Design and Implementation of an X Double Bazooka Antenna In a Hybrid Communication System

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Abstract— The double bazooka antenna is an antenna developed for military applications and later adapted by amateur radio enthusiasts for high-frequency (HF) communication. The double bazooka antenna consists of two elements: the main element, which functions as the transmitter element that transmits and receives radio frequency (RF) signals, and the auxiliary element, which serves to widen the bandwidth. The main element is the most significant factor influencing the antenna's parameter characteristics. This study aims to realize a double bazooka antenna with a semi-directional radiation pattern at an operating frequency of 433 MHz, which will be applied as an external antenna in a hybrid communication system. The antenna material used in this study is RG-8 cable with a relative permittivity (ε_r) of 2.3. Antenna parameter testing was conducted at the Telecommunication Engineering Laboratory of the State Polytechnic of Semarang using a Spectrum Analyzer, Vector Network Analyzer, Radio Frequency Generator, and Antenna Trainer Kit. The results of the double bazooka antenna parameter testing showed a return loss value of -23,345537 5 and a VSWR of 1:1.24 at a frequency of 433 MHz, which is in accordance with standards, and has a gain of 19.55 dBi with a semi-directional radiation pattern and vertical elliptical polarization. The double bazooka antenna was successfully implemented in a hybrid communication system, with test results showing that the antenna operates optimally.

Keywords— double bazooka antenna, radio communication, hybrid communication system, handy talkie

1. Introduction

To support smooth communication in the field, hybrid communication systems have become a widely used solution, especially in highly mobile work environments. These systems combine various communication technologies, one of which is radio communication using Handy Talkie (HT) devices. HT is chosen because it is practical, easy to use, and does not depend on cellular networks. However, factors such as terrain, building density, or population density can affect radio communication performance [1].

An antenna is a device used for the transmission and reception of radio frequency (RF) signals. A transmitting antenna is a conductor that converts RF electrical current into electromagnetic waves for transmission. A receiving antenna is a conductor that converts electromagnetic waves into RF electrical current [6]. A double bazooka antenna is a type of closed dipole antenna designed to have a wider bandwidth and better noise reduction capabilities. This antenna is usually made from coaxial cable and has a central section that functions as the main transmitting element, while the ends are made from ordinary conductor cable as additional elements to widen the bandwidth [4].

this study, an antenna will be designed for testing on HT devices as a supporting element in hybrid communication systems, particularly in toll road construction projects. Through the development of a double bazooka antenna design operating at a frequency of 433 MHz, it is hoped that the performance of hybrid communication systems can be supported.

2. Literature Review

To support the design and implementation of double bazooka antennas in hybrid communication systems, a relevant theoretical foundation is needed as a reference in the research process.

Previous research by developing a Quadrifilar Helix antenna for inter-island communication in the UHF band [7]. This research leverages the advantages of the Quadrifilar Helix antenna, along with considerations for simple, lightweight, and cost-effective materials, as a receiving antenna in the inter-island communication system in the Riau Islands. The results yielded a return loss value of -13.06 dB and a VSWR of 1.5. This antenna can also receive data from GPS sensors, temperature, humidity, air pressure, wind speed, and wind direction up to 9 kilometers. Under line-of-sight (LOS) conditions, the antenna can reach a range of up to 9 kilometers. In general, the Quadrifilar Helix antenna was successfully fabricated using simple, lightweight, and cost-effective materials and is suitable for use as an antenna for inter-island communication in the UHF band. However, the antenna has a drawback, namely a shift in the operating frequency from 433 MHz to 452.5 MHz.

Next, conducting a performance analysis of Radio Over Internet Protocol (RoIP) on a Private Mobile Radio (PMR) system with clients and radio gateways [2]. This study discusses the RoIP system used to improve communication effectiveness in the ITN Malang campus environment. The factors analyzed include network quality, signal range, and system reliability in the ITN Malang campus environment. The results indicate that the RoIP system can operate optimally, thereby expanding communication range. However, RoIP still faces challenges regarding network stability and signal interference, and additional antennas for repeaters are needed to cover the entire campus area.

Other research Modifying the ⅝ λ vertical antenna at a frequency of 144–147 MHz to improve omnidirectional transmission performance while expanding the coverage area [5]. By adding the phase method, this study succeeded in maintaining the antenna impedance at 50 ohms even though the antenna dimensions were enlarged. The antenna has good reception power of -34 dBm, an omnidirectional radiation pattern, and a VSWR of 1.1. However, this antenna has drawbacks, including frequency shift and less effective return loss.

Based on previous research, the development of various types of antennas for radio communication has been extensively studied. However, most of these studies still rely on conventional antenna types. Additionally, some antenna applications are only focused on a single communication system. Therefore, this research aims to develop an X double bazooka antenna that will be implemented in a hybrid communication system.

3. Sytem Design

3.1. Design of the X Double Bazooka Antenna

The double bazooka antenna was discovered by the Radio Amateur Civil Emergency Service (RACES) in the United States during World War II. This design was originally developed for military applications and later adapted by amateur radio operators for HF (High Frequency) communications. The antenna was first popularized by John H. Clemens (W1DF) in an article in QST magazine in 1968.

The antenna consists of a coaxial cable of half a wavelength, with the outer conductor opened at the center, and the feed point connected to the open end. The outer part of the cable functions as a half-wave dipole. The inner non-radiating part is a quarter-wave shorted stub, providing very high resistive impedance at the feed point during resonance. At frequencies outside the resonance, the stub's reactance changes, tending to cancel out the antenna's reactance, thereby widening the bandwidth. This antenna can be constructed using readily available cable. Although it does not meet the ideal design conditions of the original design, the losses are not significant [3].

