Received 29 September 2022 | Revised 05 November 2022 | Accepted 01 December 2022
Vol. 03, No. 02, 10 pages

RESEARCH ARTICLE

Tobruk University Journal of Engineering Sciences

Performance Analysis of mm-Wave Inset-Fed Rectangular Patch Antenna Employing Polyimide Substrate for 5G System

Salem A. Almazok

Electrical and Computer Engineering Department, Al-Asmarya Islamic University, Zliten, Libya
s.almazok@asmarya.edu.ly

Abstract. This paper presents a design and analysis of a compact inset-fed polyimide-based substrate rectangular patch antenna for a fifth-generation (5G) system. The proposed design operates at a resonant frequency of 28 GHz and uses copper material for ground and radiating patch elements with polyimide plastic material has a dielectric constant of 3.5 for the substrate. The thickness of the substrate was fixed at h= 0.27 mm. While the thickness of the patch and ground was kept at t = 0.035 mm. The Computer Simulations Technology (CST) program was used to simulate and evaluate the performance of the proposed antenna. It shows a returns loss ($\boldsymbol{S}_{11}$) value of -17.68 dB. Voltage standing wave ratio (VSWR) of 1.3. Bandwidth (BW) value of 1.427 GHz. Gain (G) value of 5.406 dBi and radiation efficiency (ηrad %) 86%. These obtained results are used to be compared with similar existing designs in the scientific literature.

Keywords: Rectangular Patch Antenna, Antenna Performance Parameters, Polyimide, 28 GHz, mm-wave frequency band, fifth-generation (5G) system.

1. Introduction

The cellular mobile communication system has encountered significant growth in recent decades. It has evolved from an analog first-generation (1G) system to a digital second-generation (2G) system, afterward to third generation (3G) system which had multimedia transmission and then to fourth generation (4G) system through high-speed packet access (HSPA) and long term evolution (LTE) systems which are capable to support high data rate transmission [1,2]. The new upcoming cellular mobile communication technology, which is still in the nascent stage, is the fifth generation (5G) system [3]. For the 5G system, the International Telecommunication Union (ITU) has nominated a frequency band extending from 24GHz - 80GHz, which is located in the mm-wave spectrum band [2,4]. In general, 5G will provide additional services and add more advantages around the world over previous systems, 5G system is expected to significantly increase the communication capacity by utilizing a massive unlicensed bandwidth, mainly in the millimeter-wave range, furthermore, 5G will capable to connect a large number of devices, minimize end-to-end delay approximately 5 times, prolong battery life for lower battery communication equipment, and providing higher data rate which is greater ten to hundred times than the previously existing systems [3,5].

To satisfy these expected services, the 5G network needs a challenging replacement in terms of antenna design [3]. The goal of any communication system is to exchange information in form of electromagnetic waves between sender and receiver, for this purpose, the communication system needs an antenna that acts as an electromagnetic device to radiate and receive the electromagnetic device[2], on the other hand, due to the development of wireless communication technologies, the antenna in such an advanced 5G communication system needs to have a low profile, inexpensive mass fabrication, ease of installation, appropriate to a planar and nonplanar surfaces and able to transmit and receive electromagnetic waves at mm-wave frequency band [3,5,6].

Despite their limited bandwidth, the mm-wave microstrip patch antenna could be a promising choice to satisfy all the above needs in 5G [2, 6]. The structure of a microstrip patch antenna consists of three layers; the top layer represents the radiating metallic patch element; the bottom layer is the ground plane, and in between these layers is a dielectric substrate layer [2,7,8]. Typically, the patch is printed on a dielectric substrate using the printed circuit board (PCB) technique; therefore, microstrip patch antenna is known as the printed antenna.[5,7]. Although there are several possible geometrical shapes for the radiating patch, the rectangular geometrical shape is the most frequent [2,8]. There are various feeding approaches for a microstrip patch antenna including coaxial probe, aperture coupling, and microstrip line, which is commonly used [2,8].

