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Original Article

New Log Periodic Dipole Array Antenna for 162 MHz AIS Receiver

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Abstract *- The omnidirectional antenna currently used by the Automatic Identification System (AIS) receiver has a gain of 5 dB to receive signals from ships at sea that are in certain positions or directions. Certainly, this is very inefficient since omnidirectional antennas were designed to receive signals from all directions. While the use of a traditional directional antenna, having a greater gain than that of the omnidirectional antenna of about 7 dB, was designed to receive signals from only one direction. Based on the limitations of omnidirectional and traditional directional antennas mentioned above, the authors have designed a New Log Periodic Dipole Antenna (LPDA) to receive signals from two opposite directions. Based on the simulation of the proposed antenna using a 4NEC2 software package, the antenna has a gain value between the values of omnidirectional and traditional directional antennas, which is 5.3 dB. In addition, the proposed antenna also has a larger reception range than that of the desired range. Therefore, the proposed antenna can be used in AIS system receivers to overcome the shortcomings of omnidirectional or traditional directional antennas.*

Keywords *- Automatic Identification System, Log Periodic Dipole Antenna, Directional antenna, VHF Terrestrial, 4NEC2.*

1. Introduction

AIS is a radio frequency-based communication system standardized by the International Maritime Organization (IMO) for sea transportation traffic. AIS operates by continuously transmitting position information through the use of onboard AIS transmitters. As a result, this technology not only helps ships avoid collisions with each other at sea but also provides a ready-to-use solution for ship tracking at sea through Ship-to-shore Vessel Traffic Services (VTS).

AIS messages are transmitted every 2, 4, 6, or 10 seconds in VHF terrestrial-based systems, depending on the ship's speed or direction change at anchor or at speeds less than 3 knots (Class B units send every 30 seconds); the intervals are 3 minutes [1]. However, the data received by the AIS base station rarely meets the requirements due to adverse effects of transmission characteristics, power, base station status, geographical features, receiving antenna coverage, etc. [2]. This condition can reduce the level of acceptance of AIS data and have an impact on decreasing the accuracy of predicting future movements of ships at sea.

In general, the main components of AIS are the AIS receiver and VHF Antenna. The VHF antenna picks up the signals coming from the AIS transmitter on board, and the AIS receiver processes these signals into AIS information. Depending on the location of the installation of the AIS receiver, in receiving AIS signals, the VHF antenna can use either an omni-directional or a Uni-directional antenna. VHF omnidirectional antenna can pick up signals coming from all directions with a 360º reception cone. At the same time, the VHF Uni-directional antenna can capture signal transmissions coming from a certain direction (the direction facing the antenna). So, the Uni-directional antenna must be pointed in the direction of the potential signal transmitter. Efficient VHF antenna alignment that takes into account the antenna's reception cone is crucial to ensuring optimal shooting when it comes to AIS signal reception performance.

According to the study [2], the Uni-directional AIS antenna outperforms the Omni antenna regarding signal range and distance when receiving AIS messages under identical circumstances. In high-traffic ports and channels, uni-directional antennas can effectively boost signal coverage, decrease AIS signal blind areas, minimize message loss, and make up for the shortcomings of omnidirectional antennas in terms of AIS data reception rate.

Terrestrial VHF AIS generally uses an Omni-directional VHF antenna, and the Radio Base Station (RBS) position is placed near the coast so that most of the coverage area of the antenna catchment island. In this functional requirement, several antenna designs were proposed by the researchers by relying on the Yagi model [3],[4],[5] and LPDA. Directional antennas in AIS generally work with a large radiation pattern in one direction, so they cannot reach other areas. Using an omnidirectional antenna does not get the expected gain; a directional antenna with the required radiation pattern is required. [6],[7],[8],[9].

Yagi antennas, which are directional antennas, are made of dipole antennas arranged into an array consisting of 3 kinds of elements: reflectors, driven and directors. A Yagi antenna can be made of parallel cylindrical elements. The Director element is a directional element placed in front of the driven dipole antenna, the director will provide radiation from the driven in one direction. The number of directors on a Yagi antenna can be more than 1 element.The Yagi antenna design with 4 elements, each consisting of one reflector, one driven, and two directors and used a balun and T match as impedance regulators in a frequency environment of 142 MHz was proposed by Farid Thalid et al. [4]. Research on other Yagi antenna models at a frequency of 150 MHz has shown that they can produce a gain of 13.19 dB for a single antenna.