The bazooka antenna is designed to work with RG-8 coaxial cable that does not have aluminum foil under the fiber shield because the presence of aluminum foil protecting the inner layer will reduce reception sensitivity. Therefore, it is better to use RG-8 coaxial cable that is slightly leaky [4].

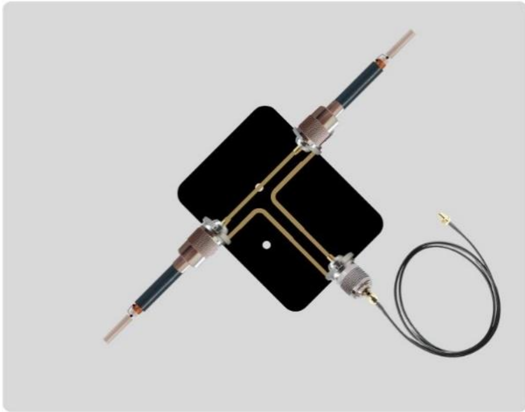

Fig. 1. Trasmitter Antenna Design

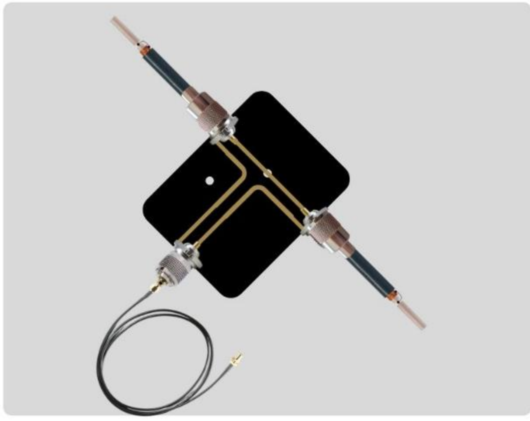

Fig. 2. Receiver Antenna Design

Figures 1 and 2 show the design of the X double bazooka antenna, which functions as both a transmitter and receiver antenna. This antenna is designed using Belden 9311 RG-8 coaxial cable, consisting of a radiator element, an additional element, and a black box as the antenna feed connection point, which also contains an impedance matching circuit. The installation configuration is arranged in a crossed pattern (45° orientation) between the transmitter and receiver antennas, with an aluminum reflector as a separator between them. This design allows the X double bazooka antenna to be mounted on the same mast.

In this design, the antenna is targeted to have operating frequency characteristics of 433 MHz, omnidirectional radiation pattern, VSWR value < 2, return loss < –10 dB, high gain, wide bandwidth, and optimal performance in hybrid communication systems. To achieve an operating frequency of 433 MHz, the antenna dimensions are calculated as follows [6]:

Total Antenna Length

$$L = \frac{1}{2}\lambda = \frac{c}{f \times \sqrt{\varepsilon_R}}$$

$$L = \frac{1}{2}\lambda = \frac{3 \times 10^8}{303 \times 10^6 \times \sqrt{2{,}3}}$$

$$L = \frac{1}{2}\lambda = 32{,}64\ cm$$

Radiator Element Length

$$L = \frac{1}{2}\lambda = \frac{c}{f \times \sqrt{\varepsilon_R}}$$

$$L = \frac{1}{2}\lambda = \frac{3 \times 10^8}{433 \times 10^6 \times \sqrt{2{,}3}}$$

$$L = \frac{1}{2}\lambda = 22{,}84\ cm$$

3.2. Hybrid Communication System Design

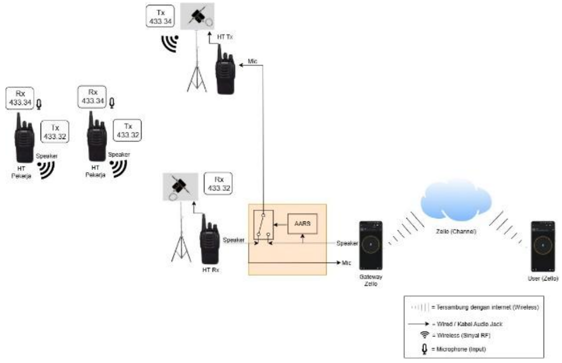

Fig. 3. Hybrid Communication System Series

Figure 3 shows the implementation scheme of the X double bazooka antenna in a hybrid communication system. This system is designed so that signals from the worker's HT can be received by the User (Zello) as the supervisor. When the worker speaks into the HT, the RF signal is transmitted and the HT Rx receives the signal received by the X double bazooka receiving antenna. This signal activates the PTT (Push To Talk) of the HT transmitter and sends the signal to the Zello Gateway. Thus, other workers' HT devices can simultaneously receive the audio, and the Zello Gateway sends the audio to the Zello user.

Conversely, when a Zello user sends a voice message, it is transmitted via the internet and received by the Zello gateway. The voice from the Zello gateway enters the COR system, which is equipped with an Audio Activated Relay Switch (AARS). When the AARS detects an audio signal from the gateway, the HT Tx begins transmitting the voice using the X double bazooka transmitter antenna to the same frequency as the worker's HT. As a result, workers can directly hear instructions from their supervisors in real-time through their respective HT devices, without needing to use the Zello app directly. The X double bazooka antenna was tested as an alternative to using an external antenna in a hybrid communication system based on HT.

