PERFORMANCE ANALYSIS OF SISPELSAT MSK-DGNSS RADIO SIGNAL IN PENINSULAR MALAYSIA

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KEY WORDS: Radio Beacon, MSK, SISPELSAT, DGPS, GPS, GNSS

ABSTRACT:

The use of Global Navigation Satellite System (GNSS) has become essential in providing location based information and navigation. Due to low accuracy of navigation solution, differential technique such as radio-beacon DGNSS has been used widely to augment the user single positioning using GPS. The *Sistem Pelayaran Satelit* (SISPELSAT) is a national DGNSS radio-beacon system in Malaysia consists of four broadcasting and two monitoring stations operated and managed by Marine Department of Malaysia. It provides a range of frequency from 283.5 to 325 kHz Minimum Shift Keying (MSK) radio-beacon DGNSS correction service within the shore of Peninsular Malaysia. In this study, the performance of SISPELSAT radio signal was assessed on-board of the Malaysian Vessel (MV) Pedoman and MV Pendamar. The study area covers 20km shore distance extending from shoreline of Peninsular Malaysia with continuous tracking from SISPELSAT radio beacon signal. The DGPS observation data as well as the coverage of the signal strength, signal-to-noise ratio, accuracy and DGPS status were recorded for data processing and further analysis of SISPELSAT radio signal performance.

1. INTRODUCTION

Global Positioning System (GPS) is a space- based positioning, navigation and time distribution system designed for world- wide positioning and navigation applications with positional accuracy of 10 to 100 meters. The accuracy of GPS solution can be improved through a Differential GPS (DGPS) technique by reducing the error in GPS-derived satellite orbital error which consists of position and satellite clock error, tropospheric and ionospheric error. These errors, known as Pseudorange Correction (PRC), are determined by DGPS radio beacon station at a precisely known coordinate. It will then transmit in real time as corrections to the user measurement thus improving their position accuracy as shown in figure 1. DGPS application is widely used in maritime activities to support critical positioning and navigation applications. The DGPS radio beacon provide shore-to-ship DGPS correction services by transmitting Medium Frequency (MF) marine radio frequency band to the users.

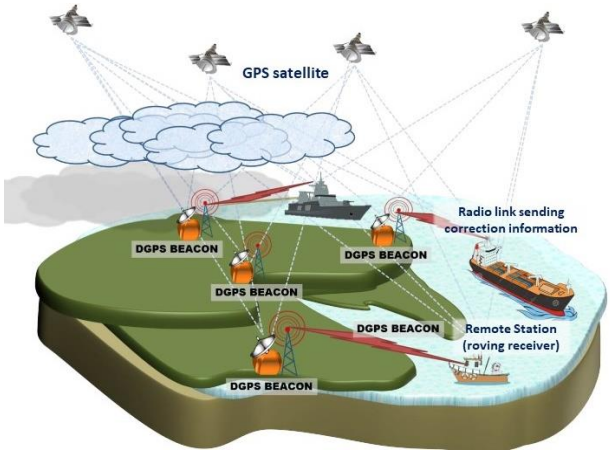

Figure 1. DGPS application concept

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) have come out recommendation guidelines which distinguishing the need to ensure that DGPS services are operated in accordance with certain minimum standards that take into account relevant to International Telecommunication Union Radiocommunication Sector (ITU-R) Recommendations and International Maritime Organization (IMO) Resolutions (IALA.,2015; Rozaimi and Mohd.,2005). Currently there is hundreds of countries provide DGPS services and IALA has listed all DGPS station operated around the world as shown in figure 2 including Malaysia known as SISPELSAT.

Figure 2. DGPS station coverage
(Source: http://www.gnsspro.com/referencestations.php)

2. SISPELSAT

Sistem Pelayaran Satelit (SISPELSAT) is national DGNSS / DGPS radio-beacon system in Malaysia develop by Marine Department of Malaysia since 2003 and latest upgrade in early 2009 to fulfill maritime navigation requirements over

Malaysian's coastal areas and inland waterways without any charge (Subari et al., 2004; Ooi et al., 2013; Yusup et al., 2014). The system provides range of MF of 283.5 to 325 khz radio-beacon Minimum Shift-Keying (MSK) type-DGPS correction service in Radio Technical Commission for Maritime Services (RTCM) data format over the peninsular Malaysia in accordance to IALA, IMO and International Hydrographic Organization (IHO) standard (AMSA., 2016; Magee et al., 2008; IALA., 2015). SISPELSAT consists of four (4) broadcasting stations, i) Bandar Hilir Melaka , ii) Bagan Datuk Perak , iii) Kuala Besar Kelantan , iv) Kuantan Pahang and two (2) monitoring stations, i) Jabatan Laut Port Klang Selangor, ii) Jabatan Laut Kuala Terengganu Terengganu as shown and described in figure 3.

