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A Slotted Elliptical Patch Antenna for Six Generation Communication System in Terahertz Band

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Abstract

The advancement of wireless communication toward 6G networks necessitates the development of antennas that can function at terahertz (THz) frequencies (0.1-10 THz). This is essential to satisfy the growing need for rapid data transmission and minimal latency connectivity. However, conventional antenna designs often fail to deliver the required bandwidth, gain, and efficiency at these elevated frequencies, which constrains their applicability for 6G technologies. This research introduces the design and development of a multi-slotted elliptical patch antenna specifically optimized for 6G systems operating in the THz band. The primary objective is to enhance the antenna's performance, making it well-suited for high-frequency applications. The antenna is constructed on a Roger 5880 substrate with a dielectric constant of 2.2, a tangent loss of 0.0009, and a thickness of 6 μm. It measures precisely 140 × 100 μm^2. A 50-ohm microstrip feedline excites the antenna, ensuring optimal power transfer. Simulations conducted with Computer Simulation Technology software yield promising outcomes, showcasing a return loss (S_{11}) of −27.08 dB, a broad operational bandwidth of 1.25 THz (2.12-3.37 THz), a gain of 7.769 dB, directivity of 8.613 dB, and an efficiency of 89%. This multi-slotted elliptical patch antenna exhibits remarkable potential for 6G applications, offering a robust solution to meet the demands of forthcoming THz communication systems. Its superior performance positions it as an ideal candidate for high-speed communication networks, propelling the advancement of the next generation of wireless technology.

Categories: Microwave and RF Engineering, Wireless Communication Systems
Keywords: elliptical patch, 6g communication, thz band, computer simulation technology (cst) software, slotting technique

Introduction

The rapid increase in global demand for faster and more dependable wireless communication has expedited the evolution of next-generation technologies. The anticipated sixth-generation (6G) technology promises to be groundbreaking, offering exceptionally high data rates, expansive bandwidth, and ultra-low latency. Although 6G remains in the conceptual stage, it will debut around 2030. It will be instrumental in various high-demand applications, such as virtual reality, augmented reality, holographic communication, autonomous vehicles, and advanced wireless networks [1].

To fulfill the requirements of 6G, the terahertz (THz) band, generally ranging from 0.1 THz to 10 THz, has emerged as a promising spectrum. The THz band holds significant potential for ultra-high-speed communication, which is vital for the data-intensive applications envisioned for 6G [2]. However, developing efficient THz-band antennas present bandwidth, gain, and efficiency challenges, which are crucial for high-frequency applications. Consequently, crafting antennas that excel in the THz band is imperative for realizing the full capabilities of 6G [3]. Patch antennas have garnered attention as an ideal solution for high-frequency applications due to their compact size, ease of manufacturing, and compatibility with integrated circuit technology. Furthermore, they provide a cost-effective option for large-scale deployments. Nevertheless, antennas functioning within the THz band must demonstrate high gain, wide bandwidth, and minimal signal losses to ensure robust and efficient communication [4].

Various designs have been proposed to meet these needs. For example, a dual-band reconfigurable graphene-based antenna detailed in [5] achieved a bandwidth of 50 GHz with a gain of 4.01 dB. To further enhance performance, photonic band gaps and defective ground structures were utilized in [6], leading to a gain increase to 6.93 dB; however, this design did not tackle bandwidth and size limitations. Another study presented a miniaturized graphene-based patch antenna operating in the THz band, which obtained a high return loss of −57.54 dB and a bandwidth of 199.6 GHz, although its gain was restricted to 2.76 dB [7]. An asymmetric coplanar waveguide-fed patch antenna was developed recently, offering a gain of 6.14

dB and a compact design but with a narrower bandwidth of 92 GHz [8]. Given the shortcomings of existing THz antennas, this paper introduces a multi-slotted elliptical patch antenna specifically designed for 6G applications within the THz band. Elliptical patch antennas provide several advantages, including smoother current distribution, reduced surface wave losses, and the potential for enhanced gain and directivity [9]. Incorporating multiple slots into the design can further optimize performance by improving impedance matching, radiation efficiency, and return loss, which are critical for effective 6G communication [10,11].

This study presents a compact, high-performance antenna tailored for THz-band communication systems in 6G. The innovative elliptical, multi-slotted design offers significant bandwidth, gain, and efficiency advancements, establishing it as a promising candidate for next-generation high-speed communication networks.

This paper is structured as follows: Materials and Methods section examines the domain of 6G communication systems, investigating various frequency bands and their applications and also addresses the vital topic of antenna size determination, offering an in-depth explanation. Results section presents the simulation results obtained during the study. Discussion section analyzes the outcomes, featuring a comparative assessment of current THz antennas in relation to the proposed design. Lastly, Conclusion section wraps up the paper by summarizing the major findings and insights derived from the research.

Materials And Methods

THz band for 6G communication system

The increasing demand for data traffic largely drives the development of the 6G communication system. A study indicates that the global traffic volume was 7.4262 Exabyte (EB) per month in 2010, and it is projected to reach 5016 EB per month by 2030 [12]. Furthermore, our modern world is moving toward a fully automated environment, with sectors such as industry, healthcare, transportation, space, and marine systems becoming increasingly automated. In this evolving landscape, billions of sensors will need to be integrated into various systems. As a result, high data rates and reliable connectivity will be essential for advanced wireless communication. The 6G communication system promises high data rates, low latency, wide bandwidth, and rapid data transfer capabilities. Therefore, 6G communication could be crucial for enhancing wireless communication and managing escalating traffic volumes.