4. System Test Result

4.1. Fabrication of Double Bazooka X Antenna

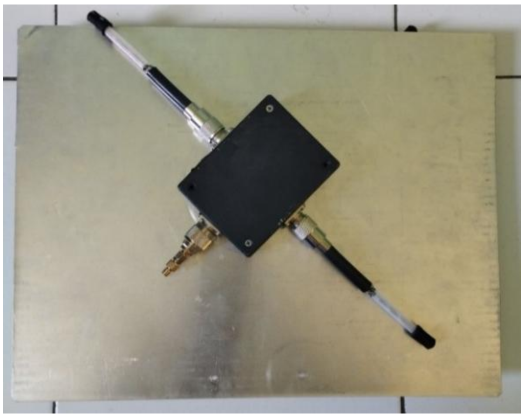

Fig. 4. Transmitter Antenna Fabrication Results

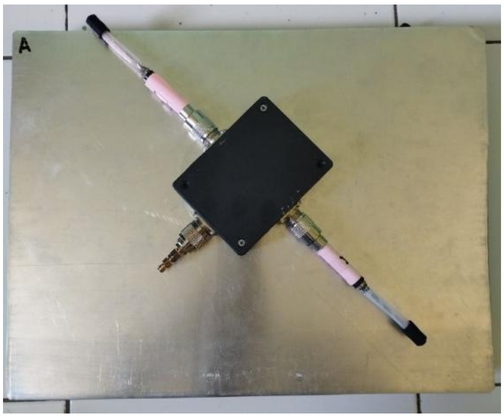

Fig. 5. Receiver Antenna Fabrication Results

The fabricated X Double Bazooka antenna is shown in Figures 4 and 5 A number of antenna parameters were measured, such as impedance, bandwidth, VSWR, gain, and return loss, to evaluate the performance of the antenna that had been made..

4.2. Transmitter Antenna Test Results

4.2.1. Return Loss

Return loss is a measure of the ratio between the amplitude of the reflected wave and the amplitude of the transmitted wave, or can be interpreted as the power loss that occurs due to impedance mismatch between the antenna and the transmission line..

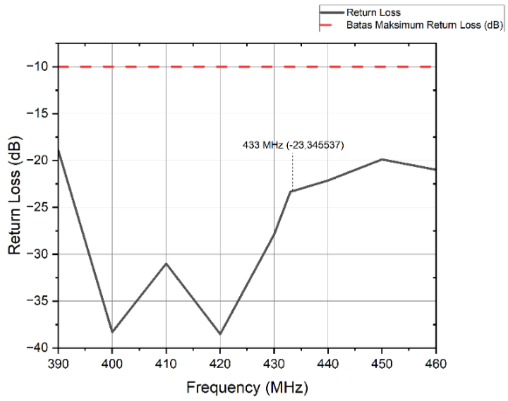

Fig. 6. Return Loss of Transmitter Antenna

Figure 6 shows a graph of the return loss measurement results of the transmitter antenna using NanoVNA. From the graph, it can be seen that the return loss value is below –10 dB in the frequency range of 390 MHz to 460 MHz. At a frequency of 433 MHz, the transmitter antenna shows a return loss value of -23.345537 dB. This indicates that the antenna has good matching performance across the entire range, with low power reflection and high signal transmission efficiency. Based on the return loss measurement results, the reflection coefficient can be calculated and subsequently used to determine the antenna impedance and VSWR values [6].

$$RL\ (dB) = 20\log|\tau|$$

$$-23{,}345537 = 20\log|\tau|$$

$$\frac{-23{,}345537}{20} = \log|\tau|$$

$$\tau = 10^{\frac{-23{,}345537}{20}}$$

$$\tau = 0{,}0680335526$$

4.2.2. Antenna Impedance

Antenna impedance consists of antenna resistance and reactance components. To obtain the impedance value, testing was carried out using a NanoVNA device with the aim of obtaining the return loss value and calculating the reflection coefficient [6]. The reflection coefficient obtained at a frequency of 433 MHz is 0.0680335526, with a characteristic impedance of the connector of 50 Ω..

$$Z_A = Z_0\frac{1+\tau}{1-\tau}$$

$$Z_A = 50 \times \frac{1+0{,}0680335526}{1-0{,}0680335526}$$

$$Z_A = 57{,}3\Omega$$

With an impedance value of 57.3 Ω, the transmitter antenna shows good compatibility with the standard system impedance of 50 Ω, so it is expected to minimize power reflection and support optimal signal transmission performance..

4.2.3. Voltage Standing Wave Rasio (VSWR)

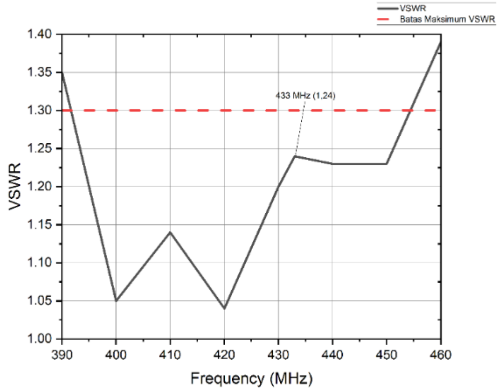

Fig. 7. VSWR of Transmitter Antenna

Figure 7 shows the results of measuring the VSWR of the transmitter antenna using Nano VNA. At an operating frequency of 433 MHz, the VSWR value obtained is 1.24. The following is the theoretical calculation of the VSWR value. [6]:

$$VSWR = \frac{1+\tau}{1-\tau}$$

$$VSWR = \frac{1+0{,}0680335526}{1-0{,}0680335526}$$

$$VSWR = 1{,}146$$

The theoretical VSWR value calculated is 1.146, indicating that the transmitter antenna has excellent impedance matching with the transmission system, thereby minimizing power loss due to reflection and improving signal radiation efficiency..

