Dual-Band Rectangular Microstrip Antenna of 2.4 And 6 GHz for New WLAN Standard

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This research aims to design a dual-band antenna with a rectangular-shaped slot obtained after optimization, enabling the antenna to be applied to WLAN with working frequencies of 2.4 GHz and 6 GHz. The substrate material used is FR-4 (lossy) with a relative permittivity value of 4.3. To obtain the basic antenna design, calculations for each antenna parameter are necessary, allowing for simulation in CST Studio 2022. Based on the conducted research, the antenna design results with the formula have ground and substrate dimensions of 92.14 mm × 79.638 mm, and the antenna patch size is 38.39 mm × 29.77 mm for 2.4 GHz and 15.35 mm x 11.46 mm for 6 GHz. The simulation results for the formula-based antenna at a frequency of 2.4 GHz show a VSWR (Voltage Standing Wave Ratio) of 2.581, and at a frequency of 6 GHz, it has a VSWR of 1.17.

After optimizing the antenna, the results differ from those of the formula-based antenna. The ground and substrate dimensions become 101.74 mm x 89.23 mm, and the patch size becomes 32.15 mm x 29.77 mm for 2.4 GHz and 34.26 mm x 11.46 mm for 6 GHz. Simulation results for the antenna at a frequency of 2.4 GHz show a VSWR of 1.54, a gain of 3.3062 dB, and a bandwidth of 67 MHz. Meanwhile, for the 6 GHz frequency, a VSWR of 1.54, a gain of 0.86 dB, and a bandwidth of 392 MHz are obtained.

In conclusion, the antenna performs in accordance with specifications as the VSWR values are ≤ 2, and the s-parameters are ≤ -10 dB.

I. INTRODUCTION

Telecommunication is a very important thing nowadays. The era of information technology now demands fast, real-time, anywhere and anytime. Wireless communication system is a communication system with transmission media in the form of propagation of electromagnetic waves without having to be connected to cables. Application examples of this system is WLAN that uses the IEEE 802.11 standards that commonly called Wi-Fi.

IEEE 802.11ax, officially marketed by the Wi-Fi Alliance as Wi-Fi 6 (2.4 GHz and 5 GHz) and Wi-Fi 6E (6 GHz), is an IEEE standard for wireless local-area networks (WLANs) and the successor of Wi-Fi 5 (802.11ac). It is also known as High Efficiency Wi-Fi, for the overall improvements to Wi-Fi 6 clients in dense environments. It is designed to operate in license-exempt bands between 1 and 7.125 GHz, including the 2.4 and 5 GHz bands already in common use as well as the much wider 6 GHz band (e.g. 5.925–7.125 GHz in the US, a band 1.200 GHz wide).

WLAN “Wireless Local Area Network” is one of the most popular wireless communication standards. In the market, this technology is widely used both in offices, campus or other public places. In practice, the antenna is a device used to access WLAN, the antenna functions as a device that used to transmit and receive radio waves or electromagnetic waves that radiated to the free medium to be emitted.

A microstrip antenna is a metal conductor (patch) attached to the ground plane which contains a dielectric material. Through decades of research, It is known that the operational capability of a microstrip antenna is connected to its shape. Microstrip antenna is one of the most popular antennas today, this is because Microstrip antenna are very suitable in today's telecommunication devices which pay attention to shape and size. Besides that, microstrip antennas are easy to make, easy to install,and have a low cost. But, microstrip antennas also have some drawbacks which is narrow bandwidth. This can be solved because the antenna bandwidth can be increased by various methods such as increasing the thickness of the substrate with the dielectric value low constant, with probe feeding cutting slot, as well as by testing the antenna with different forms.

In this final project, there are several types of microstrip antennas that can be designed for meet the needs of WiFi technology, this design uses a rectangular shape and look for the microstrip antenna formula needed by WLAN technology that works at 2.4 and 6 GHz frequencies.

