Design of Truncated Microstrip Square Patch Antenna for Terahertz Communication

(1)Muhammad Zubair, (1)Abdul Jabbar, (2)Mobayode O. Akinsolu, (1)Muhamamd Ali Imran, (1)Bo Liu and (1)Qammer H. Abbasi

(1)James Watt School of Engineering, University of Glasgow, UK
(2)Faculty of Arts, Science and Technology Wrexham Glyndŵr University, UK
{m.zubair.1; a.jabbar.1@student.gla.ac.uk
{Muhammad.Imran; Bo.Liu; Qammer.Abbasi }@glasgow.ac.uk

***Abstract*— This paper presents the effect of truncation on each corner of a microstrip square patch that can be utilized for Terahertz (THz) communication. The truncated microstrip patch antenna has a bandwidth of 410 GHz (-10 dB impedance bandwidth from 3.48 THz to 3.90 THz). Moreover, the proposed antenna reveals a minimum reflection coefficient of about -29 dB, maximum gain of 5.01 dBi, directivity 6.06 dBi and a total radiation efficiency of 80.2% at 3.65 THz frequency. The proposed antenna is suitable for future Terahertz communication and imaging applications.**

Keywords— Truncated microstrip antenna, THz, PBG.

I. INTRODUCTION

Wireless communication networks are becoming increasingly crowded and denser. According to current statistics and market demand for data transmission rates, their bandwidth will certainly exceed gigabits per second (Gbps) and possibly go up to terabits per second (Tbps) in the next 10 to 15 years[1]. Therefore, to keep up with the present-day and future trends, high-speed internet and substantial bandwidths are required for better performance.

In particular, the advancement in the terahertz (THz) range of frequencies has proven to have the necessary capabilities to meet the demand for high data rate. The terahertz (THz) frequency spectrum comprises the range from 0.1 to 10 THz and lies between microwave and infrared regions. In a typical THz communication system, the transmission antenna must be low-cost, small-size, with wide-bandwidth and high gain. Due to these characteristics, the design of efficient antennas is crucial in THz wireless communication. Microstrip patch antennas are one of the promising candidates for the THz wireless communication [2].

This paper discusses a modified compact (100 µm × 100 µm) design of a truncated microstrip patch antenna for THz wireless communication. The truncation are implemented at each corner of a radiating square patch for the first time (to the best our knowledge), with a bandwidth of 410 GHz and an impedance bandwidth of 11%. Prior to the truncating the edges of the radiating square patch, the performance of the structure was not satisfactory due to low radiation and limited bandwidth at the resonance frequency (see Section III)
Thus, the truncated design shows an improved radiation parameter (see Section III). The performance of the truncated patch antenna was compared with a previously published THz patch antenna built on a homogeneous substrate [3][4][5][6].

II. ANTENNA DESIGN

The geometry of the proposed antenna is shown in Fig. 1. The antenna is designed on a polyamide substrate having a dielectric constant of 3.5, a thickness of 10 µm and loss tangent (tan δ) of 0.0025. It is fed by microstrip line connected to its radiating square patch. The choice of polyamide substrate is due to the fact that it is appropriate for applications that require a high degree of dimensional stability under extreme environmental conditions [2]. In this study, the truncated square patch is fed with an in-set microstrip technique to ensure that the antenna is properly fed. The modified truncated square patch structure enhances the bandwidth, radiation efficiency and reflection coefficient of the antenna has the significant effect on the performance of bandwidth. The antenna dimension are depicted in Fig 1 and the overall is quite compact.

III. SIMULATED RESULTS

The truncated patch antenna structure was designed and simulated in CST Microwave Studio using a maximum cell density of 15 cells per wavelength, a total of about (657,688) hexahedral mesh, while the radiation of the antenna was examined in the frequency range of 2.4 to 4 THz, using the finite integration approach (FIT) available in CST Microwave studio.

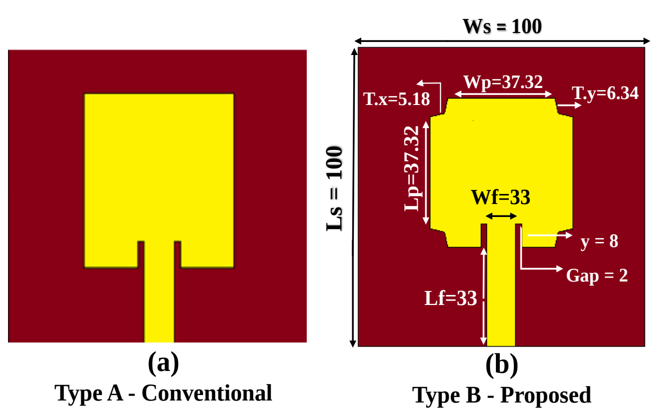

Fig. 1. (a) Type A (conventional) antenna (b) Type B (proposed) antenna Truncated microstrip patch antenna (dimensions in micrometer).

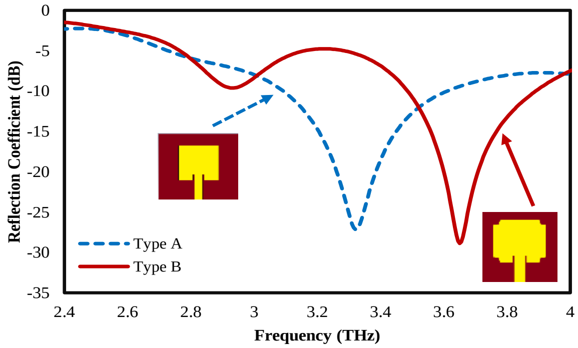

Fig. 2. Comparison of reflection coefficient of the type A and B antenna.