4.2.4. Bandwidth

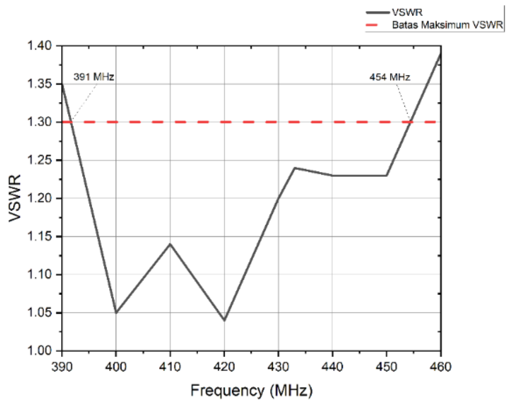

Fig. 8. Bandwidth of Transmitter Antenna

Figure 8 shows the results of bandwidth measurements using NanoVNA. In testing the operating frequency of the transmitter antenna based on the measured VSWR value, a lower limit frequency of 391 MHz and an upper limit frequency of 454 MHz were obtained..

$$BW = \frac{fh - fl}{fc} \times 100\%$$

$$BW = \frac{454 - 391}{433} \times 100\%$$

$$BW = 14{,}54\ \%$$

Based on the calculation results, a bandwidth of 14.54% was obtained. This indicates that the transmitter antenna is capable of operating effectively across a fairly wide frequency range, making it highly suitable for communication applications that require wide frequency tolerance and stable performance under various spectrum conditions..

4.2.5. Radiation Pattern

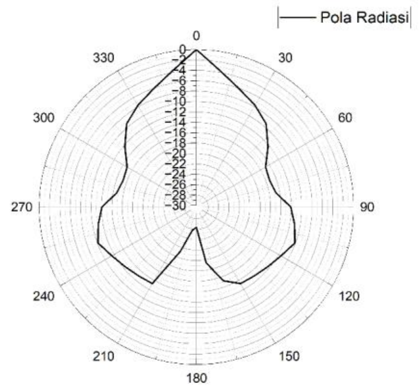

Fig. 9. Horizontal Radiation Patterns of Transmitting Antennas

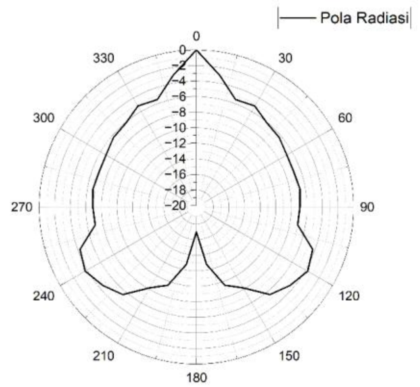

Fig. 10. Vertical Radiation Patterns of Receiving Antennas

The horizontal and vertical radiation patterns of the transmitter antenna in Figures 9 and 10 show the signal distribution in the azimuth plane (0°–360°) with a fixed elevation (θ = 90°). Since the transmitter antenna is mounted facing one side of the reflector and grounded to an aluminum plate, radiation toward the rear of the antenna is completely blocked by the reflector. As a result, the resulting radiation pattern is only visible in the front half-circle of the antenna. This indicates a semi-directional characteristic, where the signal is only strongly transmitted in a specific direction and not toward the rear, consistent with the reflector's role as a signal reflector.

4.2.6. Gain

Calculating antenna gain based on the ratio between the maximum power of the tested antenna and the maximum power of the reference antenna [6].

Table 1. Maximum Power Measurement Results

No	Instalasi	Frekuensi (MHz)	PREF (dBm)	PAUT (dBm)
1.	Horizontal-Horizontal	433	-65,4	-60
2.	Vertikal-Vertikal	433	-71,3	-53,9

The gain is obtained using the following formula:

$$G = 2{,}15 + P_U\ (dBm) - P_R\ (dBm)$$

1. Horizontal – Horizontal

$$G_{AUT(dBi)} = 2{,}15 + P_U\ (dBm) - P_R\ (dBm)$$

$$G_{AUT(dBi)} = 2{,}15 + (-60) - (-65{,}4)$$

$$G_{AUT(dBi)} = 7{,}55\ dBi$$

2. Vertikal – Vertikal

$$G_{AUT(dBi)} = 2{,}15 + P_U\ (dBm) - P_R\ (dBm)$$

$$G_{AUT(dBi)} = 2{,}15 + (-53{,}9) - (-71{,}3)$$

$$G_{AUT(dBi)} = 19{,}55\ dBi$$

The antenna gain measurement results show a value of 7.55 dB in the horizontal position and 19.55 dB in the vertical position. This indicates that the antenna has stronger radiation capabilities in the vertical orientation, making it suitable for applications that require a wider vertical range.

2.2.7. Polarization

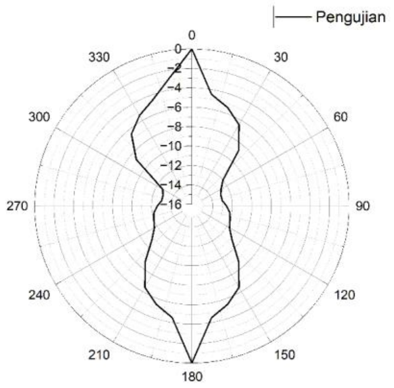

Fig. 11. Transmitter Antenna Polarization

Figure 11 shows the results of the transmitter antenna polarization measurements. To determine the antenna polarization, a comparison method was used between the maximum and minimum received power levels using the axial ratio equation. Based on the measurement results, the maximum received power level was recorded at an angle of 0° with a value of –40.1 dBm, while the minimum received power level was at an angle of 70° with a value of –53.1 dBm. These values were used to calculate the axial ratio to determine the antenna's polarization characteristics quantitatively.

