Analysis of Design of Double Layer Biquad Microstrip Antenna for WLAN Application

Fernanda A.D. Silaban
alexanderfernanda@yahoo.com
Hamdani
hamdani.stmt@dosen.pancabudi.ac.id
Muhammad Erfandi Dalimunthe
Erfandimunthe25@gmail.com

University of Pembangunan Panca Budi

ABSTRACT
The design of a double-layer biquad microstrip antenna for WLAN applications aims to develop an antenna with optimal performance at a frequency of 2.4 GHz, which is the main frequency for wireless communication, especially for Wi-Fi networks. The double-layer biquad microstrip antenna is designed with specific dimensions, including biquad sides of 25 mm and 20 mm, and diagonal lengths of 50 mm and 40 mm. The design was carried out using a simulation method to obtain optimal parameters, including return loss, VSWR, gain, bandwidth, and radiation pattern. The simulation results show that this antenna has a return loss of -21.1 dB, VSWR of 1.19, gain of 5.82 dB, bandwidth of 95.4 MHz, and unidirectional radiation pattern at a frequency of 2.4 GHz. After fabrication, the measurement results using VNA showed an increase in performance with a return loss of -30.62 dB and VSWR of 1.06, and a gain of 5.82 dB. This antenna also shows better connection quality, with a two-fold improvement compared to the single-layer antenna. Thus, this double-layer biquad microstrip antenna is very suitable for WLAN applications, providing higher efficiency and better connection stability at 2.4 GHz.

Keywords: Microstrip Antenna, Double Layer Biquad, WLAN, 2.4 Ghz Frequency, Simulation, Fabrication, Connection Quality.

Introduction

In the digital era, wireless communication technology has become an inseparable part of human life. One of the most commonly used technologies is Wireless Local Area Network (WLAN), which allows users to connect to the internet and share data wirelessly in various locations, such as offices, homes, and public facilities (Rappaport, 2010). The rapid growth of WLAN networks creates a need for innovation that can improve network performance, including in terms of range, signal quality, and data transfer speed.

One of the technical aspects that plays an important role in WLAN network performance is antenna design. Antennas function as the main component in transmitting and receiving radio signals used in WLAN networks. Therefore, antenna performance will greatly affect the quality of connectivity and network stability (Balanis, 2016). In this context, microstrip antennas are one type of antenna that is widely used because they have various advantages, such as small size, light weight, and ease of integration with modern electronic devices (Pozar, 2005).

In this study, attention is focused on the design of a double layer biquad microstrip antenna, which is a development of the conventional biquad antenna. The structure of this antenna consists of two layers of patch antennas placed vertically, which aims to increase gain and directivity. High-performance antennas are essential in WLAN networks to answer the challenges of modern wireless communications, including the need for increasingly high data transfer rates, especially with the development of technologies such as 5G (Yang & Rahmat-Samii, 2009).

Several key parameters that affect antenna performance, such as gain, directivity, bandwidth, and the ability to reduce interference, will be the focus of this study. In addition, other factors, such as antenna dimensions and materials, will also be studied to produce an optimal and efficient design. This analysis will be carried out through simulation using electromagnetic software to evaluate the performance of a double layer biquad microstrip antenna in WLAN applications (Rao, 2011).

This study aims to provide a deeper understanding of the influence of the design of a double layer biquad microstrip antenna on the performance of a WLAN network. By developing a more efficient and optimal antenna design, it is expected to create a solution that supports better signal quality, wider coverage, and higher data transfer rates. The contribution of this study is also expected to be the basis for the development of other wireless communication systems, along with the increasing demand for better connectivity in various modern applications.

Formulation of the problem:

1) How does the design of a double layer biquad microstrip antenna affect WLAN performance?
2) How to design an optimal double layer biquad microstrip antenna for WLAN applications?
3) How to optimize the bandwidth of double layer biquad microstrip antenna to achieve good signal quality in WLAN range?

LITERATURE REVIEW

1) Antenna Technology for WLAN Applications

Antenna technology plays an important role in the development of Wireless Local Area Network (WLAN) networks, especially in terms of improving network performance, such as signal quality, range, and data transfer speed. One type of antenna that is popularly used is the biquad antenna. This antenna is designed to improve forward radiation performance, reduce interference, and offer flexibility in wireless network applications (Balanis, 2016).

