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Design of half circular wideband antenna for ship radar

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Abstract. The research aims to design a wideband antenna for the ship's radar. The ship's radar works on the S-Band range whose wavelengths range from 8 to 15 cm with a frequency of 2-4 GHz, This antenna design uses a new approach involving the use of Defected Ground Structure (DGS) and Defected Microstrip Structure (DMS), which builds on the initial theory. The results of the study obtained a bandwidth value of 1.6 GHz, an impedance antenna value of 49.7 ohms, with a total efficiency of -0.3356 a working frequency range ranging from 1.74 GHz to 3.3 GHz. The radiation pattern obtained the main lobe magnitude value of 3.85 dBi, Main lobe direction of 162.0 deg, angular width (3dB) of 76.7 deg, and side lobe level of -1.1 dB. From the results of working frequency, it is found that the antenna can be used for airborne warning & control (AWACS), remote sensing, WiFi, Bluetooth, mobile communication, XM radio, airport surveillance radar (ASR), radioastronomy, wireless LAN, ZigBee, missile guidance.

Keywords. Microstrip antenna, wideband, DGS (Defected Ground Structure), DMS (Defected Microstrip Structure)

1. Introduction

In line with the advancement of telecommunication systems from time to time, microstrip antennas are one type of antenna that is developing rapidly. This antenna was chosen because it has various advantages such as lighter weight, practicality, compact dimensions, and an easy fabrication process. Thanks to these advantages, microstrip antennas have been applied in modern telecommunications equipment and surveillance systems[1]–[5] .

Radio Detection and Ranging, is a navigation tool that can detect objects using a transmit and received signal system. In navigation, radar is used as a [6]–[9] ery important means of preventing collisions at sea, especially in foggy and/or night conditions. Because radar can provide the same information in every condition. Thus, even at night, we can see the ship and its movement as it were during the day. The radar on board is divided into two, namely X X-band and S-band. X band is a radar that has a short antenna with a frequency range of 8.0 – 12.0 GHz and a wavelength of 2.5 – 3.75 cm. In the S-band, the antenna is longer, the frequency range is 2 – 4 GHz and the wavelength is 7.5 – 15 cm. Because the size and frequency of the S-band radar are larger, the production of radio waves with penetration power is also greater. Thus the S-band radar can be used for observation of objects or weather with long distances. In contrast, the X band, which has a short antenna, is more sensitive and suitable for detecting small objects.

This research focused on developing a wideband semicircular radar antenna specifically designed for shipboard applications. Wideband antennas have the ability to work on a wide number of frequencies, which is an important advantage in improving the performance of radar systems. In a broader view, improved ship radar performance impacts safer and more efficient navigation, and ultimately, improved maritime security.

This research becomes relevant in the context of maritime technology development. Investigations into wide-band semicircular antenna designs will provide important insights into how maritime radar technology can continue to improve, and how it can be used to support shipping and navigation security in potentially dangerous waters.[10]–[13]

This research aims to design and develop efficient wideband semicircular antennas for radar applications on ships. The success of this research will have a positive impact on the ship's overall radar system and the safety of maritime operations. An efficient antenna will improve the quality of information received by radar systems, which in turn will allow the ship to identify objects more accurately and respond more effectively to emergencies or threats that may arise. This research approach involves an in-depth understanding of antenna design principles, proper material selection, antenna geometry optimization, and careful testing and maintenance. This methodology will assist in achieving antenna designs that meet specific requirements in the context of ship radar applications.

Success in the development of this wide-band semicircular antenna will make a positive contribution to the development of ship radar technology and shipping safety. Within this research time frame, we will evaluate and document the design, test, and results analysis processes to provide a better understanding of the importance of these antennas in efficient and safe vessel operations in diverse waters. The novelty of this research is that in addition to the form of its design, it is also in the range of work frequencies ranging from 1.7 GHz to 3.3 GHz so that this application can be used for other applications including.