II. PROBLEM IDENTIFICATION

The exponential growth of telecommunication over the past three decades increases the amount of data the average person uses exponentially. This growth is more noteworthy especially with the evolution of wireless communications which requires the development of low cost, lightweight, and low profile antennas that are capable of maintaining high performance over a wide bandwidth \cite{du2016millimeter}. In order to fulfil this needs, this proposal tries to make an antenna that can fulfil this role by making a dual-band antenna, the dual-band is very effective for such an important devices as WLAN, if there is a problems with one of the band, the other band will be the secondary option, the chance for the WLAN devices to lost a connection will be reduced, the 2.4 and 6

GHz is the best choice for an WLAN devices, as it carry more data the higher the frequency and better the modulations in the futures with a trade off the higher the frequency the shorter the coverable area, there is also a disadvantage of the dimension of the antenna the higher the frequency the smaller the antenna patch will be, this disadvantage lead to another disadvantage that is the smaller the antenna the worse the performance of the antenna will be, the dimension and the cost of the electricity will be higher by using the dual-band, in spite all of that, the future of telecommunication will move forward to more higher frequency as we can see the history of it, the disadvantage of this antenna will become a small price to pay.

Define abbreviations and acronyms the first time they are used in the text, even after they have already been defined in the abstract. Abbreviations such as IEEE, SI, ac, and dc do not have to be defined. Abbreviations that incorporate periods should not have spaces: write “C.N.R.S.,” not “C. N. R. S.” Do not use abbreviations in the title unless they are unavoidable (for example, “IEEE” in the title of this article).

III. Objectives and Contribution

To solve the problems described in subsection \ref{sec:problem}, this thesis design and the realization of Dual-Band Microstrip antenna using a 2.4 and 6 GHz frequency to achieve the best results to solve this problems, this proposal using the CST microwave to simulate and to achieve a desired results before comes into the fabrication and the realization of the antenna, the design of the antenna will be very similar to this paper \cite{7380721}, the main objective of this proposed proposal is to make a Dual-Band 2.4 Ghz and 6 Ghz Rectangular Patch Microstrip antenna and come into the realization of the antenna.

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 0 dBi
5) The frequency range that was observed only from 2.4 to 6 GHz.

V. Research Method

1) Literature Study this thesis, the author studies about Dual-Band antenna and the antenna in general from lecturer, textbooks, journals, and papers.
2) Calculating the antenna using the basic and given formula to create the basic of the antenna before created it in the simulation.
3) Simulation process is done to give a desired results and dimension to the antenna before Fabrication process to ensure the best performance of antenna.
4) Fabrication and Antenna measurement was done after the antenna finished the simulation process, after fabrication the next step is to calculate the parameters of the antenna that had been printed out.
5) Analysis after the simulation and measurement results were obtained, both were compared and analyzed to ensure that the results were in accordance with desired specifications.
6) Writing report, after all of the results and analysis were obtained, the next step was writing the report in the form of thesis.

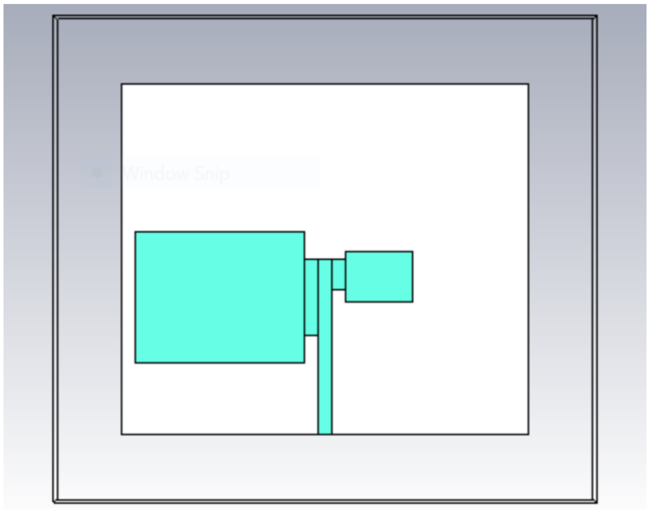
VI. Antenna

Antenna is an electrical device that can convert electrical signals into electromagnetic waves and then emit them into free space or as electromagnetic waves from free space and then into electrical signals. Antennas are also classified as transducers because they can change the form of energy into other forms of energy. Antenna has several parameters, Antenna parameters are various references regarding the performance and quality of the antenna expressed in the form of numerical and graphic data measurement results from the antenna so that it can be understood and explained technically and mathematically \cite{Nando}. This thesis focuses on several antenna parameters such as Gain, VSWR, and Radiation Pattern.

