

Planar Rectangular Micro-strip Patch Antenna Design for 25 GHz



Amandeep Kaur, Praveen Kumar Malik, and Ramendra Singh

Abstract The research article demonstrates the unconstrained optimization of planer rectangular micro-strip patch antenna for 5G communications. Proper dimensions of the antenna were adhering as per the accord and analogy of theoretical concept and adapted. The proposed antenna design is for the operation of the 5G band, especially at 25 GHz. The design of the antenna and its simulation are done on antenna simulation software and are optimized to have better return loss, transmission efficiency, directivity, and gain. For the entire band of operation of frequency as keen obtained results from the simulation are found close agreement with those obtained theoretically is unprecedented.

Keywords 5G · Bandwidth · Efficiency · Gain · Radiation power

1 Introduction

Factually, in this modern contemporary word, wireless transmitting devices archival now becomes compact in size and useful for different aspects of applications like IoT, artificial intelligence, mobile communication, and satellite communication and 5G networks. One of the significant challenges in wireless communication is the lack of frequency bandwidth as numbers of users are increasing day by day [1, 7]. To allay this problem, concept of millimeter wave technology and use description, which works on three different frequency bands 3300–3600 MHz, 24.25–27.5 GHz, and 27.5–29.5 GHz, is to fulfill the high data rate requirements of users that leads

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Table 1 Antenna design parameters

Parameters	Operating frequency	Dielectric constant	Substrate material	Loss tangent
Values	25 GHz	2.2	Rogers RT duroid	0.009
Parameters	Height of substrate	Length of Gnd (Lg)	Width of Gnd (Wg)	Length of Patch (Lp)
Values	1.6 mm	12.46 mm	14.34 mm	2.86 mm
Parameters	Width of patch (Wp)	Feed line length (Lfl)	Feed line width (Wfl)	Impedance of patch
Values	4.74 mm	2.156 mm	0.453 mm	144ohm

to challenging network design requirements. Apparently, in this type of structure, it is necessary to integrate high radio frequency design into a single antenna with a high degree of compactness [2, 9]. So, perusal based on network requirements needed for 5G, an antenna with less weight, small in size, and compatible with microwave circuits are highly regarded. Gravely planer rectangular micro-strip patch antenna plays a remarkable and veteran role in wireless communications [3]. The geometric shape of a micro-strip antenna consists of a radiating element on the dielectric substrate and a ground plane on the other side [13, 14]. There are several categories of the micro-strip patch antenna depending upon the shape of the patch, for example, the circular, square, triangular, and semicircular. However, the most common from all is rectangular patch antenna, as oratory [4, 8].

2 Micro-strip Antenna Design

A gambit rectangular micro-strip patch antenna for 5G applications is proposed in this article. The antenna has dimensions of 4.74 mm wide and 2.86 mm in length, which is very small in size. Substrate material used for antenna configuration is Rogers RT 5880 with a thickness of 1.6 mm, the dielectric constant of 2.2, and having a loss tangent of 0.0009. The antenna is simulated using antenna simulation software, and antenna performances are analyzed in terms of S-parameter, VSWR, gain, and radiation pattern and directivity. The proposed antenna is suitable to be operated in the frequency range of 5G communication, especially 25 GHz [5, 6].

In Fig. 1, proper validation and hypothesis of mathematical expression are taken care of cautiously and emphasized while designing the length and width of the antenna [10]. The impedance of the antenna is calculated certainly with the help of the transmission line concept. In Fig. 2, the width and length of the transformer are correctly matching the impedance of the patch by keeping cognizance with the port of 50 Ω [15–16].