This was followed by a Yagi model with an 8 × 2 pattern proposed by Efratmur et al. [6], resulting in a better Gain performance of 22.58 dB. This condition shows that the determination of the number of elements is the main factor in improving the performance of the Yagi antenna. Both models still produce a narrow radiation pattern and limit antenna performance in AIS environments with only radiation patterns in one direction. The Log Periodic Dipole (LPDA) antenna offers greater directivity and gain with a wider bandwidth than the Yagi antenna, which has a relatively narrow bandwidth and poor directivity. Based on the LPDA model, an antenna design was designed using a scale factor of 0.93, a distance factor of 0.16 and an apex angle of 6.3°.

The designed antenna has a high gain of 8.76 dBi and consists of 12 elements designed for the 1350–2690 MHz frequency range. The radiation efficiency of the designed antenna is about 94.6%, with a peak directivity of 8,524 dBi, a return loss of -17 dB and a radiation intensity of 0.406 W/sr. [10].

In another study [11],[12],[13], the Log-Periodic Dipole Array (LPDA) antenna was designed in a wide frequency range with high gain by using the specified scale factor (τ) and space factor (σ). Although the Yagi Antenna will provide higher gain at its optimal frequency, the LPDA antenna is designed to work over a wide frequency range. With a wide frequency range, it can reduce data communication failures when the ship is moving. This paper aims to realize an AIS antenna receiver model at a frequency of 162 MHz based on LPDA, which has a radiation pattern in a certain direction so that it can cover a wider area. A total of 4 models have been analyzed by varying the length and distance parameters of the elements. The goal is to obtain a maximum radiation pattern towards the front and back of the antenna position. All antenna models were analyzed on gain parameters, radiation pattern and bandwidth.

2. Log Periodic Dipole Array (LPDA) Antenna

If a dipole array is set up both sequentially and in parallel, it transforms into an LPDA antenna. Frequency range is crucial to antenna design since it dictates how many antenna elements are needed. [3].

A few characteristics need to be taken into account when building antennas: l_n, or the n-th dipole's overall length, and d_n, or the distances between the wires on the n-th dipole, as shown in Figure 1 and equations 1 and 2. [3][4].

A scale of geometric constant τ :

$$\frac{1}{\tau} = \frac{l_{n+1}}{l_n} = \frac{d_{n+1}}{d_n} \quad (1)$$

Spacing (distance) factor σ :

$$\sigma = \frac{d_{n+1}-d_n}{2l_{n+1}} \quad (2)$$

A scale element parameter, τ, and a relative distance, σ, also are required. These parameters are depicted inside the directivity curve in Figure 2 [9].