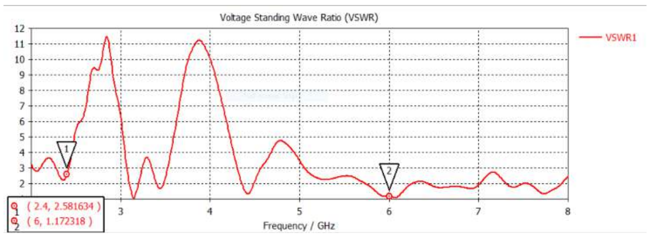
VII. The Specification of Initial Antenna Design

This Thesis is making 2.4 and 6 GHz Dual Band Rectangular Microstrip Antenna. The frequency that will use is 2.4 and 6 GHz, in order to fulfil both of the frequency, this thesis will make 2 rectangular patches, for the rectangular patches and feed line the materials that will be used is copper with density of 0.035 mm, for substrate, 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	2.4 GHz patches width($W_{2.4GHz}$)	38.3934
8	2.4 GHz patches length($L_{2.4GHz}$)	29.77855
9	2.4 GHz Feed Line Width($W_{f2.4GHz}$)	3.112
10	2.4 GHz Feed Line Length($L_{f2.4GHz}$)	17.29
11	Main Feed Line Width(W_{fmain})	3.112
12	Main Feed Line Length(L_{fmain})	39.819
13	The width of ground plane combined($W_{groundplanecombined}$)	92.14
14	The length of ground plane combined($L_{groundplanecombined}$)	79.638
15	Substrate width(S_w)	92.14
16	Substrate length(S_l)	79.638



Results of the First Simulation



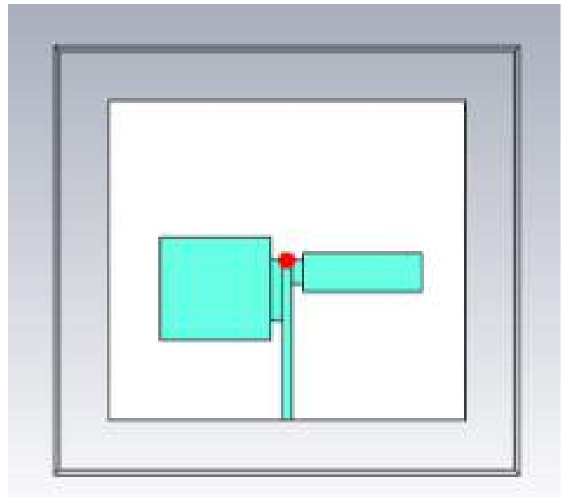
VSWR is the only parameter that observe in antenna design iteration. The ob jective is to search the best VSWR for 2.4 and 6 GHz Dual-Band Rectangular Mi crostrip Antenna, by doing this, in the final will this thesis will have the best perfor mance antenna with a better gain and bandwidth, this method can also make a tweak to the antenna and get a desired results and antenna models. The initial antenna is built from the calculations that have been obtained previously in Section 3.3. The initial specifications of the antenna is listed in table 3.9.

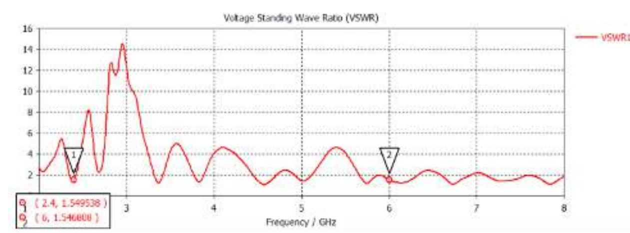
The VSWR from this design is bad and didn't fulfil the target that is VSWR below 2, at 6 GHz the VSWR from this design is 1.172318 and at 2.4 GHz the VSWR from this design is 2.581634, this design is still far from target and therefore need another iteration to find the best design with the best performance.