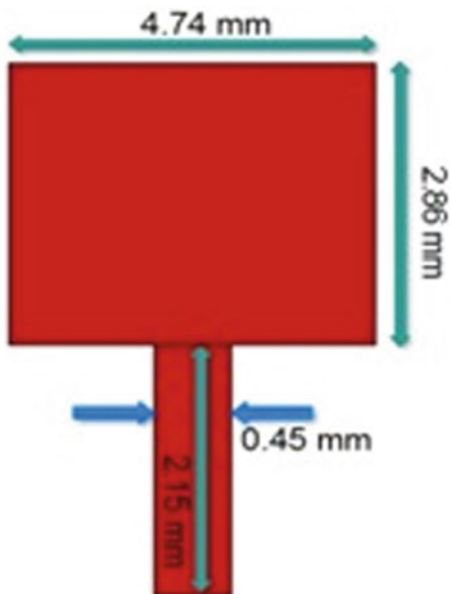


Fig. 1 Proposed antenna design top view



Fig. 2 Proposed antenna design patch, feed, and its excitation

Designing the antenna resonating frequency F_r , substrate dielectric constant and height of substrate h should be known utter. Synthesis of the wavelength of the antenna done by using the articles [10–12] (Table 1).

3 Result and Discussion

Consequently, the above antenna is designed in an antenna simulation software, and another performance parameter, including return loss, is verified with the help of a vector network analyzer (VNA). Performance parameters like gain voltage standing wave ratio and impedance of the antenna are simulated and reported using the software itself. One of the factual parameters which define the reflection coefficient or return loss of the antenna is shown in Fig. 3. Antenna design parameters are also listed in table [1–3]. Results obtained after the simulation are discussed as follows.

3.1 Return Loss

Reflection coefficient of any antenna as a performance parameter is defined by the equation of reflection coefficient. Where Z_{in} is input impedance of the antenna and Z_o is the impedance of transmission lines. Typical values of reflection coefficient are in between zero and one. Maiden, Fig. 3 depicts the efficacy efficiency return loss of rectangular patch antenna in dB. The scattering parameter analysis is quintessential for micro-strip antenna because it represents the loss of power reflected by the antenna. As per the theoretical analysis, this ratio value should be zero, and practically, it should be less than -10 dB as it complies in the design. It also reveals the operating bandwidth of the antenna, extensively from graphs, and it is evident that for operating frequency at 25 GHz, the value of significant return loss is less than -15 dB. From the graph, it can also be purportedly stated the antenna resonates for frequency 23.3–26.9 GHz with return loss less than -10 dB. The value of return

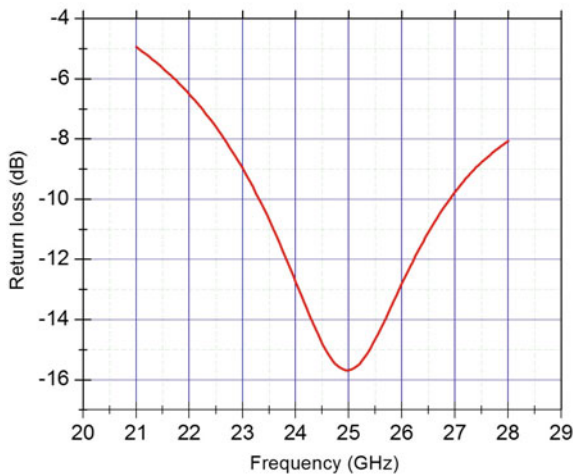
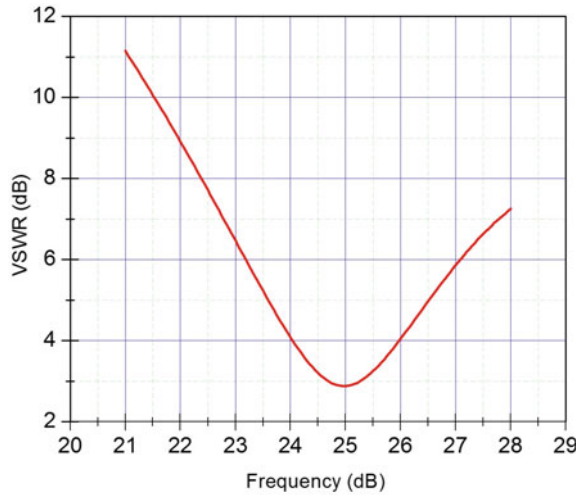