The antenna is an essential element in any communication system because its main function is to transmit and receive information in the form of electromagnetic waves. Hence, it is important to design an efficiently performing antenna. For this purpose, many research studies have suggested and designed a microstrip patch antenna as a type of antenna for 5G wireless cellular systems. Mohammed et al. [9] presented a comprehensive overview of the previous and subsequent studies' achievements carried out on patch antennas operating at 28 GHz for 5G applications. Kavitha et al. [10] suggested a design of FR-4 based substrate rectangular microstrip feed line patch antenna. The proposed single-element antenna operates at a resonant frequency of 28GHz. The simulation results show that the proposed antenna has a return loss (S_{11}) value of -14.150 dB. Voltage standing wave ratio (VSWR) of 1.487 and gain (G) value of 6.06 dB. Darboe et al. [6] introduced a compact rectangular patch antenna for 5G applications. The introduced inset fed Roger RT Duroid 5880-based substrate antenna resonant at 27.954 GHz and provides (S_{11}) value of 13.48 dB. (G) of 6.63. The efficiency of 70.18% and the bandwidth (BW) of 847 MHz. Goyal and Modani [11] designed a compact inset-fed rectangular patch antenna for 5G systems. The proposed antenna uses Roger RT5880 as substrate and provides (S_{11}) value of -18.25dB at 28.06 GHz. (VSWR) 1.278 at 28.06 GHz and (G) value of 6.83 dB. In [5], the authors have designed a single element inset fed rectangular patch antenna based on the FR-4 substrate material; the antenna provides (S_{11}) value of -15.352dB at 27.901GHz. (VSWR) value of 1.787 at 28 GHz and a directivity value of 6.921 dBi. It can be noticed from previous literature that most of the studies focused on designing patch antennas for 5G applications using non or semi-flexible substrate materials such as FR-4, Roger RT5880 and Roger RT Duroid 5880, which are commonly used in this research area. However, this research proposed a new design based on polyimide (PI) as a flexible substrate for flexible patch antennas for 5G applications.

This article presents a new design of mm-wave rectangular patch antenna that operates at 28GHz for a 5G system. This proposed antenna design uses an inset-fed technique for feeding purposes and employs a polyimide material that has a 2.5 dielectric constant as substrate. The main contribution of this research is to employ polyimide (PI) which belongs to plastic or polymer materials and they can be the best choice for flexible antenna fields [12]. The proposed antenna design is simulated using Computer Simulations Technology (CST) program [13] to evaluate its performance and compare it with similar structures existing in the literature. The remainder of the research is structured as follows. In section 2 mm-Wave rectangular patch antenna designed for the 5G System is introduced. The simulation results analysis and discussions are provided in section 3. Section 4 provides a comparison of the proposed structure with similar structures for the 5G system. The conclusion is in section 5.

2. mm-Wave Rectangular Patch Antenna Designed for 5G System

The proposed antenna design consists of a rectangular patch element and ground plane which are made from copper material having a conductivity of 5.96e+07 [S/m] and thickness of 0.035 mm. This proposed antenna is using a flexible material polyimide (PI) which has a dielectric constant, loss tangent and thickness of 3.5, 0.0027 and 0.27 mm, respectively. Polyimide (PI) is categorized under the high-glass transition temperature Tg materials as one of the plastic or polymer materials which are desirable for flexible antenna applications

[12]. To start the design process, it is required to identify the operating frequency, the substrate material, and its relative permittivity [14]. The design introduced in this work is capable of operating for 5G systems at 28 GHz and is based on polyimide (PI) with a dielectric constant of 3.5.
In the design process. The value for the thickness of the substrate (h) was determined based on the following equation [14,15].

$$h \leq \frac{0.3c}{2\pi f_r \sqrt{\varepsilon_r}} \leq \frac{0.3 \times 3 \times 10^8}{2\pi \times 28 \times 10^9 \sqrt{3.5}} \leq 0.27mm \tag{1}$$

Where (f_r) is the resonant frequency, c = 3×10^8 represents the electromagnetic waves' speed in free space and (ε_r) relative permittivity.

The width of the patch (W_P) element is calculated according to the following equation [14,15]:

$$W_P = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{3 \times 10^8}{2 \times 28 \times 10^9}\sqrt{\frac{2}{3.5+1}} = 3.57mm \tag{2}$$

For patch length. The effective dielectric constant (ε_{reff}) is required to be determined first, (ε_{reff}) can be obtained based on the following equation [14,15] :

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2 \times \sqrt{1+12(\frac{h}{W_P})}} = \frac{3.5+1}{2} + \frac{3.5-1}{2 \times \sqrt{1+12(\frac{0.27}{3.57})}} = 3.16 \tag{3}$$

Moreover. The effective length (l_{eff}) of the patch is needed to be calculated based on the following formula [14,15]:

$$l_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} = \frac{3 \times 10^8}{2 \times 28 \times 10^9\sqrt{3.16}} = 3.01\ mm \tag{4}$$

The next step is to calculate decreased rate value (Δl) in radiating element length based on the following formula [14,15]:

$$\Delta l = \frac{0.412 \times h\,(\varepsilon_{reff}+0.3)\,(\frac{W_P}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W_P}{h}+0.8)} = \frac{0.412 \times 0.27 \times 10^{-3}\,(3.16+0.3)\,(\frac{3.57}{0.27}+0.264)}{(3.16-0.258)(\frac{3.57}{0.27}+0.8)} = 0.13\ mm \tag{5}$$