1. Radar Theory

The working principle of radar is based on a system of measuring distances with the reflection of radio waves. Such is the case with calculating the reflection of sound based on the speed of sound. For example, by sounding the sound of a cannon towards the cliff of an island, will be measured in time when receiving the reflection sound again. Because we already know the speed of sound in the air is 3x108 m / s meters per second. So the time between the time when the popping sound sounds until the reflected sound is received again will be calculated as the distance. Accuracy will be calculated using a stopwatch, as illustrated in the following picture: [6]–[8], [14]–[18]

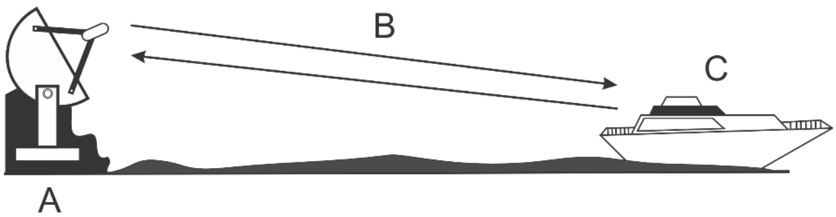

Figure 1. Working principle of echo signal

In Figure 1, there is an explanation of the radar process. The letter A describes the radar station as an antenna, while B is the Echo Signal emitted by the radar station and then collides with target C, returning to the radar station. Echo Signal measurements are made using the formula S = (c * t) / 2, where S is the distance traveled by the signal, c is the speed of radar waves in the air, and t is the travel time of the signal. This formula allows the calculation of the target distance based on the travel time of the radar signal so that the radar can detect and track surrounding objects.

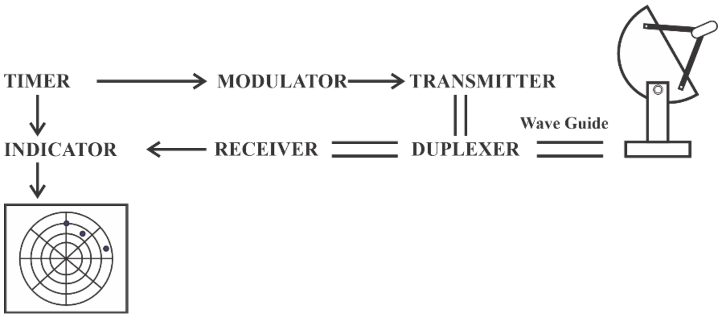

Figure 2. Radar working system

The blocks described above are important units as explained below: timer/trigger is a timer unit for the emission of electromagnetic wave pulses. The pulses generated by the Timer / Trigger function like a trigger or trigger regulate pulses to be forwarded to the transmitter unit and the indicator unit simultaneously. The effect is in the form of continuous pulses with a regular distance of time and is called the pulse-repetition rate of the radar system before entering the transmitter unit must go through the Modulator unit. A modulator is a unit of energy for electromagnetic wave pulses (microwave) by the magnetron subunit which is usually referred to as the magneton power oscillator. The transmitter is a microwave wave-generating unit with high power that will be forwarded to the duplexer unit. A duplexer is a unit that works as an intermediary/successor to microwave wave oscillations only during the pulse power triggered in the form of microwave energy which will pass through the duplexer through the waveguide pipe to the antenna unit. Then the transmission stops and then the receiver unit is ready to tune/listen if there is a reflection coming from the target/object. In other words, the function of the duplexer unit is an electron switch that will forward microwave waves with high power from the transmitter unit through the waveguide pipe to the antenna unit and also through the waveguide pipe. Forward microwave waves that are already weak (not as strong as the radiance power) from the antenna unit through the waveguide pipe to be forwarded to the receiver unit and also through the waveguide pipe. A receiver is a unit that receives back reflections from the object through the antenna by passing through waveguide pipes and duplexers, the incoming signal to the receiver unit. The indicator is a unit to observe signals that have been amplified by the amplifier in the receiver unit and have been demodulated again. Antene radar aircraft function to transmit and receive back a narrow, directional beam of electromagnetic waves while rotating around horizontally, so this antenna part is also called a scanner.

2. Design Antenna

Here are the material specifications required for this project. For patches, copper with a thickness of about 0.035 mm is used. As a substrate, Fr-4 is used with a thickness of about 1.6 mm. The ground layer is also made of copper with a thickness of about 0.035 mm. The enumeration process uses the Insert Feeding method. This specification is particularly relevant in the design and manufacture of components required in this project, such as antennas or other printed circuits. The right combination of materials and thickness becomes an important factor in achieving the desired performance.