Calculating total gain:

$$G_{Total} = 10\log(10^{\frac{GH}{10}} + 10^{\frac{GV}{10}})$$

$$G_{Total} = 10\log(10^{\frac{7,55}{10}} + 10^{\frac{19,55}{10}})$$

$$G_{Total} = 10\log(5,692 + 90,288)$$

$$G_{Total} = 10\log(95,980)$$

$$G_{Total} = 19,82\ dB$$

Calculating the propagation constant:

$$K = 20\log f - G - 29,8$$

$$K = 20\log 433 - 19,82 - 29,8$$

$$K = 3,109$$

Then the power reception level can be determined.:

1. Maximum Receive Power Level

$$dB\mu\frac{v}{m} = Daya\,Terima\,Maksimum + 107 + K$$

$$dB\mu\frac{v}{m} = (-40,1) + 107 + 3,109$$

$$db\mu\frac{v}{m} = 70,009$$

2. Minimum Receive Power Level

$$dB\mu\frac{v}{m} = Daya\,Terima\,Minimum + 107 + K$$

$$dB\mu\frac{v}{m} = (-53,1\,) + 107 + 3,109$$

$$dB\mu\frac{v}{m} = 57,009$$

3. Axial ratio

$$AR = \frac{E_{Major}}{E_{Minor}}$$

$$AR = \frac{70,009}{57,009}$$

$$AR = 1,22803417$$

Based on the calculation results, the transmitter antenna has an axial ratio value of 1.228. This value is within the standard range of 1 < AR < ∞, which indicates that the antenna has elliptical polarization characteristics..

2.2.8. Directivity

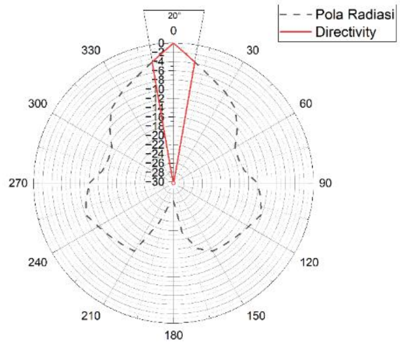

Fig. 12. Horizontal Directivity of Transmitter Antenna

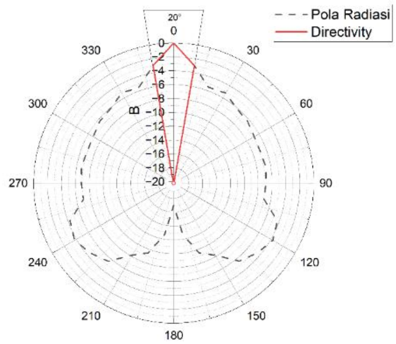

Fig. 13. Vertical Directivity of Transmitter Antenna

Directivity can be calculated using the results of radiation pattern measurements. Figures 12 and 13 below show the radiation patterns of the transmitter antenna in the horizontal and vertical planes, which are used as the basis for calculating the directivity value. Before calculating directivity, the first step is to determine the Half Power Beamwidth (HPBW) value for each pattern. HPBW is obtained from the angle between two points where the transmitted power decreases by 3 dB from the maximum value. Thus, it can be determined.:

1. $HPBW$ Horizontal Radiation Pattern

$$HPBW = \left| \theta\, HPBW_{Left} - \theta HPBW_{Right} \right|$$

$$HPBW = |\, 10° - (-10°) \,|$$

$$HPBW = 20°$$

2. $HPBW$ Vertikal Radiation Pattern

$$HPBW = \left| \theta\, HPBW_{Left} - HPBW_{Right} \right|$$

$$HPBW = |\, 10° - (-10°)|$$

$$HPBW = 20°$$

Once the HPBW values for each field are known, the next step is to calculate the directivity value.:

3. $D = \frac{4\pi(\frac{180}{\pi})^2}{\emptyset\theta}$

$$D = \frac{41{,}253}{20° \times 20°}$$

$$D = 103{,}1325$$

$$D = 10 \log 103{,}1325$$

$$D = 20{,}13\ dBi$$

A directivity value of 20.13 dBi on the transmitter antenna indicates that the antenna is capable of efficiently focusing its transmission power in a specific direction, thereby greatly supporting increased range and signal strength in directional communication systems.

2.3. Receiver Antenna Test Results

2.3.1 Return Loss

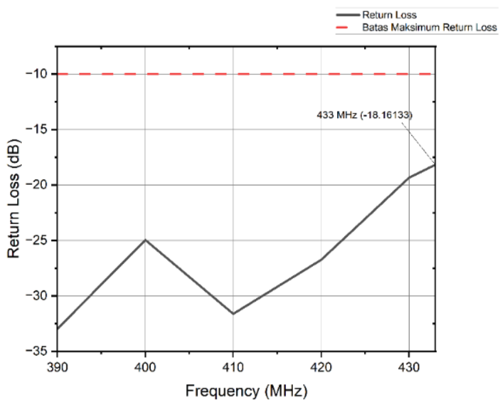

Fig. 14. Return Loss of Receiver Antenna

Figure 14 shows the graph of the double bazooka antenna return loss measurement results using NanoVNA. From the graph, it can be seen that the return loss value is below –10 dB in the frequency range of 390 MHz to 433 MHz. At 433 MHz, the return loss value is –18.16133 dB. Based on the return loss measurement results, the reflection coefficient can be calculated and subsequently used to determine the antenna impedance and VSWR..