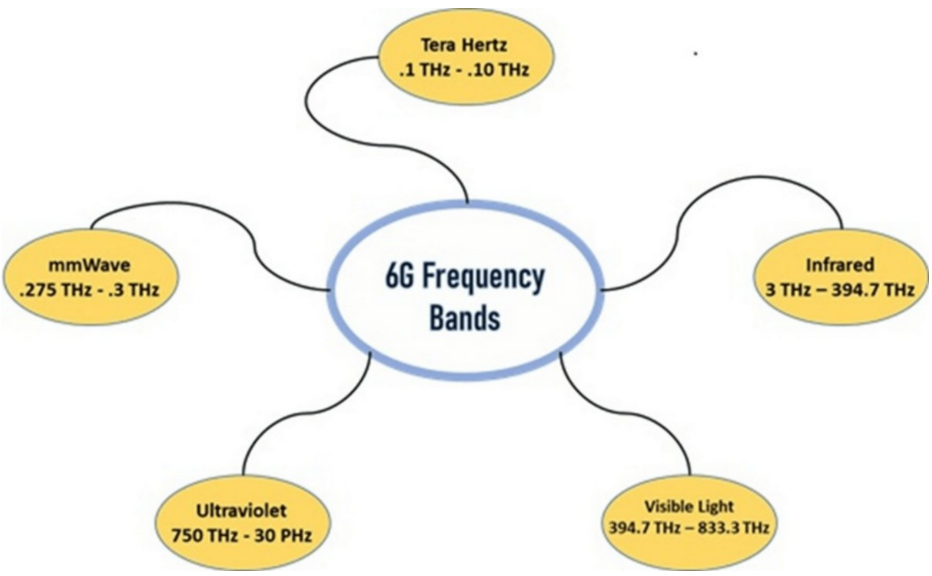

FIGURE 1: Frequency bands in 6G communication

A graphical representation of the supported frequency bands for 6G communication is shown in Figure *1*. From this figure, it is evident that the 6G communication system supports bands such as millimeter-wave (mmWave), THz, infrared, visible light, and ultraviolet. Among these, mmWave technology is currently implemented, while significant research is ongoing in the THz band. This paper specifically focuses on the THz band. With its high data rates, wide bandwidth, and low latency, the THz band offers a promising future for telecommunications. It enables ultra-broadband communication, enhances network capacity, and increases spectrum availability. The potential of the THz band in 6G communication is fascinating for applications such as virtual reality, augmented reality, and 3D holographic video conferencing [13]. These applications require substantial data transfer and ultra-fast processing capabilities, which the THz band is well-equipped to provide.

In addition, THz communication plays a vital role in applications like smart cities and autonomous vehicles, where high-speed, short-range data transmission is essential for communication between sensors, vehicles, and infrastructure. For critical safety operations, real-time responsiveness and timely decision-making are imperative, and the low latency feature of THz communication addresses these needs [14]. The THz band also supports THz imaging and non-invasive sensing, making it suitable for applications in security scanning and industrial quality control [15]. However, THz communication faces several challenges, including high atmospheric attenuation and limitations related to short-range connectivity. These challenges can be mitigated using an antenna model designed with high gain and directivity to effectively focus transmission energy [16]. Our proposed model aims to overcome these challenges, support diverse applications, and meet the requirements of 6G communication through the THz band.

Antenna dimension determination

In the realm of 6G communication systems, which operate across mmWave and THz frequencies, it is imperative to determine the optimal dimensions of antennas to achieve essential performance metrics, including gain, bandwidth, and efficiency. Precise calculations regarding these dimensions are vital to fulfill the demanding performance standards required by 6G applications. This research centers on the development of a compact antenna designed to function within the THz spectrum, facilitating high-speed communication. A key aspect of this design is the selection of the antenna's patch shape, which significantly impacts its overall performance. While earlier studies have investigated a variety of patch shapes, such as rectangular, circular [17], T-shaped [18], and triangular [19], the current design opts for an elliptical shape. This elliptical patch configuration is particularly advantageous for 6G applications in the THz band, as it is capable of delivering high data rates and expansive bandwidth, thus meeting the escalating demands of next-generation communication systems.

