Analysis of Automatic Identification System (AIS) data LAPAN-A2 satellite acquired by S-Band receiver at Rancabungur Ground Station

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ABSTRACT

LAPAN A2 is an Indonesian microsatellite built by Indonesia National Institute of Aeronautics and Space (LAPAN). It carries an Automatic Identification System (AIS) receiver as one of its payloads for ship monitoring with capability to record identity and position data of ships around the world along LAPAN-A2 satellite track. AIS data recorded by this satellite is acquired through S-Band frequencies using a S-Band receiver at Rancabungur Ground Station. An analysis is needed to determine the performance of the S-Band receiver. This paper provides quantity analysis of S-Band receiver by analyzing the AIS data that was acquired by the S-Band receiver. From this study, it can be concluded that the difference in the amount of data is not significant because the elevation used is also spread evenly from the smallest to the largest in terms of satellite elevation and acquisition duration.

Keywords: AIS data, LAPAN-A2 satellite, S-Band receiver

1. INTRODUCTION

LAPAN-A2 is the first Indonesian microsatellite which designed and developed in Indonesia launched in September 28th, 2015 in Sriharikotta, India. This satellite orbit in Low Earth Orbit (LEO) with altitude 630 km, and 6-degree orbit inclination (equatorial orbit). LAPAN-A2 main mission is Earth Observation (video/matrix RGB camera surveillance). In addition to that the satellite carry Automatic Identification System (AIS) receiver to monitor maritime traffic, a reaction wheel made by LAPAN (LPN-001) for space proofing, and an amateur radio Automatic Packet Reporting System (APRS), as well as amateur radio voice repeater, for Indonesian Amateur Radio Organization (ORARI) [1].

AIS systems is a technology developed to detect and monitor the activities of cruise ships in certain areas [2]. Indonesia National Institute of Aeronautics and Space (LAPAN) with one of LAPAN-A2 satellite's payload, participate in national marine security monitoring. LAPAN-A2 is a satellite with near equatorial orbit with 6 degree inclination. This satellite would pass Indonesian area 14 times per day [3]. AIS receiver in LAPAN-A2 satellite would record AIS data received from marine vessel along its ground track around the world. AIS data stored in the satellite is sent to the Rancabungur ground station 4 times a day so that the updated time difference is not too wide.

This paper analyzes the characteristics of the AIS data quantity acquired from the LAPAN-A2 satellite by comparing the quantity of data received at the ground station with the satellite elevation to the ground station reaching the maximum during the data acquisition process, whether in the north of the equator (low elevation) or south of the equator (high elevation). This analysis uses data received from 27 June - 27 July 2019. The results of this study could be used as a reference in the AIS data acquisition mission in order to obtain the optimal quantity of AIS data.

2. AUTOMATIC IDENTIFICATION SYSTEM

Automatic Identification System - AIS is a technology used to track ship traffic around the world. AIS is an automated shipboard system operating on marine VHF channel which is around 161,975 MHz and 162,025 Mhz for the purpose of transmit and receive vessel-specific information [8]. Some information obtained from AIS system such as Maritime Mobile Service Identity (MMSI), Position, Course, Call Sign, and AIS base station [6]. AIS devices operate with a time division multiple access TDMA, which makes it possible to send about 2000 reports per-minute [11].

The implementation of AIS is set in several regulations, including International Maritime Organization (IMO), Marine Safety Committee (MSC), International Telecommunication Union (ITU), International Electrotechnical Commission (IEC), International Standards Organization (ISO), International Hydrographic Organization (IHO), Radio Technical Committee for Maritime Services (RTCM), International Association of Marine Aids to Navigation and Lighthouse

Authorities (IALA), and National Maritime Electronics Association (NMEA) [9]. According to the International Maritime Organization (IMO) requirements, shipboard AIS equipment is mandatory installed on most vessels. This equipment including an AIS Transponder which could continuously transmit vessel information through the VHF channel. That information will be transmitted to another AIS Transponder or Receiver installed on other vessels or base stations [10].

