

Design of a Dual Band Yagi Antenna For Amateur Radio At a VHF Frequency of 143 MHz

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Abstract—This research discusses the design and realization of a four-element Yagi antenna optimized for amateur radio communications in the VHF 143 MHz frequency band. The research process was carried out through simulations using CST Studio Suite software, antenna prototype assembly, and laboratory and field testing. The simulation results show that the antenna has a return loss of -22.14 dB, VSWR of 1.168, impedance of 50.23 Ω , and a gain of 7.613 dBi. After the antenna was realized, measurements using NanoVNA resulted in a return loss of -12 dB, VSWR of 1.4, impedance of 49.41 Ω , and a gain increasing to 10.9 dBi. Field testing proved that the antenna is able to work stably at a frequency of 143 MHz with an effective communication range of more than 10 km, although signal quality decreases at longer distances due to environmental obstacles and interference. Overall, the results of this study indicate that the designed four-element Yagi antenna meets the technical criteria of low VSWR, impedance approaching 50 Ω , adequate return loss, and high gain, making it suitable for use in supporting long-distance communications in amateur radio systems.

Keywords—Yagi Antenna, VHF 143 MHz, Return Loss, VSWR, Gain.

I. INTRODUCTION

The development of wireless communication technology in the last decade has experienced a significant acceleration, along with the increasing needs of the community for high -speed, stable and efficient data communication services. Modern communication systems no longer only focus on the capacity of the transmission, but also requires the reliability of the hardware used, including antennas as one of the key components. The antenna acts as a link between free space and electronic devices, so that the quality, reach, and communication efficiency is strongly influenced by the performance of the antenna used [1], [2].

Among the various types of antennas that have been developed, Yagi-Auda antennas remain a popular choice because of its characteristics that are able to produce directors of directors, have a relatively high reinforcement, and simple and easily realized structures [3]. This advantage makes many antennas applied in various fields, for example in receiving digital television broadcasts [4], Wi-Fi communication systems [5], [3], LTE cellular technology [6], [7], [8] Maritime radar system [9], to VHF radar used to detect stealth target [10] In addition Very low frequency [11] While the design of print antennas is used in lightning detection systems because of its light and concise nature [5].

Although it has many advantages, conventional antennas also hold a number of limitations, especially in aspects of physical size and narrow bandwidth. The relatively long antenna dimension is an obstacle in implementing modern devices that demand portability and compact, while the limitations of bandwidth make it difficult for the antenna to work on several frequency bands at once [12]. This condition encourages various studies to

present Yagi's antenna design innovations. One directional direction that is quite significant is the integration of the concept of microstrip antenna so that it gives birth to quasi-yagi antennas, which are planar antennas that combine traditional yagi advantages with microstrip patch so as to produce a light design, easily diffracted, and support multiband operation [6], [13].

Along with the development of computing, Machine Learning -based optimization techniques have also been applied in the design of Yagi antennas to speed up the process of predictions of performance parameters such as gains, directivity, and returns loss [8]. Miniature efforts are carried out through a fractal approach, for example the use of Koch curves, which are proven to be able to reduce the physical dimensions of the antenna without reducing radiation performance [12]. On the other hand, the development of multi-element array is used to increase gains and improve radiation patterns [10], [14]. In fact, in the latest generation systems such as 5G, triangular patch antennas have been studied to support operations on MMWAVE ribbons [15], while for Lora -based IoT applications, Yagi antennas are chosen because they are able to increase the range of communication compared to the innate module antenna [16].

ased on these various developments, it can be seen that the antenna and its derivatives remain relevant in supporting the needs of present and future communication. However, research that focuses on dual-band antenna design for amateur radio communication, especially in the VHF ribbon is still limited. Therefore, this research is directed to design dual-band yagi antennas at a frequency of 143 MHz with the aim of obtaining optimal performance in the form of low VSWR values, high gains, and radiation patterns that support long distance communication. The results of this study are expected to make a practical contribution to the amateur radio community in Indonesia, as well as enrich the literature regarding the innovation of cost -effective antenna design with good performance.

II. RELATED WORKS

The literature study shows that research on antennas continues to develop with a variety of applications. In the fields of cellular communication, Haque, Zakariya, Singh, Rahman and Paul. [6] Designing Quasi-Yagi Dual-Band Antennas based on FR-4 substrates capable of working on 1.8 GHz LTE bands and 2.6 GHz with gain values of 6 dB and 8.3 dbi respectively. This design uses a microstrip-to-coplanar stripline (MS-to-CPS) technique as a method of integrating. Further research from the same team [8] introduces the Machine Learning approach to predict the performance of the Quasi-Yagi antenna. The results show high prediction accuracy with efficiency reaching 83.05% and return loss of -50.44 dB.