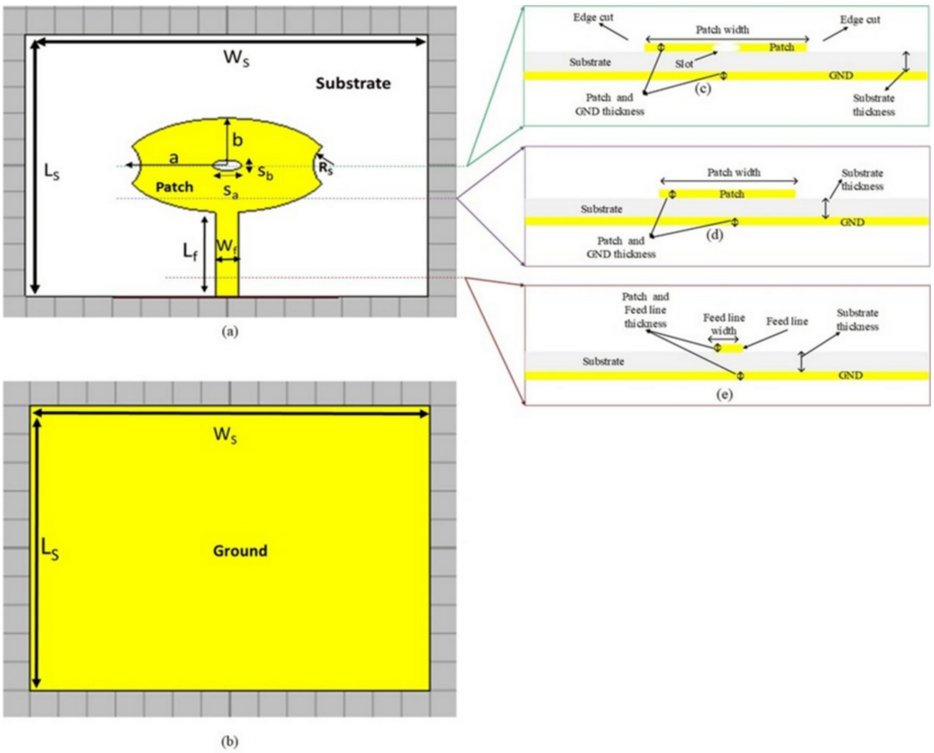

FIGURE 2: Structure of proposed antenna (a) front view, (b) back view, (c) cross-sectional view on the slotted area, (d) cross-sectional view on the patch, and (e) cross-sectional view on the feedline

The subsequent phase in the design process involves establishing the dimensions of the antenna structure, which are directly affected by its resonant frequency (☒0). This antenna is intended to function within a frequency range of 1-3.5 THz, with an operational frequency set at 2.5 THz. At this frequency, the wavelength of the signal is considerably shorter than that at lower frequencies, significantly influencing the antenna's dimensions. When designing an elliptical patch antenna, it is essential to determine both the semi-major axis and semi-minor axis of the patch. This calculation relies on the targeted resonant frequency, substrate properties, and operating environment conditions. The semi-major axis, denoted as 'a', of the elliptical patch is computed as described in the references [20,21].

$$a \approx \frac{\lambda_d}{2} \quad (1)$$

Where, λ_d is the wavelength in the dielectric medium which can be calculated as

$$\lambda_d = \frac{c}{f_0\sqrt{\varepsilon_{reff}}} \quad (2)$$

Here, C is the speed of light (3×10^8 m/s), f_0 is the resonant frequency, and ε_{reff} is the effective dielectric constant. And semi-minor axis, b of an elliptical patch is calculated as

$$b = \frac{a}{AR} \quad (3)$$

Where, AR is the aspect ratio, which is chosen based on the design requirements and radiation characteristics.

Proposed Antenna Design

Figure *2* illustrates the design of the proposed elliptical patch antenna, featuring two circular slots on either side and a central elliptical slot. In Figure *2a*, the front view is presented, while Figure *2b* displays the back view of the antenna. The overall dimensions of the antenna measure 140 × 100 µm², with a substrate thickness of 6 µm. The ground plane, patch, and feedline all have a uniform thickness of 1.2 µm. The feedline is 32 µm long and 7.76 µm wide, utilizing a thin microstrip configuration. The line impedance of the feedline is set at 50 ohms. Table *1* provides a detailed list of the parameters used in the design of the proposed antenna. Figure *2c*, *2d*, and 2e show the cross-sectional view of the patch, slotting area, and feed line, respectively.

Parameters	Value (µm)
Width of substrate (W_S)	140
Length of substrate (L_S)	100
Thickness of substrate	6
Semi-major axis (a)	35.9
Semi-minor axis (b)	17.96
Thickness of patch	1.2
Length of feedline (L_f)	32
Width of feedline (W_f)	7.76
Thickness of feedline	1.2
Circular slot radius (Rs)	5
Elliptical slot (Sa) & (Sb)	5 & 2

TABLE 1: Antenna parameters

Results

Simulation result

This section delves into the meticulous analysis of the proposed pentagonal patch antenna, a crucial step in understanding its performance and capabilities. By leveraging a robust simulation environment like Computer Simulation Technology (CST), we meticulously evaluate key performance metrics to unveil the true potential of this novel antenna design. Our investigation encompasses a comprehensive range of parameters, including the antenna's resonant frequency operating in the THz spectrum, bandwidth, reflection coefficient (S_{11}) expressed in decibels (dB), gain (dB), voltage standing wave ratio (VSWR), efficiency, radiation pattern, and surface current distribution. This multifaceted analysis provides a complete picture of the antenna's characteristics, paving the way for its optimal application in diverse THz communication and sensing scenarios.

Simulation Environment

The design and analysis of antenna performance is a complex process, often involving sophisticated simulation software. Popular tools like COMSOL, MATLAB, FEKO, CST MS, and HFSS [22] offer a wide range of capabilities. However, we chose to leverage the power of Computer Simulation Technology Microwave Studio (CST-MWS) for our project. CST-MWS has become a go-to tool for antenna design, renowned for its accuracy and user-friendly interface. Its high-performance electromagnetic (EM) solver makes it ideal for tackling challenging antenna designs, such as our proposed elliptical patch antenna (Figure *2*). Our approach involved a multi-step process. First, we meticulously designed the antenna using the design parameters outlined in Table *2*. Next, we employed CST-MWS to simulate its performance, allowing us to evaluate various design iterations. This rigorous simulation allowed us to optimize our antenna for maximum efficiency and optimal performance. By exploring multiple antenna models and their simulated results, we were able to refine our design and ultimately achieve a highly effective antenna. This comprehensive simulation approach ensures superior antenna performance and contributes to significant cost savings during the fabrication phase. By leveraging simulation tools like CST-MWS, we eliminate the need for costly and time-consuming physical prototyping iterations, ultimately streamlining the development process.

