



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 3, March 2024

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

Design and Analysis of Dual-band Microstrip Patch Antenna for 5G Communication

¹N Dilip Kumar² K Siva Kumar³ M Dileep⁴ M Balaji⁵ V Govardhan, ⁶A. Vishnuvardhan

¹Assistant professor, Department of ECE, Annamacharya Institute of Technology & Sciences, Tirupati, India

^{2,3,4,5,6}Students of ECE, Annamacharya Institute of Technology & Sciences, Tirupati, India

ABSTRACT: The rapid development of mobile technologies such as 4G, 5G, and wireless networks has led to more investigation for employing a new band of frequencies, besides reducing the size and power consumption. This paper proposes a novel design for a compact dual-band rectangular patch antenna operating at 26 GHz and 29 GHz, specifically designed for 5G applications. The antenna boasts a miniature size of 70mm x 70mm x 1.6mm, including the ground plane, making it suitable for integration into various mobile devices. The design utilizes FR4_epoxy substrate with a dielectric constant of 4.4 and a thickness of 1.6mm for cost-effectiveness and ease of fabrication. The proposed antenna exhibits high gain at both operating frequencies, with measured and simulated return loss values of -21.1 dB and -21.5 dB at 26 GHz and 29 GHz, respectively.

KEYWORDS: MicroStripAntenna (MSA), High-Frequency Structure Simulator (HFSS), 5G Communication, Dual-Band Frequencies.

I. INTRODUCTION

This project focuses on creating a special antenna for 5G communication. We're using specific materials like FR4 for the antenna's base, a substance called a dielectric with a constant of 4.4, and copper for the grounding. These choices are crucial for the antenna to work effectively in the 5G spectrum. Its compact design facilitates seamless integration into modern communication systems.

The rectangular Microstrip patch antenna is popular for 5G applications due to its design and wideband capabilities. Operating in the 26 GHz to 29 GHz range, this antenna boasts a gain of 5.7dB. This requirement leads to achieving tradeoffs between design, high gain, low return loss, small antenna size, high bandwidth, 80% plus radiation efficiency, low cost and high data rate, and high capacity. The Dual-band Microstrip patch antenna operates at two frequencies for two applications.

These are commonly used in mobile phones, Wi-Fi routers, satellite communication systems, radar systems, 5G antennas bring faster speeds, virtually instant downloads, and improved user experiences. Their low latency enables real-time communication for applications like autonomous vehicles. They support more devices simultaneously, critical for the expanding Internet of Things. Operating across various frequency bands, 5G antennas provide broader coverage and reliability, transforming communication with unprecedented speed and connectivity.

Dual-band antennas have clear advantages over single-band counterparts. They bring more flexibility by operating in two frequency bands simultaneously, which is crucial in crowded signal environments. This allows for better signal quality, reduced interference, and improved overall performance. Additionally, dual-band antennas support higher data transfer speeds, contributing to better reliability and lower latency, especially in applications like 5G communication.

II. LITERATURE SURVEY

A. "Design of Dual-Band Microstrip Antenna for 5G Communication"

Authors: Ahmad Firdausi, Lusi Damayanti, Galang P. N. Hakim, Umaisaroh

This paper proposes a dual-band rectangular patch antenna designed for 5G technology, operating at 29 GHz and 38 GHz. The 2x2 array microstrip antenna, constructed with RT Duroid 5880 material, demonstrates return loss values of -12.5 dB and -16 dB at the respective frequencies, with bandwidths of 4.5 GHz and 3.75 GHz. It is observed that the dual-band antenna exhibits good 5G characteristics.