For Wi-Fi, Gusni, Lindawati and Sopian applications [17] proposed Yagi antennas with 15 elements at 2.4 GHz frequency. The design produces gain 14.59 dB with a VSWR value of 1.16, so that it can support remote signal reception. Other studies conducted by Halliru, Babale, Opponents, Muhammad, Abubakar, Pole, Roslee and Yusuf [3] optimize the Yagi antenna using Folded Dipole, which is proven to be able to increase bandwidth to 0.33 GHz with a return loss reaching -52 dB. Meanwhile, Fahmi, Novalia, Joni, Hasim, and Rizky [14] designed the 1×8 rectangular patch microstrip antenna for WLAN, with a gain achievement of 6.81 dB and Return Loss -18.13 dB, which showed the effectiveness of the use of array in increasing the antenna strengthening.

In the context of digital television broadcasts, Labusab, Akil and Wahyudi [4] designing Yagi antennas with a work frequency of 578 MHz. This antenna is proven to be able to support the reception of more stable digital TV signals, especially in the transition period from analog to digital broadcasts. In the LTE system for the Rural, Ninda and Rizadi regions [7] designed the Yagi antenna at a frequency of 450 MHz. With a configuration of 10 elements, this antenna produces a return loss -32.26 dB and gain is close to 10 dbi, so it is suitable for expanding tissue coverage in rural areas.

Radar application is also one of the important focus in the Yagi antenna research. Gunawan and Zulfajri [9] developed the Yagi-Udi Array antenna on the HF ribbon (28 MHz) for maritime radar. The simulation results show that the antenna has 10.89 dB gains and bandwidth 351.3 KHz. On a larger scale, al-Shammari, synonym, Naman, Alrikabi, Khazaal, Neamha and Qasim [10] modify the VHF radar design by adding the arrangement of two lines of 14 elements each. This modification has succeeded in increasing gains more than 3 dB compared to 16 conventional elements.

In addition, Barshikar, Yanpure, Atre, Jagdale, Iyengar, Parate, Rampirkar, and Kunte [11] developed Dual-Polarized Cross Yagi antennas for a frequency of 50-500 MHz intended for Astronomy Radio applications. This design has the advantage in the form of multiple polarization capabilities with gains up to 13.61 dB. On the other hand, Perez Salgado, Gerardo, Freddy, and Silvia [1] utilize the software for the design of the UHF antenna. The results of this study confirm that the software can be a cost -effective alternative in the design of the antenna.

In the fields of censorship, Maria, Dean, Asthan and Munir [5] designed the print antenna for lightning detection in the VHF ribbon. The implementation results show that this antenna is 33% smaller than conventional yagi but still produces 8.8 dbi gains, so it is suitable for a storm monitoring system. Miniature efforts were also carried out by Bryan Wakita [12] by applying Koch's fractal techniques. The simulation results show a reduction in the antenna dimension by 7.4% with an increase in gains up to 12.9 dbi. For the applications of IoT, Fajar, Koesmarijanto and Hendro [16] comparing the 12 elements with the internal antenna of the Lora module. The results of trials in Line-of-Sight (LOS) and Non-Line-of-Sight (NLOS) conditions prove that the Yagi antennas have better acceptance performance.

The direction of the antenna research also developed towards the fifth generation communication (5G). Imelda, Agus and Situ [15] proposed the design of a triangular Microstrip Patch antenna in the frequency of 28 GHz, which produced 8.8 dB gain with a return loss -26.98 dB. On the other hand, Prabowo Nico [2] emphasizes the use of yagi antennas in the aviation navigation system (AirNav). The monopole antenna is used to detect interference, while the antenna can allow the identification of the direction of interference with more precise.

From the results of the literature study it can be concluded that the yagi antennas and variants are still very relevant for various modern communication applications. However, special research on dual-band antenna design to support amateur radio communication on the VHF ribbon is relatively rare. This research is expected to be able to fill the gap by presenting a simple dual-band antenna design that is simple, cost-effective, but has optimal performance.

III. METHOD

This study uses a design approach with a systematic experimental stage. The research process starts from the literature study to obtain the basis of the theory of Yagi antennas, design parameters, and reference to the calculation of element dimensions. Based on the results of the study, an initial design of the Dual Band antenna was made using CST Studio Suite software, where each antenna element was modeled according to the theoretical calculation results. The simulation is carried out to obtain the main characteristics of the antenna such as returns loss, VSWR, impedance, radiation patterns, and gains, as well as optimizing the dimensions to match the desired specifications. The next stage is the physical prototype of antenna with aluminum material according to optimization results. After the antenna has been assembled, testing is carried out in the laboratory using Vector Network Analyzer (Nanovna) to measure impedance, VSWR, and Return Loss, and use spectrum analyzer and signal generator to measure gains and comparative radiation patterns with reference antennas. Subsequent testing is carried out in the field to evaluate the

performance of the antenna in real conditions, especially to the reach of communication, signal quality, and transmission stability. The results of the simulation, laboratory measurements, and field testing are then compared to analyzed, so that the level of conformity can be known between the initial design and physical realization. All of these stages are documented and evaluated to draw conclusions and provide further antenna development recommendations. From this explanation can be seen in Figure 1 below:

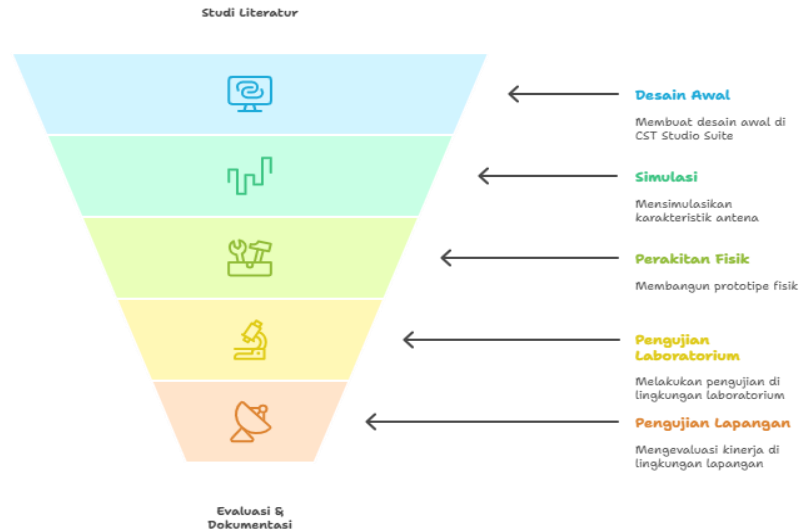


Figure 1 Research Flow Display

In Figure 1. Explain that each stage in the diagram has an important role. The literature study stage functions as a basis for determining the antenna design parameter. The initial design was carried out at the CST Studio Suite to model the antenna according to theoretical calculations. Simulation is used to analyze the characteristics of antennas, including VSWR, Return Loss, Gain, Radiation Pattern, and Impedance. After the simulation results meet the specifications, an antenna physical assembly is carried out using conductive material. The prototype then underwent laboratory testing with measuring devices such as vector network analyzer and spectrum analyzer. The next stage is field testing to evaluate the performance of the antenna in real communication conditions. Finally, all data were analyzed at the evaluation and documentation stage to compare the simulation results with realization, as well as drawing research conclusions.

IV. RESULT AND DISCUSSION

This section presents the results of the study including an antenna design simulation, prototype realization, laboratory testing, and field test. The main parameters analyzed are returns loss, VSWR, impedance, gain, and radiation patterns. The simulation results are compared with concrete measurements to assess the suitability of the initial design with physical implementation. Furthermore, the discussion was carried out by linking the results obtained with previous research to show the superiority of the design of this antenna.

A. Parameter Calculation

In the dual-band antenna design stage, one important aspect is to determine the dimensions of each antenna element. This dimension includes the length of the reflector, driven element, and director, as well as the distance between elements. Determination of size is based on the theoretical calculation results using the Yagi-Auda antenna equation and adjusted to work on the VHF frequency band. In addition, the diameter of the element and the length of the gap in the Driven Element is also determined to be in accordance with the needs of impedance and stability. The design parameters are summarized in the following table 1.

Table 1
Antenna Modeling Parameters In CST Studio

Variable Name	Value (mm)	Description
d	12.7	Diameter of the antenna element
r	25.4	Length for gap/fed driven antenna
lrvhf	1084.311	VHF reflector length
ldrvhf	980,17	Long driven VHF
ldvhf1	880,24	Length of Director 1 VHF
ldvhf2	780,31	Length of Director 2 VHF
srdrvhf	350,82	Distance of reflector elements - Driven VHF
sddrvhf	170,09	Driven element distance - Director 1 VHF
sdvhf1	431,61	Distance of Director 1 Element - Director 2 VHF

Table 1 displays the main parameters used in the Yagi antenna modeling process on CST Studio software. Each variable represents the physical size of the antenna element, which is determined based on the theoretical calculation results in the VHF frequency band. The antenna element (D) is set at 12.7 mm, which functions to determine the conductivity and mechanical strength of the antenna. The length of the gap or fed driven (R) of 25.4 mm is used to regulate signal festering in the driven element so that the impedance is in accordance with the transmission system. The length of the reflector element (LRVHF) of 1084,311 mm is made longer than the Driven (LDRVHF) element which has a length of 980.17 mm, according to the principle of antenna yagi where the reflector is always longer than the driven. Furthermore, Director 1 (LDVHF1) and Director 2 (LDVHF2) are 880.24 mm and 780.31 mm. The length of the shorter director element aims to strengthen the direction of the signal beam and increase the antenna gain. The distance between elements is also an important factor in design. The distance between the reflector and the driven (SRDRVHF) is regulated by 350.82 mm to ensure optimal reflection functions. Meanwhile, the distance between Driven and Director 1 (SDDRVHF) of 170.09 mm, and the distance of Director 1 to Director 2 (SDVHF1) of 431.61 mm, designed to produce radiation patterns directed by a good front-to-back ratio. With this configuration, yagi antennas are modeled to work optimally at VHF frequencies, produce adequate gain values, low VSWR, and appropriate radiation patterns for remote communication.