Return Loss (S_{11}) and Bandwidth

Return loss or reflection coefficient (S_{11}) serves as a vital parameter for assessing the radiation performance of an antenna, reflecting the amount of power bounced back from it. A more negative S_{11} value indicates reduced power reflection, signifying enhanced antenna performance. In Figure *3*, the return loss spectrum illustrates the relationship between frequency (in THz) along the *x*-axis and return loss (in dB) on the *y*-axis. The S_{11}, which characterizes the reflection properties at the antenna's input port, is employed in this study to evaluate the antenna's efficacy. The S_{11} is instrumental in defining the operational frequency range of an antenna by pinpointing the frequencies at which the antenna efficiently radiates and quantifying the power reflected. Typically, S_{11} values are negative, with values exceeding −10 dB regarded as acceptable. The characteristics of S_{11} also determine the antenna's bandwidth, indicating the frequency range in which the antenna maintains effective operation.

As depicted in Figure *3*, the antenna records a minimum S_{11} of −27.08 dB at its resonant frequency of 2.67 THz. Additionally, the figure highlights a broad operational bandwidth of 1.25 THz, extending from 2.12 THz to 3.37 THz. This expansive bandwidth is particularly advantageous for achieving high data transfer rates, which are crucial for meeting the demands of future telecommunications systems, especially within the context of 6G networks operating in the THz frequency band.

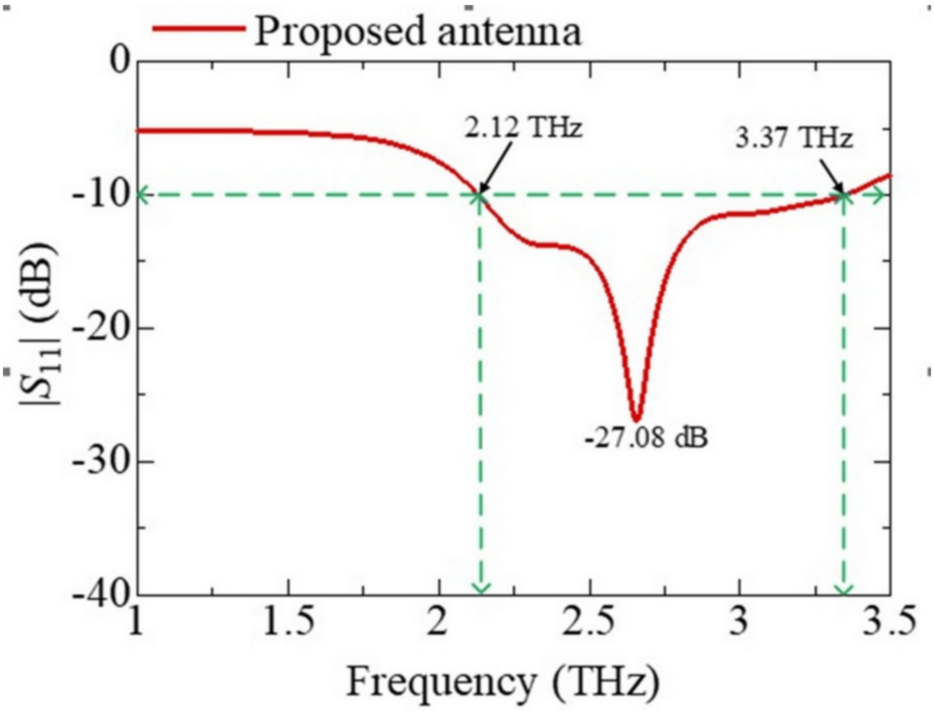

FIGURE 3: Spectra of return loss

VSWR

The VSWR is a crucial parameter in antenna design, reflecting the power transfer efficiency from the feeding source to the antenna. Think of it as a measure of how well the antenna “accepts” the signal being fed to it. A high VSWR indicates a significant mismatch, leading to power being reflected toward the source rather than radiated. The ideal scenario is a perfect impedance match, achieved when VSWR reaches unity (1). This signifies zero reflected power and optimal energy transmission. The VSWR can be calculated from the antenna’s return loss, a measure of reflected power, using a specific formula.

$$VSWR = \frac{1 + 10^{\frac{S_{11}}{20}}}{1 - 10^{\frac{S_{11}}{20}}} \quad (4)$$

This equation quantifies the mismatch degree based on the incident and reflected power ratio. Figure 4 visualizes the VSWR spectrum, depicting the relationship between frequency and VSWR. In this case, the resonant frequency of the antenna lies at 2.67 THz, where the VSWR value is measured at 1.173. Crucially, this minimum VSWR value below 2 confirms excellent impedance matching. This implies that the proposed antenna design efficiently transfers power from the feedline to the antenna, minimizing signal losses and ensuring optimal performance.

