Journal of Nano- and Electronic Physics
Vol. **16** No 4, 04006(5pp) (2024)

Журнал нано- та електронної фізики
Том **16** № 4, 04006(5cc) (2024)

REGULAR ARTICLE

A Massive 0.3 THz Bandwidth with High Gain 6G Antenna

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(Received 12 April 2024; revised manuscript received 18 August 2024; published online 27 August 2024)

In this paper, A Massive bandwidth High gain Compact 6G antenna is proposed. The antenna attains a massive bandwidth of 300 GHz with resonant at 148.6 GHz, 190.2 GHz, 257.8 GHz, 308.8 GHz, and 363.6 GHz covering 100 GHz to 400 GHZ which is otherwise termed as 0.1 THz to 0.4 THz spectrum. The reflections are observed to be below – 10 dB with the maximum reflection at – 65 dB. The maximum gain of 17 dBi and a minimum of 1 dBi is observed throughout the operating band. The gain at resonant points 148.6 GHz, 190.2 GHz, 257.8 GHz, 308.8 GHz, and 363.6 GHz are 6.600199 dBi, 16.30173 dBi, 8.14491 dBi, 6.260792 dBi, 13.33571 dBi respectively. The proposed design is embedded over a Rogers RT Duroid 5880 substrate material with a thickness of ($t = 0.08$ mm), dielectric constant ($\varepsilon_r = 2.2$), and loss tangent (0.0009) using a High-Frequency Structure simulator. Furthermore, the design steps and evolution of the antenna have been discussed. Supporting the parametric analysis which explains the impedance match at each stage of evolution such as development from Rectangular patch antenna (RPA) to Circular patch antenna (CPA). Configuration of inset feed with Full Ground being deployed, the proposed design becomes an eminent prototype for mobile communication in 6G Spectrum.

Keywords: Sixth generation (6G), Terahertz (THz), Massive bandwidth, High Gain, Full Ground.

DOI: 10.21272/jnep.16(4).04006 PACS numbers: 73.61.Jc, 71.20.Mq, 88.40.jj, 88.40.hj

1. INTRODUCTION

Technologies for wireless communication rely heavily on flexibility and agility to handle unpredictable and dynamic radio environments. Among the numerous instances of adaptation, we can discover in today's mobile communications networks are adaptive power regulation and modulation, dynamic frequency allocation, and intelligent scheduling. [1] Since 6G wireless communication technology is still in its early stages of development, it is currently undefined. An important use of the terahertz (THz) spectrum will be to support the 6G wireless communication infrastructure. The wave-length from 3 mm to 0.03 mm, or the frequency range between 0.1 and 10 THz, is referred to as the THz band. Between 0.1 and 0.3, THz is defined as a sub-THz region and from 0.3 – 10 THz is defined as a THz region. From 0.1 – 0.3 THz is defined as a sub-THz region and from 0.3 – 10 THz is defined as a THz region. [2-3]. Among millimeter-wave and infrared regions, the THz band – also called the THz gap because of the dearth of materials responding to these frequencies is the least explored frequency range. Terra waves or T waves are other names for the THz band [4].

The frequency range of 1 – 10 GHz is the most ideal range to meet wireless needs, but propagation losses resulting from precipitation and atmospheric absorption play a supporting role and are typically ignored [1]. However, there is a lot of congestion in the frequency up to 10 GHz. At the September 2018 Mobile World Congress, the Federal Communication Commission (FCC) of the United States recommended that 6G technology be used for THz spectrum-based networks and spatial multiplexing technologies [5-6]. When it comes to communication distance propagation, the THz wave can withstand higher path losses than the mm Wave because of humid air conditions. A significant limitation on communication lengths is a very high route loss, which is one of the key issues of THz band frequencies [7-8]. strong-gain antennas are essential at THz frequencies to counteract strong atmospheric absorption and high path loss, which will have an impact on the wireless link's budget. In recent decades, there has been extensive research conducted on the average attenuation of THz

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Cite this article as: M. Jeyabharathi et al., *J. Nano- Electron. Phys.* 16 No 4, 04006 (2024) https://doi.org/10.21272/jnep.16(4).04006

radiation caused by atmospheric gases and rain. As a result, the International Tele-communication Union (ITU) has developed thorough guidelines P.676-11 and P.838-3, which are currently available for frequencies up to 1 THz. [9-11]. Along with active components and related technologies, the antenna is an essential part of any THz wireless communication system [12-14]; the system's overall communication quality has a direct impact on the antenna's performance [13-16].