VIII. FINAL ANTENA ITERATION

No	Specifications	Value(mm)
1	6 GHz patches width(W_{6GHz})	34.26
2	6 GHz patches length(L_{6GHz})	11.46
3	6 GHz Feed Line Width(W_{f6GHz})	3.11
4	6 GHz Feed Line Length(L_{f6GHz})	6.915
5	2.4 GHz patches width(W_{5GHz})	32.15
6	2.4 GHz patches length(L_{5GHz})	29.77
7	2.4 GHz Feed Line Width(W_{f5GHz})	3.11
8	2.4 GHz Feed Line Length(L_{f5GHz})	17.29
9	Main Feed Line Width(W_{fmain})	3.11
10	Main Feed Line Length(L_{fmain})	39.819
11	The width of ground plane combined($W_{groundplanecombined}$)	101.74
12	The length of ground plane combined($L_{groundplanecombined}$)	89.23
13	Substrate width(S_w)	101.74
14	Substrate length(S_l)	89.23

In this subsection, this iteration is the final optimization for this antenna, the reason is it the best antenna that fulfil the objective of this thesis, the width of both patches changed while the length is using the initial antenna size calculation. The changes in the specification is in Table 3.12, the last antenna iteration design is rendered in Figure 3.15.





The VSWR in this final antenna iteration is the best than the previous antenna iteration, the best VSWR is in antenna iteration 2 before as in Figure 3.14, now this final antenna iteration has the best VSWR result as in Figure 3.15, for the 2.4 GHz frequency the VSWR dropped to 1.54 in this final antenna iteration from VSWR 3.03 in the antenna iteration 2 before, for the 6 GHz frequency, the VSWR has a little raise to 1.54 in the final iteration as the VSWR is 1.43 in the antenna iteration 2 before. Both the VSWR in 2.4 and 6 GHz frequency is better than the previous antenna iteration

IX. ANTENNA REALIZATION AND ANALYSIS

(a) Top view (b) Bottom view

Figure 3.17 Printed Antenna of Dual-Band Rectangular Microstrip Antenna of 2.4 and 6 GHz Compared with Rp. 500

The printed antenna is the version of the final antenna iteration from the Sub sections 3.4.4, the fabrication was done in Spectra Bandung that located in Ahmad Yani street no.34, the result of antenna fabrication and realization is in Figure 3.17.

Antenna Measurement

For chapter 4, this thesis divide the results and analysis between the 3D model simulation software and Antenna Lab analysis that were carried out in SatComm Radar lab that located in Telkom University, for the 3D model simulation software results and analysis, the parameters that measured is VSWR, Gain, Γ (also known as s11), Bandwidth, Directivity and Radiation pattern using far-field functions in 3D model simulation software, for the Antenna Lab measurement, its focused on measuring the VSWR and Radiation pattern.

Result And Analysis in 3D model simulation software

This simulation will consist of analysing the results of the antenna design that is from the Final Antenna Iteration from subsection 3.4.4, this subsection consist of measuring the VSWR, Gain, Γ (also known as s11), Bandwidth, Polarization and Radiation pattern.

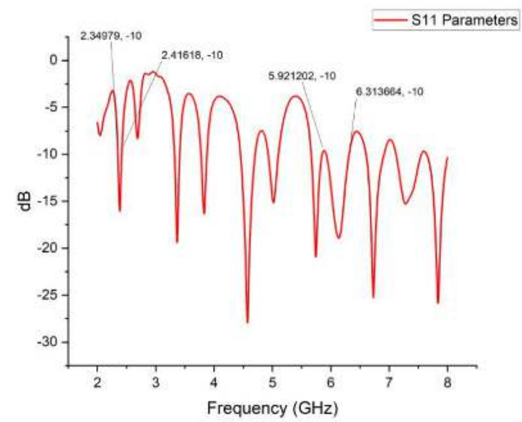
VSWR

Table 4.1 The VSWR Analysis.

No	Specifications	Value
1	2.4 GHz Reflection Coefficient (Γ)	0.2126
2	2.4 GHz Reflected Power (%)	4.5199%
3	2.4 GHz Mismatch Loss (dB)	0.20087 dB
4	6 GHz Reflection Coefficient (Γ)	0.2126
5	6 GHz Reflected Power (%)	4.5199%
6	6 GHz Mismatch Loss (dB)	0.20087 dB