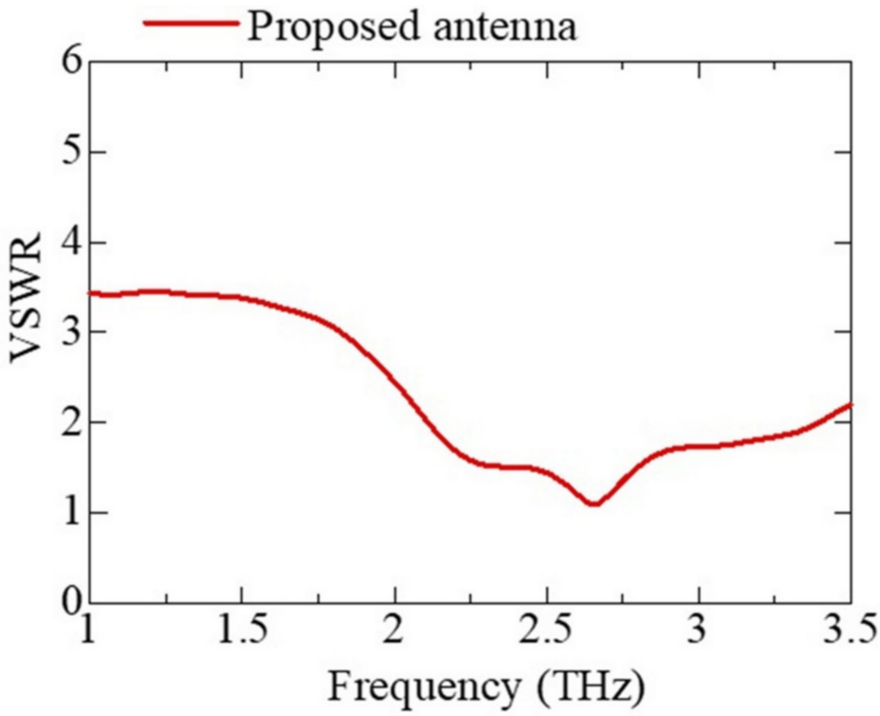

FIGURE 4: Spectra of VSWR

VSWR, Voltage Standing Wave Ratio

Gain, Directivity, and Efficiency

Gain quantifies an antenna's ability to concentrate its radiation, much like a magnifying glass focuses sunlight. A higher gain translates to a stronger signal transmitted in the desired direction, improving signal strength and reach. For instance, the antenna illustrated in Figure *5* achieves a maximum gain of 7.769 dB at 2.67 THz, demonstrating its ability to deliver a powerful signal in the intended direction, which is crucial for optimal coverage and performance. On the other hand, directivity measures the antenna's focus-how much of its radiated power is directed toward a specific point in space. A high directivity indicates that the antenna concentrates its energy in one direction, minimizing wasted energy and improving communication efficiency.

As evidenced in Figure *6*, the proposed antenna boasts a maximum directivity of 8.61 dB at 2.67 THz, highlighting its ability to focus its radiation effectively, which is vital for applications demanding precise and directional communication. Finally, efficiency reflects how effectively an antenna converts input power into radiated power. An efficient antenna minimizes losses due to resistance or other factors, ensuring the maximum power is utilized for transmission. The antenna in question exhibits a high efficiency of 89% at 2.67 THz (as illustrated in Figure *7*), indicating that most of the input power is effectively radiated. This is essential for maximizing performance in high-frequency applications like 6G communication, where minimizing power loss is crucial for optimal signal strength and range. By understanding these three fundamental performance metrics, we gain a comprehensive view of how antennas work and what makes them practical for different communication applications.