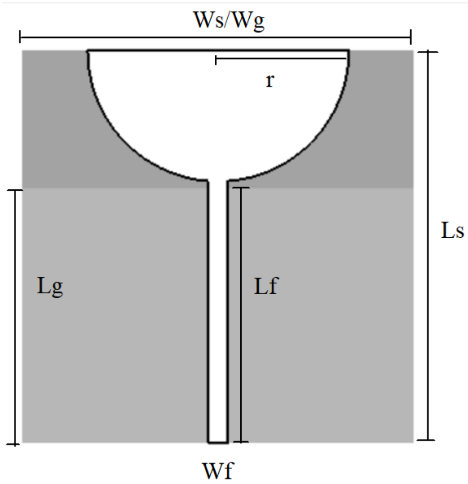

Figure 3. Half circular antenna

Figure 3 illustrates the antenna design of the circular thing with specific dimensions. The values of Ws (channel width) and Wg (ground width) are 60 mm, while the r (radius) values are 20 mm. The slot width (Ls) is about 39 mm, while the ground width (Lg) is 60 mm. There is also a feeder slot (Wf) with a width of about 3 mm. These details are key in designing these half-circular antennas, and those values will affect antenna performance characteristics, such as impedance and radiation patterns. In this project, meticulous and accurate dimensions became a key element to achieve the desired results in this-circular antenna.

This antenna uses a material (Material Set) with the properties given: This Material Set has a Lossy metal type with mu of 1. Its electrical properties are characterized by an electrical conductivity of about 5.8 x 10^7 S/m, while the mass density (rho) of this material reaches 8930 kg/m^3. The ability of a material to conduct heat is determined by a thermal conductivity of about 401 W/K/m. In addition, it has a heat capacity of about 0.39 kJ/K/kg and a diffusivity of about 0.000115141 m^2/s. Its mechanical properties include a Young's modulus of 120 kN/mm^2 and a Poisson ratio of about 0.33. In addition, it has a thermal expansion coefficient of approximately 17 x 10^(-6)/K. These properties are important in a wide range of applications involving this material in electrical, heat, and mechanical contexts. Meanwhile, the substrate specifications used are Fr-4 with the following technical details: Material Set = Default, Type = Normal, Epsilon = 4.3, Mu = 1. The dielectric property of the substrate is characterized by an epsilon of 4.3, while mu, which refers to its magnetic permeability, is equivalent to 1. In addition, this substrate has an electrical conductivity expressed as an electric tand of about 0.025 (Const. fit), and its thermal conductivity is about 0.3 W/K/m. This substrate specification is important in applications involving the use of Fr-4 in the context of electronics and printed circuit design.

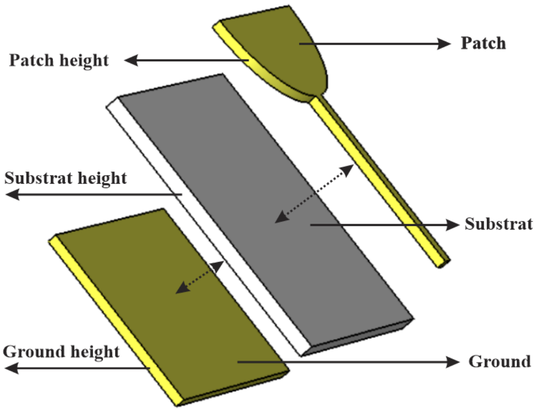

Figure 4. Half circular antena

Figure 4 depicts a wideband antenna with a semicircular design in three dimensions. This antenna is made with FR-4 substrate 1.6 mm thick, and uses copper with a thickness of 0.035 mm as its ground and patch values, as shown in Figure 4. This representation shows the details of the physical design of the antenna, which can be a reference in understanding the characteristics and functions of this wideband antenna.