Then, The actual length of the patch (L_P) the element will be calculated based on the following equation [14,15]:

$$L_P = l_{eff} - 2\Delta l = 3.01 - 2(0.13) = 2.75mm \tag{6}$$

The ground plane length (L_g) is calculated using the following formulas [14, 15]:

$$L_g = L_P + 6h = 2.75 + 6(0.27) = 4.37mm \tag{7}$$

Also, the ground plane width W_g is determined using the following formula [14, 15]:

$$W_g = W_P + 6h = 3.57 + 6(0.27) = 5.19mm \tag{8}$$

The substrate length (L_s) and width (W_s) are the same ground plane length and width as it is placed on the ground plane. Therefore $L_s = L_g$and width $W_s = W_g$.

Regarding the inset feed depth F_i. The inset depth can be calculated using the following formula [6]:

$$F_i = 10^{-4}[0.001699\varepsilon_r{}^7 + 0.1376\varepsilon_r{}^6 - 6.1783\varepsilon_r{}^5 + 93.187\varepsilon_r{}^4 - 682.69\varepsilon_r{}^3 + 2561.9\varepsilon_r{}^2 - 4043\varepsilon_r + 6697]\ \frac{L_P}{2} \quad (9)$$

$$F_i = 10^{-4}[0.001699(3.5)^7 + 0.1376(3.5)^6 - 6.1783(3.5)^5 + 93.187(3.5)^4 - 682.69(3.5)^3 + 2561.9(3.5)^2 - 4043(3.5) + 6697]\frac{2.75\times10^{-3}}{2} = 0.78mm$$

In addition. To identify the feed line width with characteristic impedance ($Z_c = 50\ \Omega$) the auxiliary parameters (A)and (B) are needed to be calculated [14,15] :

$$A = \frac{Z_c}{60}\sqrt{\frac{\varepsilon_r+1}{2}} + \frac{\varepsilon_r-1}{\varepsilon_r+1}(0.23 + \frac{0.11}{\varepsilon_r}) = \frac{50}{60}\sqrt{\frac{3.5+1}{2}} + \frac{3.5-1}{3.5+1}(0.23 + \frac{0.11}{3.5}) = 1.4 \quad (10)$$

$$B = \frac{60\pi^2}{Z_c\sqrt{\varepsilon_r}} = \frac{60\pi^2}{50\sqrt{3.5}} = 6.33 \quad (11)$$

Since (A) value is less than 1.52. The feed line width (W_f) can be determined from the following equations [14,15]:

$$W_f = \frac{2}{\pi}\left\{B - 1 - ln(2B-1) + \frac{\varepsilon_r-1}{2\varepsilon_r}\left[ln(B-1) + 0.39 - \frac{0.61}{\varepsilon_r}\right]\right\}.h \quad (12)$$

$$W_f = \frac{2}{\pi}\left\{6.33 - 1 - ln(2\times6.33-1) + \frac{3.5-1}{2\times3.5}\left[ln(6.33-1) + 0.39 - \frac{0.61}{3.5}\right]\right\}\times 0.27\times10^{-3}$$

$$W_f = 0.61mm.$$

The notch width (g) is calculated based on the following formula [7]:

$$g = \frac{W_P}{50} \quad (13)$$

$$g = \frac{3.57}{50} = 0.07mm.$$

After the initial numerical values of the antenna parameters were calculated, these numerical values were used to design the proposed antenna. Furthermore, the trial and error technique is applied to obtain a better performance of the proposed antenna [8, 16]. According to this principle, W_f value is changed to 0.52 mm and L_P is modified to 2.751 mm. Whereas, the reminder calculated numerical value is kept the same. The detailed parameters of the suggested design are provided in table 1. The top and back view sides of the proposed simulated antenna in the CST program are also shown in Figure 1

Table 1. Design Parameters of Proposed Antenna.

Parameter	Symbol	Value
Dielectric Constant	ε_r	3.5
Substrate Thickness	h	0.27 mm
Patch Width	W_P	3.57 mm
Patch Length	L_P	2.751 mm
Ground Plane Width	W_g	5.19 mm
Ground Plane Length	L_g	4.37 mm
Substrate Width	W_s	5.19 mm
Substrate Length	L_s	4.37 mm
Feed Line Width	W_f	0.52 mm
Feed Line Length	L_f	1.59 mm
Cooper Thickness	Cu_{th}	0.035 mm
Inset feed depth	F_i	0.78 mm
Notch Width g	g	0.07mm