LAPAN-A2 satellite carries an AIS Receiver which allows it to receive some vessel information at sea level beneath its orbit. A Satellite-based AIS Receivers could receive more vessel information because it has wider coverage than a vessel based AIS Receiver. AIS data received by LAPAN-A2 AIS Receiver is stored on satellite memory before downloaded to LAPAN Rancabungur Ground Station via S-Band frequency using S-Band receiver. The download process explained by figure 1 :

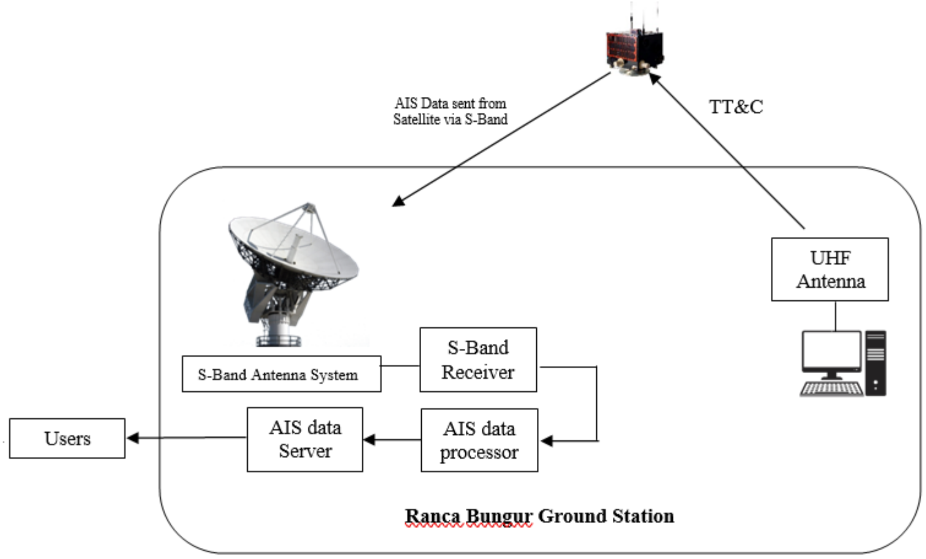

Figure1. LAPAN-A2 Satellite AIS data process

LAPAN Operator sends Telemetry, Tracking, and Command (TT&C) to download AIS data from the satellite via UHF channel. Then, LAPAN-A2 satellite sends AIS data using S-Band transmitter. AIS data acquired at Rancabungur Ground Station using S-Band Antenna system combined with S-Band receiver devices. Then, AIS data processed using AIS data processor to produce vessel information that can be used for further purposes by LAPAN's stakeholders [7].