2. DESIGN OF PROPOSED ANTENNA

The components of a planar microstrip patch an-tenna are a dielectric substrate sandwiched between the two bottom and top layers, referred to as the ground layer and patch, respectively. The design of these Planar Microstrip Patch Antennas (PMPAs) can be achieved by etching various shapes onto the copper layers of a double-sided PCB, such as squares, circles, ellipses, E, H, and S. While the bottom PCB layer serves as the ground plane and may have a defective or plane surface, the top patch layer serves as both a radiator and a receptor for transmitting and receiving antennas. Antenna variations in Microstrip Patch Antennas (MPAs) are caused by the fringing effect that exists between the ground plane and the corners of the specified patch structure. Different geometries can be used by patch antennas to find resonant frequency bands for needed applications. These days, because of their ability to exhibit circular polarization among various patch structures, elliptical patch antennas are receiving a lot of interest. The only antenna type that can meet the requirements of today's wireless communication systems for broadband and numerous features is the elliptical patch fractal antenna.

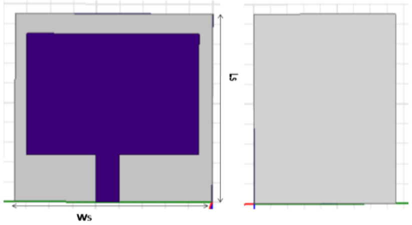

Fig. 1 – Front and Rear view of the proposed antenna

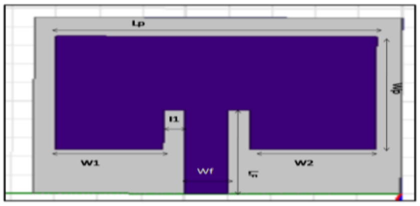

Fig. 2 – Rear view of Patch

The suggested multiband antenna design for THz spectrum applications is depicted in Fig. 1. A Rogers RT Duroid 5880 substrate material with a thickness ($t = 0.08$ mm), dielectric constant ($\varepsilon_r = 2.2$), and loss tangent (0.0009) is used in the design of the suggested structure. The dimensions of the RT Duroid substrate are 1.9 mm × 1.7 mm × 0.08 mm, with a rectangular patch. With *Y*- and *Z*-axis dimensions of 0.02 mm and 0.08 mm, respectively, a lumped port with 50 Ohm resistance is employed to accomplish impedance matching, and the antenna is fed using the microstrip inset feed method.

Table 1 – Dimensions of patch

PARAMETER	DIMENSION
L_S	1.9 mm
W_S	1.7 mm
L_P	1.4823 mm
W_P	1.2 mm
D_H	0.08 mm

Several iterations and optimizations were undertaken to attain huge bandwidth and multi-resonance; these are covered in the development section. The dimensions of the substrate and patch are given in Table 1, with the figure shown in Fig. 2.

3. DEVELOPMENT OF PROPOSED ANTENNA

Initially, the microstrip rectangular patch antenna has been designed by regulating with the design procedures. The design formulas are listed below and the evolution proposed antenna is given in Fig. 3.

$$L_S = L + 6h \qquad (1)$$

$$W_S = W + 6h \qquad (2)$$

$$Feed\ length\ \ L_f = \frac{\lambda_g}{4} \qquad (1)$$

λ_g is guided wavelength and it is given by

$$\lambda_g = \frac{\lambda}{\sqrt{\varepsilon_{r\,eff}}} \qquad (4)$$

$\varepsilon_{r\,eff}$ is given as,

$$\varepsilon_{\mathrm{reff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{\frac{-1}{2}} \qquad (5)$$

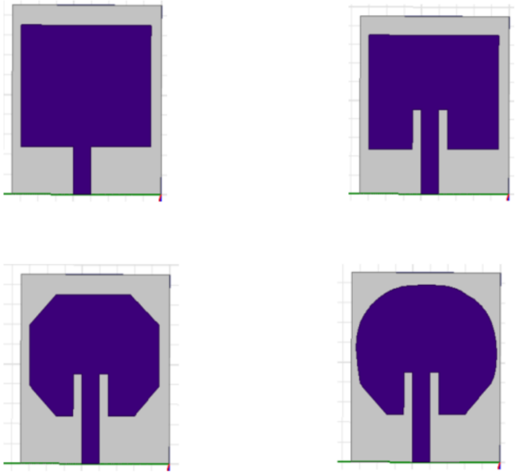

Fig. 3 – Evolution of Proposed antenna

Further, after analyzing the reflection coefficients, modifications have been made which are listed as steps as follows.

Step 1: Design of Microstrip Patch Antenna using Design Equations.

Step 2: Modifying the feeding technique. The Centre Inset Feeding Technique is being deployed to Improve the Impedance match which is reflected in the improvement of the reflection coefficient.

Step 3: Etching triangular slots at all 4 corners of the patch, to improve the bandwidth coverage.