After getting the parameter obtained then it will display the design results of the parameter as shown in Figure 2. Below:

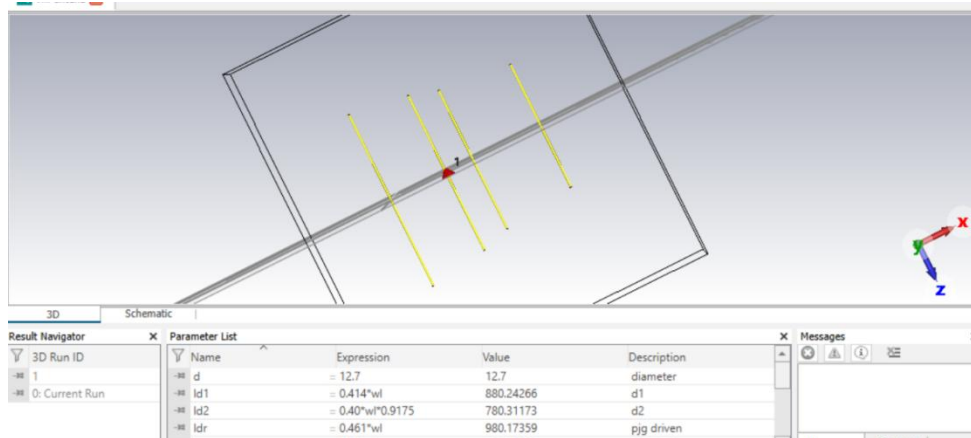


Figure 2. VHF Antenna Design on CST Studio

Figure 2 shows the design of the Yagi antenna four elements in the VHF ribbon using the CST Studio Suite. The antenna element consists of one reflector, one driven element, and two directors that are displayed in the shape of a yellow stem and mounted parallel to the buffer boom. Dimensional parameters for each element, such as driven length, reflector, director, and antenna diameter, are displayed on the list parameter at the bottom. This model is used to simulate the characteristics of antenna, including VSWR, Return Loss, impedance, gain, and radiation patterns before making physical prototypes.

B. Return Loss

After optimizing to get the results of the return loss from the antenna, the results are obtained as in Figure 3. Where we can see the value of the return loss obtained at the VHF frequency of 143 MHz is -22,14915 dB. The results obtained in this simulation have met the parameters that have been made before and are quite good and show adequate antenna performance, where the parameters of the return loss are ≤ 15 dB.

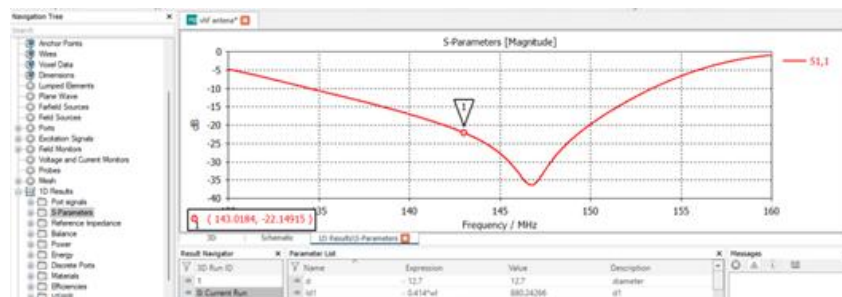


Figure 3. Return Simulation Results Loss

Figure 3 shows the results of the simulation of the Yagi Antenna Return Simulation of four elements in the VHF frequency band using the CST Studio Suite. The S11 curve shows the minimum return value of loss of -22.19 dB at a frequency of 143,018 MHz. This value indicates that the antenna has been well-matched in the work frequency, because most of the power from the source can be emitted and only a few are reflected again. These results are in accordance with good antenna performance criteria, where Return Loss should be smaller than -10 dB.

C. Voltage Standing Wave Ratio (VSWR)

The value of the VSWR parameter in this antenna is ≤ 1.5 . In the graph in Figure 4. obtained the VSWR value at the 143MHz frequency is 1,168. From the results that have been obtained from the simulation results prove that the antenna is in accordance with the

initial purpose of designing the antenna so that it can be used properly on the VHF band. The results of VSWR can be seen in Figure 4.