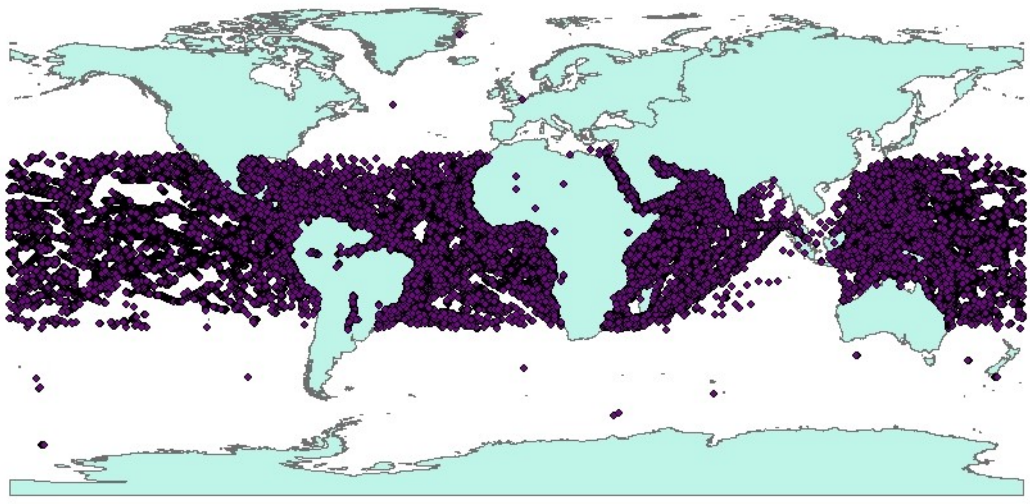

Figure 2. Example of LAPAN-A2 AIS Data plotted on world map (July 1st - 5th, 2019)

3. MATERIAL AND METHOD

In daily satellite mission operation activities, AIS data stored in the satellite is sent to the Rancabungur ground station using the S-Band frequency, specifically 2220 MHz. The data acquisition target is 4 times a day so that the updated time difference is not too wide.

LAPAN-A2 is a satellite with an equatorial orbit at an inclination of 6 degrees, so that from the viewpoint of the Rancabungur ground station has different maximum elevation each time it passes through the earth station coverage. To meet the AIS data acquisition target, the acquisition process carried out when satellites have different elevations, high and low elevations. Noteworthy is that the AIS data acquisition schedule must be adjusted to other missions carried out by the LAPAN-A2 satellite, considering that this satellite has several other payloads besides the AIS sensor.

This paper analyzes the characteristics of the AIS data quantity acquired from the LAPAN-A2 satellite by comparing the quantity of data received at the ground station with the satellite elevation to the ground station reaching the maximum during the data acquisition process, whether in the north of the equator (low elevation) or south of the equator (high elevation). This analysis uses data received from 27 June - 27 July 2019.

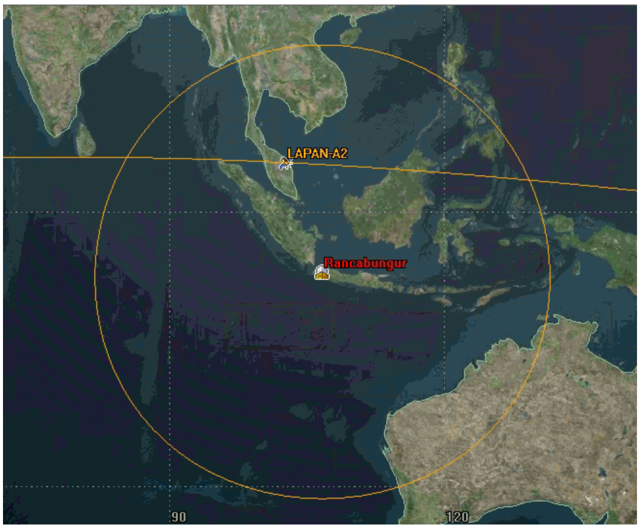

Figure 3. Rancabungur ground station coverage and LAPAN-A2 satellite ground track

3.1 AIS Data Acquisition Planing

One of the procedure before conducting daily satellite operations is updating Two Line Elements (TLE) in the tracking tools. Two-Line Element Sets portrays satellite's motion in arranged format contains a reference epoch, satellite information such as launch date and year, and drag coefficient. TLE catalog is released publicly through NASA, www.space-track.org website, and http://www.celestrak.com/ and updated daily. The exact process of updating the TLEs in unknown, but in the essence, Joint Space Operation Center (JSPOC) operated by the US Air Force Space Command (AFSPC) performed the observations several times a day [4]. From the previous study it was known that that the more outdated the TLE is used, the greater the satellite position error occurred. With the significance of this error, the need for satellite prediction with high precision cannot be met. Hence, satellite's mission could not perform in the best way [4]. The TLE in the System Tool Kit (STK) software and the S-Band antenna system needs to be updated daily as a reference to predicting the movement of the satellite towards the ground station.