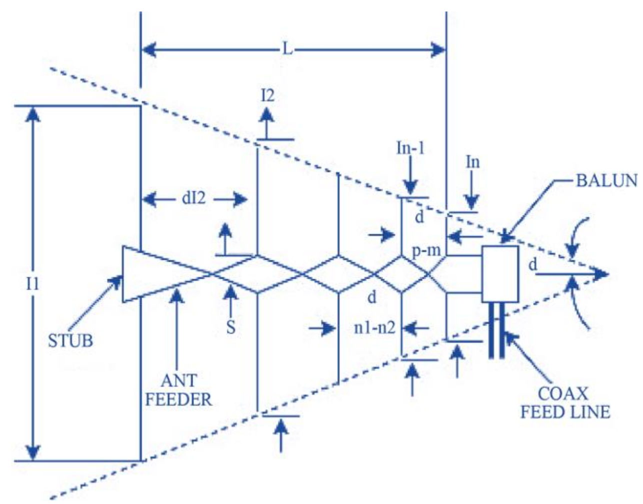


Fig. 1 Two wire line LPDA feeder antenna

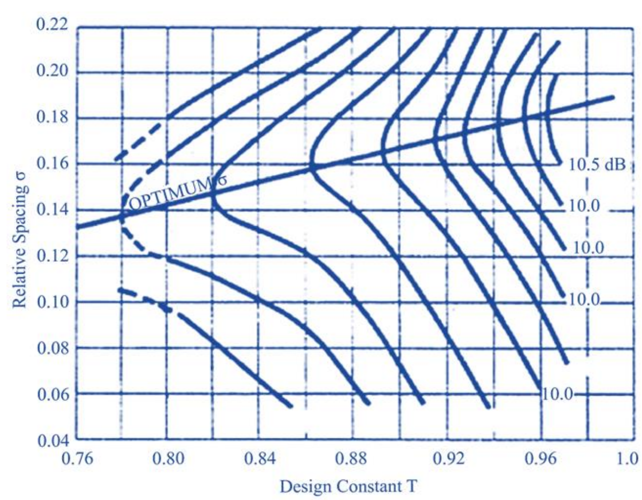


Fig. 2 Graph of τ, σ and LPDA gain

In designing a log periodic dipole antenna, 3 one-of-a-kind bandwidth forms must be considered. The 3 bandwidths are desired bandwidth B, active region bandwidth, B_{ar}, and designed bandwidth B_s. These portions may be calculated by the usage of equation (3) – (6) [3].

Required bandwidth are:

$$B = \frac{f_{max}}{f_{min}} \quad (3)$$

$$B_{ar} = 1.1 + 7.7(1 - \tau)^2 \cot \alpha \quad (4)$$

Half apex angle:

$$\alpha = \tan^{-1} [(1 - \tau) / 4 \sigma] \quad (5)$$

$$B_s = B \times B_{ar} \quad (6)$$

Where,

B_s= designed bandwidth
B = desired bandwidth
B_{ar}= active region bandwidth.

The number of elements (N) can be determined by equation (7).

$$N = 1 + \frac{\ln (Bs)}{\ln (\frac{1}{\tau})} \quad (7)$$

3. Materials and Methods

The proposed log periodic antenna for the AIS device has elements operating in the 162MHz frequency range. To design the proposed antenna, the author performed four combinations of variable LPDA antennas, namely the length of elements and space between elements. Based on this combination, three designs will be obtained, where the design with the best results will be selected. The selected design should have two nearly identical main lobes in two different directions. Given the value of τ in the range of 0.76 to 1, based on the graph in Figure 2, different values of σ (spaces between elements) are obtained in the range of 0.04 to 0.22. Based on the range of sigma values, the range of element lengths is computed using equations (1) and (2), and the results are shown in Table 1 to Table 4, indicating the first, second, third and fourth antenna design results, respectively. All four designs use the same element diameter of 0.007 m, as indicated in all tables.

4. Results and Discussion

This chapter describes the results and discussion on a simulation exercise of an antenna proposal, which includes its gain, radiation pattern and bandwidth.

4.1. Radiation Pattern of the Proposed Antenna

Using the 4NEC2 software, each radiation pattern of those four designed antennae can be plotted, as shown in Figures 3 to 6. The best result of the antenna radiation pattern is shown in Figure 6 since it has the most optimum radiation pattern, i.e., the smallest difference in radiation pattern in two opposite directions. Therefore, the antenna variables in Table 4 will be used as variables for candidates of the LPDA antenna.

Table 1. First design of LPDA antenna

Element number	Length of element (m)	Space between element (m)	Diameter of Element (m)
1	0.926	0	0.007
2	0.765	0.277	0.007
3	0.632	0.506	0.007

Table 2. Second design of LPDA antenna

Element number	Length of element (m)	Space between element (m)	Diameter of Element (m)
1	1.06	0	0.007
2	0.92	0.277	0.007
3	0.90	0.506	0.007

Table 3. Third design of LPDA antenna

Element number	Length of element (m)	Space between element (m)	Diameter of Element (m)
1	0.926	0	0.007
2	0.765	0.44	0.007
3	0.632	0.92	0.007

