Dual-Band Rectangular Microstrip Antenna of 5 And 6 GHz for Wifi Network

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The rapid expansion of wireless communication systems, particularly in WiFi networks, underscores the need for efficient and high-performing antennas. This paper addresses this requirement by presenting the design and simulation of a dual-band rectangular microstrip antenna tailored for wireless local area network (WLAN) applications. The proposed antenna features a rectangular patch with two pairs of slots positioned on opposite edges, fed by a microstrip line. These slots are strategically designed to produce two distinct resonant frequencies at 5 GHz and 6 GHz.

The design methodology incorporates standard equations for rectangular patch and microstrip antennas to determine the optimal patch size, feedline position, and slot dimensions. Following this, a 3D modeling software is utilized for simulation. This tool enables detailed electromagnetic analysis and provides a range of param eters and plots, including return loss, voltage standing wave ratio (VSWR), input impedance, current distribution, radiation pattern, and gain, facilitating a thorough evaluation of the antenna's performance.

The anticipated results suggest that the antenna will achieve a VSWR of less than 2, with peak gains of 2 dBi at both 5 GHz and 6 GHz. The proposed antenna is expected to be well-suited for dual-band WLAN applications, offering advantages such as a compact size, simple structure, and low cost, thereby meeting the growing demands of modern wireless communication systems.

I. INTRODUCTION

T is crucial in today's world. The information technology era requires fast, real-time communication that is accessible anywhere and anytime.
Wireless communication systems use electromagnetic wave propagation as their transmission medium, eliminating the need for cables. A common example of this system is WLAN, which operates using the IEEE 802.11 standards, commonly known as Wi-Fi.

One way to use microstrip antennas is for WLAN, which is a network that con nects devices in a small area using wireless technology. WLAN can provide fast data transfer, mobility, and convenience for users. WLAN works in different fre quencies, such as 2.4 GHz, 5 GHz, and 6 GHz, depending on the rules and stan dards. The most common standards for WLAN are IEEE 802.11, which have dif ferent versions, such as 802.11a, 802.11b, 802.11g, 802.11n, 802.11ac, 802.11ax, and 802.11ay. Each version has different features, such as speed, mode, channel, and distance.

One challenge of making microstrip antennas for WLAN is to make them work in more than one frequency. This is called dual band or multi band operation. Dual band or multi band antennas can do more things, work with more devices, and avoid more problems for WLAN devices. For example, dual band antennas can work in both 2.4 GHz and 5 GHz, which can make the data faster and the signal clearer. Multi band antennas can work in more frequencies, such as 6 GHz, which can give more space and power for WLAN.

In Indonesia, WLAN is very popular and widely used, especially for home, office, and public places. According to the Indonesian government, the number of WLAN users in Indonesia was 171.17 million in 2020, which was 17.8 percent more than in 2019. The number of WLAN hotspots in Indonesia was 6.68million in 2020, which was 23.4 percent more than in 2019. The demand for WLAN services in Indonesia is expected to grow more in the future, as more people use devices that 1 need wireless connection.

Therefore, making dual band or multi band microstrip antennas for WLAN ap plications in Indonesia is a good and important topic for research and development. The goal of this research is to make a dual band rectangular microstrip antenna of 5 6GHz for wifi network in Indonesia. The antenna will use a rectangular patch with two pairs of holes on the opposite sides, connected by a thin line. The holes will make two frequencies at 5 GHz and 6 GHz, which will give a good range, power, and quality for WLAN applications. The antenna will use a FR4 board with a thickness of 1.6 mm and a dialectric constanta of 4.4, which are normal and cheap materials for antenna making. The antenna performance will be tested and measured using software and equipment. The antenna will be good for dual band WLANapplications in Indonesia with small size, simple structure, and low cost.

II. PROBLEM IDENTIFICATION

The growing demand in the Wi-Fi sector, with requirements for high data trans fer rates, low latency, and ample bandwidth, poses a significant challenge. To meet these needs, wireless standards have evolved from the 802.11-1997 Standard to Wi Fi 6 (802.11ax). Opting for the 5 GHz and 6 GHz frequency bands is ideal for Wi-Fi devices. These bands allow greater data transmission, lower latency, and wider bandwidth. While this choice sacrifices some connection range, the addition of dual-band capability ensures that if one band encounters issues, the other serves as a reliable backup, reducing the risk of lost connections.