Figure 3. SISPELSAT Broadcasting and Monitoring Stations

Currently all broadcasting and monitoring station are functioned normally except for broadcasting station Kuantan Pahang due to ongoing maintenance work causing absence for radio coverage on the south east of peninsular Malaysia.

For safety of navigation, DGNSS / DGPS services such as SISPELSAT, its needs to meet four (4) reliability criteria which are: i) integrity, that is the ability of the service to provide timely warning to users when it should not be used for navigation or other purposes; ii) accuracy, that is the degree of conformance between the position provided by the service and the true position at a given time; iii) availability, that is the ability of the service be used for navigation when and wherever it is needed by the users, and iv) continuity, that is the probability that the service will perform its function within defined performance limits for a period of time given (Carroll, 2003; Terry and Chris.,2002; Ochieng and Sauer.,2002). Each broadcasting stations operate 24 hours days consist of the following main components as shown in figure 4:

i. High Voltage Power with Uninterrupted Power Supply (UPS) module
ii. GPS reference and integrity receiver and computer
iii. Radio Transmitter and antenna
iv. Supporting component CCTV and etc

Therefore, periodic maintenance should be carried out at each station to ensure that every component are well maintain and operated optimally.

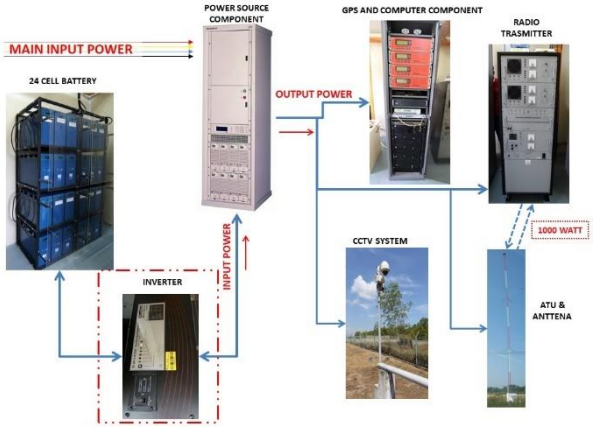

Figure 4. SISPELSAT broadcasting station main component

The study aims to determine the performance of SISPELSAT services onshore Peninsular Malaysia. The intensive analysis on Signal Strength, Signal to Noise Ratio, DGPS status and accuracy was conducted towards the SISPELSAT broadcasting station. Subsequently, further analysis was carrier out to understand the behaviour of the signal propagation by comparing simulation signal of SISPELSAT station with result obtain.

3. THE ASSESSMENT

3.1 Study Area

The study was conducted approximately 20km of peninsular Malaysia coastal water area at the Straits of Melaka and South China Sea on-board of the Malaysian Vessel (MV) Pedoman and MV Pendamar owned by the Marine Department of Malaysia. The study area is divided into 3 sectors; Sector A and Sector B covering the area of the Straits of Malacca. Meanwhile Sector C covering South China Sea area of Peninsular Malaysia as shown in figure 5. Only 3 operating broadcasting stations is being assess in this study; i) Bandar Hilir Melaka in Sector A, ii) Bagan Datuk Perak in Sector B and iii) Kuala Besar Kelantan in Sector C.