B. "Dual Band Microstrip Patch Antennas"

Authors: Mrs. A. Shamim banu, RKavitha, R Aayishasiddika, M. Elakkiya and S. Kaovyya

This paper introduces a square microstrip patch antenna designed for dual-band operation in the C band and X band. VSWR falls within the ideal 1-2 range for both bands, meeting optimal antenna specs. The dual-band antenna, outperforming the reference paper, suits applications like Satellite Communications, Wi-Fi, WiMAX, and WLAN proposed antenna using HFSS software

C. “Design and Simulation of Insert feed Microstrip patch Antennas”.

Authors: Ketki Patanka, Dr Rupesh and C Jaiswal

This paper involves designing and simulating a microstrip patch antenna for WLAN at 2.4 GHz. The antenna, placed on an FR-4 Epoxy substrate, uses an inset for impedance matching. Ansys HFSS software is utilized to analyze parameters like reflection coefficient, gain, VSWR, and bandwidth. Fabrication typically involves the photolithographic technique used in PCB design.

D. “Design of T-Shaped MicroStrip Patch Antenna for Wireless Communication”.

Authors: B Shilpa, Charan Malothu, M Sai Prasanthi, and Sai Janardhan Ragavandra

The paper introduces a T-shaped ridged Rectangular Microstrip patch wideband antenna designed for 55 GHz millimeter-wave wireless communication. Utilizing CST SOFTWARE, the antenna demonstrates low return loss (-19.13dB), a VSWR of 1.248, and a gain of 6.821dB, highlighting its promise for modern communication systems.

III. PROPOSED RECTANGULAR SLOTTED PATCH ANTENNA

As mentioned earlier, researchers have designed a rectangular slotted microstrip patch antenna that will work on dual band i.e. 26 GHz and 29 GHz using copper patch and ground plate. For better gain, the substrate is chosen as FR4-epoxy with an epsilon value of 4.4 and loss tangent 0.017 - 0.025. The authors have used the inset feed method for impedance matching where the characteristic impedance is assumed to be 50Ω. Initially, the rough dimensions of the rectangular patch antenna have been calculated using the below-mentioned conventional equations with a 1.6mm thick substrate. The dimensions used for the patch are 50 × 35 mm. The patch is fed by a 50 Ω microstrip line with a width of 5 mm and a length of 25 mm. The outline structure of the proposed antenna is given in Fig. 3.1

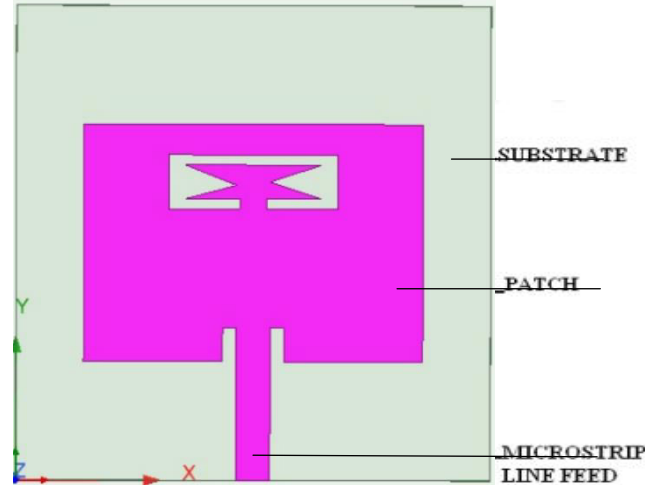


Figure 3.1: Proposed antenna geometry

IV. MATHEMATICAL EXPRESSIONS AND DESIGN PARAMETERS

The antenna design mainly depends on the dielectric constant of the substrate (ϵ_r), the height of the substrate (h_s), and the resonant frequency (f_r). The equations used for the designing of the antenna parameter are mentioned below

Step 1: The radiating patch width and length are calculated using the following Eq.(4.1) and Eq.(4.2) respectively.

$$W_p = \frac{1}{2f_r \sqrt{\mu_0 \epsilon_0}} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (4.1)$$

$$L_p = \frac{1}{2f_r \sqrt{\epsilon_{eff}} \sqrt{\mu_0 \epsilon_0}} - 2\Delta L \quad (4.2)$$

Where:

W_p -width of the patch

L_p -length of the patch

ϵ_0 – permittivity of the free space

μ_0 – permeability of the free space

Step 2: The effective permittivity (ϵ_{eff}) of the substrate is calculated using Eq.(4.3), ΔL is the differential length which is calculated using Eq.(4.4):