In designing a circular microstrip antenna, it is necessary to know several parameters, including circular patch radius, patch and ground thickness, substrate length, substrate width, substrate thickness.(a) The radius of a circular patch (a) can be determined using equation 2.1 where is the thickness of the substrate in meters, is the working frequency in Hz, and the dielectric constant of the substrate. A$h f_r \varepsilon_r$circular patch radius (a) specified in meters (m).

$$F = \frac{8{,}791 \; x \; 10^9}{f_r \; \sqrt{\varepsilon_r}} \tag{1}$$

$$a = \frac{F}{\{1+\frac{2 \; x \; h}{\pi \; x \; \varepsilon_r \; x \; F}[ln\left(\frac{\pi \; x \; F}{2 \; x \; h}\right)+1{,}7726]\}^{\frac{1}{2}}} \tag{2}$$

where:

a : Circular patch radius (cm)
h : Substrate thickness (cm)
f_r : Working frequency (Hz)
ε_r : Dielectric constant

The antenna enumeration channel width also greatly affects the performance of the antenna, therefore the antenna enumeration channel width can be calculated using equation 2.2.

$$B = \frac{60\pi^2}{Zo\sqrt{\mathcal{E}r}} \tag{3}$$

$$W_f = \frac{2h}{\pi}\left\{B - 1 - \ln(2B-1)\frac{\mathcal{E}r-1}{2\mathcal{E}r}\begin{bmatrix}\ln(B-1)+ \\ 0.39 - \frac{0.61}{\mathcal{E}r}\end{bmatrix}\right\} \tag{4}$$

where:

W_f : Supply width (mm)

B : large impedance on the channel
h : substrate thickness (mm)
ε_r : Dielectric constant
Zo : Impedance

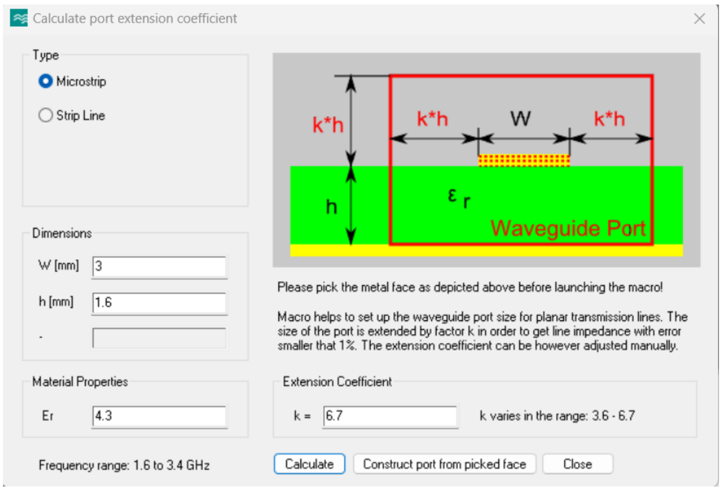

Figure 5. Calculated port extension coefficient

After the calculation and design process, before the simulation is carried out, the Calculated port extension coefficient is carried out as shown 5 above to produce a feeding dimension value of 3 mm a feeding height of 1.6, and a permeability of 4.3, a value of the waveguide port coefficient of 3.6 to 6.7 is obtained. The calculation in the figure shows that the type of substrate material is not observed in the calculation system. The calculation system pays attention to the height of the substrate for efficient waveguide ports.

3. Result and Discussion

The diagram seen below is a visual representation of the return loss in the context of the working frequency of the antenna. The x-axis on this graph reflects the various frequency values examined, while the y-axis displays the corresponding rate of return loss. In the picture, three triangles are the main highlights. The first and second triangles in the graph show the limits of the working frequency of the antenna with a return loss rate of about -10 dB. It describes the considered frequency range according to the specified operating criteria, during which the return loss should not exceed -10 dB. This triangle provides a clear visual view of the working frequency that can be used for this antenna with the appropriate performance. The third triangle, on the other hand, marks the frequencies included in the antenna's bandwidth. In this triangle, there is a frequency range where the antenna performs well and is capable of sending or receiving signals with high efficiency. Thus, this graph provides a comprehensive view of the working frequency characteristics of the antenna, aiding in the optimal selection and understanding of antenna performance in various frequency contexts.

