Design of VHF Directional Antenna on Class B Automatic Identification System (AIS) for Vessel Traffic Monitoring

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Abstract— The majority of Automatic Identification System (AIS) equipment used on ships, harbormasters, and monitoring stations utilizes antennas that possess an omnidirectional beam pattern, covering all directions in a 360-degree range. One limitation inherent to omnidirectional antennas is their susceptibility to signal dispersion, resulting in suboptimal signal gain in certain directions. In the context of using omnidirectional antennas at Port AIS stations or other Monitoring Stations situated in expansive terrestrial regions, it is observed that the monitoring range is reduced. The objective of this study is to develop a prototype of a directional antenna capable of enhancing the monitoring range of ship traffic monitoring stations in alignment with the specific direction requested by land-based monitoring stations. The approach being utilized is the prototype method. This methodology encompasses the sequential steps of data collection, material and issue identification, planning, modeling, building, testing, and implementation.

Keywords— antenna, AIS, marine traffic, boat

1. Introduction

The Automatic Identification System (AIS) is a radio wave-based system that facilitates the automatic transmission of ship information, including location data, between ships and receiving stations on land [1]. The navigation system is crucial for ensuring the safety of ships throughout their voyages. The International Maritime Organization (IMO) mandates the Automatic Identification System (AIS) as a maritime safety and vessel traffic system. The system transmits position reports and brief communications containing ship and voyage-related information [2]. Using frequencies in the maritime VHF band, the coverage is comparable to that of other VHF applications and is primarily determined by the antenna's height.

The Automatic Identification System (AIS) is a navigation system used in Vessel Traffic Services (VTS) to identify and exchange data electronically [3]. Furthermore, the AIS system is capable of providing a substantial amount of data on ship identification (ship name, IMO number, MMSI number, and call sign symbol), ship position (longitude and latitude), speed, direction of travel, and destination port [4]. The management of ship traffic in ports requires implementing an Automatic Identification System (AIS) to prevent collisions between large vessels and between vessels and fishing boats [5]. The transmission process of information using radio frequency, particularly in AIS technology, becomes advantageous for the safety of passengers and crew members [6] .

The Automatic Identification System (AIS) and Geographic Information System (GIS) are used to track ship movements. AIS data that has been decoded is entered into the Geographic Information System (GIS) so that the coordinates of a ship can be determined in real time [5]. The purpose of installing AIS is to facilitate ship detection and enhance maritime safety. The Harbor Master imposes sanctions delaying the ship's departure until AIS has been installed. Consequently, AIS equipment is crucial, and an expansion of monitoring stations is required now and in the future. The AIS system is designed for terrestrial communications, so the antenna utilized by the AIS receiver is a vertically polarized antenna with an omnidirectional beam pattern. This antenna's ring-shaped antenna radiation pattern extends to the sides with the electromagnetic field. Various AIS antenna configurations will result in multiple coverage areas, which can affect radio signal reception, data speed, and accuracy [7].

Extending the range of terrestrial monitoring stations by designing and constructing directional antennas is possible. This is because the AIS equipment utilized by ships, harbor managers, and monitoring stations uses antennas with an omnidirectional 360° beam pattern. This type of omnidirectional antenna has the disadvantage of receiving and transmitting radio signals scattered in a circle, resulting in a suboptimal signal gain in the required direction for using omnidirectional antennas on Port AIS stations and other Monitoring Stations in expansive land areas. Therefore, the purpose of this research is to construct a prototype VHF directional antenna on the frequency used by AIS class B and to extend the monitoring range between the ship and the AIS receiving station on land.

2. The Configuration of AIS System

As depicted in Figure 1, class B of the Automatic Identification System (AIS) has been designed for this prototype. They consist of an antenna, a VHF radio receiver and accessories, a computer, a gateway router, and an internet network. Land-based AIS signal-receiving stations receive AIS signals or data from multiple vessels. Ships equipped with AIS devices can autonomously transmit and receive various data information about adjacent boats through radar screen displays and electronic maps (Electronic Navigation Chart or Electronic Chart Display and Information System). The developed monitoring application is a more real-time website that can display ship information and ship travel history. This monitoring system is utilized during the berthing procedure of ships at the port.