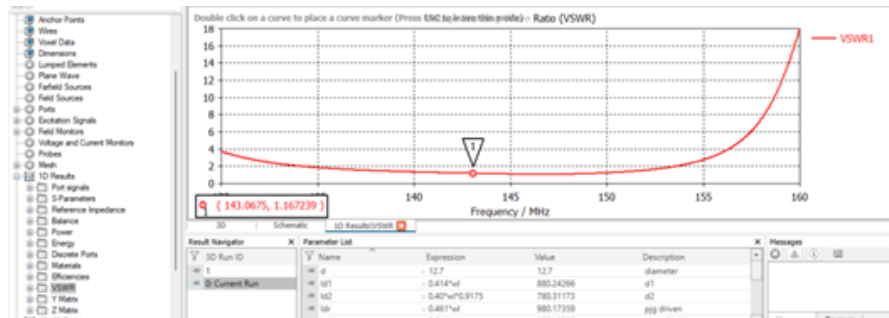


Figure 4. VSWR Simulation Results

Figure 4 shows the results of the Voltage Standing Wave Ratio (VSWR) simulation of four elements of the VHF frequency band using the CST Studio Suite. The VSWR curve shows a minimum value of 1.16 at a frequency of 143,067 MHz. This value is below the general standard of 1.5, so that it indicates that the antenna has a very good impedance compatibility with a transmission system. With a low VSWR value, the reflected power back to the source is minimal, so that the efficiency of the antenna beam is more optimal. The results of this simulation are also consistent with the performance of Return Loss that has been shown previously, namely -22.19 dB at the same work frequency.

D. Impedance

From the results of the impedance simulation shown in the impedance image obtained for the 143MHz work frequency is 50.23 Ω . The impedance value of the two frequency bands is quite good because the value obtained from the simulation results has reached the target parameter. With the addition of the length of the matching stub and feed point through the optimization process so as to reach a value of 50 Ω . The addition of the matching stub and feed point values of 1.5 cm affects in reaching the tolerance limit of 50 Ω . In Figure 5 below can be seen the results of the impedance simulation.

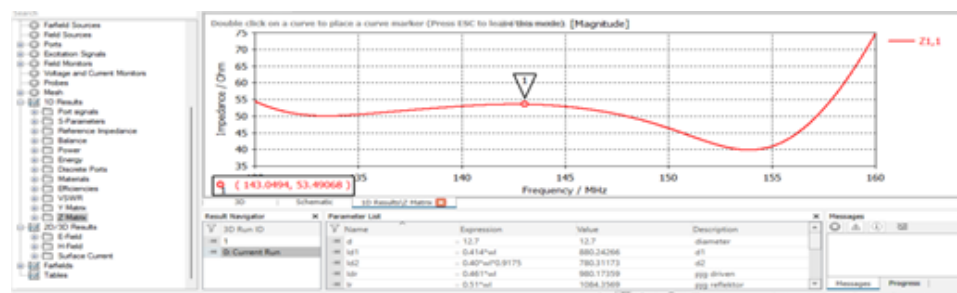


Figure 5. Impedance Simulation Results

Figure 5 displays the results of the simulation of the four elements of the VHF frequency antenna impedance using the CST Studio Suite. At the work frequency of 143,049 MHz, the impedance value obtained is around 50.49 ohms. This value is very close to the standard impedance of the transmission system, which is 50 ohms. This condition shows that the antenna already has a good matching with the pencipa channel, so that the power transfer from the source to the antenna takes place optimally with a minimal loss of reflection power. The harmony of this impedance also supports the results of the previous loss and VSWR return simulation, thus strengthening the conclusion that the antenna design is in accordance with the expected specifications.

E. Radiation Pattern

In CST, radiation pattern parameters are shown in the Far Field menu. The image will be seen from the radiation pattern. The radiation pattern simulated in this simulation is a pattern with the elevation plane of 90° ($\theta = 0^\circ$ to 360°). Based on the simulation process, an antenna radiation pattern is obtained in Figure 6.

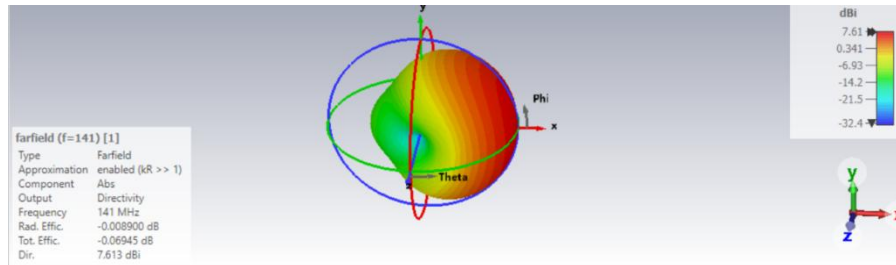


Figure 6. Radiation Pattern

Figure 6 shows the radiation pattern of the results of the simulation of the four elements in the work frequency of 141 MHz using the CST Studio Suite. The radiation pattern is displayed in a three-dimensional form, where the red color indicates the direction of the radiant with the highest intensity. From the simulation results it can be seen that the antenna has a directed radiation pattern with the main reinforcement into one dominant direction. The gain value obtained from the simulation is around 7,613 dBi, which shows the ability of the antenna to focus energy in a certain direction to increase the reach of communication. In addition, radiation distribution shows a pretty good front-to-back ratio, meaning that the energy emitted backwards is relatively small thereby reducing the potential for interference. These results are in accordance with the characteristics of the Yagi antenna which is designed to produce a narrow and directed radiation pattern, so it is very effective in long distance communication with stable signal needs.

F. Gain

Based on the simulation process, the gain value of the antenna is 7.613 dBi. The gain simulation results in this simulation are quite good with a greater value compared to the initial parameter value.