2) Biquad Antenna

A biquad antenna is a type of double cube loop wire antenna consisting of a dipole element and a reflector. The driven element in a biquad antenna has a length of 1λ, where the wavelength is calculated based on the speed of light (3×10^8 m/s) divided by the antenna's operating frequency (Hz). The antenna reflector is square, with a side length slightly larger than the length of the dipole element, to maximize forward radiation and reduce rearward radiation (Pozar, 2005).

The main advantage of the biquad antenna is its ability to produce high gain with a directional radiation pattern, making it very suitable for WLAN applications. In addition, the biquad antenna also offers flexibility in design, such as the use of a certain distance between the dipole and the reflector (1/8λ) to optimize gain and bandwidth. This antenna can also be modified into a folded dipole antenna to adjust the impedance, making it more compatible with modern electronic devices (Rao, 2011).

3) Microstrip Antenna and Its Applications

Microstrip antennas are known for their small size, light weight, and ease of integration with electronic devices. In the context of WLAN, microstrip antennas can be designed to operate at a wide range of frequencies with adjustable radiation patterns and gains. The combination of microstrip and biquad structures can produce efficient antennas for WLAN applications, especially with the incorporation of double-layer elements, which allow for increased directivity and bandwidth (Yang & Rahmat-Samii, 2009).

4) Double Layer Biquad Microstrip Antenna Structure

The double layer biquad microstrip antenna is a development of the conventional biquad antenna. This structure consists of two layers of patch antennas placed vertically. With this structure, the antenna can increase gain, directivity, and overall performance. The use of reflectors with specially designed dimensions provides additional benefits in terms of reducing interference and improving the radiation pattern in the forward direction.

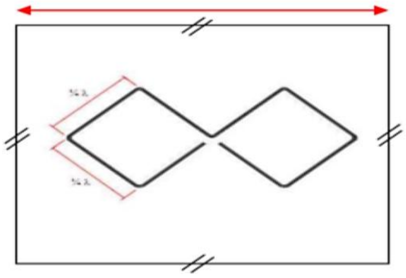


Figure 1. Biquad Antenna Design

5) Factors Affecting Antenna Performance

The optimal antenna design depends on several factors:

Gain and Directivity: Adjusting the distance between the dipole element and the reflector greatly affects the antenna's performance in producing a strong and directional signal.

Bandwidth: Larger bandwidth can support better and more stable connectivity. In a biquad antenna, smaller reflector spacing results in narrower bandwidth but higher gain. Material and Dimension: The choice of material and dimensions of the dipole elements and reflectors affect the radiation efficiency and impedance of the antenna (Rappaport, 2010).

Research Method

System workflow planning on Solar Boats that use *solar* :

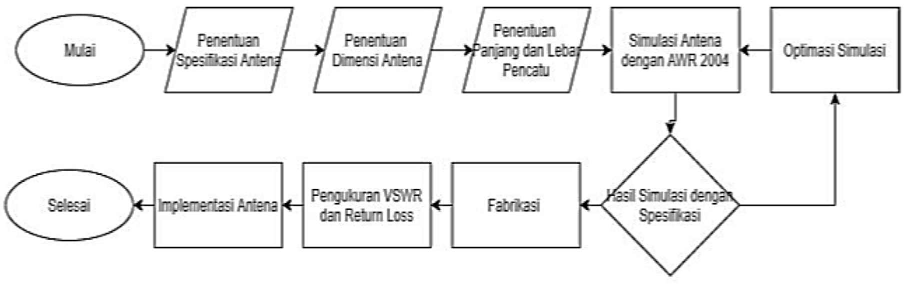


Figure 2. Flowchat Diagram

1). Literature Study

- Collecting references and theories related to microstrip antennas, biquad antennas, and working frequency characteristics at 2.4 GHz.
- Studying the design parameters of biquad-based microstrip antennas, such as biquad element dimensions, substrate materials, and radiation patterns.

2). Antenna Geometry Design

- Determining the initial dimensions of a microstrip antenna based on wavelength theory and basic calculations:
    - The length of the side of the biquad (¼λ=33 mm).
    - Diagonal length (a=50 mma b=40 mmb = 40mm).
    - Length of center band (c=3mm).
    - Distance between center bands (d=2 mm).
- Design the antenna geometric structure using antenna design software, such as CST Microwave Studio, HFSS, or MATLAB.