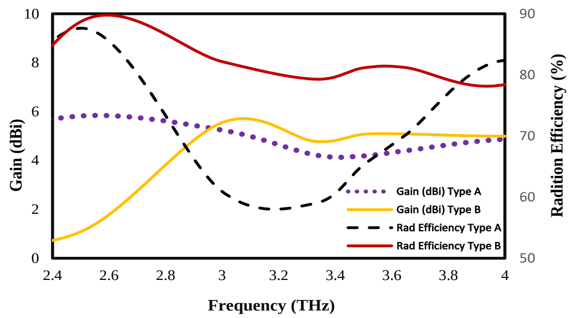

Fig. 3. Comparison of radiation efficiency and gain of the type A and type B (proposed) antenna

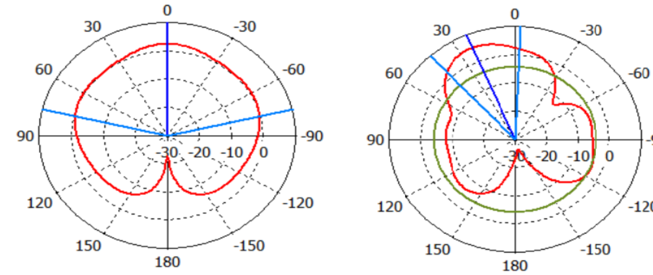

Fig. 4. Radiation patterns for the truncated microstrip patch antenna for phi = 0º (left) and phi = 90º (right).

TABLE I. COMPARISON OF THE PROPOSED ANTENNA WITH OTHER RELATED WORKS

Ref.	**Freq (THz)**	**S11 (dB)**	**Efficiency %**	**Directivity (dBi)**
[3]	2.6	-27	78	-
[4]	1.08	-55	-	-
[5]	5.5	-65	70	5.42
[6]	3.62	-12.25	-	4.20
This work	**3.65**	**-29**	**80.2**	**6.06**

In Fig. 2, the conventional type A and proposed type B THz antenna structures have simulated reflection coefficients considerably below -10 dB at center resonance frequency (3.32 and 3.65 THz) with reflection coefficients of-26dB and-29dB, respectively. The -10dB bandwidth is from 3.48 to 3.90 THz for type B antenna, hence the impedance bandwidth is 11.12% (420 GHz centered at 3.65 THz and 320 GHz centered at 3.32 THz, respectively). This comparison shows that type B antennas are more efficient (80–90%) than type A antenna.

Furthermore, the proposed type B antenna radiation efficiency is more accurate approximately (80–85%) throughout -10db bandwidth, specifically at the center resonance frequency of 3.65 THz is 80.2%, which is much better than type A having a radiation efficiency of 50% at the center resonance frequency of 3.32 THz. It can be observer in Fig.3 that the type B antenna gave a better peak gain of 5.06 dBi at the center resonance frequency (3.65 THz) for wider bandwidth, as compared to the type A antenna. Additionally, the radiation patterns are persistent and directional, as noticed in Fig. 4. Ultimately, the performance of the modified truncated microstrip patch antenna is shown in Table 1 and compared with previous literature work.

In addition to the single truncated patch antenna design, to achieve high directivity with large bandwidth, a photonic crystal (PC) technique was also designed and simulated. The PBG-based substrate has a high gain and directivity of 6.41 dBi and 6.50 dBi with wide bandwidth. The detailed design of truncated patch with PBG-based substrate, radiation patterns, scanning performance, of the proposed antenna are not included in this paper due to concision. However, they are anticipated to be included in more detailed work in the future along with the fabricated prototypes of the PBG-based truncated patch design with measurements.

IV. CONCLUSON

The design and analysis of a truncated microstrip patch THz antenna are discussed in this paper. For comparison purposes, a similar antenna with a square radiating patch was employed. It was observed that the proposed antenna with a truncated microstrip patch antenna achieved a better reflection coefficient of around -29 dB at a center resonance frequency of 3.65 THz, an impedance bandwidth of 11.12%, a peak gain of 5.06 dBi, a peak directivity of 6.061 dB, and a total radiation efficiency of 80.2%. The proposed antenna is suitable for future THz wireless communication and imaging applications.

REFERENCES

.[1] Z. Chen et al., "A survey on terahertz communications," China Commun., vol. 16, no. 2, pp. 1–35, 2019, doi: 10.12676/j.cc.2019.02.001.

[2] Y. He, Y. Chen, L. Zhang, S. W. Wong, and Z. N. Chen, "An overview of terahertz antennas," China Commun., vol. 17, no. 7, pp. 124–165, 2020, doi: 10.23919/J.CC.2020.07.011.

[3] J. N. George and M. G. Madhan, "Analysis of single band and dual band graphene based patch antenna for terahertz region," Phys. E Low-Dimensional Syst. Nanostructures, vol. 94, no. August, pp. 126–131, 2017, doi: 10.1016/j.physe.2017.08.001.

[4] Y. Denizhan Sirmaci, C. K. Akin, and C. Sabah, "Fishnet based metamaterial loaded THz patch antenna," Opt. Quantum Electron., vol. 48, no. 2, pp. 1–10, 2016, doi: 10.1007/s11082-016-0449-6.

[5] M. A. K. Khan, T. A. Shaem, and M. A. Alim, "Analysis of graphene based miniaturized terahertz patch antennas for single band and dual band operation," Optik (Stuttg)., vol. 194, no. April, 2019, doi: 10.1016/j.ijleo.2019.163012.

[6] Z. Mezache, "Analysis of multiband graphene-based terahertz square-ring fractal antenna," Ukr. J. Phys. Opt., vol. 21, no. 2, pp. 93–102, 2020, doi: 10.3116/16091833/21/2/93/2020.