III. OBJECTIVES AND CONTRIBUTION

This study aims to develop a cost-effective dual-band rectangular microstrip an tenna operating at 5 GHz and 6 GHz, tailored specifically for enhancing wireless network connections in Indonesia. The antenna design will focus on strategically positioned holes within a rectangular patch to enable resonance at both frequen cies, aiming to improve signal quality and range for local network setups. Rigor ous performance assessments will include frequency response testing, signal qual ity evaluations, and efficiency checks. By utilizing practical materials and testing methodologies, this research endeavors to create an antenna solution that addresses Indonesia's growing demand for reliable and budget-friendly wireless connectivity, particularly in local network environments. Ultimately, the goal is to deliver an op timized antenna design that significantly improves the accessibility and reliability 2 of wireless networks across Indonesia.

IV. Scope of The Thesis

1) The observation is done by simulation using 3D model simulation software and measurement in the antenna lab.
2) To gain VSWR below 2
3) To gain huge value of bandwidth
4) The value of gain must be above 2 dBi
5) The frequency range that was observed only from 5 to 6 GHz.

V. Research Method

There search methodology involves initial antenna design using electromagnetic simulation software to create a dual-band rectangular microstrip antenna for 5 GHz and 6 GHz frequencies. Prototyping with cost-effective materials like FR4 boards follows, leading to laboratory testing to measure frequency response, signal qual ity, radiation patterns, and power efficiency. Real-world testing in Indonesian local network settings validates the antenna's performance. Data analysis guides itera tive design refinements, aiming to optimize antenna parameters. Validation through extensive testing and comparison with predefined criteria concludes the process, culminating in comprehensive documentation and reporting of findings, showcas ing the antenna's effectiveness in enhancing wireless network connectivity within Indonesia.

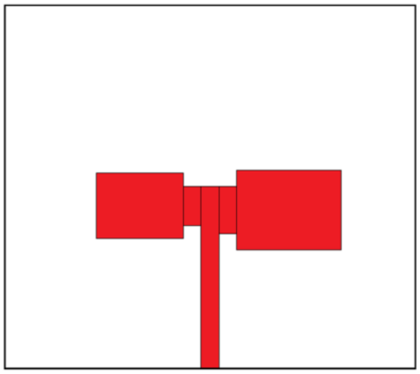
VI. Antenna

Antenna is an electrical device that transforms electrical signals into electro magnetic waves and radiates them into free space. Conversely, it can also capture electromagnetic waves from free space and convert them back into electrical sig nals. Antennas are considered transducers because they convert energy from one form to another. These devices have various parameters that describe their perfor mance and quality, often expressed through numerical and graphical data obtained from measurements. This information allows us to understand and explain antenna behavior both technically and mathematically. This thesis centers around var ious antenna parameters, including gain, VSWR (Voltage Standing Wave Ratio), and the radiation pattern.

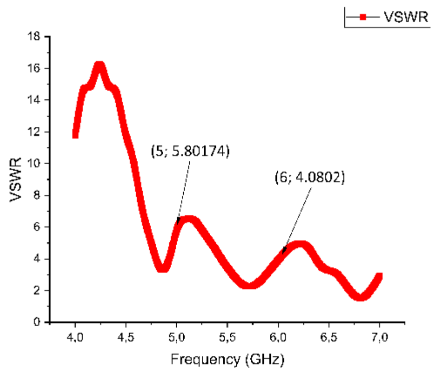
VII. The Specification of Initial Antenna Design

This thesis focuses on creating a dual-band rectangular microstrip antenna operating at 5 and 6 GHz. To achieve these frequencies, two rectangular patches will be designed. Copper with a thickness of 0.035 mm will be used for the patches and feed line, while the substrate material will be specified. the materials that will be used is Epoxy FR 4 with ϵ_r 4.3 and for the {\it h}is 1.6 mm with the impedance input of 50Ω.