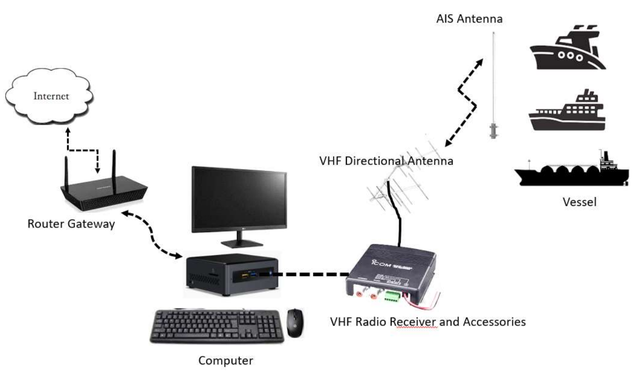

Figure 1. Configuration of AIS system

The Automatic Identification System (AIS) based on Indonesian Small Coastal Fishing Vessels is intended to be implemented on vessels registered in a particular area or among a specific group of fishermen. Data centers in fishing groups or districts receive information from AIS-VMS devices on ships up to 4 nautical miles (nm) from the district littoral. In addition to transmitting and receiving data, vessels equipped with AIS can monitor and trace the movements of other boats outfitted with AIS (within the VHF range). Land-based base stations, such as the Vessel Traffic Services (VTS) station, can also receive these ships' data.

3. Research Methods

Directional antennas are essential components of radio communication systems, especially during the signal-focusing procedure. Directional antennas are used to achieve a longer range since they are more effective at transmitting power in a certain direction. The research methods used were literature, computer simulation, and experimental testing. Below is a general summary of the methods used in this directional antenna research.

Scientific articles and conference proceedings are utilized to conduct literature studies to identify new directions in the study of directional antennas. This can aid in locating knowledge gaps and potential study fields. The MMana-GAL Basic program is used to simulate antennas. Through the use of this application, antenna designs are developed and simulated. This device has the ability to predict antenna properties and performance such as radiation pattern, impedance, and antenna gain. The design of the directional antenna utilizes theoretical analysis, literature research, and simulation results to construct an antenna with the operating frequency of the automatic identification system of the vessel.

Followed by laboratory measurements to evaluate the efficacy of the antenna. Included in the measurements are parameters for the radiation pattern, gain, impedance, and SWR 50. Field tests are conducted to evaluate antenna performance in the real world, considering environmental factors such as interference, multipath propagation, and terrain into account. The following phase is to compare the performance of the directional antenna to that of other types of antennas or alternative designs, specifically the omni-directional ground plane antenna. Evaluate the pros and cons of impedance, SWR, and gain.

The dimensions and distance of each element in this 5-element directional antenna design, including the reflector element, driven element, and 3 director elements. Figure 1 depicts the design of a directional antenna for the AIS system, based on the geometry information presented in Table 1.