Step 4: Surfing the triangular slots with elliptical patches, to make the corners smooth whose results are being discussed in the parametric analysis and the final stage antenna is given in Fig. 4.

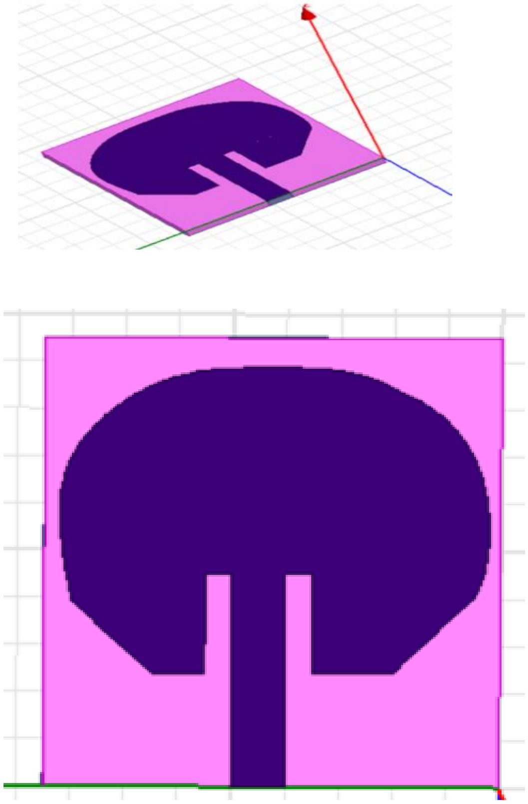

Fig. 4 – Final Stage Antenna

The layout of the antenna without altering the physical length of the antenna, a corner circularized patch with $n = 3$ iterations (i.e., 3 stages of modification) is employed to achieve the multiband and huge bandwidth features of the proposed antenna structure. The suggested antenna's radiator or receptor element is a circular patch construction with fractal corners, supplied by a microstrip inset feed line. Every stage covered in the development section of the suggested design shows certain outcomes, as seen in Fig. 5.

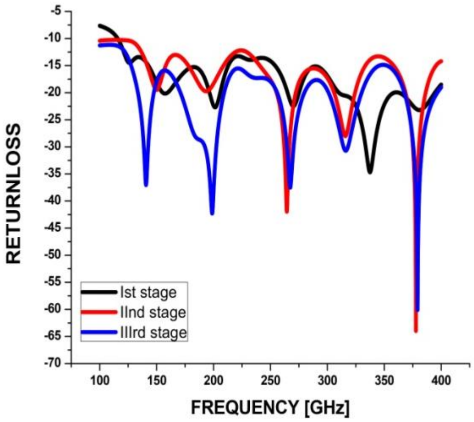

Fig. 5 – Comparative analysis of reflection coefficient of each stage

4. RESULT AND DISCUSSION

Operating at five distinct remnant points – 148.6 GHz, 190.2 GHz, 257.8 GHz, 308.8 GHz, and 363.6 GHz – the proposed system spans a total bandwidth of 300 GHz, ranging from 100 GHz to 400 GHz, also known as the 0.1 GHz to 0.4 GHz spectrum. The antenna operates magnificently, displaying a large band-width and good gain. The outcomes are displayed below from Figs. 6 to 8.