Table 4. Fourth design of LPDA antenna

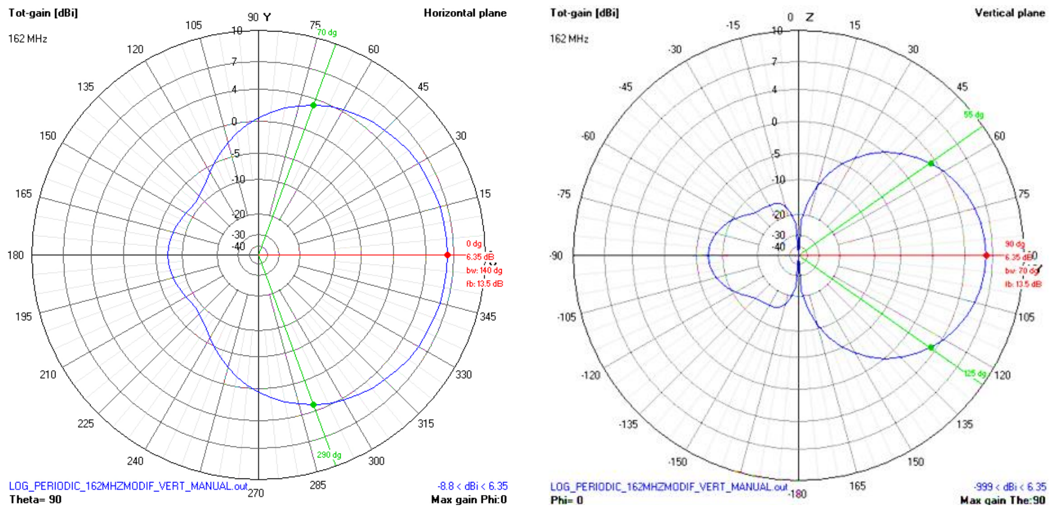
Element number	Length of element (m)	Space between element (m)	Diameter of Element (m)
1	1.06	0	0.007
2	0.92	0.44	0.007
3	0.90	0.92	0.007

4.2. Antenna Gain of the Proposed Antenna

Another parameter considered in antenna design is the antenna gain. As seen in Figure 6, the antenna candidate possesses a gain of 5.3 dB. This gain is greater than that of an omnidirectional antenna; however, it is smaller than that of the traditional directional antenna. Therefore, the antenna candidate mentioned in Section A was selected as the strong candidate for the proposed antenna used in the AIS receiver to accept signal AIS from two opposite directions.

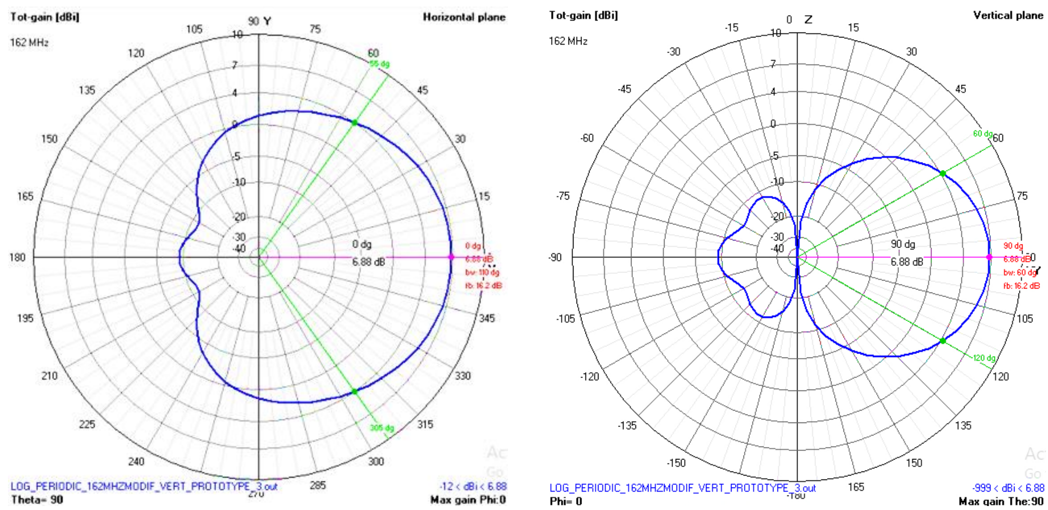
4.3. Bandwidth of the Proposed Antenna

Bandwidth is the last parameter used to see the reception range of the antenna. This parameter is used to make the final decision in selecting the best candidate from the proposed antenna. More bandwidth means a better range of reception. Using equations 3 to 6, the variable of the strong candidate of the proposed antenna was obtained, as shown in Table 5, to determine antenna bandwidth. As shown in Table 5, the bandwidth of the designed antenna (B_s = 1.914112 MHz) is greater than the desired bandwidth (B = 1.0062), which means it can reach a greater reception.