No	Specifications	Value(mm
1	Copper Thickness(H_c)	0.035
2	Substrate Thickness (H)	1.6
3	6 GHz patches width(W_{6GHz})	15.35
4	6 GHz patches length(L_{6GHz})	11.46
5	6 GHz Feed Line Width(W_{f6GHz})	3.112
6	6 GHz Feed Line Length(L_{f6GHz})	6.915
7	5 GHz patches width(W_{5GHz})	18.42
8	5 GHz patches length(L_{5GHz})	13.92
9	5 GHz Feed Line Width(W_{f5GHz})	3.112
10	5 GHz Feed Line Length(L_{f5GHz})	8.3
11	Main Feed Line Width(W_{fmain})	3.112
12	Main Feed Line Length(L_{fmain})	31.89
13	The width of ground plane combined($W_{groundplanecombined}$)	72.17
14	The length of ground plane combined($L_{groundplanecombined}$)	63.78
15	Substrate width(S_w)	72.17
16	Substrate length(S_l)	63.78



Results of the First Simulation

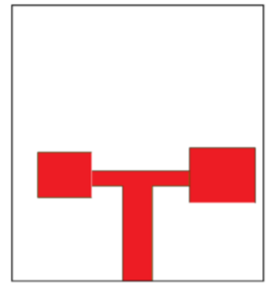


In this thesis, VSWR is the sole parameter monitored during the antenna design iterations. The goal is to achieve the optimal VSWR for a dual-band rectangular microstrip antenna operating at 5 and 6 GHz. By focusing on this, the thesis aims to develop an antenna with superior performance, including improved gain and bandwidth. This approach also allows for adjustments to the antenna to achieve desired results and models. The initial antenna design is based on calculations detailed in Section 3.3, with its specifications outlined in Table 3.3.
in Figure above, The VSWR from this design is bad and didn't fulfil the target that is VSWR below 2, at 6 GHz the VSWR from this design is 4.08 and at 5 GHz the VSWR from this designis 5.80, this design is still far from target and therefore need another iteration to find the best design with the best performance.

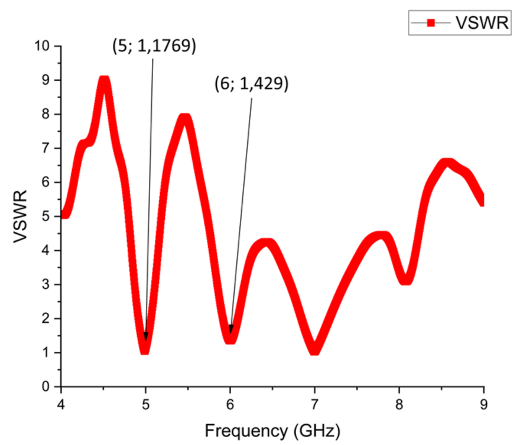
VIII. FINAL ANTENA ITERATION

No	Specifications	Value(mm)
1	6 GHz patches width(W_{6GHz})	11.46
2	6 GHz patches length(L_{6GHz})	9.6
3	6 GHz Feed Line Width(W_{f6GHz})	6.59
4	6 GHz Feed Line Length(L_{f6GHz})	3.185
5	5 GHz patches width(W_{5GHz})	13.92
6	5 GHz patches length(L_{5GHz})	11.67
7	5 GHz Feed Line Width(W_{f5GHz})	7.91
8	5 GHz Feed Line Length(L_{f5GHz})	3.185
9	Main Feed Line Width(W_{fmain})	6.31
10	Main Feed Line Length(L_{fmain})	23.56

In this subsection, the final optimization for the antenna is presented. This iteration is considered the best as it meets the thesis objectives. The lengths of both patches are shorter compared to previous iterations, and the lengths of the 5 GHz feed line, 6 GHz feed line, and the main feed are also reduced. The specification changes are detailed in Table 3.5, and the final antenna design is illustrated in Figure 3.7. This design is neater than the previous iterations.



In this final antenna iteration, the VSWR is the best compared to previous iterations. The optimal VSWR was previously seen in antenna iteration 1 (Figure 3.6), but now the final iteration (Figure 3.7) shows even better results. For the 5 GHz frequency, the VSWR has improved significantly, dropping from 3.15 in iteration 1 to 1.17 in the final iteration.



For the 6 GHz frequency, the VSWR has slightly increased from 1.35 in iteration 1 to 1.42 in the final iteration. Overall, the VSWR at 5 GHz is better in the final iteration, and the 6 GHz frequency performance has also improved compared to previous iterations. Additionally, the dimensions of the patches and feed lines are smaller, resulting in a more compact and tidy design.

