Analysis of Two Monopole Antennas Placement on Satellite for AIS Signal Reception

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***Abstract*— Receiving AIS (Automatic Identification System) signal using satellite makes it possible to track the seafaring vessels beyond coastal areas that cannot be covered by ground AIS receiver that have limitation in coverage. Based on IALA (International Association of Maritime Aids to Navigation and Lighthouse Authorities), AIS has a purpose to enhance the maritime safety and navigation efficiency, the marine environment protection. LAPAN-A2 and LAPAN-A3 have been constructed by LAPAN (National Institute of Aeronautics and Space). LAPAN-A2 and LAPAN-A3 carry AIS Receiver as one of the payloads to monitoring ship. Next-generation satellite of LAPAN will also carry AIS receiver as one of the payloads. This AIS receiver is an improvement from AIS Receiver that carried in LAPAN-A2 and LAPAN-A3. To improve the AIS reception in next-generation satellites, the satellite will carry two VHF antenna. This paper simulated the radiation pattern of the VHF antenna to know the direction of the radiated signal, the coverage of AIS signal reception by the satellite and the link budget to receive the AIS signal.**

Keywords—AIS, monopole antenna, antenna placement, coverage, link budget

I. INTRODUCTION

National Institute of Aeronautics and Space (LAPAN) of Indonesia has developed and launched 3 satellites successfully. They are LAPAN-TUBSAT satellite, LAPAN-A2/ORARI satellite and LAPAN-A3/IPB satellite. Each of them has different payloads and missions. The first satellite of LAPAN is the LAPAN TUBSAT satellite. It was developed by LAPAN and Technical University of Berlin (TUB). It was launched in 2007 as "piggyback" satellites and has 630-km altitude orbit[1]. It has a surveillance mission using analog video then transmitted using S-band to the ground station.

The second Indonesian microsatellite is LAPAN-A2/ORARI. The design and development process of this satellite was done in Indonesia. It was launched in 2015. The mission of this satellite is disaster mitigation. LAPAN-A2/ORARI carry some payloads such as Automatic Identification System (AIS) which is used to identify and monitor the ship at the sea, digital camera (space camera), video camera and amateur communication using Voice Repeater (VR) and Automatic Packet Reporting System (APRS)[2].

While the 3rd Indonesian microsatellite is LAPAN-A3/IPB. It uses a multispectral line imager for food security support. This satellite has a collaboration with Bogor Agricultural Institute (IPB). Besides multispectral line imager, It carries some payloads such as AIS, digital camera and experimental thermal imager[3].

The LAPAN-A4 and LAPAN Communication Satellite satellite will become the next microsatellites that are developed by LAPAN. LAPAN-A4 satellite is designed in polar orbit and LAPAN Communication Satellite in an equatorial orbit. One of the payloads of the satellites is also AIS. AIS is an automatic system used on shipboard. It operates on marine VHF channels and has function to transmit and receive the position of the vessel, vessel speed, heading and other specific information of the vessel. AIS was known as a reporting system for between ships and between ships and shore to enhance the safety at the sea and also monitor and control the traffic of maritime. The AIS system is clearly described in the International Telecommunication Union Recommendation ITU-R M.1371 [4]. There are two AIS channels, the first is AIS1 at 161.975 MHz and the second known as AIS2 at 162.025 MHz. There is channel use for long-range AIS as AIS3 and AIS4, those are 156.775 MHz and 156.825 MHz.

The LAPAN-A2 satellite and LAPAN-A3 satellite uses a single antenna and two channels AIS receiver. The issue of AIS signal reception is the collision data. Therefore, the LAPAN-A4 and LAPAN Communication Satellite use an improved AIS Space Receiver. An improved AIS Space Receiver has better decoder performance, supporting multi-antenna, and enhancement of the algorithm. Next-generation satellites use two antennas for AIS signal receiving. The use of more than one antenna increases the probability of detecting a message than using single antenna. Two VHF monopole antennas used in next-generation satellite to improve the AIS signal reception. In this paper, the antennas mounted in different axis to get more coverage. The aim of this paper is to determine the optimal position of placement antennas.

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II. METHODOLOGY

The microsatellite used as models in this study is LAPAN-A4 satellites with 744 x 700 x 520 mm dimensions. This satellite has polar orbit and brings the AIS receiver as one of its missions. In this satellite, two quarter-wavelength monopole antennas are installed on the satellite plate that made from a black anodized aluminum structure, which has an omnidirectional radiation pattern. The simulation is carried out to find the right direction so that the placement of the two antennas is expected to be directed to the Z+ axis where the axis is facing the earth. In this simulation, the satellite is placed in a nadir position.