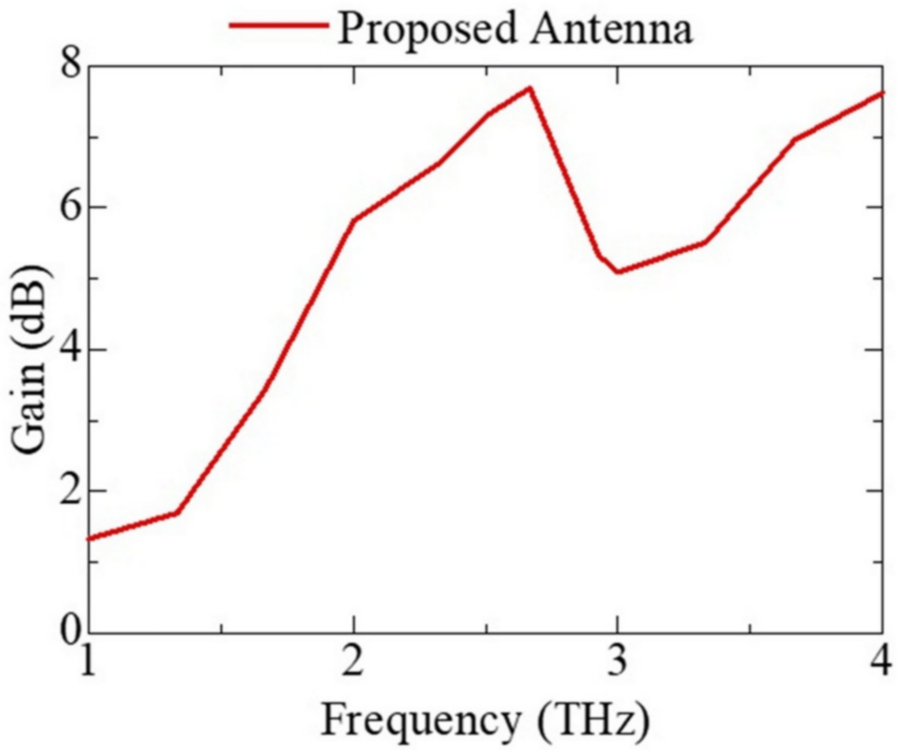

FIGURE 5: Spectra of gain vs frequency

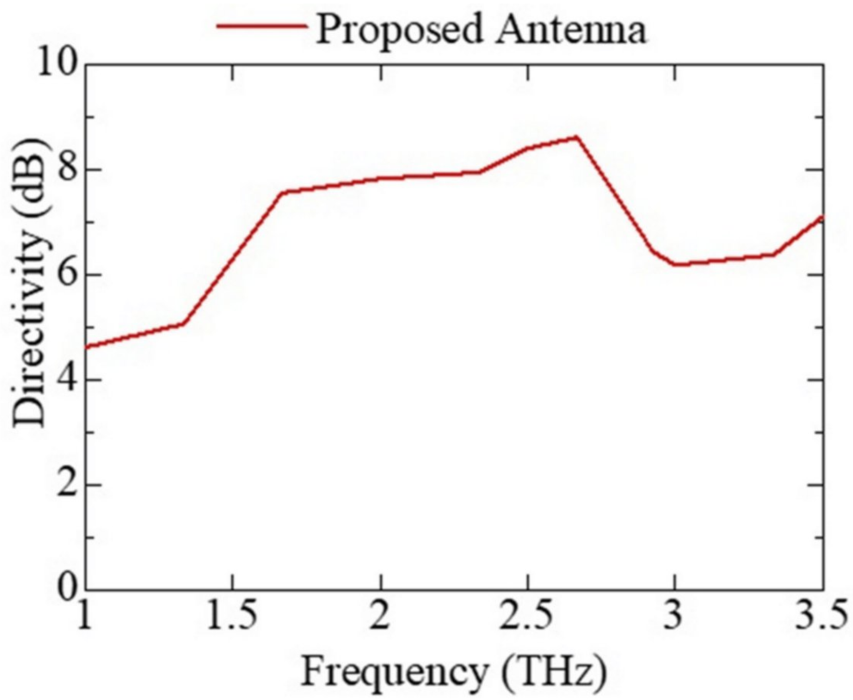

FIGURE 6: Spectra of directivity vs frequency

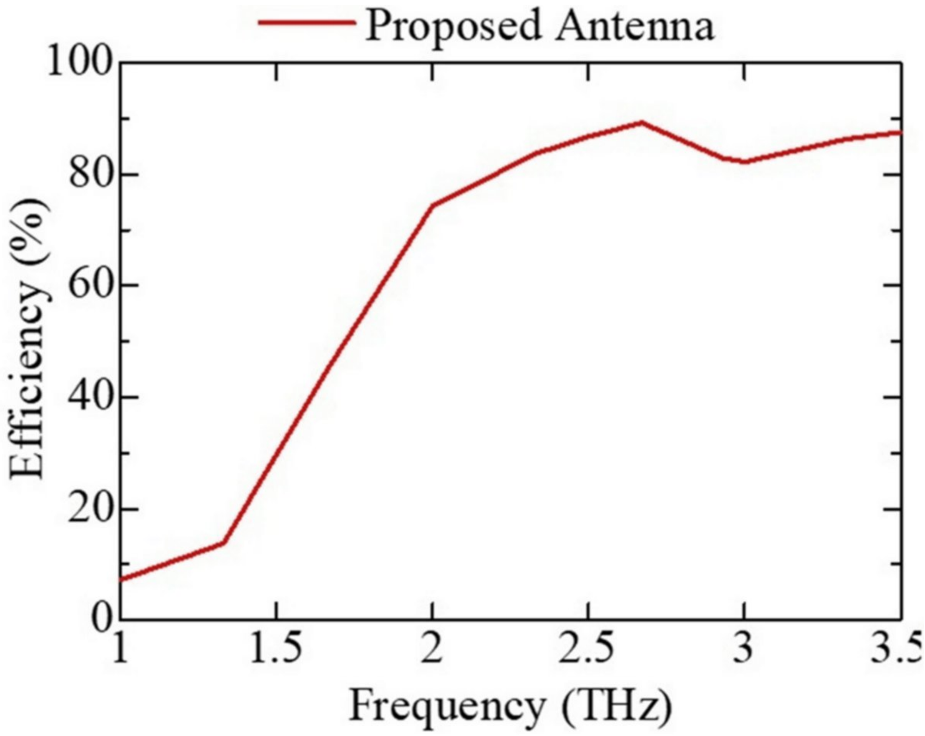

FIGURE 7: Spectra of efficiency vs frequency

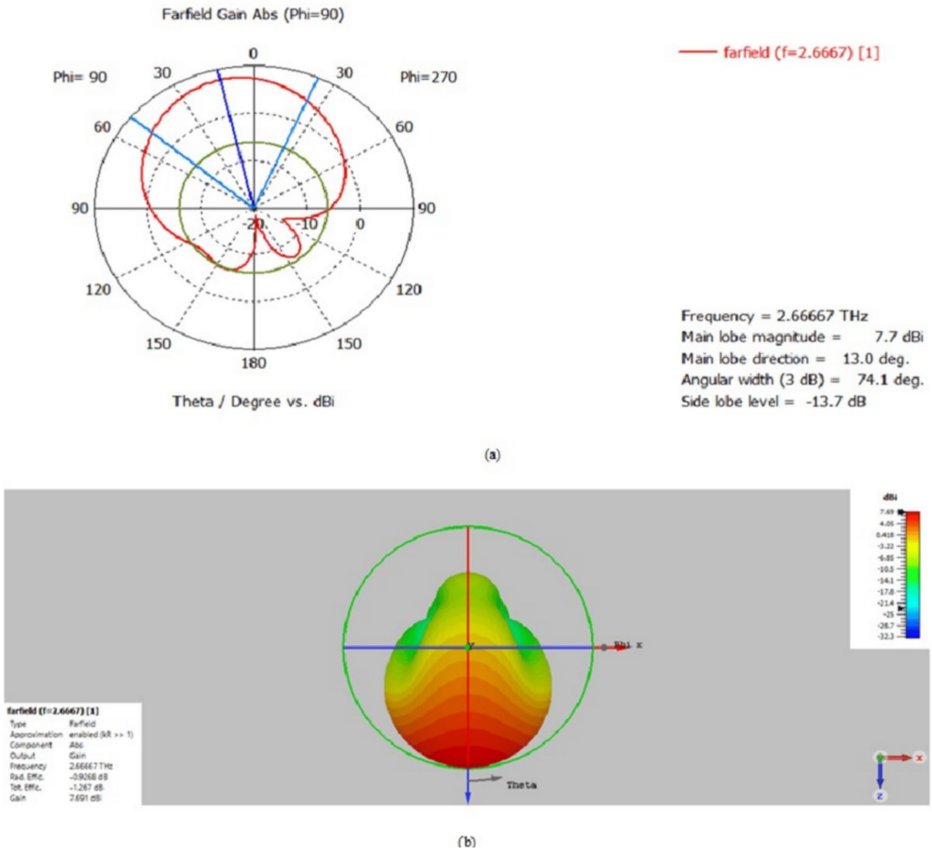

FIGURE 8: Radiation pattern at resonant frequency of 2.667 THz (a) polar view (b) 3D view

Radiation Pattern

The radiation pattern of an antenna is akin to its signature, revealing its unique ability to radiate or receive EM energy in different directions. This graphical representation, often displayed in polar or 3D formats, unveils the intricate dance of power distribution as the antenna interacts with the surrounding space. The radiation pattern serves as a vital compass, guiding our understanding of the antenna's performance and revealing its strength in transmitting and receiving signals effectively.