IX. ANTENNA REALIZATION AND ANALYSIS

(a) Top view (b) Bottom view

The printed antenna represents the final iteration as described in Subsection 3.4.3. It was fabricated at Spectra Bandung, located at 34 Ahmad Yani Street. The results of the antenna's fabrication and realization are shown in Figure 3.9.

Antenna Measurement

Chapter 4 of this thesis separates the results and analysis into two sections: the 3D model simulation software and the Antenna Lab analysis conducted at the SatComm Radar Lab at Telkom University. The 3D model simulation software results and analysis include measurements of VSWR, Gain, Γ (also known as s11), Bandwidth, Directivity, and Radiation pattern using far-field functions. In the Antenna Lab, the focus was on measuring VSWR and Radiation pattern. These measurements were carried out in room 10-09 of the Telkom University Landmark Tower (TULT), which is not the usual room for antenna measurements and lacks a Chamber room, thus the measurements were not in optimal conditions. The first measurement taken was VSWR using a Vector Network Analyzer (VNA), followed by the antenna radiation pattern using a Signal Generator, Spectrum Analyzer, and Horn antenna as the transmitter.

Antenna Measurement in 3D Model Simulation Software

This simulation will involve analyzing the results of the antenna design from the Final Antenna Iteration detailed in Subsection 3.4.3. This includes measurements of VSWR, Gain, Γ (also known as s11), Bandwidth, Polarization, and Antenna Directivity.

VSWR

No	Specifications	Value
1	5 GHz Reflection Coefficient (Γ)	0.174
2	5 GHz Reflected Power (%)	3.02%
3	5 GHz Reflected Power (dBW)	-15.211 dBW
4	5 GHz Mismatch Loss (dB)	0.133 dB
5	6 GHz Reflection Coefficient (Γ)	0.078
6	6 GHz Reflected Power (%)	0.60%
7	6 GHz Reflected Power (dBW)	-22.120 dBW
8	6 GHz Mismatch Loss (dB)	0.027 dB

In the figure above, the final antenna iteration shows a VSWR of 1.42 at 5 GHz and 1.17 at 6 GHz, both meeting the objectives. Using the calculations from Section 2.6 and Formulas 2.17 to 2.20, the VSWR at 5 GHz is 1.42, resulting in a reflection coefficient (τ) of 0.174. This reflection coefficient leads to a reflected power of 3.02%, which converts to -15.211 dB using Formula 2.19. The mismatch loss, calculated using Formula 2.20, is 0.133 dB.

For the 6 GHz frequency, the VSWR is 1.17. Following the same steps and formulas as for the 5 GHz frequency, the reflection coefficient (τ) is 0.078, the reflected power is 0.60%, and this converts to -22.120 dB. The mismatch loss for the 6 GHz frequency is 0.027 dB, which is better than the 5 GHz frequency. The results of this VSWR calculation analysis are summarized in Table 3.6.

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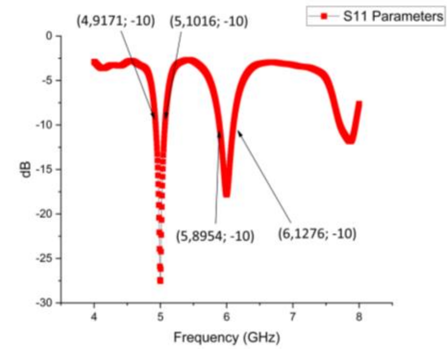
Bandwidth

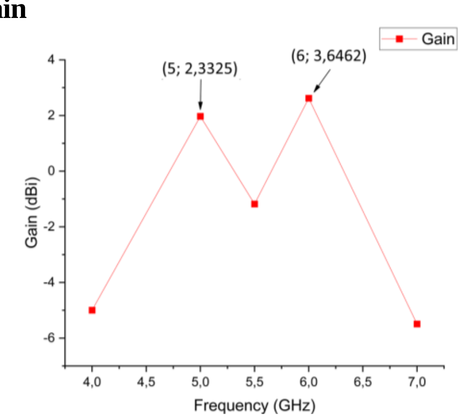


The figure above illustrates S-Parameters, with S11 being the most frequently referenced parameter in antenna discussions. S11, also known as the reflection coefficient, indicates the amount of power reflected from the antenna. Ideally, antennas are designed to be low-loss, meaning most of the power delivered to them is radiated, which is closely related to S11.

