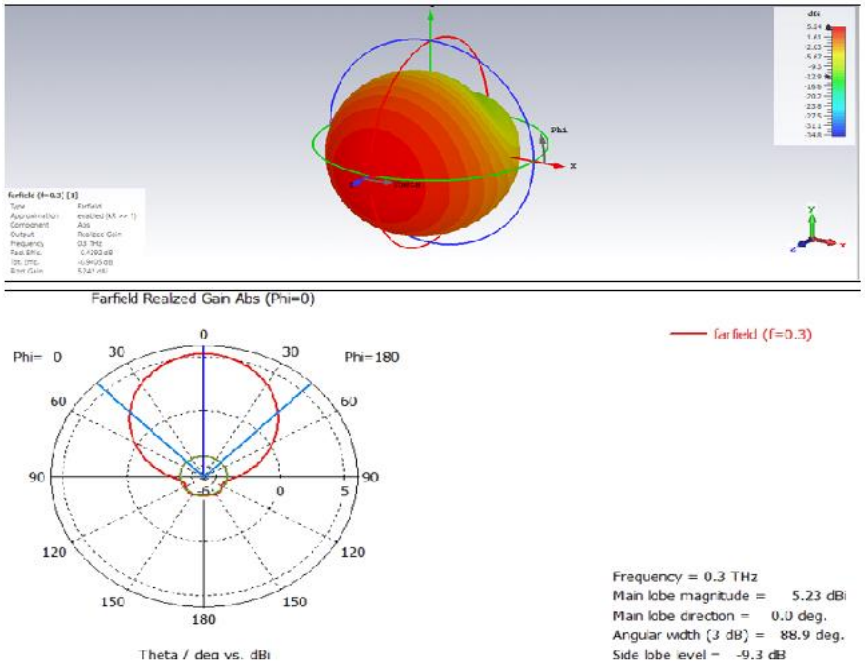



***Figure 5. Radiation pattern for 5.242 dBi.***

**Table 3. The results of first paramantes antenna**

| Parameter | Value |
|---|---|
| Gain | 5.744 dBi |
| BW | 21.89 GHz |
| Return Loss | -41.05 dB |
| VSWR | 1.0178 |
| Realized Gain | 5.242 dBi |
| total efficiency | -0.9434dB |

## *B. Simulation Results and Discussion (Second design):*

An array is a group of single elements that is used to improve the directionality of the antenna beam and therefore achieving better efficiency and gain. There are different types of the array configurations such as, a linear phased shape, planar and phased array [10]. The main reason for applying array scheme is to generate tiny beam and avoid pattern of side lobes. Figure 6 shows the design of identical linear array elements 2x2 with a spacing of d= $\lambda/2$ mm between the antennas.

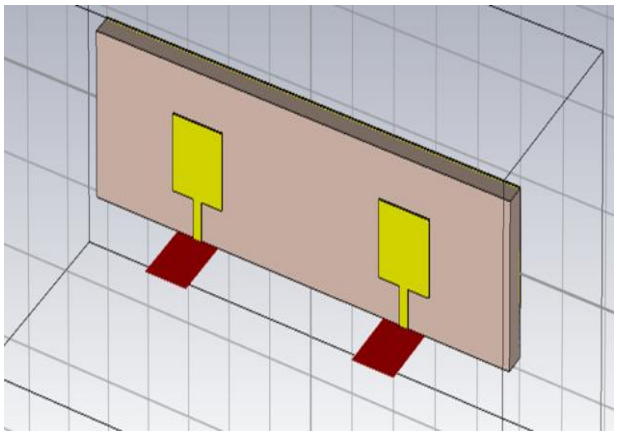


**Figure 6. 2x2 Antenna Array.**

The simulation of the second antenna design yielded promising results; it also provided a gain of 6.769, amplifying the signal for improved communication performance. The return loss for both designs was −25.85 dB, indicating good compatibility between the antenna and transmission line. The VSWR of the second design was low at 1.107, indicating minimal signal reflections and improved power transfer. However, the radiation efficiency showed some losses with a value of −0.750 dB. The overall efficiency was also negative at −1.523 dB, reflecting the effectiveness of the antenna in converting input power into radiated power. In conclusion, the second antenna design displayed positive performance in terms of directivity, gain, achieved gain, return loss, VSWR, radiation efficiency, and overall efficiency. These findings suggest that the design holds promise and may be suitable for the intended application. However, practical measurements and further design optimization are necessary to validate these results. Figure 7. illustrates the relationship between the voltage standing wave ratio (VSWR) and frequency for an antenna [11].