In International Maritime Organization (IMO) installation guideline, IMO states very specific about the antenna being mounted such that the radiation is vertically polarized. It is used to have uniform strength signals in all directions from the ship. It means that AIS transmitter from the ship has vertical polarization. To having maximum signal reception, the satellite antenna receiver must have similar polarization as the AIS antenna transmitter. Satellite antenna tilting will cause the change in polarization to not be entirely vertical. It affects the signal reception of the satellite AIS receiver. It also changes the coverage of the satellite AIS receiver. But this can be used to minimize the collision data of signal reception.

After simulating the radiation pattern of the antennas, the antenna placement that leads the radiation to the Z+ axis is projected to the earth to know the footprint of the satellite to receive the AIS signal using simulation software. Then, the link budget is calculated to know the capability of the AIS receiver to receive the AIS signal from the ship.

There are four variants of the antenna placement that simulated in this study. The placement of the antenna in X+ and Y- axis shows in Fig.1. Fig.2 shows that antennas are placed in X+ with a 45-degree rotation angle in Y axis and Y- axis. Fig.3 shows that antennas are placed in X+ and Y- axis with 45-degree rotation in X axis. Fig. 4 shows that both antenna that placed in X+ and Y- is rotated 45-degree.

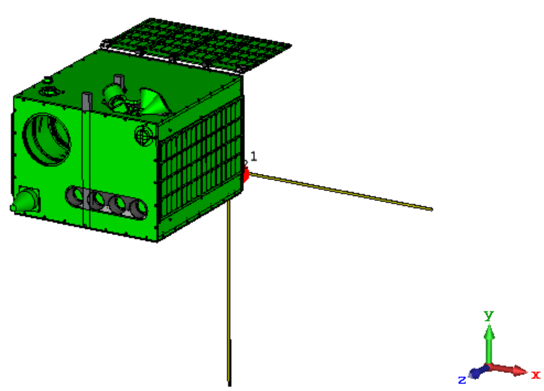
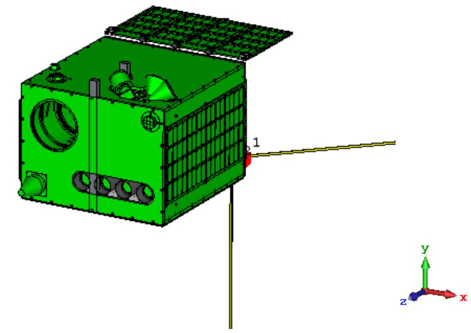
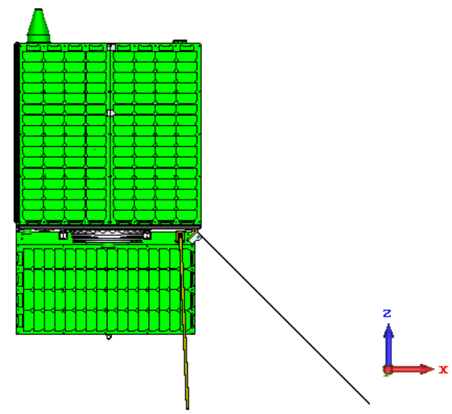


Fig. 1. Antennas in X+ and Y- axis

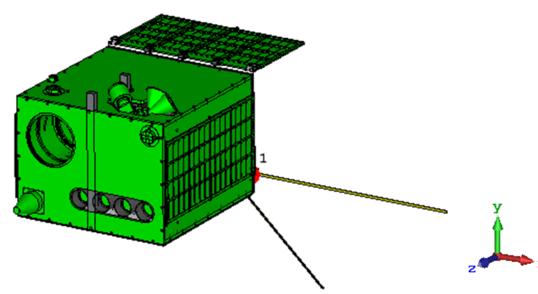


(a)

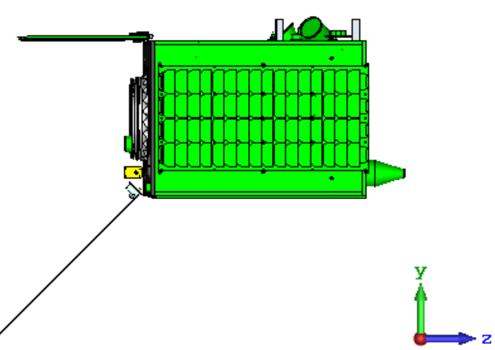


(b)

Fig. 2. Antennas in X+ axis with rotation angle 45^0 in Y axis and Y- axis (a) front view (b) top side view



(a)



(b)

Fig. 3. Antennas in X+ axis and Y- axis with tilting angle 45^0 in X axis (a) front view (b) left side view