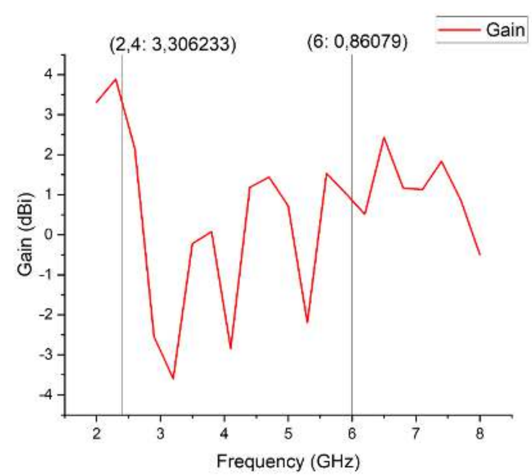
In Figure 3.16 of the final antenna iteration, the VSWR for the 2.4 GHz fre quency is 1.54 and for the 6 GHz frequency is 1.54, both are fulfilled the objective, in this subsection, using the calculation from Section 2.6, using the Formula 2.17 to 2.20, for the 2.4 GHz frequency, the VSWR is 1.54 using the Formula 2.17 the reflection coefficient(τ) is 0.2126, using this reflection coefficient(τ) to fulfil the Formula 2.18 requirement, the reflected power is 4.5199%. And the last analysis in this subsection is the mismatch loss using the Formula 2.20, the results is 0.20087 dB.For the 6 GHz frequency,since the VSWR is the same as 2.4 GHz then the cal culations will be the same. The further away the VSWR from 1, the results will be worse, for the result of the analysis of this VSWR calculation is in Table 4.1.

Bandwidth



In Figure 4.1, is called S-Parameters, the most commonly quoted parameter
in regards to antennas is S11. S11 represents how much power is reflected from the antenna, and hence is known as the reflection coefficient. Since antennas are typically designed to be low loss, ideally the majority of the power delivered to
the antenna is radiated, which is directly related to S11. The antenna bandwidth can also be determined from the Figure 4.1. If the bandwidth is defined as the frequency range where S11 is to be less than -10 dB, the bandwidth for the 2.4 GHz frequency is roughly 67 MHz with frequency 2.416 as the high end and frequency 2.349 as the low end, while for the 6 GHz frequency the bandwidth is roughly 392 MHz with frequency 6.313 as the high end and frequency 5.921 as the low end. The bandwidth of the patch antenna is very small. Rectangular patch antennas are notoriously narrowband, the bandwidth of rectangular microstrip antennas are typically 3% [6], the bandwidth for this antenna is fulfil the objective by having a moderate amount of bandwidth.

Gain



In Figure 4.2, the gain for the 2.4 GHz is 3.3062 dBi while the gain for the 6 GHz is 0.8607 dBi.

Antenna Directvity and Radiation Pattern

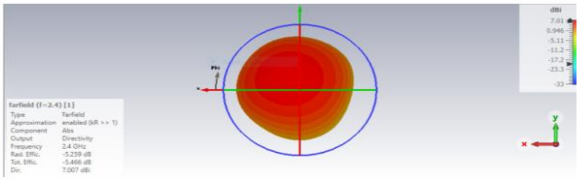


Figure 4.3 2.4 GHz radiation Pattern.

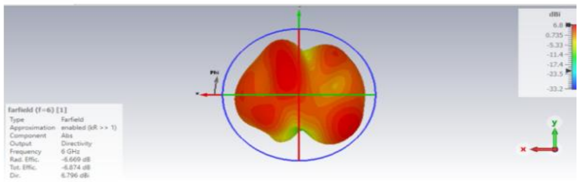
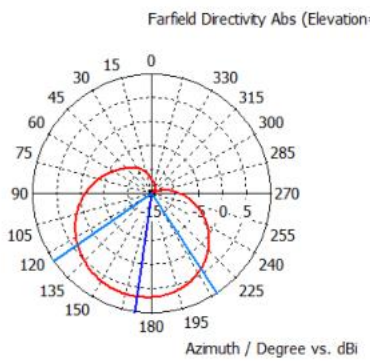


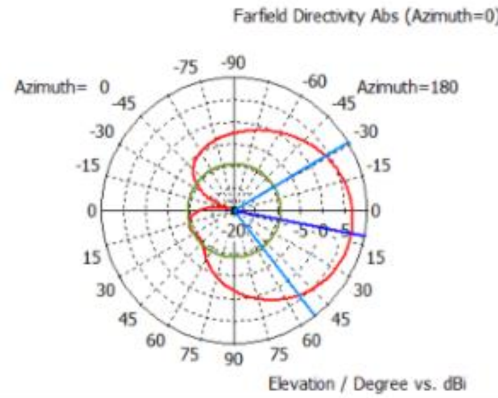
Figure 4.4 6 GHz radiation Pattern.