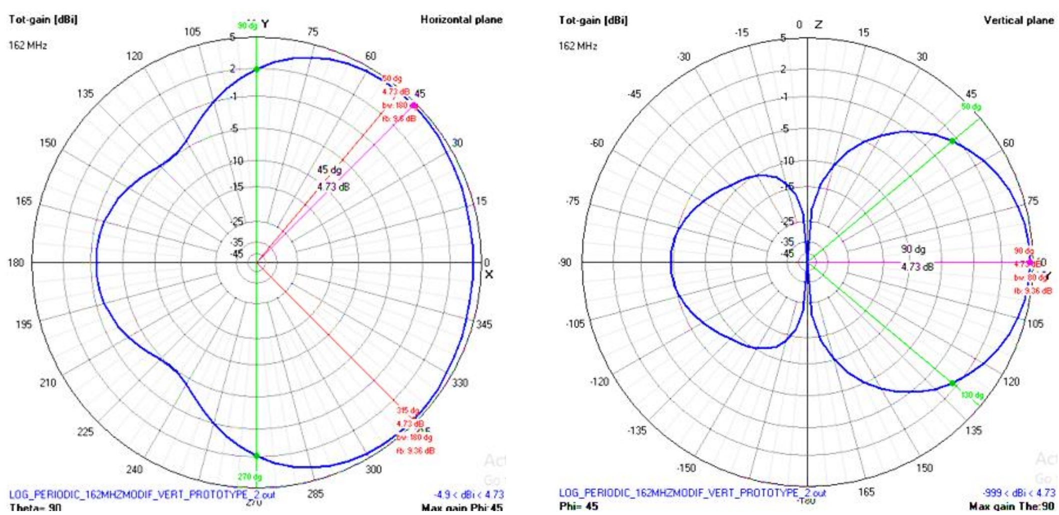
(a) **(b)**

Fig. 3 Horizontal (a) and vertical (b) radiation pattern of the first antenna design



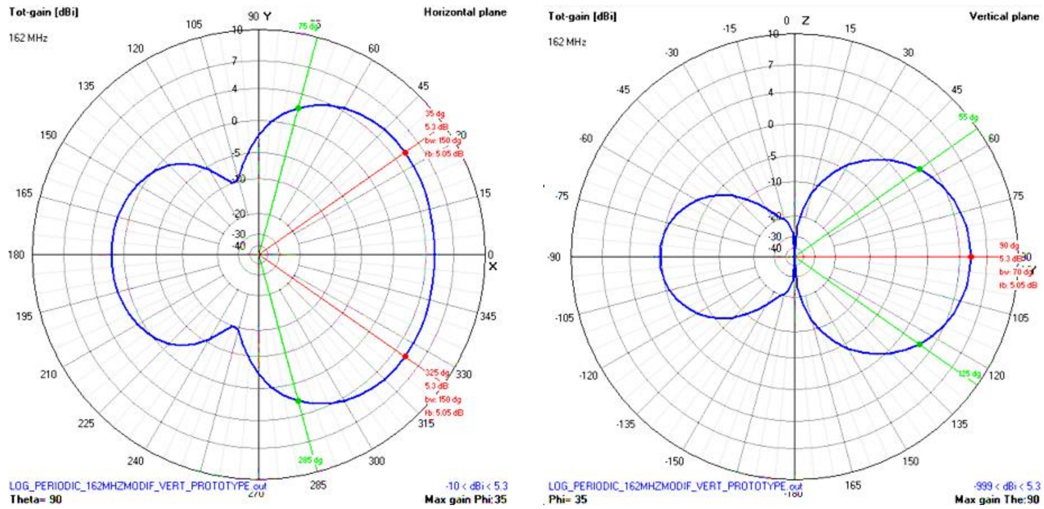
(a) **(b)**

Fig. 4 Horizontal (a) and vertical (b) radiation pattern of second antenna design



(a) **(b)**

Fig. 5 Horizontal (a) and vertical (b) radiation pattern of third antenna design



(a) (b)

Fig. 6 Horizontal (a) and vertical (b) radiation pattern of fourth antenna design

Table 5. Variable of the LPDA

No	Parameter	Nilai
1	Alpha	32.402
2	B_{ar}	1.902369 MHz
3	B	1.0062 MHz
4	B_s	1.914112 MHz
5	N	3.00

Since the strong candidate of the proposed antenna mentioned in section 4.2 also has a wide range of reception, the antenna has ultimately been chosen as the proposed antenna for the AIS receiver.