Fig. 3 Return loss of antenna in dB

Fig. 4 Proposed antenna design patch, feed, and its excitation



loss for frequency 23.3 GHz is -10 dB, and till 26.9 GHz, it is -10 dB. With an important attribute, it is evident that the operating range of antenna would prevail at 3.6 GHz [26.9–23.3 GHz].

3.2 Voltage Standing Wave Ratio

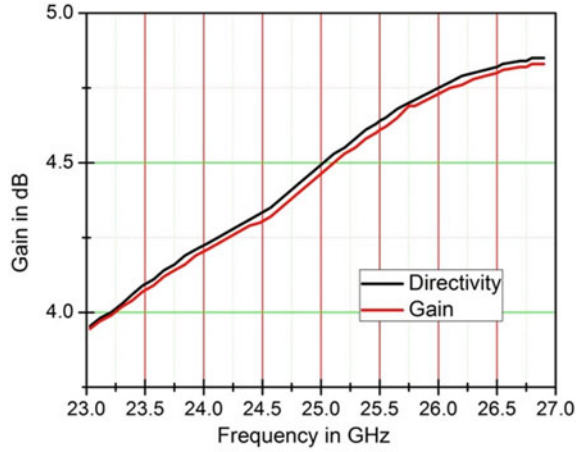
Intuitively appealing voltage standing wave ratio (VSWR) inward is a function of reflection coefficient which is given in equation \ref{abc} , and it is defined in equation number $\ref{abc1}$.

In antenna, maximum power can transfer if antenna transmission line impedance matches the load impedance. The voltage standing wave ratio elicited and shows the impedance matching of the source with the load. The ideal value of VSWR should be unity. Figure 4 illuminates the VSWR vs. frequency response of the proposed antenna. It is found that VSWR for operating frequency 25 GHz is around 2 (2.88). Deficiency in VSWR is due to the disclaimer of the extended length of the patch.

3.3 Gain of Antenna

Figure 5 illustrates the solemn rectangular plot between the gain and directivity of proposed design and frequency in terms of GHz. It is perceived that gain should be more than 3 dB; graph cohesion shows that for the value of theta from -180 to $+180$, the highest value of directivity and gain is achieved for the proposed antenna which is around 4.7 dB at phi zero. Gain and directivity of the antenna, which come from

Fig. 5 Plot of directivity and gain versus frequency



the simulated result and measured gain at a different frequency, especially when the return loss is minimum, are vetted. It is clear from Fig. 5 that gain and directivity vary from 3.94 to 4.83 dB over the frequency range from 23.3 to 26.9 GHz.

3.4 Polar Plot Radiation of Proposed Design

A dominant gain in terms of the polar plot of the proposed design is shown in Fig. 6.