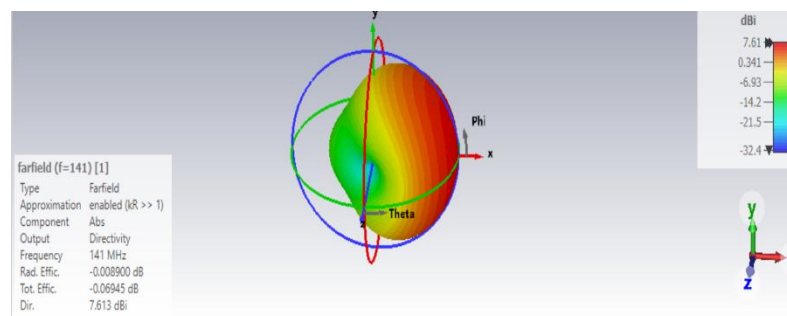


Figure 7. Gain

Figure 7 displays the results of the Gain Antenna simulation of four elements in the work frequency of 141 MHz using the CST Studio Suite. From the simulation results obtained a gain value of 7.613 dBi, which shows the ability of the antenna to strengthen the signal in the main direction of radiation. The red color in the figure shows areas with the highest radiation intensity, while green to blue indicates areas with lower intensity. This distribution confirms that the antenna has a directed radiation properties, according to the characteristics of the Yagi antenna which is designed to focus energy in a certain direction. With gain values above 7 dbi, this antenna is quite effective for the application of long

distance communication on the VHF band, because it can increase the signal range while reducing interference from unwanted directions.

G. Antenna Measurement

This antenna measurement stage is useful for obtaining data from the tools that have been made. Testing is also useful to determine the level of performance of the function of the tool. After that it is done as a whole, arranged with data collection. Carried out on the antenna is as follows: gain measurement, vswr measurement, impedance measurement and measurement of return loss. Figure 8 shows the physical form of the antenna that has been made.



Figure 8. Overall Display Antenna

Testing on VHF frequency bands. The antenna is mounted on a buffer stand to facilitate the process of measurement and adjusting radiation direction. The antenna structure consists of one reflector, one driven element, and two directors installed parallel to the conductive metal boom. This physical appearance confirms that the design of the simulation results has been realized in real form using aluminum material as an antenna element. This realization was then used for the laboratory testing stage and field test to compare its performance with the results of the CST Studio Suite simulation.

The antenna is made and assembled based on the results of the calculation length and distance in the previous simulation with a boom length of 104 meters summarized in Table 2 and Table 3 below:

Table 2
Length of VHF Element

Element	Size (cm)
Reflector	108,5
Driven	98
Director 1	88
Director 2	78

Table 2 displays the size of the main elements in the antenna of four elements of realization. The reflector element has a length of 108.5 cm, made slightly longer than other elements to function to reflect electromagnetic waves and strengthen the direction of radiation forward. The driven element measuring 98 cm, functions as a sign of signal lightening as well as determining the frequency of antenna resonance. The size that is shorter than the driven aims to focus the wave emission towards the front, so that the antenna radiation pattern is more directed and the gain value increases. The difference between the length between the elements is in accordance with the basic principles of the

Yagi-Uda antenna, where the reflector is made the longest, the driven is at the length of the resonance, and the director is made shorter to produce optimal radiation characteristics.

Table 3
Distance of the VHF Element

Element	Spacing (cm)
Reflector -Driven	35,5
Driven-Director 1	16,8
Director 1-Director 2	42,8

This table shows the distance between elements (spacing) in the antenna of four elements of realization. The distance between the reflector and driven is 35.5 cm, which serves to ensure the reflector is able to reflect the waves towards the driven efficiently so as to strengthen the radiant forward. The distance between Driven and Director 1 of 16.8 cm is chosen so that the energy from the driven can be directly directed to the Director, maintaining impedance compatibility and reducing the VSWR value. Meanwhile, the distance between Director 1 and Director 2 is 42.8 cm, arranged wider to produce radiation patterns that are increasingly focused forward and increase the value of antenna gain.

H. Measurement Results on the Antenna

After the measurement in accordance with the specified steps, obtained several main parameters of the antenna. In VSWR measurements at a frequency of 143 MHz, the value obtained is 1.4. This value shows good performance because it is still within the limits of acceptable impedance compatibility. Furthermore, the measurement of the antenna impedance is at 49.41 Ohm, which is close to the standard value of 50 ohms in accordance with the provisions of the antenna parameter in the reference. For return loss values, measurements at a frequency of 143 MHz produce -12 dB, which indicates the level of signal reflection is relatively low so that most of the power is successfully emitted. Meanwhile, the gain received by the measuring antenna from the design of the design of the design was recorded at -34.21 dBm. These overall results indicate that the designed antenna already has a pretty good performance, although there is still space to improve, especially in the value of gains to match the design target. From the explanation above and the results mentioned will be displayed in Table 4. With the accounts of values obtained below:

Table 4
Measurement Results Using NANO NVA

Frequency	Parameter Type	Parameter value	Picture
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143 Mhz VSWR ≤ 1.4



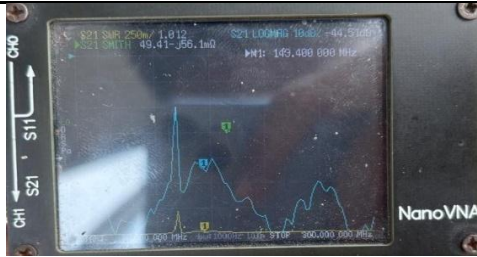
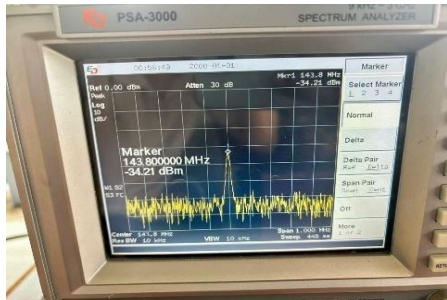
143 Mhz	Impedance	$\pm 49,41$ Ohm	
143 Mhz	Return loss	-12 dB	
143 Mhz	Gain power received	-34,21 dBm	

Table 4 summarizes the results of the measurement of Yagi antenna parameters of four elements in the working frequency of 143 MHz using the nanovna device. Some important parameters are obtained from the test. First, the VSWR value recorded ≤ 1.4 . This value is good because it shows the compatibility of impedance that is quite optimal, so that the reflected power back to the relatively small source. Both, the measurement of impedance produces a value of around 49.41 ohms, which is very close to the standard transmission system of 50 ohms. This indicates that the antenna has matching with the pencipajuan. Next, the return loss at a frequency of 143 MHz is -12 dB. This value is below -10 dB limit, so that it can be categorized quite well because most of the power that enters the antenna can be emitted. Finally, the power received by the measuring antenna of the yagi antenna, or measurable gain, is -34.21 dBm. This value illustrates how much energy emitted by the antenna can be accepted on the receiving side. Overall, the results of this measurement indicate that the designed yagi antenna has worked as expected, with the main parameters that are quite close to the simulation results and the standard of communication antennas on the VHF band.

Below this table also displayed Gain and VSWR calculations as additional validation to the measurement results obtained.

a. Gain Calculation

Power received by Yagi antenna = -34.21 dBm while the power received by the antenna dipol = -43 dBm. To calculate the gain of Yagi antenna relative to the dipole antenna, use the formula $G_{Yagi} = G_{dipol} + 10 \log_{10} \left(\frac{P_{Yagi}}{P_{dipol}} \right)$ where:

Gdipol = 2.1dBi (reference antenna gain) PYagi and Pdipol are the power in Watt, so it needs to be converted from DBM to Watt first.

Step 1: Conversion of dBm to Watt

Conversion formula:

$$P(\text{watt}) = 10^{\frac{P(\text{dBm})-30}{10}}$$

For yagi antennas:

$$P_{Yagi} = 10^{\frac{-34,21-30}{10}} = 10^{-6,421} \approx 3,79 \times 10^{-7} \text{ W}$$

For Dipol Antenna:

$$P_{dipol} = 10^{\frac{-43-30}{10}} = 10^{-7,3} \approx 5,01 \times 10^{-8} \text{ W}$$

Step 2: Calculate the power ratio

$$\frac{P_{Yagi}}{P_{dipol}} = \frac{3,79 \times 10^{-7}}{5,01 \times 10^{-8}} \approx 7,57$$

Step 3: Calculate the gain of yagi antenna

$$G_{Yagi} = 2,1 + 10 \log_{10}(7,57) = 2,1 + 10 \times 0,879 = 2,1 + 8,79 = 10,89 \text{ dBi}$$

The gain of the antenna is relative to the dipole antenna is around 10.9 dBi.

b. Calculation of VSWR

The yagi antenna impedance obtained is $z_l = 49.41\Omega$ and the standard transmission channel impedance is $Z_0 = 50\Omega$, then the VSWR calculation can be done with the

formula $VSWR = \frac{1+|\Gamma|}{1-|\Gamma|}$ then the calculation can be done as follows:

$$\Gamma = \frac{49,41 - 50}{49,41 + 50} = \frac{-0,59}{99,41} \approx -0,00593$$

The absolute value of the reflection coefficient:

$$|\Gamma| = 0,00593$$

Next, count VSWR with the formula:

$$VSWR = \frac{1 + 0,00593}{1 - 0,00593} = \frac{1,00593}{0,99407} \approx 1,012$$

So, the VSWR value obtained is around 1,012, which means matching impedance is very good and almost ideal.

I. Tool Test Results

After completing the assembly and measurement, the next step is to test the antenna to obtain specific data from the antenna made so that it knows when this tool works at the VHF frequency.

Table 5

Test results on antenna

Distance	Value	Picture	Explanation
7 km	21 dB		Antenna testing at a distance of 7 km produced a power received at the antenna at the adjusted height of 21 dB.