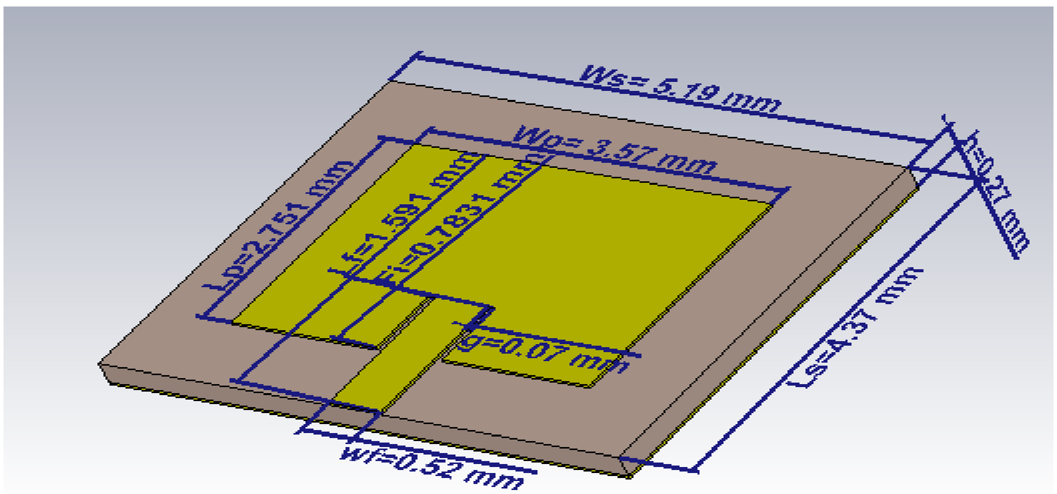

Fig. 1. Top view of the proposed structure

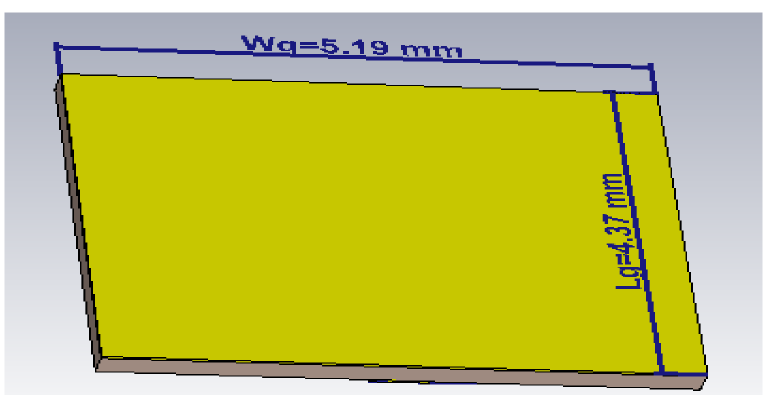

Fig. 2. Back view of the proposed structure

3. Simulation Results Analysis and Discussion

In this research paper. The performance metrics are used to evaluate the performance of the proposed Antenna structure, These performance parameters include voltage standing wave ratio (VSWR), returns loss ($\boldsymbol{S}_{11}$), bandwidth (BW), radiation pattern and gain (G), and radiation efficiency (ηrad %).

3.1 Voltage Standing Wave Ratio (VSWR)

This parameter indicates how much power is reflected in the direction of the transmitter [15,17]. Regarding the patch antenna, the acceptable range of VSWR is located within 1 and 2 through the antenna bandwidth, and its ideal value equals 1 [6,14,15,17]. Figure 3 indicates the VSWR plot of the proposed antenna. It can be noticed that the VSWR value at the resonant frequency is 1.3. This is an acceptable value as it is less than 2 and close to 1.