The proposed antenna, showcased in Figure *8*, exhibits a compelling characteristic-a directed radiation pattern. This focused energy distribution, characterized by a narrow main lobe, signifies that the antenna channels most of its power in specific directions (Phi = 90° and Phi = 270°). This inherent directionality makes it a prime candidate for applications demanding focused energy, such as point-to-point communication, where precision in signal transmission is paramount. The intensity of the radiation pattern, often depicted using a color gradient with red representing peak gain, illuminates the antenna's gain. This metric quantifies the antenna's prowess in concentrating power in specific directions. The proposed antenna boasts a peak gain of 7.7 dBi, a testament to its ability to radiate energy toward the intended target effectively.

This gain further reinforces its suitability for long-range communication or applications demanding strong signal strength in specific directions. The narrow main lobe, a distinctive feature of the radiation pattern, emphasizes the antenna's suitability for directional communication. This focus ensures that energy is transmitted over long distances with minimal interference. It is an ideal choice for high-frequency communication systems, such as the cutting-edge 6G networks operating in the THz band. In these systems, precise energy directionality is essential for achieving the high-speed data transmission that defines 6G communication. The radiation pattern, therefore, provides invaluable insights into the antenna's power distribution, ultimately determining its suitability for specific applications. In scenarios requiring directional communication and high gain, such as 6G and THz communication, the antenna's narrow main lobe and impressive directional gain at 2.67 THz solidify its potential for successful implementation in point-to-point communication and high-frequency applications.

Surface Current

The surface current distribution at 2.667 THz is depicted in Figure 9. Areas exhibiting the highest current density, reaching up to 19,003 A/m, are highlighted by red markings on the color scale, while blue regions denote the lowest current density. This simulation effectively visualizes the interplay between EM waves and the structure, illustrating how surface currents are dispersed throughout. The red and yellow zones indicate regions of maximum current density, with the center of the structure displaying the most substantial concentration of surface currents. This observation implies that the central portion of the structure resonates at 2.667 THz.

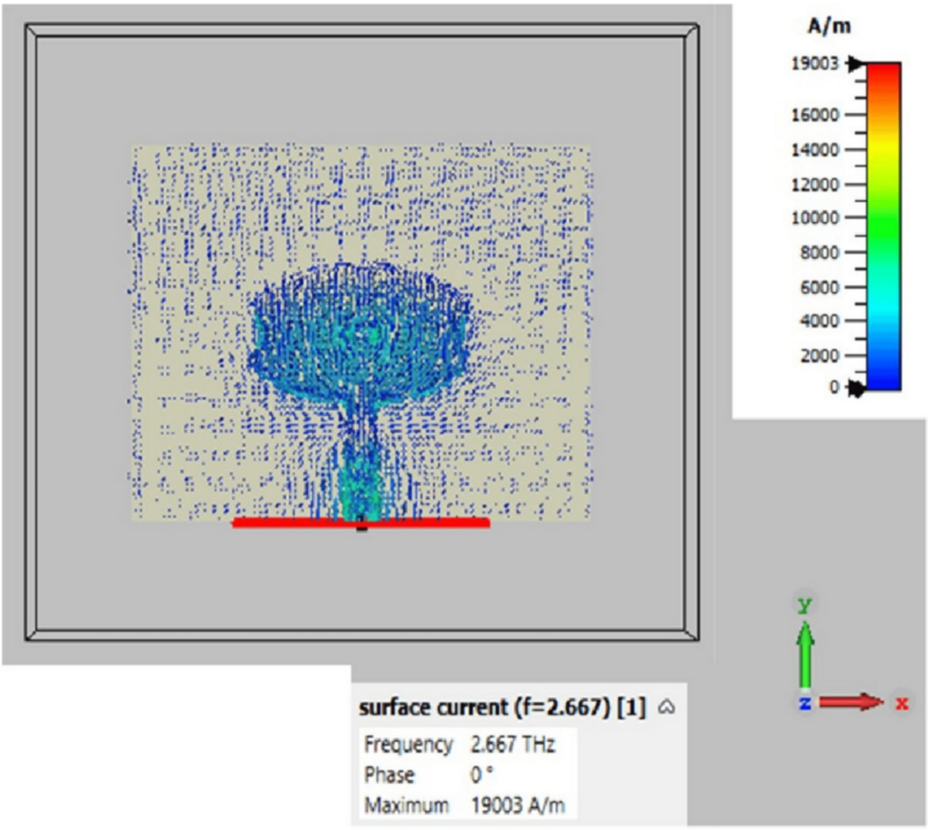

FIGURE 9: Surface current at resonant frequency 2.667 THz

From this central point, the surface current radiates symmetrically outward, with its density progressively diminishing toward the edges of the structure. The elevated surface current density at the center signifies that this area is the most actively engaged in resonance at this frequency. Resonant regions typically witness heightened EM activity, resulting in localized increases in current density. At THz frequencies, materials with particular properties, such as plasmonic resonance, can effectively concentrate surface currents within these resonant zones. The observed distribution indicates that resonance is instrumental in concentrating current density in specific areas of the structure. Given the notable accumulation of surface currents in the central region, this design may be well-suited for THz applications where the optimization and management of surface currents are vital for performance, such as in THz sensors, antennas, or filters. In such scenarios, concentrating surface currents at a defined frequency can significantly enhance the sensitivity and efficiency of the structure.