In Figures 4.3 and 4.4, the directivity is shown on bottom screen menu of both figures, for the 2.4 GHz, the directivity is 7.007 dBi, while for the 6 GHz, the directivity is 6.796 dBi, in the Section 2.3, the greater the directivity, the narrower the antenna beam will be, as shown in In Figures 4.3 and 4.4, the radiation pattern of the 6 GHz frequency is more narrower than the 2.4 GHz. For the 2D radiation pattern is shown below.



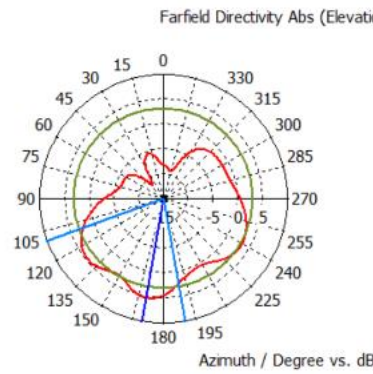
(a) Azimuth Radiation pattern at Elevation 0°.

Degrees	0°
Main Lobe Magnitude	6.76 dBi
Main Lobe Direction	172.0 deg.
Angular Width (3 dB)	88.9 deg.
Side Lobe Level	-



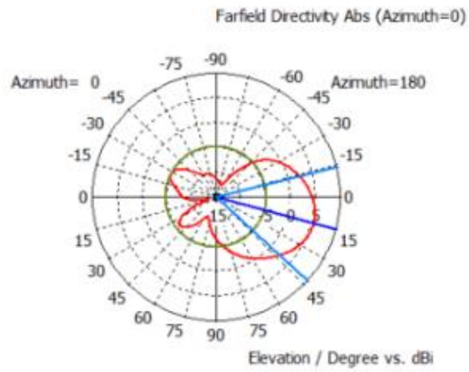
(a) Elevation Radiation pattern at Azimuth 0°.

Degrees	0°
Main Lobe Magnitude	6.89 dBi
Main Lobe Direction	11.0 deg.
Angular Width (3 dB)	83.3 deg.
Side Lobe Level	-16.3 dB



(a) Azimuth Radiation pattern at Elevation 0°.

Degrees	0°
Main Lobe Magnitude	5.18 dBi
Main Lobe Direction	170.0 deg.
Angular Width (3 dB)	80.5 deg.
Side Lobe Level	-2.1 dB



(a) Elevation Radiation pattern at Azimuth 0°.

Degrees	0°
Main Lobe Magnitude	5.27 dBi
Main Lobe Direction	15.0 deg.
Angular Width (3 dB)	56.5 deg.
Side Lobe Level	-10.0 dB

Antenna Measurement in Lab

The results for the 2.4 GHz frequency is 1.0058 for the VSWR by measuring the antenna in the lab while in CST, the VSWR is 1.54, the different is around 0.5 VSWR, for the 6 GHz frequency is 1.0001 VSWR while in CST is 1.54 VSWR, the different is also around 0.5 VSWR.

Figure 4.10 The results of the VSWR using VNA.

Radiation Pattern Measurement

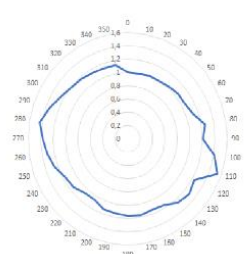


Figure 4.13 2.4 GHz Azimuth Radiation Pattern.

In figure above, for the 2.4 GHz Azimuth radiation pattern, from the measure ment that happened, the best performance for the antenna is at 280◦ with power of -72.37 dB, while the worst is at 10◦ , with the performance of the antenna at that degree is -50.44 dB, there are many differences between the antenna measurement in the lab and between the 3D model simulation software in subsection 4.2.4, this measurement is the one that affected the most by not measuring it in the chamber room.