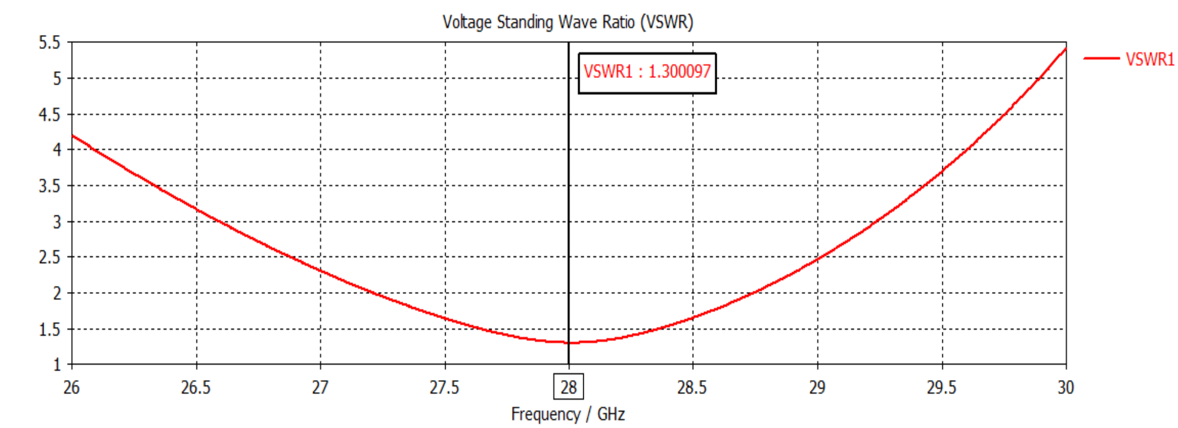

Fig. 3. VSWR plot of the proposed structure

3.2 Return Loss (S_{11})

Returns loss (S_{11}) which is also named a reflection coefficient shows the rate of incident power to the reflected power and its measurement unit is dB [15,17-19]. S_{11} value of -10dB is used to be a referenced value which means that only 10% of the incident power is reflected and 90% is received and this value is regarded as suitable for mobile communications [17]. Therefore, -10 dB or lower provides better performance [18,19]. Figure 4 presents (S_{11}) plot of the proposed structure. It can be noticed that (S_{11}) value at 28GHz is -17.69 dB meaning only 1.7 % of the incident power is reflected which is considered a reasonable result.

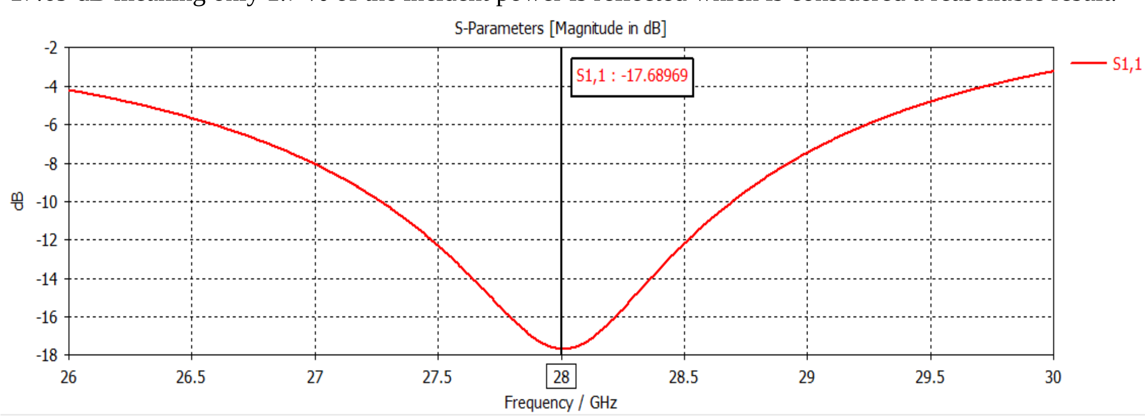

Fig. 4. S_{11} plot of the proposed structure

3.3 Bandwidth (BW)

The BW of the introduced antenna structure can be determined as the frequencies range difference on S_{11} figure where it is lower than -10 dB [17]. From figure 5, BW can be calculated as the frequency difference between 28.693 GHz and 27.269 GHz (28.696-27.269=1.427GHz). Therefore BW=1.427 GHz is considered a competitive value.