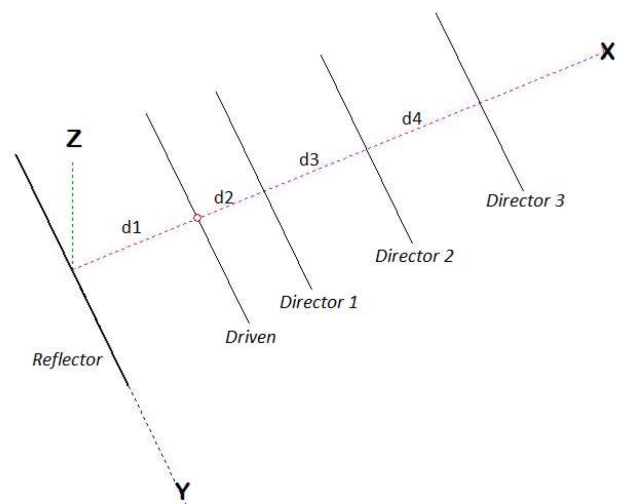

Figure 2. Design of directional antenna for AIS system

First, ascertain the working frequency of the antenna according to the frequency allocation for AIS. This setting can be adjusted based on frequency in MHz or wavelength in meters. The frequency of 162 MHz was determined based on the median of the two frequencies permitted for AIS. Second, enter geometric data for each element, such as its length and distance. This information will affect impedance, VSWR, and antenna gain results. Thirdly, the results of the antenna design based on geometric data on the x, y, and z axes are examined. In the concluding step, it can be used to calculate antenna parameters such as impedance, SWR 50, gain, polarization, and also the radiation pattern in 2D or 3D.

Tabel 1. Geometry information for antenna design

Name Yagi 5 Elements   Freq 162 MHz   ☐ lambda

Wires 5   Auto segmentation: DM1 400   DM2 40   SC 2   EC 2   ☐ Keep connect.

No.	X1(m)	Y1(m)	Z1(m)	X2(m)	Y2(m)	Z2(m)	R(mm)	Seg.
1	0.0	0.0	-0.49	0.0	0.0	0.49	0.8	-1
2	0.49	0.0	-0.448	0.49	0.0	0.448	0.8	-1
3	0.75	0.0	-0.42	0.75	0.0	0.42	0.8	-1
4	1.15	0.0	-0.402	1.15	0.0	0.402	0.8	-1
5	1.59	0.0	-0.38	1.59	0.0	0.38	0.8	-1
next								

4. Result and Analysis

According to the results of the 5-element directional antenna design with geometric data as shown in Table 1, the impedance value Z = 49.961 + j1.508 ohm, SWR = 1.03 at 50.0 ohm, gain 9.0 dBi, and Front to Back Factor F/B=13.67dB were determined. Figure 3 and Figure 5 depict the 2D and 3D radiation patterns (far field plots) of the 5-element directional antenna deriving from this research design.

To determine the benefits of the antenna designed in this study, it is necessary to compare it to the omnidirectional antenna that has been used by many ships in the past. The reference omnidirectional antenna has an impedance value of Z = 48,080 - j6,040 ohms, SWR = 1.15 at 50.0 ohms, gain of 5.83 dBi, and Front to Back F/B Factor = 0dB, according to simulation results. Figure 4 and Figure 6 depict the 2D and 3D radiation patterns (far field plots) of omnidirectional antenna deriving from this research design. In the meantime, Table 2 provides a comparison of the parameters of the omnidirectional antenna and the 5-element directional antenna in this study.