The antenna's bandwidth can be determined from Figure 3.10. If we define the bandwidth as the frequency range where S11 is less than -6 dB, the bandwidth at 5 GHz is approximately 184.5 MHz, ranging from 4.917 GHz to 5.101 GHz. For the 6 GHz frequency, the bandwidth is about 232.2 MHz, spanning from 5.895 GHz to 6.127 GHz.

Rectangular patch antennas are known for their narrow bandwidth, typically around 3%. However, this particular antenna achieves a moderate bandwidth, fulfilling its design objectives.

Gain



In Figure above, the gain for the 5 GHz is 2.3325 dBi while the gain for the 6 GHz is 3.6462 dBi.

Antenna Directvity and Radiation Pattern

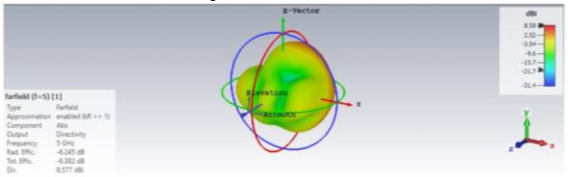


Figure 3.12 5 GHz radiation Pattern.

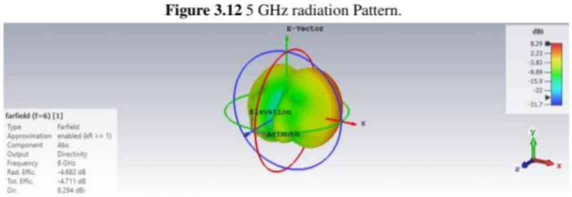


Figure 3.13 6 GHz radiation Pattern.

In Figures above, the directivity is shown on bottom screen menu of both figures, for the 5 GHz, the directivity is 8.577 dBi, while for the 6 GHz, the directivity is 8.294 dBi, in the Section 2.3, the greater the directivity, the narrower the antenna beam will be, as shown in In Figures 3.12 and 3.13, the radiation pattern of the 5 GHz frequency is more narrower than the 6 GHz.

Antenna Measurement in Lab

The results of the measurements can be seen in Figure 4.10, the results is very different from the 3D model simulation software as in subsection 3.6.1 , the results 32 for the 5 GHz frequency is 1.15 for the VSWR by measuring the antenna in the lab while in 3D model simulation software, the VSWR is 1.17, the different is around 0.02 VSWR, for the 6 GHz frequency is 1.52 VSWR while in 3D model simulation software is 1.42 VSWR, the different is around 0.1 VSWR.

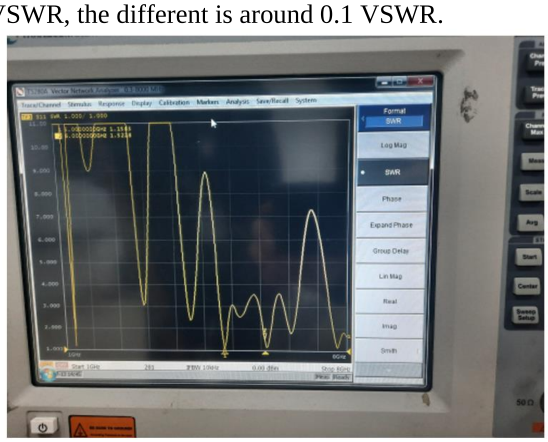


Figure 4.2 The results of the VSWR using VNA.

Radiation Pattern Measurement

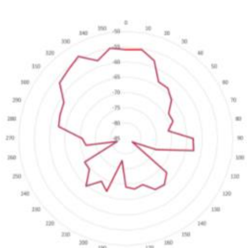


Figure 4.5 5 GHz Azimuth Radiation Pattern.

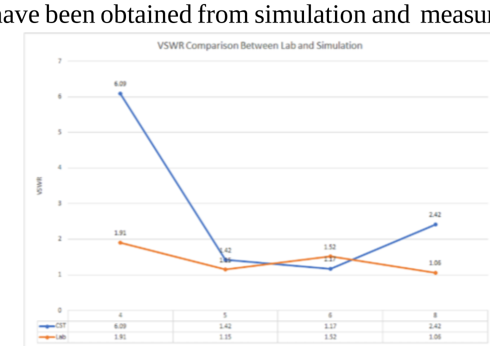
In the figure above, the 5 GHz Azimuth radiation pattern shows that the antenna performs best at 330° with a power level of -54.01 dB. Conversely, the worst performance is observed at 120°, where the power level is 82.62 dB. There are significant discrepancies between the lab measurements and the 3D model simulation results discussed in subsection 3.6.4. These differences are primarily due to the measurements not being conducted in a chamber room.