Fig. 6 Polar plot of proposed antenna

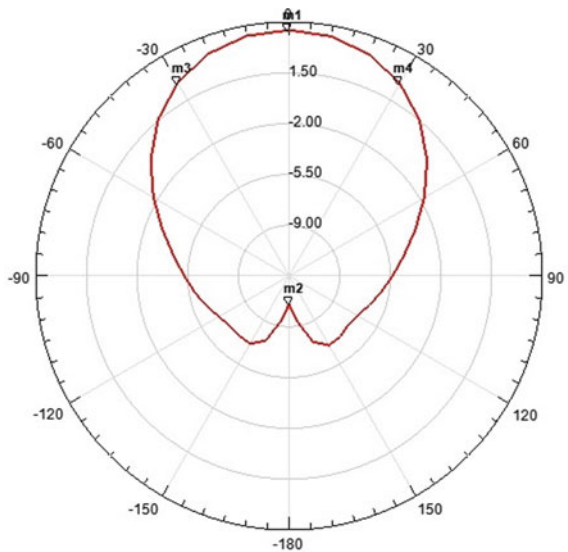
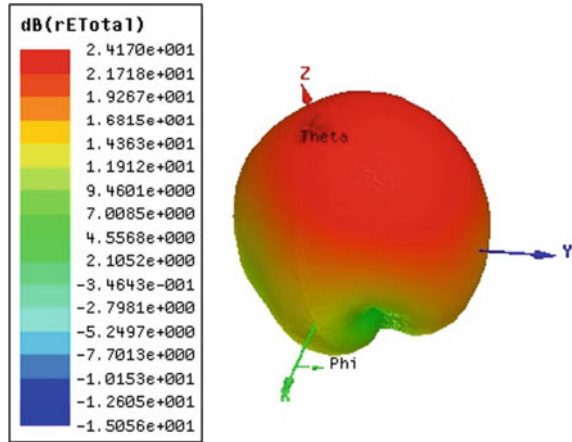


Fig. 7 Radiation pattern (3D)



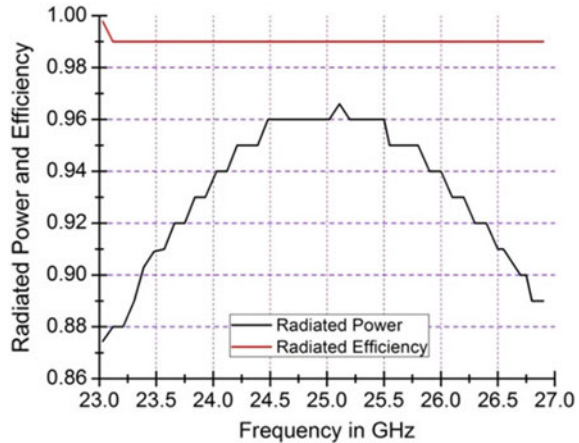
From Fig. 6, this can be quoted that the antenna is stunning directional in nature, and maximum radiation is in the direction of $\phi = 0^\circ$. The antenna also radiates its maximum in the direction of $\theta = -30$ to 30° . The value of the maximum gain elicited is around 4.47 dB readily. It is exciting, and up to the discretion of the reader to note that in the proposed antenna, there is the very bare value of power which is radiated in the back lobe, most of the power is transferred in the main lobe.

3.5 3D Radiation Pattern

Figure 7 shows the 3D radiation pattern of the proposed antenna. The discrete 3D plot shows the relation of strength of EM waves originated from the antenna is contiguous and to the source concerning values of θ and ϕ . As it is ought, antenna to radiate in one direction is buoyed.

Figure 8 displays the relation of radiated power and efficiency of the proposed design versus frequency of the operation. As stated earlier in the discussion and ascertain of return loss, the frequency of operation of the antenna is between 23.3 and 26.9 GHz. Insofar as the plot of radiated power and frequency is consider is taken between these ranges only. It is quoted that the radiated power of the antenna in between the ranges of 23.3–26.9 GHz is adequate and plenary. Notably, the radiated power is maximum at the frequency of resonance, i.e., around 25 GHz efficiently. An essential parameter of the transmitting antenna is its efficiency, and from Fig. 8, it is observed that in the operating range of 23.3 and 26.9 GHz, efficiency of the antenna is more than 90%.

Fig. 8 Plot of radiated power and efficiency versus frequency



4 Conclusion

Consequently and unanimously, it is unveiled that a planer rectangular micro-strip antenna is designed for 5G wireless applications that efficiently operate from 23.3 to 26.9 GHz frequency band. All the performance parameters are also in accord and harmony with the theoretical concept. Radiation efficiency, gain, and the radiation pattern are the prominent performance of the proposed design. Eventually, it is speculated that the proposed antenna could be used efficiently for a higher frequency, especially for 5G in the range of the Ku band, as the antenna has suitable performance parameters for radiation purposes.