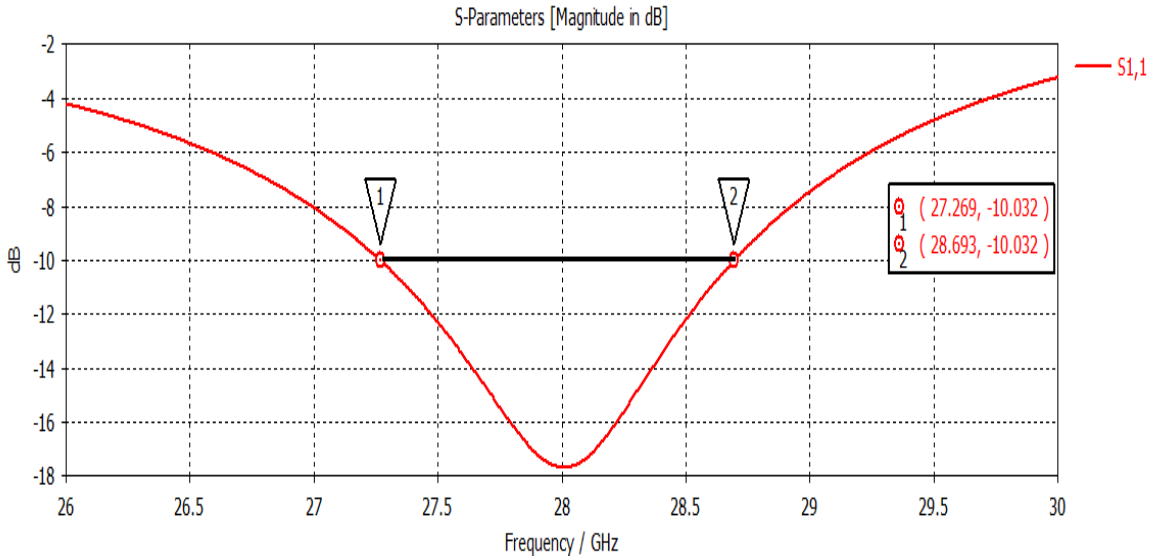

Fig. 5. BW plot of the proposed structure

3.4 Radiation Pattern and Gain (G)

The radiation pattern is an essential performance index in antenna design as it provides how much energy is radiated by the antenna [18,19]. Regarding antenna gain. It refers to the rate of the antenna power density at a specific point to the isotropic antenna power density at the same point if the two antennas feed by equal power [15]. The proposed structure provides a realized gain value of 5.33 dBi at 28GHz as indicated by the 3-D radiation pattern in figure 6, which represent a reasonable value for a patch antenna.

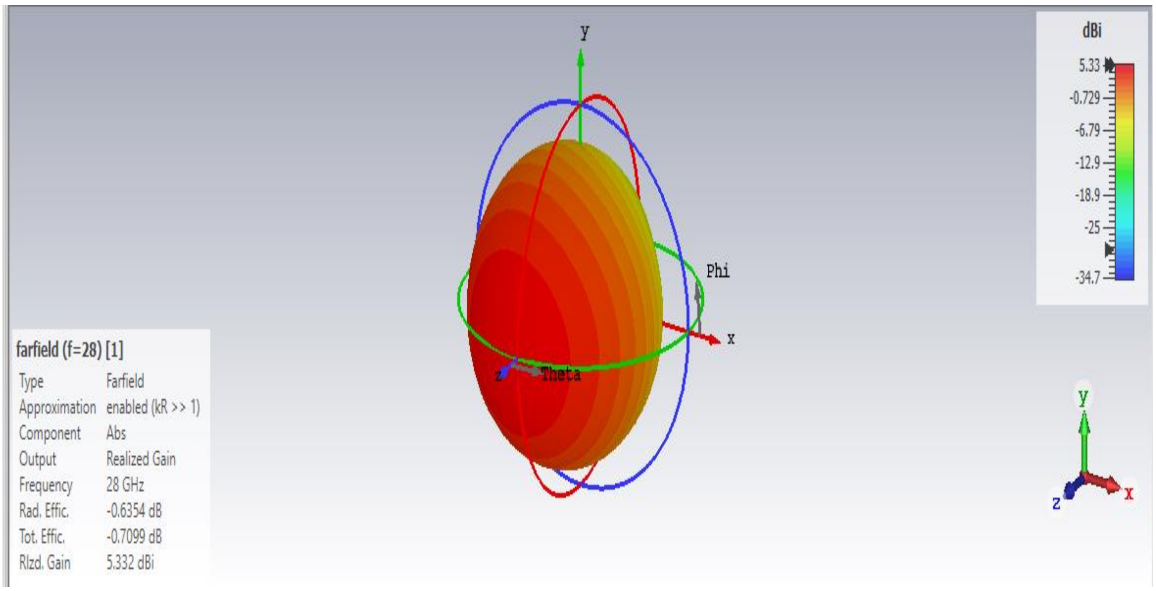

Fig. 6. 3-D radiation pattern of the proposed structure

Furthermore, the proposed antenna shows 93.4^0 angular width value and 5.35 for main lobe magnitude value as indicated in figure 7