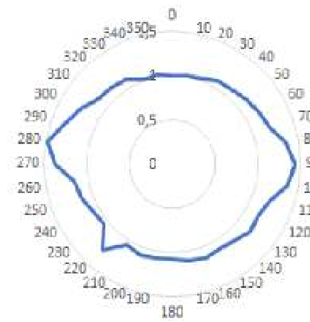


Figure 4.14 6 GHz Azimuth Radiation Pattern.

In figure above, for the 6 GHz Azimuth radiation pattern, from the measurement that happened, the best performance for the antenna is at 280◦ with a value of -84.45 dB, and the worst is at 0◦ with a value of -57.17 dB, the 6 GHz has a higher value of the worst performance of the radiation than the 2.4 GHz.

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.

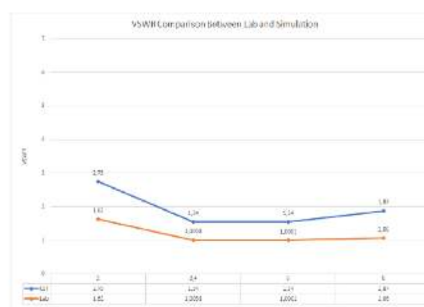


Figure 4.15 The Difference between 3D model simulation software VSWR and Antenna lab measurement VSWR.

In Figure 4.15, there is a 0.5 VSWR difference between the 3D model simulation software and antenna in the 2.4 GHz and 6 GHz frequency for the measurement in lab, for the antenna measurement in lab. There are many factors that influence this result. One of them is that the chamber room can not be used. Other influencing factors are human error, antenna defects by the manufacturer, room temperature, and equipment errors when measuring. But, the VSWR value still acceptable by the objective of this thesis that the both value of VSWR are below 2.

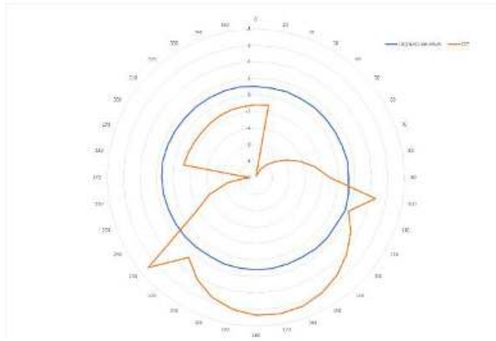


Figure 4.16 The Comparison between 3D model simulation software and Antenna lab measurement of 2.4 GHz Azimuth Pattern.

In Figure 4.17, its a graph that show Azimuth radiation pattern of 2.4 GHz, the difference is very big from the 3D model simulation software and antenna lab measurement.

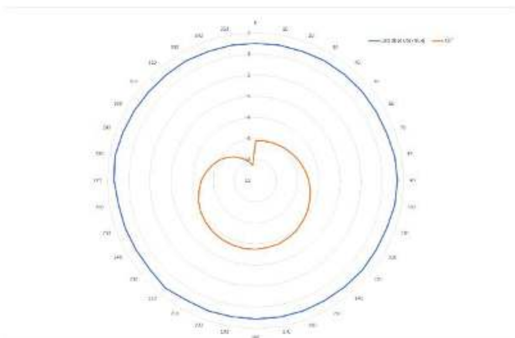


Figure 4.17 The Comparison between 3D model simulation software and Antenna lab measurement of 6 GHz Azimuth Pattern.

In Figure 4.18, the difference between Azimuth radiation pattern of lab measurement 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 difference between the antenna lab measurement and in 3D model simulation software as in subsection 4.2.4. For the elevation pattern and antenna gain, the assistance of the lab can't do that, for the elevation pattern, there is no equipment to measure the elevation pattern, for the gain, the assistance that has knowledge and experience in it, isn't in Bandung at the moment, so this will be the measurement that can be measured in the antenna lab at the moment.

X. CONCLUSION

From the research process that has been carried out in designing and analyzing microstrip antennas, it can be concluded as follows:

1. VSWR 2.4 and 6 GHz meet the requirements, since both values are below 2. By changing the patch size and ground width, the VSWR value obtained will change.

2. The directivity of the Dual-Band Rectangular Microstrip Antenna of 2.4 and 6 GHz is more than 1, the greater the directivity, the narrower the antenna beam will be.

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