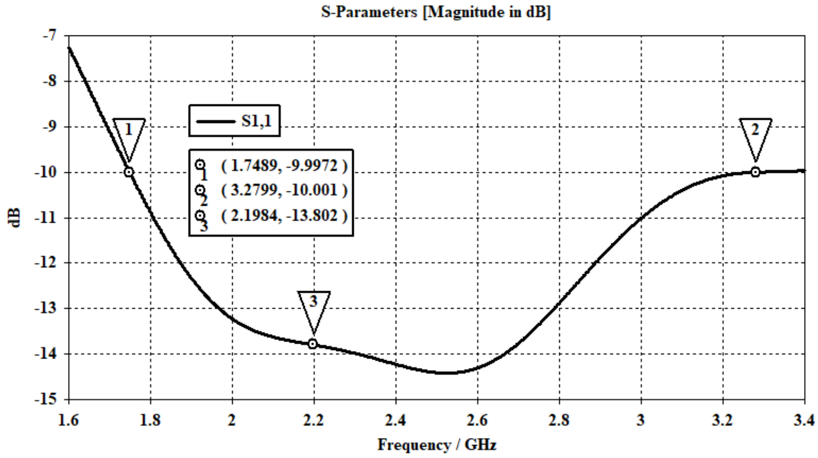

Figure 6. Wideband antenna graph

Figure 6, presented above, provides a graphical representation of wideband antenna performance. This antenna is designed to operate efficiently at a frequency of 2.2 GHz. Interestingly, this antenna still functions well in a wide frequency range, ranging from 1.748 GHz to 3.279 GHz. At a special frequency of 2.2 GHz, this antenna shows a striking return loss value, amounting to -13.802 dB. This image includes important information about antenna bandwidth and impedance matching capabilities, making it a valuable asset in a wide range of wireless communications applications where signal quality and frequency coverage are critical.

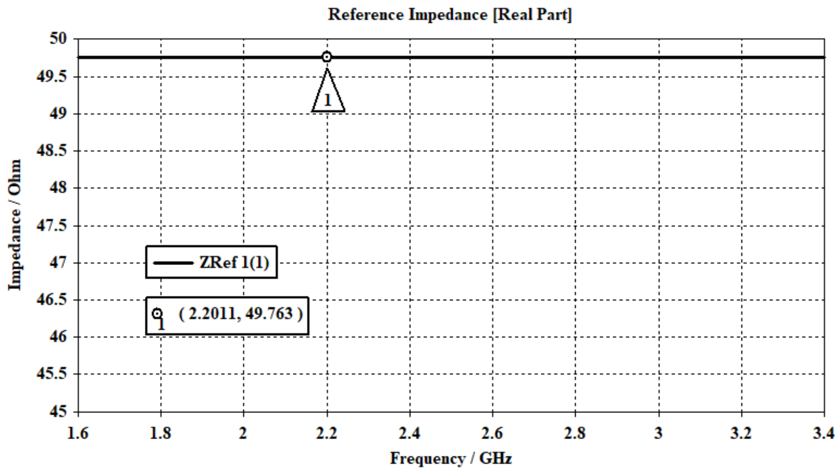

Figure 7. Antenna impedance reference value

Figure 7 displays the reference value of antenna impedance, which peaks at 49.763 GHz. This parameter has a central role in the design and performance evaluation of wireless communication systems. Impedance, in this context, indicates the resistance encountered by the signal as it flows through the antenna system. This is a very important factor that affects the overall performance of an antenna and its ability to efficiently transmit and receive signals within a defined frequency range. Understanding and optimizing impedance is fundamental in achieving smooth communication and ensuring that antennas conform to the desired operational requirements of wireless systems.

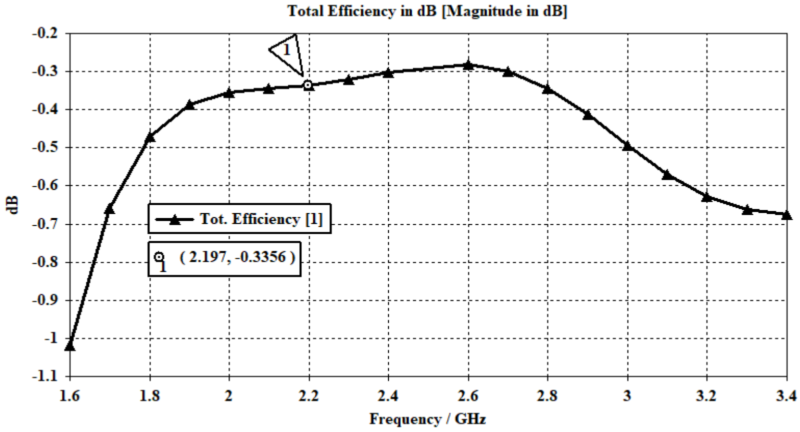

Figure 8. Total antenna efficiency.