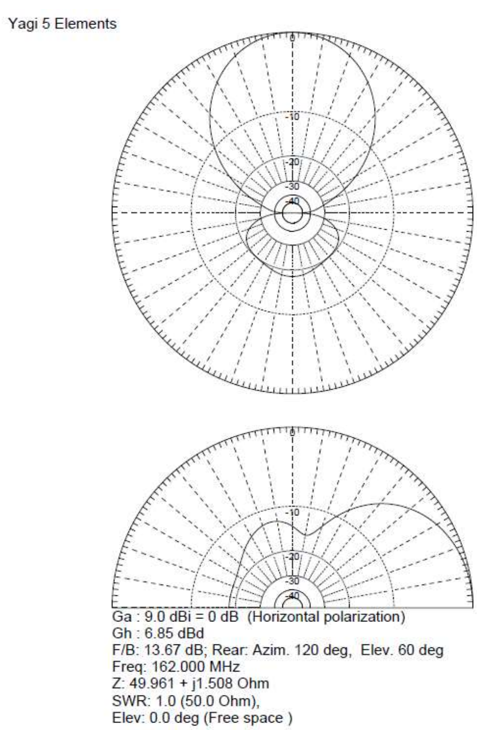

Figure 3. Far field plots directional antenna 5-elements

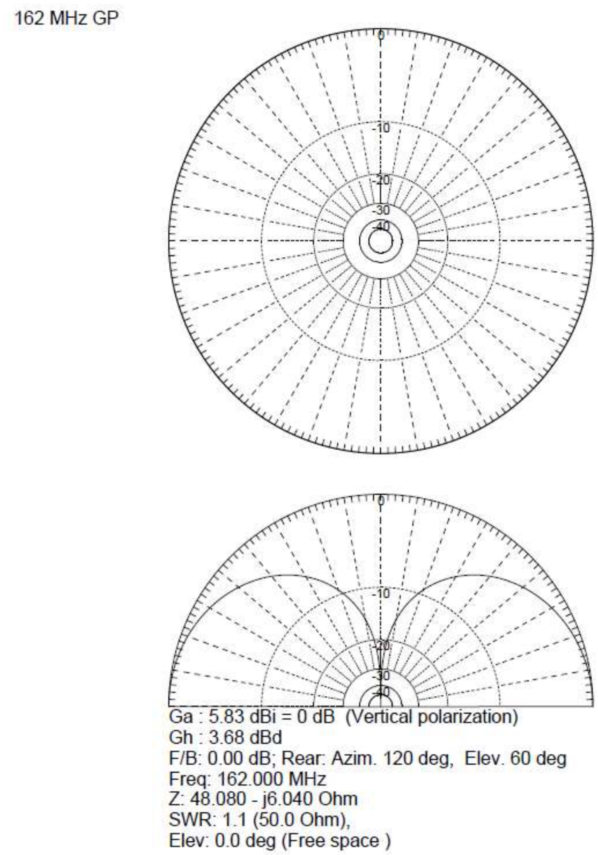

Figure 4. Far field plots of omnidirectional antenna

Radiation patterns are capable of being represented in both two and three dimensions. 2D patterns are frequently employed for simplification, whereas 3D patterns provide a more comprehensive view of the antenna's radiation in all directions. A radiation pattern is a graphical representation or mathematical description of the directional properties of an antenna's radiation. It is also known as an antenna pattern or beam pattern. It describes the manner in which an antenna emits or receives electromagnetic radiation in various directions throughout space. Radiation patterns are essential in telecommunications, broadcasting, and radar because they determine the antenna's coverage area and its ability to transmit or receive signals in specific directions.

In designing and optimizing antenna systems for specific applications, radiation patterns play an essential role. Engineers use these patterns to ensure that antennas meet their performance objectives, such as maximizing coverage in a specific direction or minimizing interference from unwanted directions.Radiation patterns reveal the antenna's directionality, signifying the optimal transmitting and receiving directions. Depending on their design, antennas can be directional, omnidirectional, or somewhere in between.

The main lobe is the pattern's principal, most significant radiation region. It indicates the direction the antenna receives or transmits the most vital signals. The width and configuration of the primary lobe are determined by the design of the antenna.Side lobes are supplementary, smaller regions of pattern radiation. They indicate directions in which the antenna may transmit or receive signals to a reduced extent than the primary lobe. In order to minimize interference with other systems, it is frequently required to decrease side lobe levels. Beamwidth is a measurement of how broad or narrow the primary lobe is. It is typically defined as the angle between the locations at which the power in the main lobe drops to 50 percent of its maximum value. A narrow beamwidth indicates high directionality, whereas a wide beamwidth indicates greater coverage. The gain of an antenna is its capacity to direct radiation in a particular direction relative to an isotropic antenna (which radiates uniformly in all directions). Frequently, gain is measured in decibels (dB). The polarization of an antenna's radiation can also be illustrated by its radiation pattern. Polarization is the orientation of the propagating electric field vector of an electromagnetic wave.landed (horizontal or vertical), circular in shape and elliptical polarizations are prevalent.