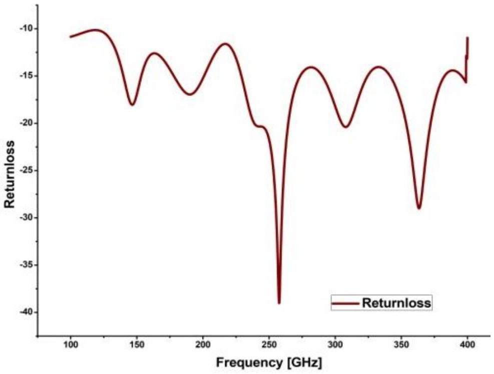

Fig. 6 – Return loss

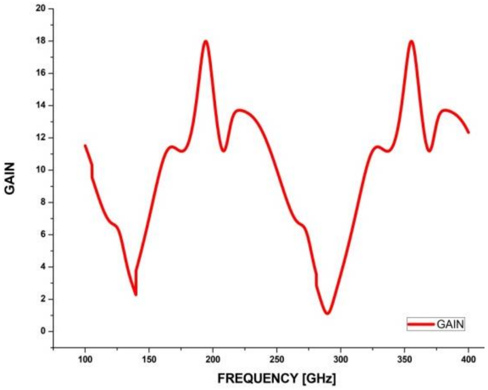

Fig. 7 – Frequency vs Gain

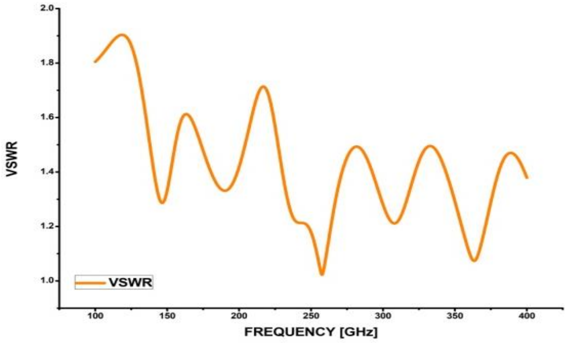

Fig. 8 – VSWR

A high gain of 17 dBi and a low gain of 1 dBi are seen throughout the operating range in Fig. 7, which shows frequency vs. gain. At resonant frequencies of 148.6 GHz, 190.2 GHz, 257.8 GHz, 308.8 GHz, and 363.6 GHz, the respective gains are 6.600199 dBi, 16.30173 dBi, 8.14491 dBi, 6.260792 dBi, and 13.33571 dBi. The impedance match is explained by the VSWR, which is clearly visible. Fig. 9 shows the current distribution plots across *E*-Filed and *H*-Field, where a medium distribution has been noted at the ports.

It may be observed that the suggested system with full ground has demonstrated a high gain and enormous bandwidth. Because of this, the system is a leading prototype for mobile communication on the 6G band. According to the literature, backward radiation from defective ground constructions should be avoided when deploying mobile communication. This design incorporates the same, making the radiator appropriate for THz applications in mobile communication.

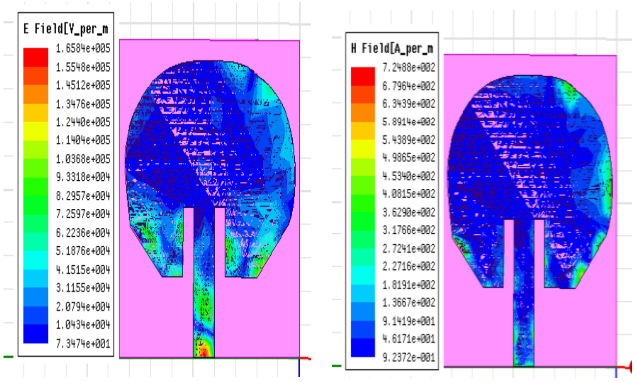

Fig. 9 – Current Distribution

5. CONCLUSION

Nowadays, the 6G antenna is important designed for many industrial applications in wireless communication. Enormous growth in the antenna system through the terahertz proposes better parameter performance. The large high-gain, compact antenna with a 300 GHz bandwidth has been presented. Its dimensions are 1.9 × 1.7 × 0.08 mm, and it has resonances at 148.6 GHz, 190.2 GHz, 257.8 GHz, 308.8 GHz, and 363.6 GHz. It has been noted that the gain and impedance match is extremely precise. This setup turns into an ideal 6G-THz mobile communication antenna. The simulated results for the proposed system are deter-mined by using the HFSS software to yield better performance than the conventional methods.

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Широка смуга пропускання 0,3 ТГц в 6G антені з високим коефіцієнтом підсилення

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У статті пропонується компактна 6G антена з великою пропускною здатністю і високим коефіцієнтом підсилення. Антена має широку смугу пропускання 300 ГГц із резонансом на частотах 148,6; 190,2; 257,8; 308,8 і 363,6 ГГц, що охоплює діапазон від 100 до 400 ГГц, що інакше називається спектром від 0,1 до 0,4 ТГц. Відбиття спостерігаються нижче – 10 дБ з максимальним відображенням на рівні – 65 дБ. Максимальне посилення 17 дБі та мінімальне 1 дБі спостерігається по всьому робочому діапазону. Коефіцієнт підсилення в резонансних точках 148,6: 190,2; 257,8; 308,8 і 363,6 ГГц становить 6,60; 16,30; 8,14; 6,26 і 13,36 дБі відповідно. Запропонована конструкція вбудована в матеріал підкладки Rogers RT Duroid 5880 із товщиною ($t = 0.08$ мм), діелектричною проникністю ($\varepsilon_r = 2.2$) і тангенсом втрат (0,0009) за допомогою симулятора високочастотної структури. Крім того, обговорювалися етапи розробки та еволюція антени. Підтримка параметричного аналізу, який пояснює відповідність імпедансу на кожному етапі еволюції, наприклад розвиток від прямокутної патч-антени (RPA) до круглої патч-антени (CPA). Конфігурація вставного каналу з розгортанням Full Ground, запропонована конструкція стає видатним прототипом для мобільного зв'язку в 6G Spectrum.

Ключові слова: Шосте покоління (6G), Терагерц (ТГц), Широка смуга пропускання, Високе підсилення, Повне заземлення.

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