In Figure 9, it is seen that the total antenna efficiency value of the antenna reaches -0.3356, making it an important parameter in the design and performance analysis of wireless communication systems. Impedance, in this context, indicates the resistance encountered by the signal as it passes through the antenna system. It has a critical role in determining how effectively an antenna can transmit and receive signals within a defined frequency range. Understanding and managing impedance is fundamental in ensuring optimal communication performance, as it directly affects the antenna's ability to match the characteristics of connected devices, reduce signal loss, and achieve a reliable wireless connection.

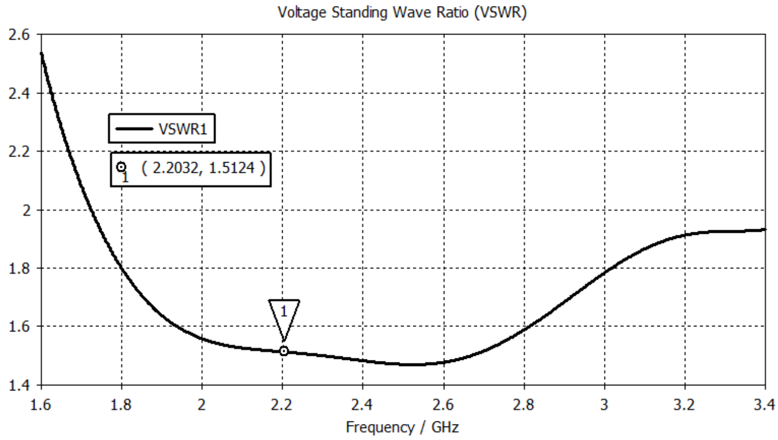

Figure 9. Standing wave ratio value.

In Figure 9 provided, we can see an overview of the value of the standing wave ratio (VSWR). The x-axis in this graph covers a range of frequency values, starting from 1.6 GHz to reaching 3.4 GHz, while the y-axis represents the corresponding VSWR values. Notably, at a frequency of 2.2 GHz, the VSWR value is 1.5124, indicating a favorable impedance matching rate. However, the highest VSWR value occurs around 3.4 GHz, reaching around 6.5. This information is important in assessing antenna performance and antenna suitability for a wide range of frequency-dependent applications, with lower VSWR values indicating better impedance matching and better signal transmission efficiency.

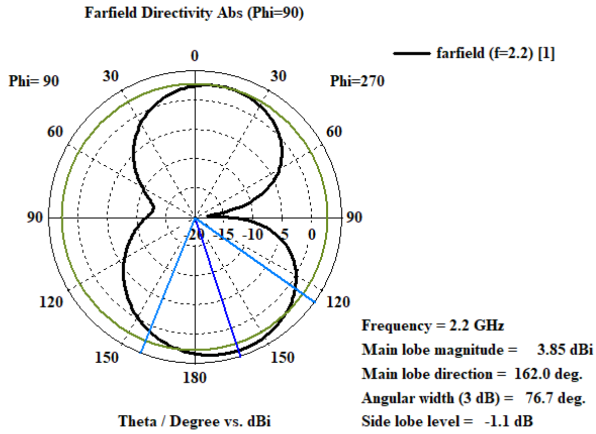

Figure 10. Radiation pattern of the wideband antenna.

In Figure 10 presented above, the illustration clearly illustrates the radiation pattern of a wideband antenna featuring a distinctive semicircular design. This graphical representation effectively communicates the radiation characteristics of the antenna. Notably, this diagram reveals that the antenna shows an omnidirectional radiation pattern, showing that the antenna emits electromagnetic waves evenly in all directions. The main lobe, or main lobe, has an apparent magnitude of 3.85 dBi, indicating its power. Its orientation is at an angle of 162 degrees from the reference point. In addition, the angle width, defined as the range in which the signal strength remains within 3 dB of the main lobe, covers 76.7 degrees. In addition, the level of side lobes, which is a measure of unwanted radiation, is very low at -1.1 dB, indicating excellent antenna performance.

4. Conclusion

Antenna research has been carried out and from the simulation results show that the defected microstrip structure and defectred ground structure methods produce a wide bandwidth value reaching 1.6 GHz thus the radar frequency of ships that are less than or greater than the 2.2 GHz frequency can use this antenna, for further research can be developed antenna research that has greater reinforcement than this study.

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