5 Conflict of Interest

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements) or non-financial interest (such as personal or professional relationships, affiliations, knowledge, or beliefs) in the subject matter or materials discussed in this manuscript.

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References

1. Balanis, C.A.: *Antenna Theory: Analysis and Design*, 3rd edn. WILEY Interscience (2009)
2. Harish, A.R., Sachidananda, M.: *Antennas and Wave Propagation*. Oxford Higher Education (2007)
3. Bahl, J., Bhartia, P.: *Microstrip Antennas*. Artech House, Inc. (1980)
4. Chen, T., Chen, Y., Jian, R.: A wideband differential-fed microstrip patch antenna based on radiation of three resonant modes. *Int. J. Antennas Propag.* **2019**, 7 p. Article ID 4656141 (2019)
5. Malik, P., Parthasarthy, H.: Synthesis of randomness in the radiated fields of antenna array. *Int. J. Microw. Wirel. Technol.* **3**(6), 701–705 (2011). <https://doi.org/10.1017/S1759078711000791>
6. Hossain, I., Noghianian, S., Pistorius, S.: A diamond shaped small planar ultra wide band (UWB) antenna for microwave imaging purpose. In: *IEEE Antennas and Propagation Society International Symposium*, pp. 5713–5716 (2007)
7. Malik, P.K., Parthasarthy, H., Tripathi, M.P.: Axisymmetric Excited Integral Equation Using Moment Method for Plane Circular disk. *Int. J. Sci. Eng. Res.*, **3**(3), 1–3 (2012)
8. Cai, Y., Li, K., Yin, Y., Gao, S., Hu, W., Zhao, L.: A low-profile frequency reconfigurable grid-slotted patch antenna. *IEEE Access* **6**, 36305–36312 (2018)
9. Malik, P.K., Parthasarthy, H., Tripathi, M.P.: Alternative mathematical design of vector potential and radiated fields for parabolic reflector surface. In: Unnikrishnan, S., Surve, S., Bhoir, D. (eds.) *Advances in Computing, Communication, and Control. ICAC3 2013. Communications in Computer and Information Science*, vol 361. Springer, Berlin, Heidelberg (2013)
10. Malik, P.K., Wadhwa, D.S., Khinda, J.S.: A survey of device to device and cooperative communication for the future cellular networks. *Int. J. Wirel. Inf. Netw.* (2020). <https://doi.org/10.1007/s10776-020-00482-8>
11. Akram, S.V., Malik, P.K., Singh, R., Anita, G., Tanwar, S.: Adoption of blockchain technology in various realms: opportunities and challenges. *Secur. Privacy.* e109 (2020). <https://doi.org/10.1002/spy2.109>
12. Malik, P.K., Tripathi, M.P.: OFDM: a mathematical review. *J. Today's Ideas—Tomorrow's Technol.* **5**(2), 97–111 (2017). <https://doi.org/10.15415/jotitt.2017.52006>
13. Malik, P.K., Parthasarthy, H., Tripathi, M.P.: Analysis and design of Pocklington's equation for any arbitrary surface for radiation. *Int. J. Sci. Eng. Res.* **7**(9), 208–213 (2016). ISSN 2229-5518
14. Kaur, A., Malik, P.K.: Tri state, T shaped circular cut ground antenna for higher 'X' band frequencies. In: *2020 International Conference on Computation, Automation and Knowledge Management (ICCAKM)*, Dubai, United Arab Emirates, pp. 90–94 (2020)
15. Tiwari, P., Malik, P.K.: Design of UWB Antenna for the 5G mobile communication applications: a review. In: *2020 International Conference on Computation, Automation and Knowledge Management (ICCAKM)*, Dubai, United Arab Emirates, pp. 24–30 (2020)