(4.3)

Normalized extension in length is given by:

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2\sqrt{1 + 12\frac{h_s}{W_p}}}$$

$$\Delta L = \frac{(\epsilon_{eff} + 0.3)\left(\frac{W_p}{h_s} + 0.264\right)}{(\epsilon_{eff} - 0.258)\left(\frac{W_p}{h_s} + 0.8\right)} * 0.412h_s \tag{4.4}$$

Step 3: Impedance of the patch can be found IN Eq.(4.5):

$$Z_a = 90 \frac{\epsilon_r^2}{\epsilon_r + 1} \left(\frac{L_p}{W_p}\right)^2 \tag{4.5}$$

Step 4: The width of the quarter-wave transition line is evaluated from Eq.(4.6) which is used for the impedance matching of the line:

$$z_T = \frac{60}{\sqrt{\epsilon_r}} \ln \left(\frac{8d}{w_T} + \frac{w_T}{4d} \right) \tag{4.6}$$

The length of the quarter-wave transition line is calculated from Eq.(4.7):

$$l = \frac{\lambda_0}{4\sqrt{\epsilon_{eff}}} = \frac{\lambda}{4} \tag{4.7}$$

Step 5: The width of the 50 Ω microstrip feed can be determined using Eq. (4.8):

$$Z_0 = \frac{120\pi}{\sqrt{\epsilon_{eff} \left(1.393 + \frac{W_f}{hs} + \frac{2}{3} \ln \left(\frac{W_p}{h_s} + 1.444 \right) \right)}} \tag{4.8}$$

Step 6: The width of the ground plane is calculated as shown below,

$$W_g = 6h + W \tag{4.9}$$

Step 7: The length of the ground plane is calculated as shown below,

$$L_g = 6h + L \tag{4.10}$$

The tentative values of the length, width, and ground plane are given in the table below which is obtained by equations(4.1) and (4.10)

Table 4.1: Optimized parameter of the proposed antenna

Variable	Parameter	Values (in mm)
L_s	Length of the Substrate	70
W_s	The width of the Substrate	70
H_s	Height of the Substrate	1.6
L_p	Length of the Patch	50
W_p	Width of the Patch	35
L_f	Length of the Feed	25
W_f	Width of the Feed	5
L_i	Length of the Inset Feed	5
W_i	Width of the Inset Feed	2

V. RESULTS

By using the above-mentioned dimensions, the patch antenna has been drawn and simulated using the Ansys High-Frequency structure simulator. From the HFSS program, all of the simulated results are extracted and loaded into the origin software, where each data plot is simultaneously plotted into a single figure. Corresponding outputs i.e. return loss, VSWR, bandwidth, current distribution, radiation pattern, directivity, and impedance are also observed and discussed in detail below.

Return loss:

S_{11} measures the amount of power that is reflected from the antenna, which is also called the return loss. It should be very small at the resonance frequency. The return loss of the antenna design being proposed is shown in Fig.5.1. It can be observed that the proposed patch antenna resonates at two frequencies at 26 GHz and 29 GHz respectively. The return losses at these frequencies are given -20.63 dB and -21.56 dB respectively which are very satisfactory for the present problem of 5G antenna designs.