$$RL\ (dB) = 20 \log|\tau|$$

$$-18{,}16133\ = 20 \log|\tau|$$

$$\frac{-18{,}16133}{20} = \log|\tau|$$

$$\tau = 10^{\frac{-18{,}16133}{20}}$$

$$\tau = 0{,}12357582$$

2.3.2. Antenna Impedance

To obtain the impedance value, testing was carried out using a NanoVNA device with the aim of obtaining the return loss value and calculating the reflection coefficient. The reflection coefficient value obtained at a frequency of 433 MHz was 0.12357582, with a characteristic impedance of the connector of 50 Ω..

$$Z_A = Z_0 \frac{1+\tau}{1-\tau}$$

$$Z_A = 50 \times \frac{1 + 0{,}12357582}{1 - 0{,}12357582}$$

$$Z_A = 64{,}1\Omega$$

The received antenna impedance obtained is 64.1 **Ω**, which is still within the acceptable range for systems with a characteristic impedance of 50 ohms, so this antenna is still able to work efficiently despite a slight impedance mismatch..

2.3.3. Voltage Standing Wave Ratio (VSWR)

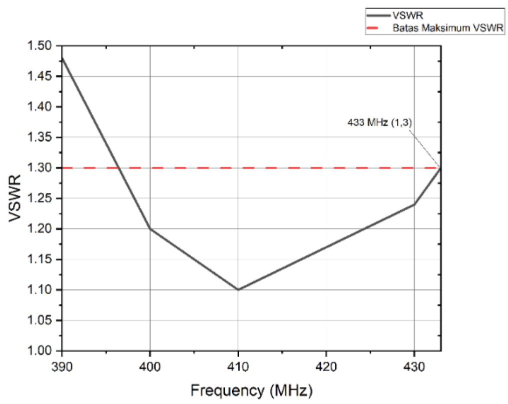

Fig. 15. VSWR of Receiver Antenna

Figure 15 shows the results of measuring the VSWR of the double bazooka receiver antenna using NanoVNA. At an operating frequency of 433 MHz, the VSWR value obtained is 1.3. The following is the calculation of the VSWR value:

$$VSWR = \frac{1+\tau}{1-\tau}$$

$$VSWR = \frac{1+0{,}12357582}{1-0{,}12357582}$$

$$VSWR = 1{,}282$$

A VSWR value of 1.282 on the receiving antenna indicates that the impedance matching is still relatively good, with a low level of power reflection, so that signal reception performance remains optimal..

2.3.4. Bandwidth

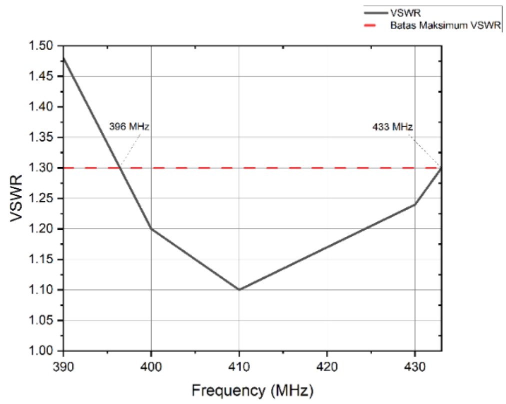

Fig. 16. Bandwidth of Receiver Antenna

Figure 16 shows the results of bandwidth measurements using NanoVNA. In testing the operating frequency of the double bazooka antenna based on the measured VSWR, a lower limit frequency of 396 MHz and an upper limit frequency of 433 MHz were obtained..

$$BW = \frac{fh - fl}{fc} \times 100\%$$

$$BW = \frac{433 - 396}{433} \times 100\%$$

$$BW = 8{,}54\ \%$$

Based on the calculation results, a bandwidth of 8.54% was obtained. This indicates that the antenna is capable of operating effectively within a relatively narrow frequency range, which is generally suitable for communication applications with specific operating frequencies and high performance stability requirements on certain channels.

2.3.5. Radiation Pattern

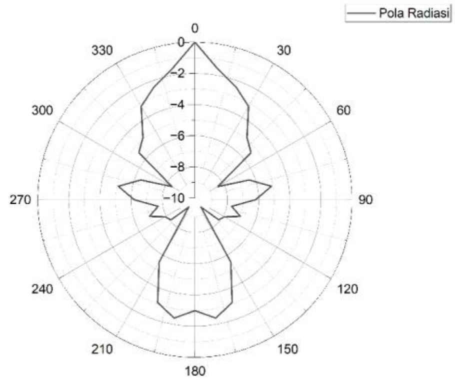

Fig. 17. Horizontal Radiation Pattern of Receiver Antenna

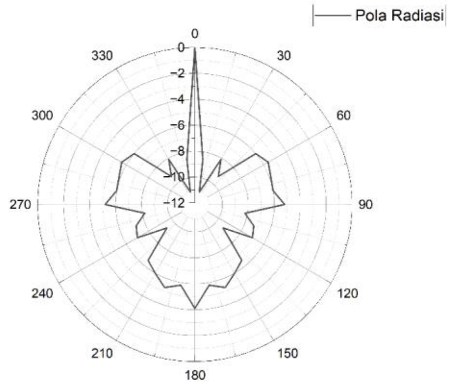

Fig. 18. Vertical Radiation Pattern of Receiver Antenna

Figures 17 and 18 show the horizontal and vertical radiation patterns of an ungrounded receiving antenna relative to the reflector. Although not directly connected to the reflector surface, the receiving antenna is still mounted on the opposite side of the transmitting antenna, and both are separated by the reflector. This reflector acts as a physical barrier to signals from the transmitter direction, so the radiation pattern of the receiving antenna is not fully symmetrical or omnidirectional. It can be seen that the strongest reception direction is on the front side of the receiving antenna, while the back side experiences signal attenuation due to reflections or obstructions from the reflector..