Discussion

The slotted elliptical patch antenna presented in this study demonstrates exceptional performance characteristics, distinguishing it from existing designs and making it an ideal candidate for 6G communication systems operating within the THz frequency range. As summarized in Table 2, the comparative analysis highlights the antenna's remarkable performance across several critical metrics. With a return loss (S_{11}) of −27.08 dB, it is slightly less negative than the values reported in references [5] (−64.16 dB), [7] (−57.54 dB), and [8] (−28 dB), yet it strikes a favorable balance with other essential performance attributes, including bandwidth and gain. Furthermore, when compared to designs with higher (less negative) S_{11} values such as [6] (−21.67 dB), [9] (−24.5 dB), and [10] (−16.86 dB), the proposed antenna exhibits superior overall performance. Notably, the antenna features an impressive operational bandwidth of 1250 GHz, significantly surpassing the capabilities of other designs, like [9] (415 GHz) and [7] (199.6 GHz), underscoring its suitability for the high-speed, data-intensive applications characteristic of 6G networks. Additionally, with a gain of 7.769 dB, it outperforms most contemporary designs, including [8] (5.00 dB) and [9] (5.87 dB), indicating enhanced directivity and signal strength. Its efficiency, rated at 89%, also exceeds many alternatives, such as [6] (64.12%) and [8] (60%). The compact dimensions of 140 × 100 μm² (14,000 μm²) further enhance its practicality, especially in comparison to larger structures like [5] (100,000 μm²), [6] (37,440 μm²), and [9] (250,000 μm²), making it exceptionally suited for miniaturized systems. This compact design, coupled with high bandwidth and efficiency, positions it as a promising candidate for next-generation communication technologies. It is crucial to mention, however, that this study does not include experimental validation, which may limit confidence in its applicability under real-world conditions. Additionally, challenges related to fabrication complexity at THz frequencies and potential restrictions on the operational frequency range remain. Future experiments are necessary to confirm the simulated results and address any discrepancies in real-world scenarios. Fabrication challenges may be alleviated through advanced techniques such as nanofabrication and precision lithography. Moving forward, future research should focus on integrating the antenna into larger 6G systems to assess its impact on overall system performance. Efforts to further enhance gain and broaden operational frequency ranges will ensure its adaptability for various 6G applications. Additionally, optimizing the design for cost-effective manufacturing while maintaining high performance will enhance its market viability. In conclusion, the proposed slotted elliptical patch antenna exhibits outstanding capabilities in bandwidth, gain, and efficiency, positioning it as a promising solution for 6G THz communication. Future research initiatives will concentrate on validation, addressing fabrication challenges, and system integration to enhance its applicability and adaptability in practical scenarios.

Ref.	Antenna Size (μm^2)	Return Loss, S_{11} (dB)	Bandwidth (GHz)	Gain (dB)	Efficiency (%)
[5]	1000 × 1000 (100,000 μm^2)	64.16	26.7	6.793	98
[6]	208 × 180 (37440 μm^2)	−21.67	50	4.01	64.12
[7]	100 × 100 (10000 μm^2)	−57.54	199.6	2.76	-
[8]	24 × 24 (576 μm^2)	−28	38	5	60
[9]	500 × 500 (250,000 μm^2)	−24.5	415	5.87	80
[10]	40 × 50 (2000 μm^2)	−16.86	92	6.14	-
Proposed Antenna	140 × 100 (14,000 μm^2)	−27.08	1250	7.769	89

TABLE 2: Comparative analysis

Conclusions

This research demonstrates the successful design and development of a multi-slotted elliptical patch antenna optimized for 6G systems operating in the THz frequency band. The antenna, fabricated on a Rogers 5880 substrate, delivers impressive performance characteristics, including a return loss (S_{11} of −27.08 dB, an operational bandwidth of 1.25 THz (ranging from 2.12 THz to 3.37 THz), a gain of 7.769 dB, directivity of 8.613 dB, and an efficiency of 89%. These results highlight the antenna's suitability for high-frequency applications and its potential to meet the increasing demands of THz communication systems. The design's superior performance makes it a promising solution for 6G networks, ensuring high-speed and low-latency connectivity. This work contributes to advancing antenna technologies required to support the next generation of wireless communication, paving the way for the efficient deployment of 6G systems in the THz band. Future work will focus on experimental validation, further optimization of the antenna structure, and exploring its integration into larger systems for broader 6G applications.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Md. Ashraful Islam, Sujan Chandra Roy, Rakibul Hasan Masum

Acquisition, analysis, or interpretation of data: Md. Ashraful Islam, Md. Reaz Hossain, Md. Firoz

Ahmed, Ripa Sarkar, Rakibul Hasan Masum, Md. Matiqul Islam

Critical review of the manuscript for important intellectual content: Md. Ashraful Islam, Sujan Chandra Roy, Md. Reaz Hossain, Md. Firoz Ahmed, Ripa Sarkar, Rakibul Hasan Masum, Md. Matiqul Islam

Supervision: Md. Ashraful Islam, Md. Reaz Hossain, Md. Firoz Ahmed

Drafting of the manuscript: Sujan Chandra Roy, Md. Firoz Ahmed, Rakibul Hasan Masum

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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