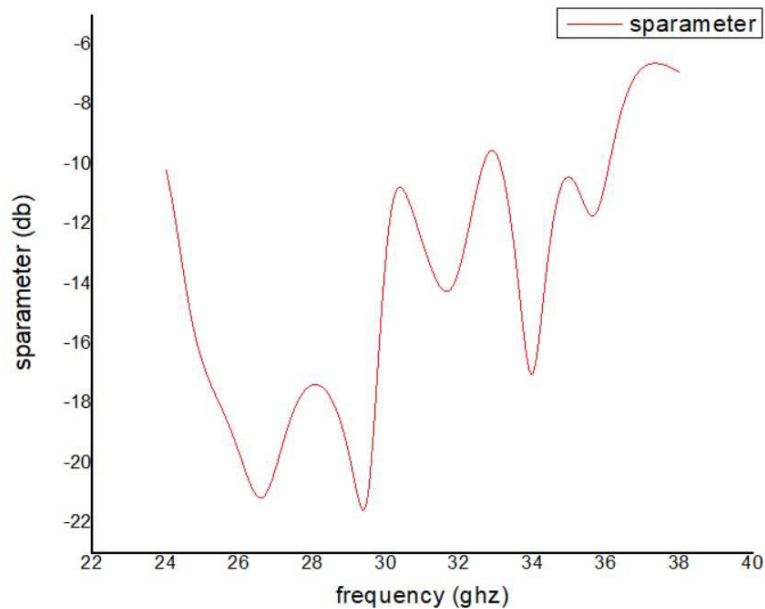


Fig. 5.1. S-parameter for the proposed dual-band patch antenna

Table 5.1. Return loss for proposed dual-band patch antenna at different operating frequency

Operating Frequency	26GHz	29GHz
Return Loss	-20.63 dB	-21.56 dB

VSWR:

VSWR stands for Voltage Standing Wave Ratio, which gives an idea about the power that is reflected from an antenna due to load mismatch. Ideally, the value of VSWR should be '1' which indicates proper matching conditions at operating frequency. Most antenna applications are thought to benefit from a VSWR value of less than 2. The VSWR graph at different frequencies for the proposed dual-band patch antenna is shown in Fig. 5.2

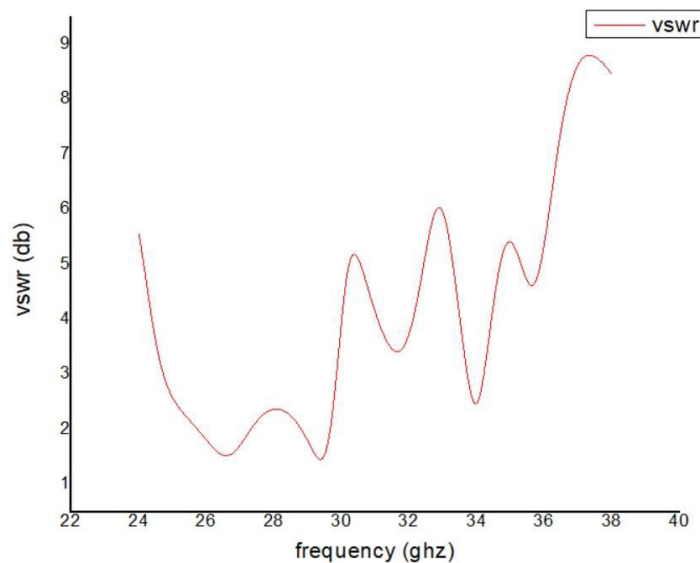


Fig. 5.2. VSWR for the proposed dual-band patch antenna

Table 5.2. VSWR for proposed dual-band patch antenna at different operating frequency

Operating Frequency	26GHz	29GHz
VSWR	1.620	1.454

The values of the VSWR at 26GHz and 29GHz resonance frequencies are found as 1.620 and 1.454 respectively. From Table 5.2 it has been found that the value of VSWR for the proposed antenna is very satisfactory and indicates a very good matching.

GAIN:

The antenna gain is one of the important antenna characteristics because it merges the radiation efficiency and directivity. When an antenna is compared to a theoretical antenna, the gain is its ability to emit more or less in any direction. The gain of the suggested antenna is 5.03 dB. The gain of the proposed antenna at 26.87 and 29.39 GHz is 5.75 dB and 5.79 dB respectively.