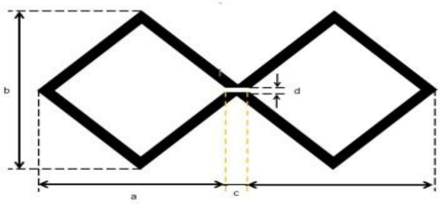


Figure 3. Design Geometry

3). Simulation and Initial Analysis
- Perform antenna design simulation with software:
    - The main parameters analyzed: radiation pattern, gain, return loss (S_{11}), VSWR, and bandwidth.
    - Ensure that the simulation results meet the antenna performance targets for WLAN applications at 2.4 GHz frequency.
- Optimize the design if the initial simulation results do not match the desired specifications.

4). Fabrication Process
- Select the appropriate microstrip substrate material, such as FR4 or Rogers RT/Duroid, based on the operating frequency requirements and antenna efficiency.
- Antenna fabrication is carried out based on a geometric design that has been simulated using PCB printing methods or other fabrication techniques.

5). Antenna Testing
- Testing the antenna that has been made using devices such as Network Analyzer and Anechoic Chamber.
- Parameters tested include:
    - Resonant frequency (f_r).
    - Return loss (S11).
    - Gain and radiation pattern.
    - VSWR and antenna efficiency.

6). Analysis and Evaluation of Test Results
- Compare antenna test results with simulation results and targeted specifications.
- Analyze the factors causing differences in results, such as fabrication accuracy or material mismatches.
- Perform design and fabrication iterations as necessary to improve antenna performance.

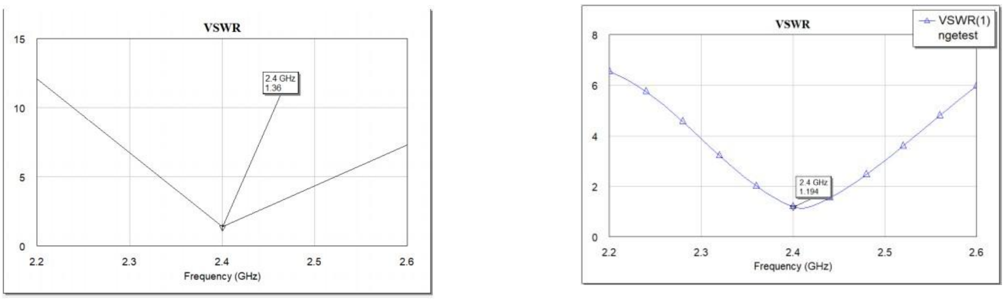
7). Conclusion and Documentation
- Summarizing the results of design, simulation, fabrication, and testing of biquad microstrip antennas.
- Prepare a research report that includes antenna performance results for WLAN applications at 2.4 GHz frequency.

Results and Discussion

The design and simulation results of the biquad microstrip antenna show performance that meets the specifications for WLAN applications at a working frequency of 2.4 GHz. The VSWR (Voltage Standing Wave Ratio) value obtained shows a good level of impedance matching between the antenna and the power source, with the VSWR value in the ideal range of 1 to 1.5. This indicates that most of the power emitted by the source is well received by the antenna without much reflection, as seen in Figure 4.

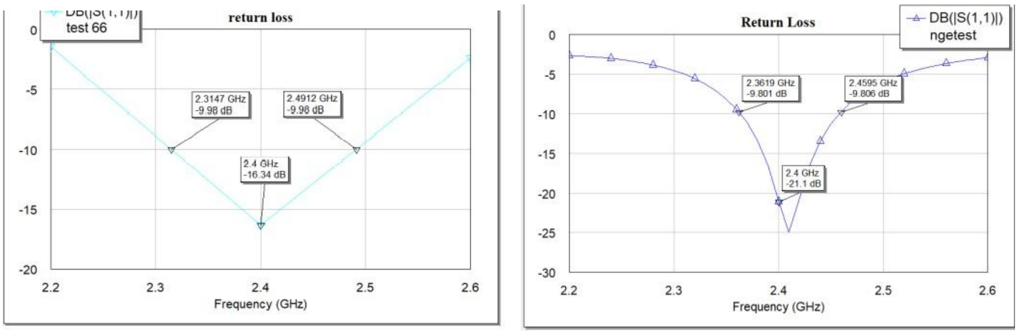
In terms of gain, the designed antenna shows the ability to focus its radiation power forward with a fairly high value, in accordance with the characteristics of a biquad antenna equipped with a reflector. This result ensures that the antenna is capable of supporting strong and stable signal transmission for WLAN applications, as shown in Figure 5. In addition, the return loss parameter (S_{11}) also shows good performance, with a value below -10 dB at a frequency of 2.4 GHz. This indicates that most of the power is received by the antenna, while only a little is reflected back to the source, as shown in Figure 6.