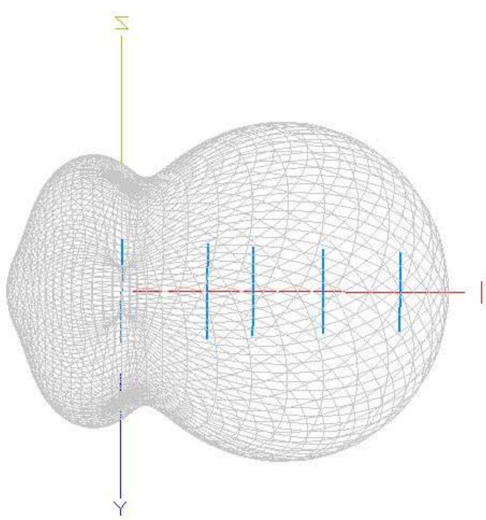

Figure 5. The 3D view of directional antenna 5-elements

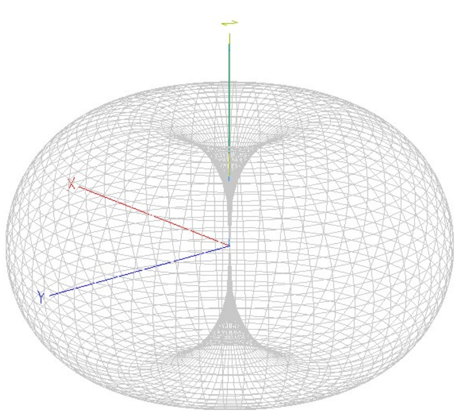

Figure 6. The 3D view of omnidirectional antenna

Tabel 2. Comparation of antenna charateristics

Type Of Antenna	Frequency (MHz)	R (Ohm)	jX (Ohm)	SWR 50	Gain (dBi)	Polar
Ground Plane 162 MHz	162 Mhz	48.08	-6.04	1.14	5.83	vertical
Directional 5 Elements 162 MHz (proposed antenna)	162 Mhz	49.96	1.508	1.03	9	vertical

5. Conclusion

As shown in Table 2, the purpose of this research is to increase the antenna range of land-based VTSs used to monitor ship traffic. The impedance of the antenna is extremely close to 50 ohms, so the voltage standing wave ratio (VSWR) value of 1.03 is virtually ideal. Likewise, the gain of the directional antenna is 3.17 dBi greater than that of the omnidirectional antenna (9 dBi versus 5.83 dBi). This antenna is intended to support surveillance coverage from land stations to ships, taking into consideration the need to concentrate in the direction of the ship's presence at sea, while other directions are predominantly land. Therefore, it is necessary to evaluate the use of this directional antenna in light of beam coverage and monitoring requirements.

The policy mandating the installation of AIS apparatus of Class A went into effect on August 20, 2019. Administrative sanctions are governed by Minister of Transportation Regulation Number PM 58 of 2019 Regarding Amendments to Minister of Transportation Regulation Number PM 7 of 2019 Regarding Installation and Activation of Automatic Identification Systems for Ships Sailing in Indonesian Maritime Territory. The requirement to install AIS is intended to facilitate ship detection and enhance maritime safety. The Harbor Master imposes sanctions delaying the ship's departure until AIS has been installed. The Master will be subject to administrative sanctions in the form of an interim revocation of the COE confirmation certificate (Certificate of Endorsement) if AIS is not activated or if incorrect information is provided regarding AIS. The sanctions listed above also apply to foreign vessels sailing in Indonesian waters. Since February 20, 2020, ships that have not installed and activated the Class B Automatic Identification System (AIS) when sailing will be subject to a delay in sailing; therefore, the provision of AIS equipment is crucial for the independence of the maritime industry. Sanctions against foreign ships, however, will adhere to international conventions or Port State Control (PSC).

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