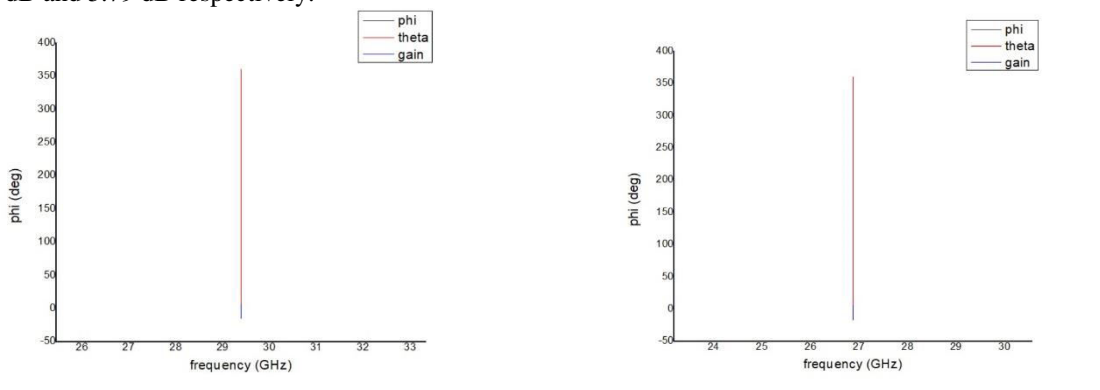


Fig. 5.3. Gain for the proposed antenna at 26 GHz and 29 GHz respectively

Table 5.3. Gain for proposed dual-band patch antenna at different operating frequency

Operating Frequency	26GHz	29GHz
Gain	5.75 dB	5.79dB

Radiation pattern:

The radiation pattern at phi=0° (H-plane) and 90° (E-plane) at 26 GHz are shown in Figure 5.4. While figure 5.5 shows the radiation patterns at 29 GHz.

Name	Theta	Ang	Mag
m1	224.0000	-136.0000	5.7588
m2	298.0000	-62.0000	5.5263
m3	324.0000	-36.0000	5.5815
m4	22.0000	22.0000	5.1034

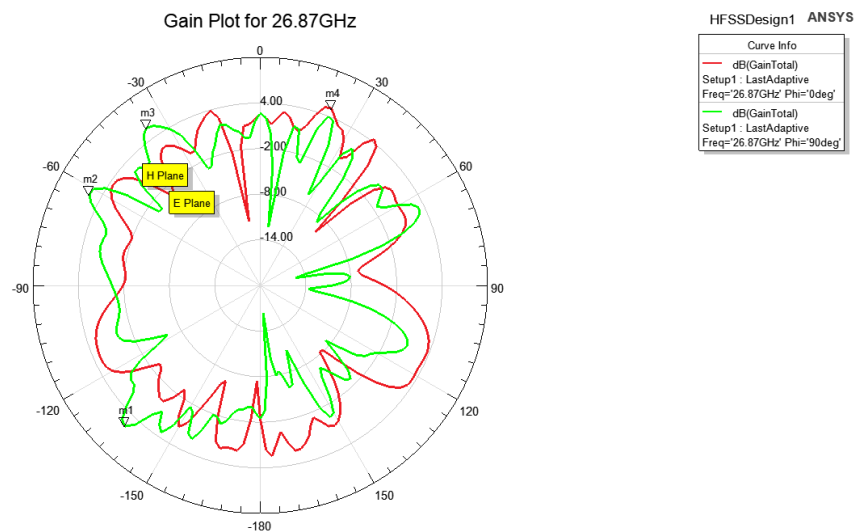


Figure 5.4. The projected antenna radiation pattern at f=26 GHz

Name	Theta	Ang	Mag
m1	190.0000	-170.0000	5.7962
m2	156.0000	156.0000	5.2839
m3	296.0000	-64.0000	5.1715
m4	214.0000	-146.0000	4.9216