The simulation results also indicate that the antenna bandwidth is wide enough for WLAN applications, so that the antenna is able to handle small frequency variations without losing performance. This wide bandwidth provides more flexibility in the use of antennas in WLAN environments, which often experience interference or frequency fluctuations. Design optimization is carried out by changing the dimensions of the antenna, including the length of the biquad side (¼λ), the length of the center band, and the distance between bands. These changes allow for optimal VSWR, gain, and return loss values. This simulation is a biquad microstrip antenna design that successfully meets the specifications required for WLAN applications at a working frequency of 2.4 GHz. The antenna shows good impedance matching, radiation efficiency, and bandwidth characteristics. The next step is to conduct physical testing to ensure that the simulation results match the actual performance of the antenna. In addition, further development can be done by adjusting the substrate material or integrating the antenna into an array to improve its performance.



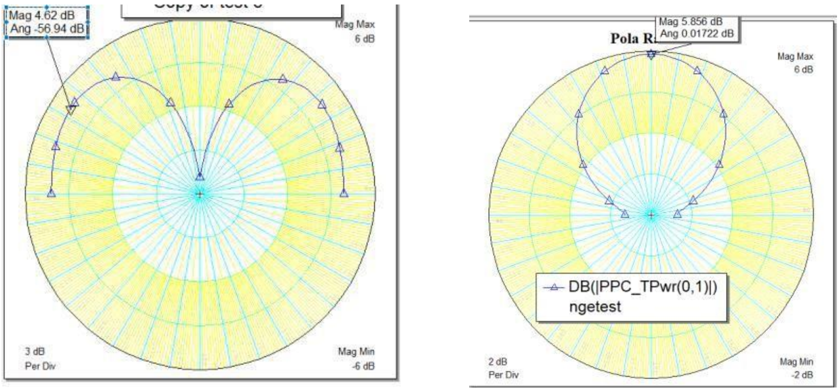
a. Single Layer b. Double Layer

Figure 4. Return Loss Based on Simulation



a. Single Layer b. Double Layer

Figure 5. Return Loss Based on Simulation



a. Single Layer b. Double Layers

Figure 6. Antenna Gain Based on Simulation

The simulation and optimization results of the biquad microstrip antenna are presented in Table 1, which compares the performance of single-layer and double-layer antennas based on several key parameters. In the VSWR parameter, the double-layer antenna shows a value of 1.19, better than the single-layer antenna with a value of 1.36. The lower VSWR value of the double-layer antenna indicates better impedance matching between the antenna and the power source.

For return loss, the double layer antenna recorded a value of -21.1 dB, lower than the single layer which reached -16.34 dB. This indicates that the double layer antenna has a lower power reflection rate, making it more efficient in receiving power from the source. However, this difference in performance is followed by a reduction in bandwidth, where the single layer antenna has a bandwidth of 176.4 MHz, greater than the double layer antenna which only has a bandwidth of 97.6 MHz.

The working frequency for both designs is at the same value, which is 2.4 GHz, according to the needs of WLAN applications. The radiation pattern produced by both designs is unidirectional, which supports applications with focused transmission needs in one direction. In the gain parameter, the double layer antenna shows an advantage with a value of 5.856 dB compared to the single layer which only produces 4.62 dB. This increase in gain indicates that the double layer antenna is able to produce stronger radiation in the forward direction.

This comparison shows that the double layer design is superior in impedance matching, radiation efficiency, and gain, although at the expense of bandwidth. The choice between single layer and double layer will depend on the application requirements, whether wider bandwidth or higher radiation performance is preferred.