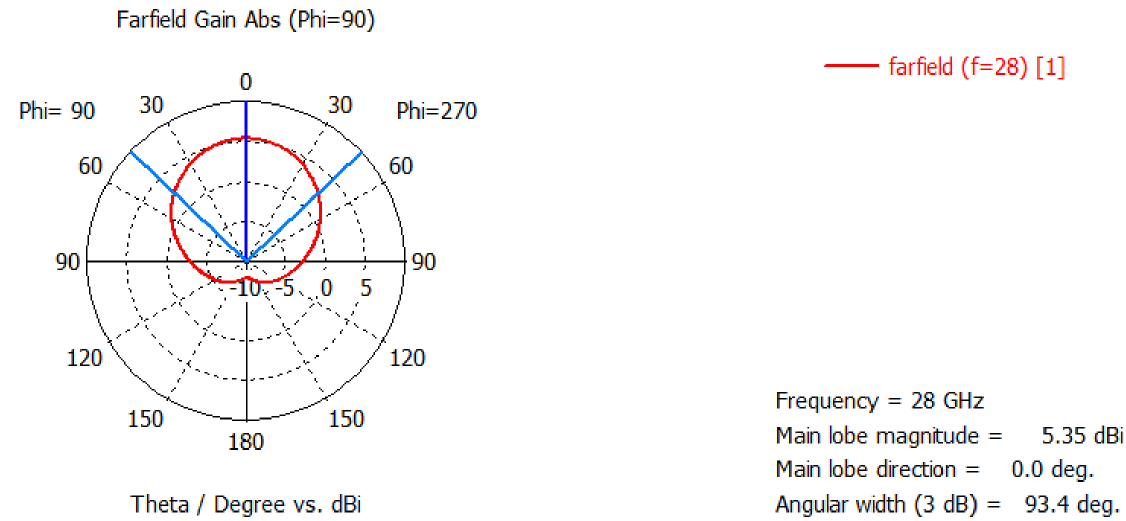

Fig. 7. 2-D radiation pattern of the proposed structure

3.5 Radiation Efficiency (ηrad %)

Radiation efficiency ηrad (%) is the ratio of total radiated power by the antenna to total input received power by the same antenna [19]. This index shows how the antenna is good in the radiation and receiving mechanism, therefore, for a better performance this performance index should be higher [15]. The proposed antenna structure provides ad (%) of -0.6354 dB as indicated in figure 6 which is equivalent to 86 %, and this value is considered a competitive result.

4. Comparison of the Proposed Structure with Similar Structures For 5G System

The performance of the proposed antenna structure has been compared with similar structures existing in the literature as presented in Table 2. In terms of VSWR, the introduced antenna structure shows better performance than other structures in [5,6,20] because the VSWR value is more close to the ideal value 1. Similarly, regarding S_{11} the proposed antenna structure provides minimal return loss in comparison with the structures reported in [5,6,20] which shows that the proposed design has again better performance in terms of S_{11}. The BW of the designed antenna is wider than the BW of the design introduced in [6]. Finally, in terms of ηrad (%). The proposed structure outperforms the ηrad (%) of the design in [6] but slightly less than the ηrad (%) of the design reported in [5]. In terms of G, the proposed structure indicates a reasonable result compared to other designs in [6,20]. Therefore, the introduced antenna design shows a reasonable and competitive performance in comparison with some similar designs reported in the scientific literature.

Table 2. Comparison of Performance Parameters of the Proposed Design and Published Designs.

Work Ref. No.	VSWR	S_{11}	BW	ηrad	G
[5]	1.78	-15.35	-	87.78 %	-
[6]	1.53	-13.48	847MHz	70.18%	6.63 dB (Rlzd.using CST)
[20]	1.77	-12.59	-	-	6.69 dB (Gain using HFSS)
This work	1.3	-17.68	1.427GHz	86%	5.33 dBi (Rlzd.using CST)

In general, the proposed design aims to obtain a good performance in terms of all antenna performance parameters. The proposed design shows reasonable and competitive results in terms of radiation efficiency, voltage standing wave ratio, gain and return loss. In terms of bandwidth, the proposed design achieves a wider bandwidth compared to many designs existing in the literature.

5. Conclusion

This article has presented a mm-W rectangular patch antenna with a polyimide plastic substrate for a 5G communication system. The compact proposed structure with dimensions 5.19 × 4.37 × 0.27 mm^3 was designed and simulated using the CST program, it is resonated at 28 GHz and shows simulation results including a VSWR of 1.3, S_{11} value of -17.69 dB and BW value of 1.42 GHz. The designed antenna achieved a G value of 5.33 dBi. The simulation results have been compared with similar structures existing in the scientific literature. The comparison indicated that the proposed antenna design can be a suitable choice for integration with modern communication devices for 5G applications.

Conflict of Interest

The author has no conflicts of interest to declare.