2.3.6. Gain

Table 2. Maximum Power Measurement Results

No	Instalasi	Frekuensi (MHz)	PREF (dBm)	PAUT (dBm)
1.	Horizontal-Horizontal	433	-65,4	-66,4
2.	Vertikal-Vertikal	433	-71,3	-62,1

Calculating gain:

1. Horizontal – Horizontal

$$G_{AUT(dBi)} = 2{,}15 + P_u(dBm) - P_r(dBm)$$

$$G_{AUT(dBi)} = 2{,}15 + (-66{,}4) - (-65{,}4)$$

$$G_{AUT(dBi)} = 1{,}15\ dBi$$

2. Vertikal – Vertikal

$$G_{AUT(dBi)} = 2{,}15 + P_u(dBm) - P_r(dBm)$$

$$G_{AUT(dBi)} = 2{,}15 + (-62{,}1) - (71{,}3)$$

$$G_{AUT(dBi)} = 11{,}35\ dBi$$

The receiver antenna gain of 1.15 dB in the horizontal orientation and 11.35 dB in the vertical orientation indicates that the antenna is more responsive to signals with vertical polarity, making it more optimal for use in communication systems with dominant vertical propagation.

2.3.7. Polarization

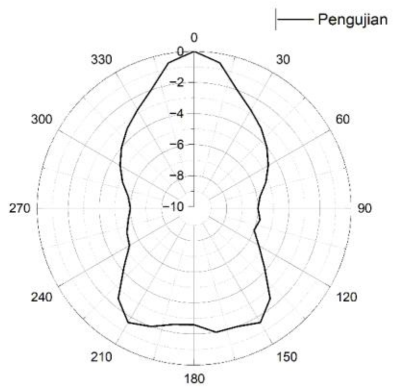

Fig. 19. Polarization of Receiver Antenna

Gambar 19 menunjukkan hasil pengukuran Receiver antenna polarization. Based on the measurement results, the maximum reception power level was recorded at an angle of 0° with a value of –44.2 dBm, while the minimum reception power level was at an angle of 90° with a value of –50.2 dBm.

Calculating total gain:

$$G_{Total} = 10\log\left(10^{\frac{GH}{10}} + 10^{\frac{GV}{10}}\right)$$

$$G_{Total} = 10\log(10^{\frac{1{,}15}{10}} + 10^{\frac{11{,}35}{10}})$$

$$G_{Total} = 10\log(1{,}295 + 13{,}629)$$

$$G_{Total} = 10\log(14{,}924)$$

$$G_{Total} = 11{,}74\ dB$$

Calculating the propagation constant:

$$K = 20\log f - G - 29{,}8$$

$$K = 20\log 433 - 11{,}74 - 29{,}8$$

$$K = 11{,}189$$

Then the power reception level can be determined.:

1. Maximum Receive Power Level

$$dB\mu\frac{v}{m} = Daya\ Terima\ Maksimum + 107 + K$$

$$dB\mu\frac{v}{m} = (-44{,}2) + 107 + 11{,}189$$

$$dB\mu\frac{v}{m} = 73{,}989$$

2. Minimum Receiver Power Level

$$dB\mu\frac{v}{m} = Daya\ Terima\ Minimum + 107 + K$$

$$dB\mu\frac{v}{m} = (-50{,}2\ ) + 107 + 11{,}189$$

$$dB\mu\frac{v}{m} = 67{,}989$$

3. Axial ratio

$$AR = \frac{E_{Major}}{E_{Minor}}$$

$$AR = \frac{78{,}989}{67{,}989}$$

$$AR = 1{,}16179088$$

Based on the calculation results, the receiving antenna has an axial ratio value of 1.1617. This value is within the standard range of 1 < AR < ∞, indicating that the antenna has elliptical polarization characteristics..

2.3.8. Directivity

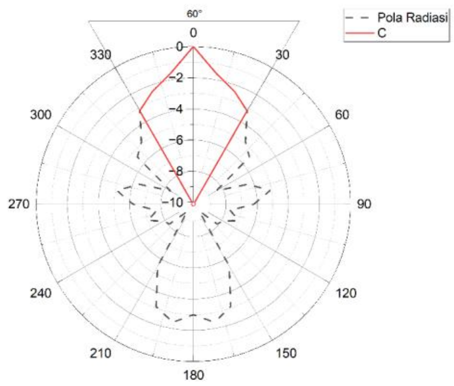

Fig. 20. Horizontal Directivity of Receiver Antenna

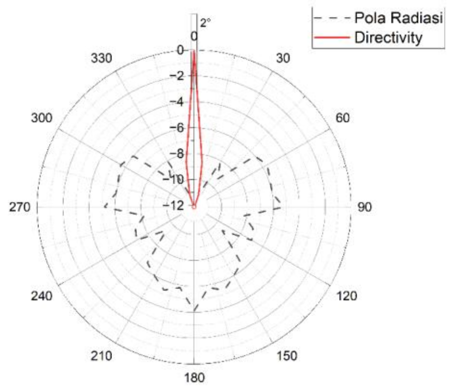

Fig. 21. Vertical Directivity of Receiver Antenna

The Directivity value can be determined using the HPBW value..