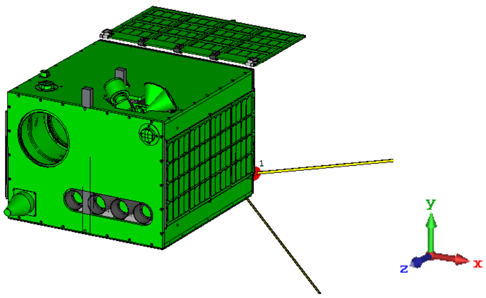


Fig. 4. Antennas in X+ axis with rotation angle 45^0 in Y axis and Y- axis with rotation angle 45^0 in X axis

III. Result and Analysis

A. Radiation Pattern

At this stage, two monopole antennas are simulated, and the satellite is set to nadir mode. The antennas are placed on the satellite at X+ and Y- axis. The radiation pattern emitted by the antennas is close to omnidirectional. The gain at frequency 161.975 MHz is 2.768 dBi for the antenna that placed in X+ axis and 2.763 dBi for antenna that placed in Y- axis. Antennas that placed in X+ and Y- axis with rotation angle 45 degree have gain 2.91 dB in X+ axis and 3.153 dB in Y- axis. The radiation pattern has a maximum direction from antenna 1 and antenna 2 leads to the Z+ axis. Based on the requirement of AIS signal reception the variation of antenna placement above can be used in LAPAN next-generation satellite because the maximum energy of the antenna radiate leads to Z+ that facing the Earth.

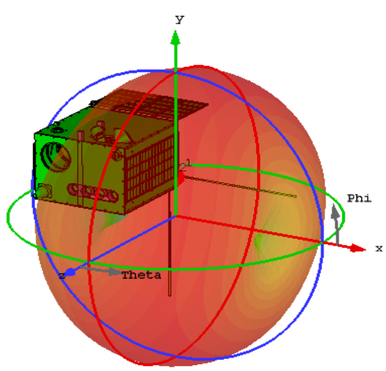


Fig. 5. 3D radiation plot of the antenna in X+ axis

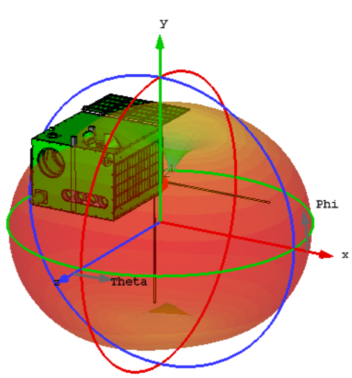


Fig. 6. 3D radiation plot of the antenna in Y- axis

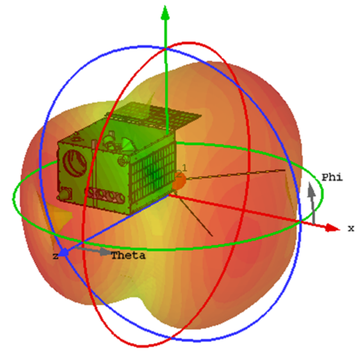


Fig. 7. 3D radiation plot of the antenna in X+ axis with rotation angle 45^0 in Y axis

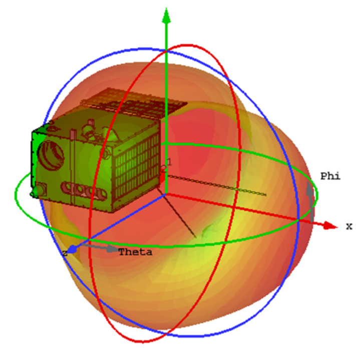


Fig. 8. 3D radiation plot of the antenna in Y- axis with rotation angle 45^0 to X axis

B. Coverage

The field of view of the antenna can be seen in Fig. 9, Fig. 10, Fig.11, and Fig.12. The simulation model for this study is LAPAN-A4 that orbit designed in nearly polar orbit with the altitude about 500 km and inclination 97-degrees SSPO. The green line in the figure is the satellite orbit. The field of view is simulated to show the coverage of the AIS signal reception using LAPAN-A4 satellite in Indonesia region. Fig.9 shows that if the antenna placed in X+ and Y- axis the field of view can be maximum. This placement produces the larger field of view if compared with three other placements. The antenna placement in X+ and Y- axis can be used to receive the full coverage of AIS signal reception. When the antenna is given an angle as in the placement in the Fig.2, Fig.3, and Fig.4, it can be seen, when the antenna is tilted 45 degree there is a reduction in coverage for receiving the AIS signal from ship.

AIS packet collision occurs when two or more arrive at the same time. Next generation LAPAN's microsatellite uses ASRx50 as the AIS payload receiver. ASRx50 have improvement in algorithm to decode the AIS packet data. So, it is possible to detect in high density and medium density area and using the placement of antenna in X+ and Y- axis without tilting angle to get full coverage.