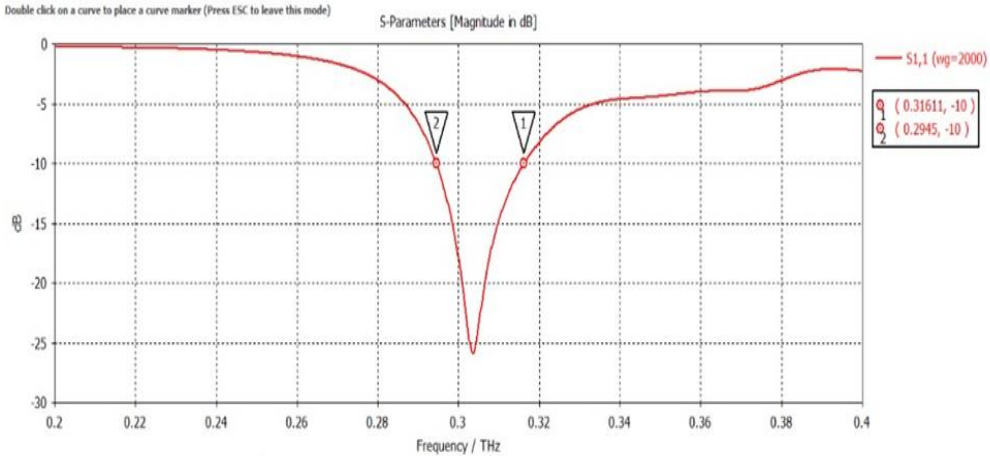



**Figure 7. The return loss (S1,1) resonating at 300 GHz with BW 21.61 Ghz.**

Figure 7. illustrates the return loss (S11) as a function of frequency for the proposed Microstrip Patch Antenna (MSPA). The data reveals a significant dip in return loss, reaching approximately −25.85 dB at the antenna's resonant frequency. Regarding the antenna's bandwidth, it is defined over the frequency range where the return loss remains below −15.8 dB, which, according to the plot, spans from 0.2945 THz to 0.31611THz. Thus, the bandwidth within which the return loss is better than −10 dB for this rectangular MSPA is calculated to be 21.61 GHz.

In figure 8, the radiation pattern is presented, with rectangular polarization geometry with gain of 9.508 dBi.

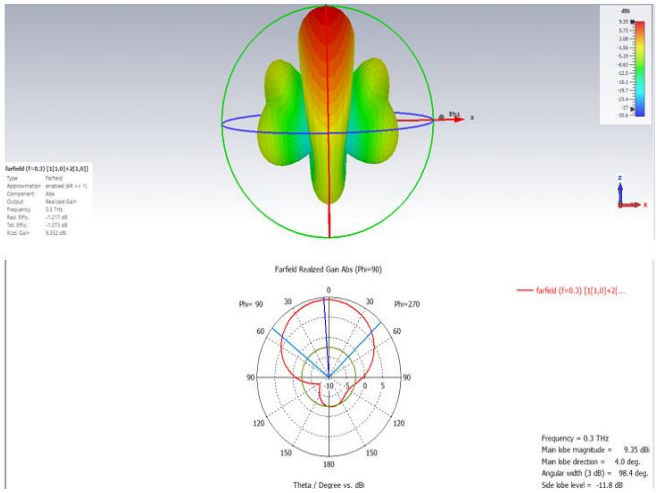



**Figure 8. Radiation pattern 9.352 dBi.**

***Table 4. the results of second parameters antenna.***

| Parameter | Value |
|---|---|
| Gain | 9.508 dBi |
| BW | 21.61 GHz |
| Return Loss | -25.85 dB |
| VSWR | 1.107 |
| Realized Gain | 9.352 dBi |
| total efficiency | -1.523 dB |

In summary as shown in table 5, the second design generally exhibits slightly improved performance compared to the first design, with higher directivity, gain, realized gain, lower VSWR, and slightly higher total efficiency. However, both designs have similar return loss and radiation efficiency.

**Table 5. the comparison design.**

| Parameter | First design (Single element) | Second design (Two elements) |
|---|---|---|
| Gain | 5.744 dBi | 9.508 dBi |
| BW | 21.89 GHz | 21.61 GHz |
| Return Loss | -41.05dB | -25.85 dB |
| VSWR | 1.0178 | 1.107 |
| Realized Gain | 5.242 dBi | 9.352 dBi |
| total efficiency | -0.9434 dB | -1.523 dB |

## 5- Conclusion

This project's goal is to create a rectangular dielectric resonator antenna designed for terahertz applications that runs at 300 GHz. CST Studio software will be used to simulate the antenna design. The results of simulations show that the suggested antenna functions in the intended 300 GHz

frequency. A number of metrics, including as the far−field pattern, S parameters, and VSWR, were assessed at the 300 GHz resonant frequency. An excellent fit between the antenna and the transmission line was shown by the antenna's measured return loss of −25.448 dB. With an overall antenna efficiency of −1.523 dB, the system was determined to have very few losses. Furthermore, the antenna's gain—a measure of its capacity to concentrate radiation in a certain direction—was found to be 6.769 dBi. The suggested antenna design is appropriate for terahertz applications, according to the simulation findings. In order to improve capacity and performance, the antenna can also be used as a component of massive MIMO (multiple−input multiple−output) antenna arrays, which are frequently employed in cutting−edge wireless communication systems.

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