1. $HPBW$ Horizontal Radiation Pattern

$$HPBW = \left| \theta\ HPBW_{Left} - \theta\ HPBW_{Right} \right|$$

$$HPBW = |\ 30° - (-30°)|$$

$$HPBW = 60°$$

2. $HPBW$ Vertikal Radiation Pattern

$$HPBW = \left| \theta\ HPBW_{Left} - \theta\ HPBW_{Right} \right|$$

$$HPBW = |\ 1° - (-1°)|$$

$$HPBW = 2°$$

3. $D = \frac{4\pi(\frac{180}{\pi})^2}{\emptyset\theta}$

$$D = \frac{41{,}253}{60° \times 2°}$$

$$D = 343{,}625$$

$$D = 10 \log 343{,}625$$

$$D = 25{,}36\ dBi$$

A directivity value of 25.36 dBi on the receiving antenna indicates a good ability to focus signal reception from a specific direction, thereby improving sensitivity and effectiveness of reception in a directional communication system..

2.4. Implementation of Double Bazooka X Antenna in Hybrid Communication Systems

Fig. 22. Implementation Series in Hybrid Communication Systems

For testing, an SMA Male to SMA Female antenna extension cable was used to connect the HT Tx to the transmitting antenna and the HT Rx to the receiving antenna. The system test was conducted at six measurement points with varying distances from the transmitter antenna, namely 50 m, 75 m, 100 m, 175 m, 200 m, and >200 m, to assess the stability of the signal and audio received by the user's HT. The implementation results of the hybrid communication system were evaluated based on a quality assessment scale for the signal and audio received on the user's HT device. This scale was designed to provide an overview of signal stability and audio clarity under real-world field conditions.

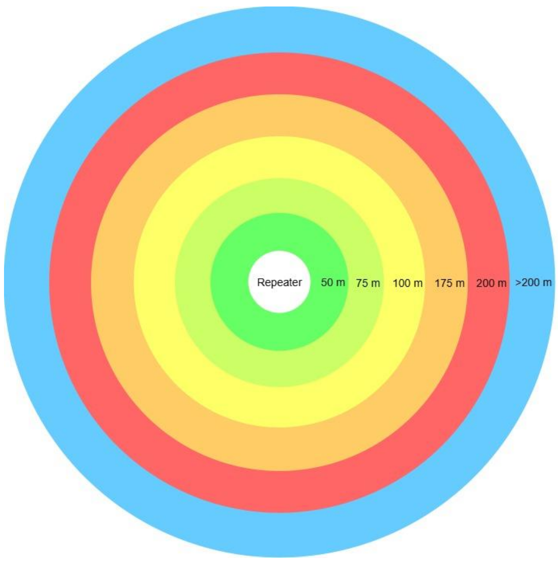

Fig. 23. Handy Talky Sound Diagram

Description:

- 0–50 meters = Audio is very clear and stable with no noise.

- 75–100 meters = Audio is fairly clear, with slight noise beginning to be heard.
- 175–200 meters = Audio is unstable, with high noise and frequent sound interruptions; this is the effective limit of the repeater.
- >200 meters = Audio cannot be heard; only the HT indicator is visible.

Audio quality is excellent up to a distance of 175 meters, and communication latency remains within an acceptable range, particularly for transmissions from HT to HP and between HTs. However, there are still limitations caused by physical environmental conditions such as antenna height, terrain, population density, device quality, maximum range, switching speed, and sensitivity to environmental noise. Additionally, based on measurement results, the maximum transmit power of the HT at 433 MHz is -7.4 dBm, equivalent to approximately 0.000182 Watts. This power level is relatively low, causing the signal to weaken more rapidly as distance increases. Without the support of an antenna with high gain and good radiation efficiency, signal quality can deteriorate significantly or even become unacceptable at distances exceeding the system's optimal range. Overall, this antenna is capable of supporting a hybrid communication system.

5. Conclusions & Recommendations

5.1. Conclusions

The fabricated double bazooka antenna demonstrated performance in line with the targeted specifications, operating at a frequency of 433 MHz with a return loss value of ≤ -10 dB, VSWR values of 1.146 and 1.282, and gains of 19.82 dB and 11.74 dB. Tests conducted in horizontal and vertical orientations yielded elliptical polarization characteristics in both planes, influenced by the measurement methods used in each orientation. The initial design based on basic calculations requires optimization and evaluation stages to achieve more optimal performance. The implementation of the antenna in a hybrid communication system has proven effective, capable of reaching distances of up to 200 meters with good transmission quality. With its simple design, efficient manufacturing costs, and adequate technical parameters, particularly the sufficiently high gain value, this antenna has the potential to become a reliable alternative solution for hybrid communication needs.

5.2. Recommendations

To improve the quality and performance of the double bazooka antenna, the dimensions must be calculated more carefully, including the precision of the element cuts to approach the ideal value and reduce the need for impedance adjustment. The soldering process on the connectors and important parts of the antenna must be done neatly and carefully to ensure a strong and stable connection. Testing should be conducted in a controlled environment with sufficient distance between the transmitter and receiver antennas to minimize reflections that could affect the accuracy of the results. Alternative materials such as aluminum pipes can be considered because they have good structural strength, environmental resistance, and electrical conductivity, thereby potentially improving antenna performance. Additionally, a hybrid communication system utilizing this antenna can be equipped with a real-time signal strength monitoring module (RSSI) to obtain more accurate performance data at various distances and conditions.

6. References

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