The placement antenna that have tilting angle can be used to reduce the coverage the of AIS signal reception. The reduction of the coverage can reduce the AIS signal that can be heard by the satellite and avoid the data collision.

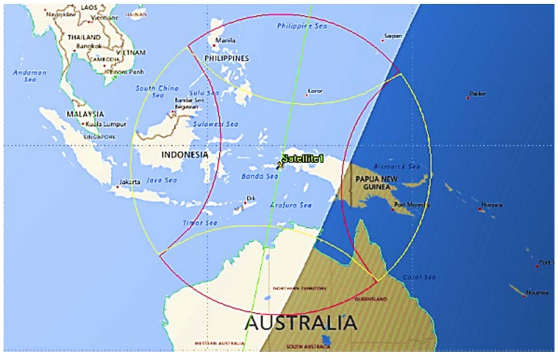


Fig.9. Antenna in X+ and Y- axis

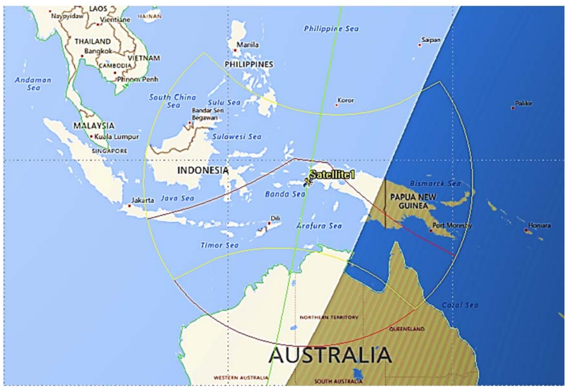


Fig. 10. An antenna in X+ axis with rotation angle 45^0 in Y axis and an antenna in Y- axis

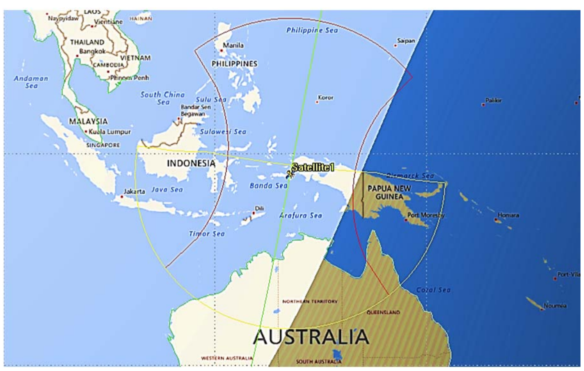


Fig. 11. An antenna in X+ axis and an antenna Y- axis with rotation angle 45^0 in X axis

Fig. 12. An antenna in Y- axis with rotation angle 45^0 in and an antenna in X+ axis with rotation angle 45^0 in Y axis

C. *Link Budget*

The link budget design in this study is to evaluate the probability of AIS signal detection using satellite with the variation of the antenna placement. This calculation is done to know the minimum antenna gain that can be used in the satellite.

TABLE I. LINK BUDGET OTHER VESSELS

Parameter	Value
Satellite range (Km)	500
AIS-1 frequency (MHz)	161.975
AIS-2 frequency (MHz)	162.025
Line code	NRZI
Modulation	GMSK
AIS transmitter power (dBm)	40
Ship antenna gain (dBi)	2
Cable loss (dB)	-3
Free space loss (dB)	-130.605
Atmospheric loss (dB)	-0.3
Antenna misspointing loss (dB)	-1
Noise temperature (K)	850
Data rate (bits/sec)	9600
Bandwidth (MHz)	0.0025
Antenna receiver gain (dBi)	2
Another loss (dB)	4
Link margin (dB)	25.57

Table I shows the link budget calculation for receiving AIS signal from ship to satellite. The link margin of the satellite is 25.57 dB with antenna gain minimum at the receiver is 2 dBi. Based on the result of the link budget calculation the AIS signal is possible to receive the via satellite with minimum antenna gain 2 dBi based on parameter in Table 1. The minimum gain of the antenna used in this study is 2.763 dBi. So, the antenna used in this study can be used in receiving AIS signal over satellite.

IV. CONCLUSION

In this paper, it can be concluded that the placement used in this study can be used to receive the AIS signal by using a satellite. In order to get the maximum coverage, the placement antenna in X+ and Y- axis can be used. Reducing coverage of the satellite to receive AIS signal can be done by tilting the antenna to avoid data collision. The minimum antenna gain at the satellite is 2 dBi and there is enough margin about 25.57 dB. Future studies can observe further the effect of polarization antenna type in the receiving signal.

Acknowledgment

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