9 km	18 dB		It can be seen that at a distance of 9 km the sound power received by the antenna decreased by 18 dB, due to factors or obstacles that existed during the test.
10 km	8 dB		In further testing at a distance of 10 km, the results obtained were 8 dB at a frequency of 143 Mhz due to the same factors as before.
11 km	4 dB		Seen at a greater distance as the existing obstacles increase, the sound power received becomes smaller, namely 4 dB.

Table 5 shows the results of field tests of a four-element Yagi antenna at a frequency of 143 MHz with varying signal reception distances. The test was conducted to determine the extent to which the antenna can maintain signal quality under real-world conditions. At a distance of 7 km, the received signal power reached 21 dB, indicating that the antenna's performance was still very good. When the distance was extended to 9 km, the signal power decreased to 18 dB, which was influenced by environmental obstacles such as buildings, trees, and geographical conditions. At a distance of 10 km, the received signal dropped drastically to 8 dB, while at a distance of 11 km, the signal power decreased to 4 dB. From these results, it can be seen that the longer the communication distance, the signal power received by the antenna decreases. Environmental factors such as physical obstacles and interference significantly affect reception quality. However, the designed Yagi antenna is still capable of working up to a distance of more than 10 km, even with increasingly weaker signal power.

J. Analysis

The evaluation was conducted to assess the extent to which the four-element Yagi antenna design for the VHF frequency band met the established technical standards. The analysis process was conducted by comparing simulation data using CST Studio,

laboratory measurements, and field trials. The primary focus parameters were return loss, VSWR, impedance, and gain, as these are important indicators of antenna performance.

Based on the simulation results, the designed antenna demonstrated satisfactory performance. The achieved return loss was -22.14 dB with a VSWR of 1.168 and an impedance of approximately 50.23 Ohms. This indicates that the antenna is adequately matched to the transmission system. The simulated gain of 7.613 dBi, although slightly lower than the standard of ≥ 9 dB, nevertheless produced a fairly directional radiation pattern with a good front-to-back ratio, effectively focusing the signal.

The next stage was laboratory testing of the prototype. Measurement results showed a return loss of -12 dB, a VSWR of 1.4, and an impedance of 49.41 Ohms. In general, these parameters closely matched the simulation results and met the technical performance criteria, particularly in terms of impedance matching. Interestingly, the measured gain value reached 10.9 dBi, higher than the simulation results. This indicates that the antenna is capable of amplifying signals better than initially estimated, thus optimally supporting long-distance communications.

Final field testing was conducted to observe the antenna's performance under real-world conditions. The antenna proved to operate satisfactorily at 143 MHz and supported communications at the required distances. Challenges encountered included physical obstacles such as trees or buildings blocking the signal, interference from external sources, and weather factors that could affect transmission quality. Despite this, the antenna was still able to maintain stable communications with adequate signal quality.

From this series of analyses, it can be concluded that the VHF Yagi antenna design demonstrated a good agreement between simulation results, laboratory measurements, and field tests. Simulations played a crucial role in providing an initial overview of the design, laboratory measurements validated key technical parameters, and field tests ensured the antenna performed reliably under actual operational conditions. Therefore, the VHF Yagi antenna at a frequency of 143 MHz can be declared suitable for use in radio communication applications with stable performance, adequate gain, and expected range.

V. CONCLUSION

This research successfully designed, modeled, and tested a four-element Yagi antenna at a working frequency of 143 MHz with systematic stages starting from simulation, prototyping, to field testing. The simulation results using CST Studio Suite showed that the antenna had good performance. The return loss value was recorded at -22.14 dB, VSWR 1.168, impedance 50.23 Ω , and gain 7.613 dBi. These parameters confirm that the antenna design is in accordance with the basic theory of Yagi antennas, where the reflector has a length greater than the driven, while the director is made shorter to produce a directional radiation pattern and increase signal amplification. After being physically realized, laboratory measurements with NanoVNA showed results that were still consistent with the simulation. The return loss value reached -12 dB, VSWR of 1.4, and impedance of 49.41 Ω , which is close to the standard value of 50 Ω . Interestingly, the measured gain value increased to 10.9 dBi, higher than the simulation results. This shows that the antenna is able to perform better than the initial estimate in amplifying the signal. Field testing shows that the antenna can operate stably at a frequency of 143 MHz with an effective communication range of up to more than 10 km. However, the signal power decreases with increasing distance and the presence of physical obstructions such as buildings, trees, and geographical conditions that can cause attenuation. Weather factors and interference from other communication systems also affect the performance of the antenna in real environments. Overall, the results of the study prove that the four-element Yagi antenna at a frequency of 143 MHz has met the technical performance criteria in the form of low VSWR, adequate return loss, impedance close to 50 Ω , and high gain. With these characteristics, this antenna is suitable for use in amateur radio communication applications

and long-distance communication systems in the VHF frequency band, because it is able to provide fairly stable signal quality with a simple structure and relatively low manufacturing costs.

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