Satellite Operators plan data acquisition schedules using the STK (System Tool Kit) software before data acquisition, to find out the detailed time, when satellites enter earth station coverage, and the time details when they reach maximum elevation. The maximum elevation is a reference when starting the acquisition of AIS data.

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Facility-Rancabungur-To-Satellite-LAPAN-A2: Inview Azimuth, Elevation, & Range

Rancabungur-To-LAPAN-A2 - AER reported in the object's default AER frame

	Time (UTCG)	Azimuth (deg)	Elevation (deg)	Range (km)
	30 Jun 2019 01:00:04.714	294.938	0.000	2915.002206
	30 Jun 2019 01:01:04.000	299.570	3.074	2594.281743
	30 Jun 2019 01:02:04.000	305.574	6.433	2289.242433
	30 Jun 2019 01:03:04.000	313.419	10.006	2014.082688
	30 Jun 2019 01:04:04.000	323.726	13.589	1783.856371
	30 Jun 2019 01:05:04.000	336.946	16.648	1618.798421
	30 Jun 2019 01:06:04.000	352.671	18.301	1540.626626
	30 Jun 2019 01:07:04.000	9.084	17.850	1562.684998
	30 Jun 2019 01:08:04.000	23.870	15.512	1680.925390
	30 Jun 2019 01:09:04.000	35.817	12.165	1876.862794
	30 Jun 2019 01:10:04.000	44.990	8.567	2128.538119
	30 Jun 2019 01:11:04.000	51.972	5.091	2417.840836
	30 Jun 2019 01:12:04.000	57.356	1.852	2731.961460
	30 Jun 2019 01:12:40.527	60.051	0.000	2931.556627
Global Statistics				
Min Elevation	30 Jun 2019 01:00:04.714	294.938	0.000	2915.002206
Max Elevation	30 Jun 2019 01:06:21.631	357.533	18.397	1536.526484
Mean Elevation			9.221	
Min Range	30 Jun 2019 01:06:21.025	357.366	18.397	1536.520469
Max Range	30 Jun 2019 01:12:40.527	60.051	0.000	2931.556894
Mean Range				2149.018622

Figure 4. azimuth-elevation-range (AER) report of Rancabungur ground station towards LAPAN-A2 satellite

3.2 AIS Data Acquitition Method

Data acquisition time is chosen when the satellite reaches maximum elevation because the moment is the closest distance in a satellite pass so it is expected that the data transmission will run more optimally. The following graph shows the movement of the satellite distance in one pass. It can be seen when the elevation reaches a maximum value, the distance between the satellite and the ground station reaches the lowest point.

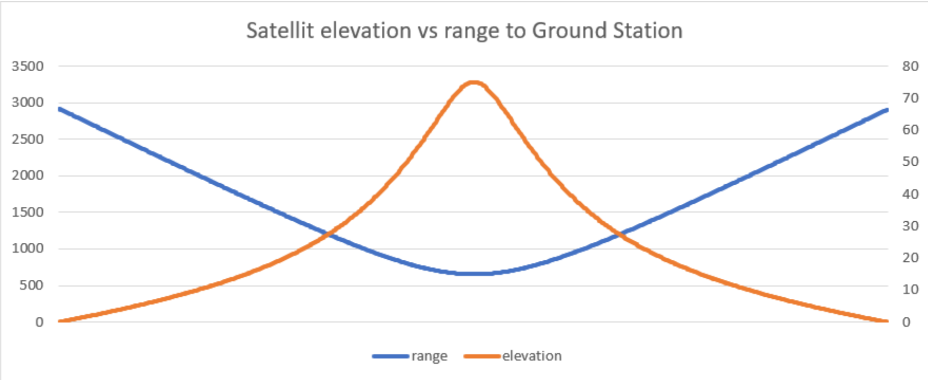

Figure 5. Comparison chart of elevation and distance of LAPAN-A2 satellite to Rancabungur ground station

The data example displayed in this figure is the LAPAN-A2 satellite movement data towards Rancabungur ground station on 29 Jun 2019 12:48:18 - 13:02:30 every second. The LAPAN-A2 satellite reaches its maximum value on 29 June 2019 12:55:25 at azimuth 3.344°, elevation 75.135° and distance of 653,536225 km.