The three-dimensional geometry display and radiation pattern of the proposed antenna are shown in Figures 7 and 8, respectively.

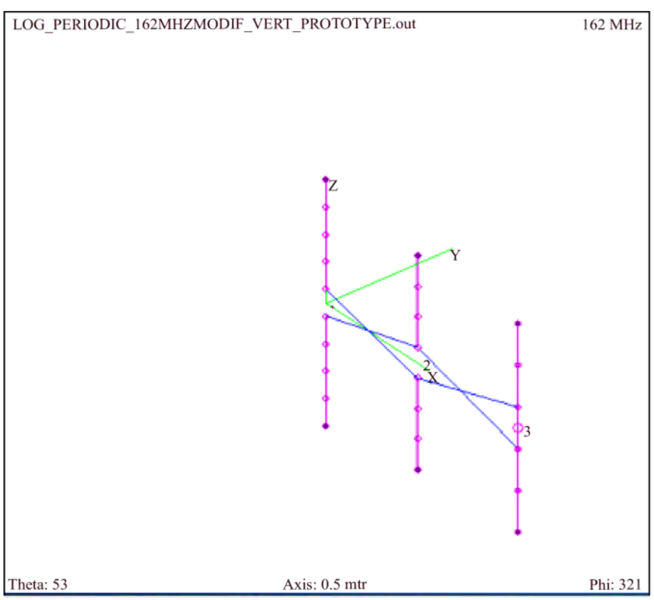


Fig. 7 Geometry display in 4NEC2 software

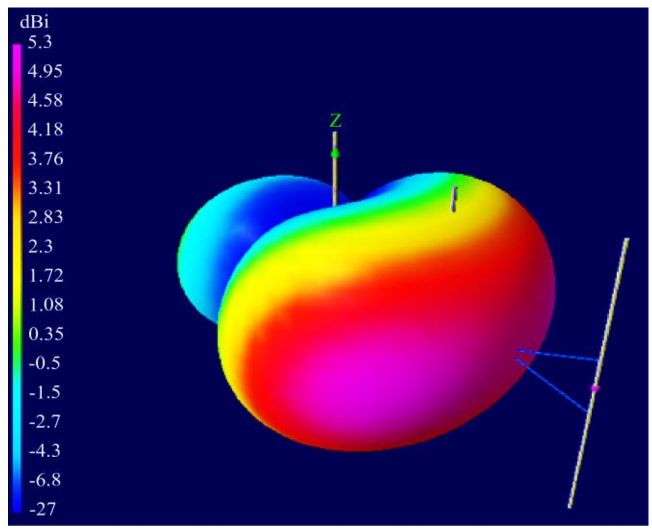


Fig. 8 Radiation pattern in 3D dimensions

Fig. 9 Coverage of the LPDA antenna in the Nusa Penida Sea, Bali and Lombok Straits

4.4. Coverage of the Proposed Antenna

Testing coverage of the LPDA antenna at a frequency of 162 MHz is carried out by connecting the AIS receiving device to the Udayana University (Unud) server so that every data from ships in the Nusa Penida sea is stored within the specified time. The appearance of the ship's position on the map can be seen in Figure 9. As seen in Figure 9, the proposed antenna can cover areas in opposite locations (Lombok and Bali Straits), which matches the radiation pattern of the proposed antenna.

5. Conclusion

In this paper, the authors have designed four different log periodic antennas. Simulation has been performed to select the most suitable antenna for the AIS receiver for application in two opposite directions. The simulation indicates that the proposed antenna has a gain of 5.3 dB, which is higher than an omnidirectional antenna but lower than a standard directional antenna. Besides, the proposed antenna possesses a wider reception range than the desired range. Therefore, the proposed antenna is the most proper application in the AIS receiver for two opposite directions than that of omnidirectional and one direction of the traditional antenna.

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