References

1. Z. Ying, "Antennas in cellular phones for mobile communications," Proc. IEEE, vol. 100, no. 7, pp. 2286–2296, 2012, doi: 10.1109/JPROC.2012.2186214.
2. T. T. B. Ngoc, "Design of Microstrip Patch Antenna for 5G Wireless Communication Applications," J. Sci. Technol. Food, vol. 20, no. 2, pp. 53–61, 2020.
3. M. Tegegn Gemeda, K. A. Fante, H. L. Goshu, and A. L. Goshu, "Design and Analysis of a 28 GHz Microstrip Patch Antenna for 5G Communication Systems," Int. Res. J. Eng. Technol., pp. 881–886, 2021, [Online]. Available: www.irjet.net
4. Prachi*, D. V. Gupta, and S. Vijay, "A Novel Design of Compact 28 GHz Printed Wideband Antenna for 5G Applications," Int. J. Innov. Technol. Explor. Eng., vol. 9, no. 3, pp. 3696–3700, 2020, doi: 10.35940/ijitee.c9011.019320.
5. M. B. El-Mashade, and E. A. Hegazy, "Design and analysis of 28 GHz rectangular microstrip patch array antenna," WSEAS Transactions on Communications, vol. 17, pp. 1–9, 2018.
6. O. Darboe, D. B. O. Konditi, and F. Manene, "A 28 GHz Rectangular Microstrip Patch Antenna for 5G Applications," Int. J. Eng. Res. Technol., vol. 12, no. 6, pp. 854–857, 2019.
7. Z. Rahman, M. Mynuddin, and K. C. Debnath, "The Significance of Notch Width on the Performance Parameters of Inset Feed Rectangular Microstrip Patch Antenna," vol. 10, no. 1, pp. 7–18, 2020, doi: 10.5923/j.ijea.20201001.02.
8. C. Mukta, M. Rahman, and A. Z. M. T. Islam, "Design of a Compact Circular Microstrip Patch Antenna for WLAN Applications," Int. J. AdHoc Netw. Syst., vol. 11, no. 03, pp. 01–11, 2021, doi: 10.5121/ijans.2021.11301.
9. M. Abdullahi SB Mohammed, Shahanawaz Kamal, Mohd Fadzil Ain, Zainal Arifin Ahmad, Ubaid Ullah and M. F. A. R. Othman, Roslina Hussin, "A Review Of Microstrip Patch Antenna Design At 28 Ghz For 5G Applications System," Int. J. Sci. Technol. Res., vol. 8, no. 10, pp. 341–352, 2019.
10. M.Kavitha, T.D.Kumar, A.Gayathri, and V.Koushick, "28 GHz printed antenna for 5G communication with improved gain using arrays," International Journal of Scientific & Technology Research, vol. 9, no.3, pp.5127-5133, Mar.2020
11. R. K. Goyal and U. Shankar Modani, "A Compact Microstrip Patch Antenna at 28 GHz for 5G wireless Applications," 3rd Int. Conf. Work. Recent Adv. Innov. Eng. ICRAIE 2018, vol. 2018, no. November, pp. 1–2, 2018, doi: 10.1109/ICRAIE.2018.8710417.
12. S. G. Kirtania et al., "Flexible antennas: A review," Micromachines, vol. 11, no. 9, 2020, doi: 10.3390/mi11090847.
13. CST Studio Suite. CST Microwave Studio. 2019. Available from: http:// www.cst.com.
14. M. B. and L. N. Rafal Przesmycki, "Broadband Microstrip Antenna for 5G Wireless Systems Operating at 28 GHz," electronics, pp. 1–19, 2020, https://dx.doi.org/10.3390/ electronics10010001.

15. S. A. Almazok, "A Flexible and Compact 28 GHz Inset Fed Rectangular Patch Antenna Based on Circuit in Plastic Technology for 5G System Title," 2021 ,مجلة الجامعة الأسمرية. Accepted, In press.
16. ICSU Introduction to Computer Science, Grade 11, University Preparation, Unit3, Problem Solving and Algorithm Design, Debugging and Validating Data, [Online]. Available: https://lah.elearningontario.ca/CMS/public/exported_courses/ICS3U/exported/ICS3UU03/ICS3UU03/ICS3UU03A01/_content.html
17. K. A. Fante and M. T. Gemeda, "Broadband microstrip patch antenna at 28 GHz for 5G wireless applications," Int. J. Electr. Comput. Eng., vol. 11, no. 3, pp. 2238–2244, 2021, doi: 10.11591/ijece.v11i3.pp2238-2244.
18. M. Faisal, A. Gafur, S. Z. Rashid, M. O. Shawon, K. I. Hasan, and M. B. Billah, "Return Loss and Gain Improvement for 5G Wireless Communication Based on Single Band Microstrip Square Patch Antenna," 1st Int. Conf. Adv. Sci. Eng. Robot. Technol. 2019, ICASERT 2019, vol. 2019, no. Icasert, pp. 1–5, 2019, doi: 10.1109/ICASERT.2019.8934474.
19. J. Colaco and R. Lohani, "Design and Implementation of Microstrip Circular Patch Antenna for 5G Applications," 2nd Int. Conf. Electr. Commun. Comput. Eng. ICECCE 2020, no. June, pp. 12–13, 2020, doi: 10.1109/ICECCE49384.2020.9179263.
20. S. Mungur, Dheeraj; Duraikannan, "Microstrip Patch Antenna at 28 GHz for 5G Applications," J. Sci. Technol. Eng. Manag. Res. Innov., vol. 1, no. 1, pp. 20–22, 2018.