Figure 4.6 6 GHz Azimuth Radiation Pattern.

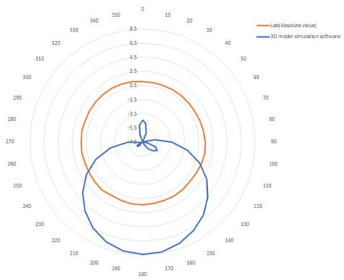
In the figure above, the 6 GHz Azimuth radiation pattern indicates that the antenna performs best at 10° with a value of -56.52 dB. The worst performance is observed at 310°, with a value of -72.25 dB. Notably, the 6 GHz frequency exhibits a lower worst performance value compared to the 5 GHz frequency.

Comparison of Measurement in Antenna Lab and Simulation Results

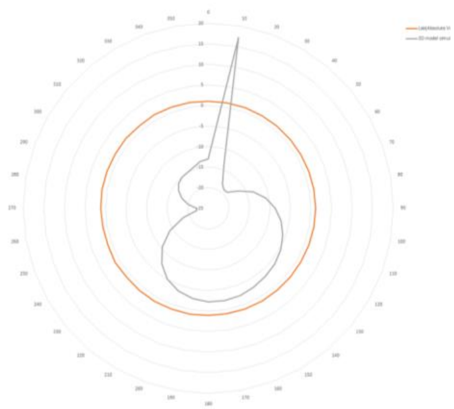
This section show a comparison of all the results that have been obtained from simulation and measurement.



In Figure above, there is a 0.02 and 0.1 VSWR difference between the 3D model simulation software and antenna in the 5 GHz and 6 GHz frequency for the mea surement in lab, for the antenna measurement in lab, the 8 GHz value is 1.08, this unexpected results made the 8 GHz frequency is the best performance frequency in this antenna. There is many factors that make this happened, such as the lab envi ronment that didn't meet a criteria for antenna measurement in the first place, the measurement didn't happen in the original antenna lab that located in O building, in the original building, there is a chamber room for an antenna measurement while in the TULT building there is none so the measurement won't be as good in cham ber room, there is also other factors that didn't count, such as human errors, printed antenna defect from the antenna manufacturers, room temperature, noise and equip ment mistake, but the VSWR value still acceptable by the objective of this thesis that the value of VSWR below 2.



In Figure above, its a graph that show Azimuth radiation pattern of 5 GHz, the difference is very big from the 3D model simulation software and antenna lab mea surement.



In Figure above, the difference between Azimuth radiation pattern of lab mea surement and 3D model simulation software is very different, both the frequency is affected by not doing the measurement in the chamber room, this also has a differ ence between the antenna lab measurement and in 3D model simulation software.

I. CONCLUSION

Conclusion from the results of design, analysis, and simulation using 3D model simulation software on Dual-Band Rectangular Microstrip Antenna of 5 and 6 GHz for Wi-fi Network are as follows:

1. The VSWR for both 5 GHz and 6 GHz frequencies meets the objectives of this thesis by achieving a value below 2. However, altering the shape of the antenna could result in different VSWR outcomes.
2. The SParameters especially the S11 or known as the reflection coefficient(Γ) or, is the one that affected the most from VSWR, the value of the S11 directly related to VSWR.
3. Rectangular patch antennas are notoriously narrowband, the bandwidth of rectangular microstrip antennas are typically 3%, the bandwidth also affected by the S11, the wider the S11 in certain frequencies, the more bandwidth will the antenna get. In this thesis, the bandwidth of the Dual-Band Rectangular Microstrip Antenna of 5 and 6 GHz already fulfil the objective, that is having a moderate amount of bandwidth.
4. Regarding antenna gain, the level achieved is moderate for an antenna that does not utilize metamaterial or Frequency Selective Surface (FSS) tech niques. The gain is primarily influenced by the antenna’s directivity.
5. The directivity of the Dual-Band Rectangular Microstrip Antenna at 5 GHz and 6 GHz exceeds 1. Higher directivity results in a narrower antenna beam.

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A%20dual%2Dband%20antenna%20is,or%20at%20the%20same%