Based on the simulation of the STK software, the maximum elevation of the satellite is divided into two, namely when the satellite is to the north of the equator, and to the south of the equator.

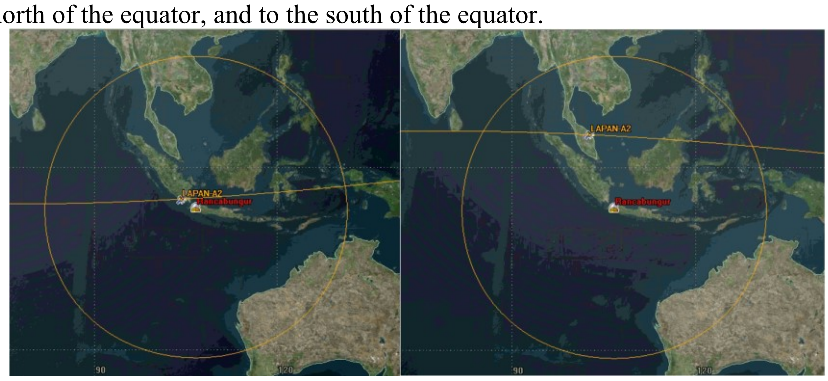

Figure 6. LAPAN-A2 satelit groundtrack on high elevation/ south of equator (left) and low elevation/ north of equator (right)

After determining the start of data acquisition mission, the next step is to determine the duration of the data acquisition. This determination is adjusted to the needs of data completeness, how many hours the distance between the current mission with the previous data acquisition mission, and whether the previous data is complete or not. Based on the AIS data acquisition database, 2 minutes duration could produce AIS data for the previous 10 hours. If more data is needed, the duration can be increased. During the 4 times AIS data acquisition process, the target data derived is not continuous, but overlaps with each other with consideration that if there is data missing in the previous acquisition process it can be patched with the data currently acquired.

4. RESULTS AND ANALYSIS

Every day from 27 June to 27 July 2019, the AIS data acquisition mission from the LAPAN-A2 satellite is carried out. The data acquisition process includes the process of downloading, decoding, storing databases, and further use by LAPAN's stakeholders. The analysis in this paper is done by counting the number of rows of AIS data that have been decoded during each data acquisition. The number of rows from each AIS data is compared with the maximum elevation according to the state of each data acquisition. The following is an example of AIS data acquisition resume :

Table 1. AIS data acquisition resume.

File	Max elevation time	rows	elevation	epoch diff.	duration
A2_AIS_2019_06_27_01_41_03_Serial.txt	2019/6/27 01:41:03	353528	20.703	01	00:04:04
A2_AIS_2019_06_27_06_50_31_Serial.txt	2019/6/27 06:50:31	130262	20.855	01	00:02:06
A2_AIS_2019_06_27_08_40_02_Serial.txt	2019/6/27 08:40:02	185598	27.478	02	00:02:00
A2_AIS_2019_06_27_12_08_54_Serial.txt	2019/6/27 12:08:54	201851	56.081	02	00:02:01
A2_AIS_2019_06_28_00_20_59_Serial.txt	2019/6/28 00:21:02	408454	23.248	00	00:04:30
A2_AIS_2019_06_28_05_34_51_Serial.txt	2019/6/28 05:34:52	118543	19.021	01	00:01:10
A2_AIS_2019_06_28_09_03_52_Serial.txt	2019/6/28 09:03:55	192915	32.825	01	00:02:00
A2_AIS_2019_06_28_12_32_00_Serial.txt	2019/6/28 12:32:04	197629	66.135	01	00:02:00
A2_AIS_2019_06_29_00_43_45_Serial.txt	2019/6/29 00:43:45	378619	20.418	00	00:04:45

The parameters used in this data analysis include the number of AIS data rows, elevation, and duration of data acquisition. The following is the result of comparing AIS data quantity received when the satellite passes through ground station with elevation to the south of the equator.