Table 1. Results of single layer and double layer antenna simulation parameters:

Parameter	Single Layer	Double Layer
VSWR	1.36	1.19
Return Loss	-16.34 dB	-21.1 dB
Bandwidth	176.4 MHz	97.6 MHz
Working Frequency	2.4 GHz	2.4 GHz
Radiation Pattern	Unidirectional	Unidirectional
Gains	4.62 dB	5,856 dB

Table 2. Comparison between simulated and manufactured antenna parameters:

Parameter	Simulation	Manufacturing
VSWR	1.19	1.06
Return Loss	-21.1 dB	-30.62 dB
Gains	5.82 dB	5.82 dB
Bandwidth	95.4 MHz	80 MHz
Working Frequency	2.4 GHz	2.4 GHz
Radiation Pattern	Unidirectional	Unidirectional

Based on the results of field measurements using VNA (Vector Network Analyzer), it can be seen that although there is a shift in the resonant frequency of the antenna, the measurement results are still within the frequency range that is in accordance with the Wi-Fi specifications, namely 2.40 GHz to 2.48 GHz. In addition, there is an increase in the VSWR and return loss parameters after the antenna is fabricated, which indicates an increase in overall antenna performance.

Several factors that affect the shift in the resonance frequency include the level of accuracy in the fabrication process and the effect of losses on the SMA port when connected using solder. These factors can affect the measurement results compared to the initial simulation, but overall the antenna still meets the desired performance criteria for WLAN applications.

Conclusion

Based on the results of the design of a solar cell-based garden watering tool that has been carried out, it can be concluded that the double layer biquad microstrip antenna has been successfully designed with the following dimensions: biquad sides 25 mm and 20 mm long, biquad diagonal length 50 mm, biquad diagonal width 40 mm, center band length 3 mm, distance between center bands 2 mm, feed channel length 32 mm, feed channel width 4 mm, substrate length 110 mm, and substrate width 65 mm.

The antenna measurement results show that the return loss value reaches -30.62 dB, VSWR of 1.06, gain of 5.82 dB, bandwidth of 80 MHz, and unidirectional radiation pattern at a frequency of 2.4 GHz. The simulation results show that the double layer biquad antenna has better performance compared to the single layer. In its implementation, the double layer biquad antenna provides a connection quality that is twice as good as the single layer. The best connection was obtained in front of the Electrical Energy Conversion Laboratory room, with a PING value of 51 ms (vs. 25 ms), download of 18.48 Mbps (vs. 35.72 Mbps), and upload of 25.03 Mbps (vs. 25.53 Mbps).

References

[1] R. Tri Lubis, “Design and Construction of 4 Element Rectangular Patch Microstrip Array Antenna at 1.8 GHz Frequency for RF Energy Harvesting” University of North Sumatra, 2017.

[2] Budi, “Design of Microstrip Dipole Antenna with Koch Fractal at 453 MHz Frequency”, Medan Area University, 2017.

[3] CA Baanis,” Antenna Theory Analysis and Design Fourth Edition, Canada; John Wiley & Sos, Inc, 2016.

[4] R. Fernandez, “Use of Dual-Layer Substrate to Increase Microstrip Antenna Bandwidth at LTE Frequency”, Andalas University, 2018.

[5] AS Sukri, “Design and Construction of Biquad Microstrip Antenna”, University of North Sumatra, 2018.

[6] MUSdT Iqbal, “Implementation of Wifi Antenna as an Alternative to Antenna Use”, Telkom Institute of Technology, 2017.

[7] E. Andrea Wijaya, “Design and Construction of Omnidirectional Antenna”, Balikpapan State Polytechnic, 2017.

[8] Y. Rahayu, M. Kurniati, IL Qodriyah, “Biosensor Microstrip Antenna for Detection

[9] Viruses in Blood”, Journal of Electrical Energy Engineering, Telecommunication Engineering, and Electronic Engineering, 9(3), pp.604-618, 2021.

[10] Marchellia, AB Simanjuntak, H. Madiawati, “Design of a Rectangular Microstrip Antenna

[11] Using a Combination of U-Slot and Parasitic Elements at 2.4GHz Frequency”, Prociding The 12th Industrial Research Workshop and National Seminar, 2021.

[12] S. Alam, NM Rizka, I, Surjati and PD Marlina, “Design and Construction of Rectangular Microstrip Patch Antenna with Parasitic Method to Increase Bandwidth”, Jurnal Tektrika, 5(1), pp. 1-5, 2020.