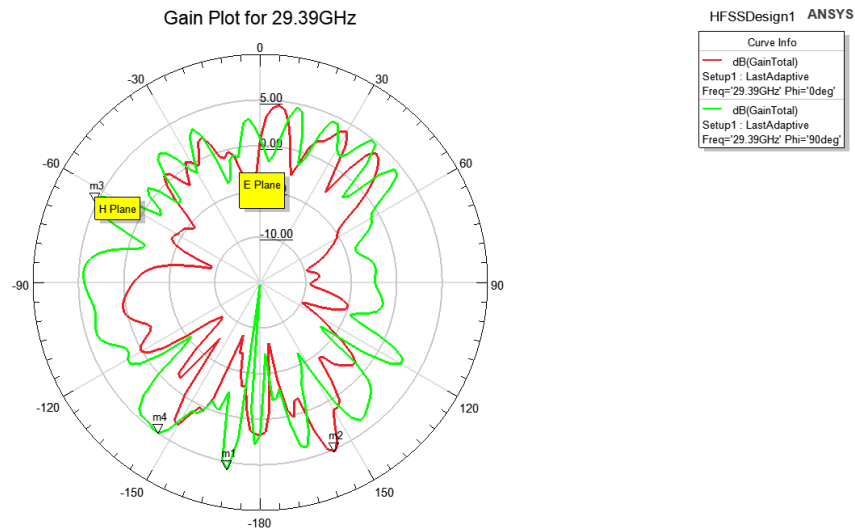


Figure 5.5. The projected antenna radiation pattern at f=29 GHz

VI. CONCLUSION

In this paper, a microstrip antenna with a slotted rectangular patch has been designed to meet the increasingly growing demand for robust 5G mobile communication services. The focus of this study was to achieve a very high antenna gain and directivity and improve the VSWR, reflection coefficient, and efficiency while retaining a wide enough bandwidth at two selected 5G bands. The produced dual band microstrip patch antenna has been operated at 26.8 GHz and 29.3 GHz frequency bands where S11 levels are -20.63 and -21.56 dB, respectively. The proposed dual-band antenna has a peak gain of 5.75 dB and 5.79 dB, also, it has good radiation efficiency of 80% and 84.4% over the first and second frequencies, respectively. Our dual-band antenna can be considered a good candidate in 5G applications.

REFERENCES

1. Ahmad Firdausi, Lusi Damayanti, Galang P. N. Hakim. Design of A Dual-Band Microstrip Antenna for 5G Communication. In 2021 Journal of Integrated and Advanced Engineering (JIAE) Vol. 1, No. 1, March 2021: 65-72.
2. R. Kalyan, Dr. K. T. V. Reddy, Dr. K. Padma Priya "Compact CSRR Etched UWB Microstrip Antenna with Quadruple Band Refusal Characteristics for Short Distance Wireless Communication Applications" Progress in electromagnetics research letters, Volume 82, 139-146, 2019.
3. R. Kalyan, Dr. K. T. V. Reddy, Dr. K. Padma Priya "Novel UWB Microstrip Antenna with Dual Band Notched characteristics for Short Distance Wireless Applications" Journal of engineering and technology
4. R. Kalyan, Dr. K. T. V. Reddy, Dr. K. Padma Priya "UWB Microstrip Antenna with Tuneable Band Notched Characteristics for Wireless Applications" International Journal of Scientific Progress and Research.
5. R. Kalyan, Dr. K. T. V. Reddy, Dr. K. Padma Priya "Compact UWB Microstrip Antenna with Quadruple Band-Notched characteristics for Short Distance Wireless Telecommunication Applications" International Journal of Engineering and Technology, Volume-7, Number-1, 2018, DOI: 10.14419/ijet.v7i1.8822.
6. R. Kalyan, Dr. K. T. V. Reddy, Dr. K. Padma Priya "Novel Ultra-wideband (UWB) antenna with dual-band notch characteristics for short distance wireless telecommunication applications" International Journal of pure and applied mathematics, Volume 114, No.12, 2017, 437-451.
7. R. Kalyan, Dr. K. T. V. Reddy, Dr. K. Padma Priya "Compact Band Notch Ultra-Wide Band Microstrip Antenna for Space Ship Applications" International Journal of Recent Trends in VLSI, Embedded Systems and Signal Processing, Volume-2-Issue-5-2017, ISSN-2454-2407.
8. Nahas, M. (2022c). A super high gain L-slotted microstrip patch antenna for 5G mobile systems operating at 26 and 28 GHz. Engineering, Technology & Applied Science Research, 12(1), 8053-8057.



INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details