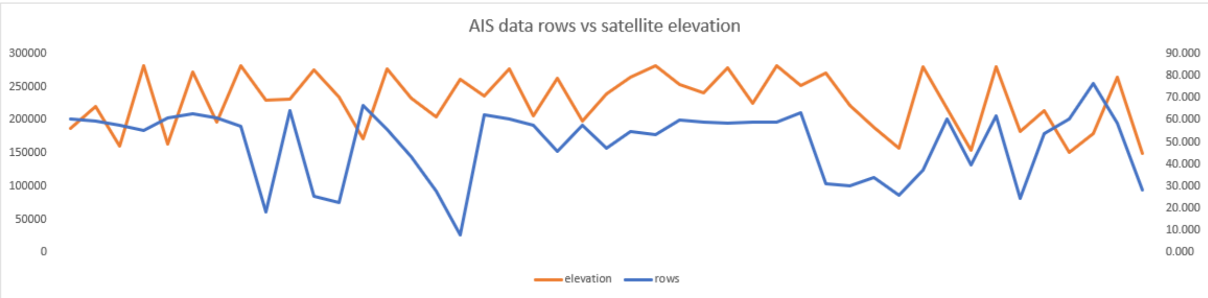

Figure 7. AIS data quantity received with high elevations and ±2 minutes durations. AIS data quantity average 165010 rows from 45 data

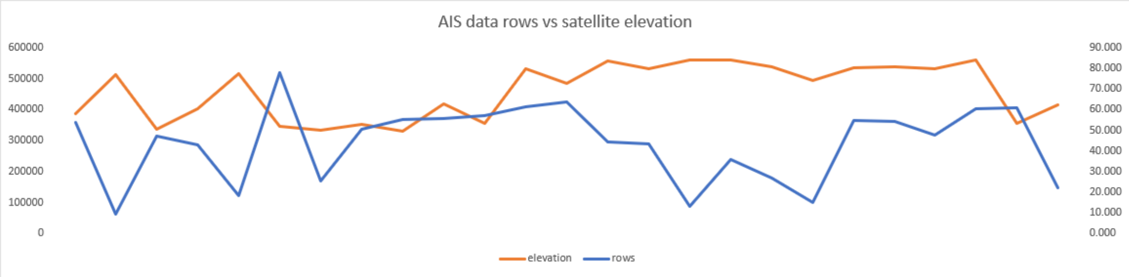

Figure 8. AIS data quantity received with high elevations and ±4 minutes durations. AIS data quantity average 292824 rows from 25 data

The following is the result of comparing AIS data quantity received when the satellite passes through ground station with elevation to the north of the equator.

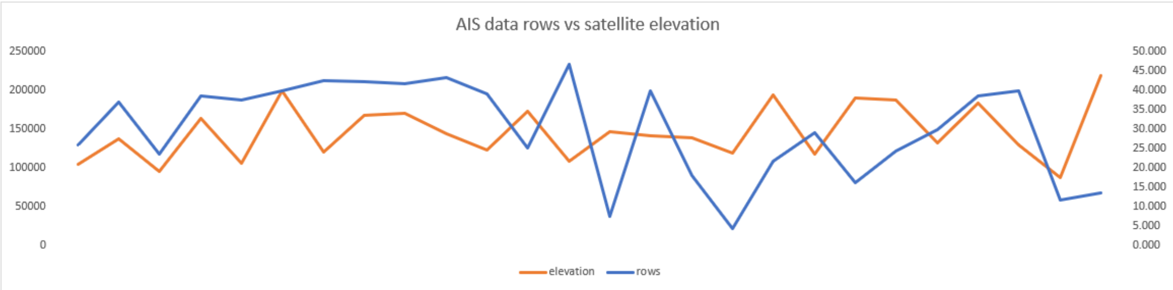

Figure 9. AIS data quantity received with low elevations and ±2 minutes durations. AIS data quantity average 149738 rows from 26 data

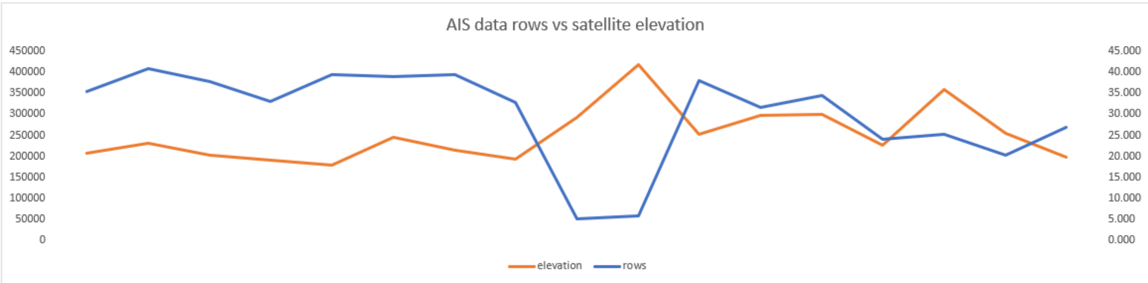

Figure 10. AIS data quantity received with low elevations and ±4 minutes durations. AIS data quantity average 299774 rows from 17 data

The following is the result of comparing AIS data quantity received with all elevations.

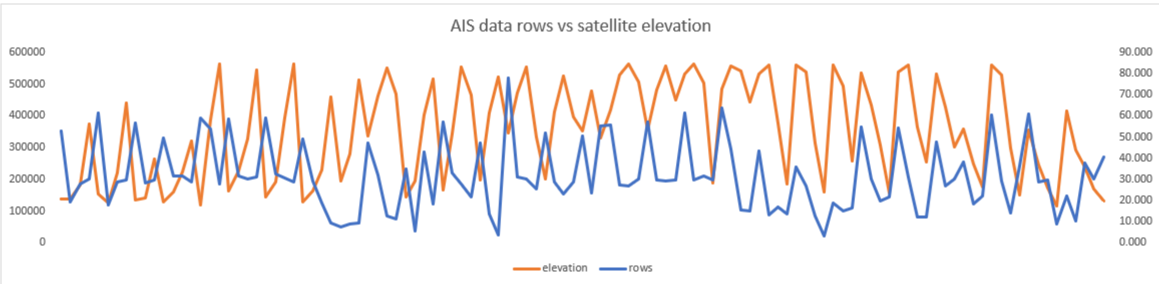

Figure 11. AIS data quantity received with all elevations and all durations. AIS data quantity average 210048 rows from 113 data

Table 2. AIS data analysis resume.

elevation	duration	average	data count
high (> 44 degree)	2 minutes	165010 rows	45 data
high (> 44 degree)	4 minutes	292824 rows	25 data
low (< 44 degree)	2 minutes	149738 rows	26 data
low (< 44 degree)	4 minutes	299774 rows	17 data

5. CONCLUSION

AIS data that is acquired with different elevation and duration gives a different average amount of data. From the data analysis, it can be concluded that the difference in the amount of data is not significant because the elevation used is also spread evenly from the smallest to the largest in terms of satellite elevation and acquisition duration.

The analysis conducted in this study only includes quantity analysis. For the next study, data quality analysis can be carried out so that more in-depth characteristics can be seen related to AIS data acquisition with different elevation and duration conditions.

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