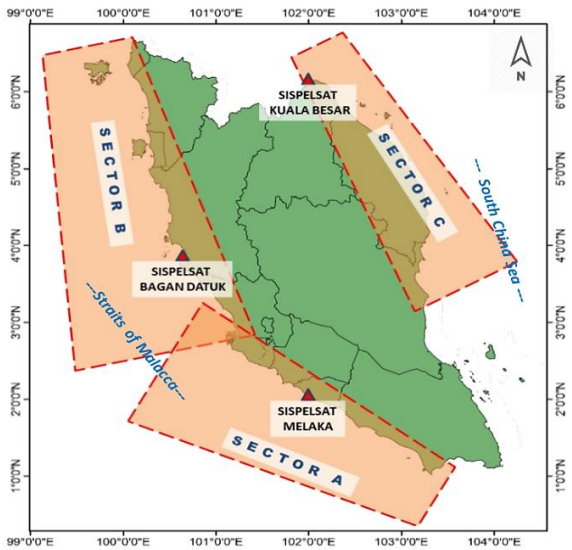

Figure 5. The study area sector

3.2 Data Collection and Equipment Setup

Data collection was conducted on 28th -29th April 2016 for sector A on board vessel MV Pedoman from Jeti Jabatan Laut Perlabuhan Tanjung Pelepas Johor to Jeti Jabatan Laut Institut Latihan Perlabuhan, Port Klang Selangor. For Sector B, data collection was conducted on 18th – 19th Mac 2017 from Jeti Jabatan Laut Institut Latihan Perlabuhan, Port Klang Selangor to Jeti Jabatan Laut Kuah Langkawi Kedah on board vessel MV Pedoman. For Sector C, data collection was conducted on 7th -8th October 2016 on board vessel MV Pendamar from Kemaman Supply base area to Tok Bali Supply base area.

Data was collected at one (1) second interval in form of National Marine Electronics Association (NMEA) and receiver raw data format. Data collection (DGPS observation data) as well as the coverage of the Signal Strength (SS), signal-to-noise ratio (SNR), accuracy and DGPS status were recorded for data processing and further analysis. All the data were recorded into Master Computer from each receiver by using open source software RTKlib. Figure 6 show the operator monitor the status of data collection into master computer and equipment on board setup.

Figure 6. Operator monitor data recorded into master computer

Three (3) unit of DGPS type receiver, Hemisphere R330 were used in this assessment and label into RCVR A, RCVR B and RCVR C. RCVR A and RCVR B were manually set to lock frequency of SISPELSAT broadcasting station signal base on sector area cover. Both antenna RCVR A and RCVR B were place close to each other on the upper deck of the vessel with fix distance of 1 meter for accuracy checking. While RCVR C were set to lock automatic DGPS signal for backup, heading and check-up purpose and the antenna were place between the antenna of RCVR A and RCVR B as shown in figure 7.

Figure 7. Antenna (Ant.) setup on upper deck of the vessel

3.3 Methodology

Mathlab programming software was used to extract and analyzed NMEA data since huge amount of data has been recorded for this assessment. The data has been categorized into 4 elements; ***1) Signal Strength (SS)***, refer to strength of SISPELSAT broadcasting radio signal that has been transmitted and capture by the antenna onboard of ship ***2) signal-to-noise ratio (SNR)***, refer to signal power over noise signal power which indicate the level of background noise in signal transmission ***3) DGPS Status,*** indicate the receiver positioning status in differential mode (DGPS FIX) or in autonomous mode (Auto) ***4) DGPS Accuracy,*** refer to the different in distance between Ant A and Ant B in fix mode that has been place fix 1 meter distance between them (refer to figure 7). All 4 elements then visualized into a map by using ArcGIS software as shown in figure 9, figure 10 and figure 11 base on sector cover. Figure 8 show the methodology used in this assessment. In addition to the observation results, the simulation of SISPELSAT signal coverage was also carried out using the Ground Wave Prediction System (GWPS) scientific software. The simulation is a guide to see the theoretical features on the 1kW power setting in the transmitter for all broadcasting station involve.

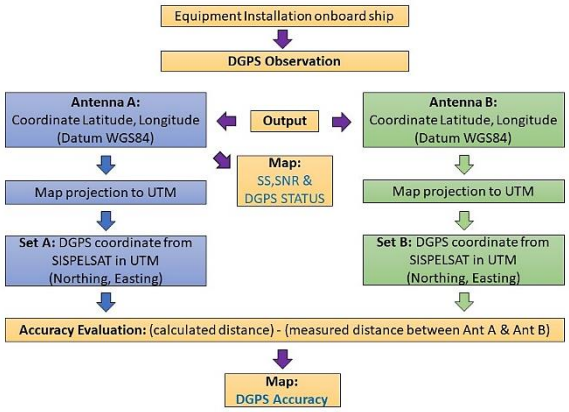

Figure 8. Methodology chart for performance assessment of SISPELSAT station

4. THE RESULT

4.1 Sector A – SISPELSAT Melaka (Refer Figure 9)

Map in 9.A shows 80% of position DGPS fixed along the Melaka strait. The map in 9.B indicate that 97.84% of DGPS accuracy are <1m. Also, map 9.C and 9.D shows that the SS and SNR are affected by the distance from the radio beacon location. These analyses have revealed that DGPS, accuracy, SS and SNR are high close to Melaka beacon. However, the DGPS performance decreases as the vessel moves away from the beacon station.

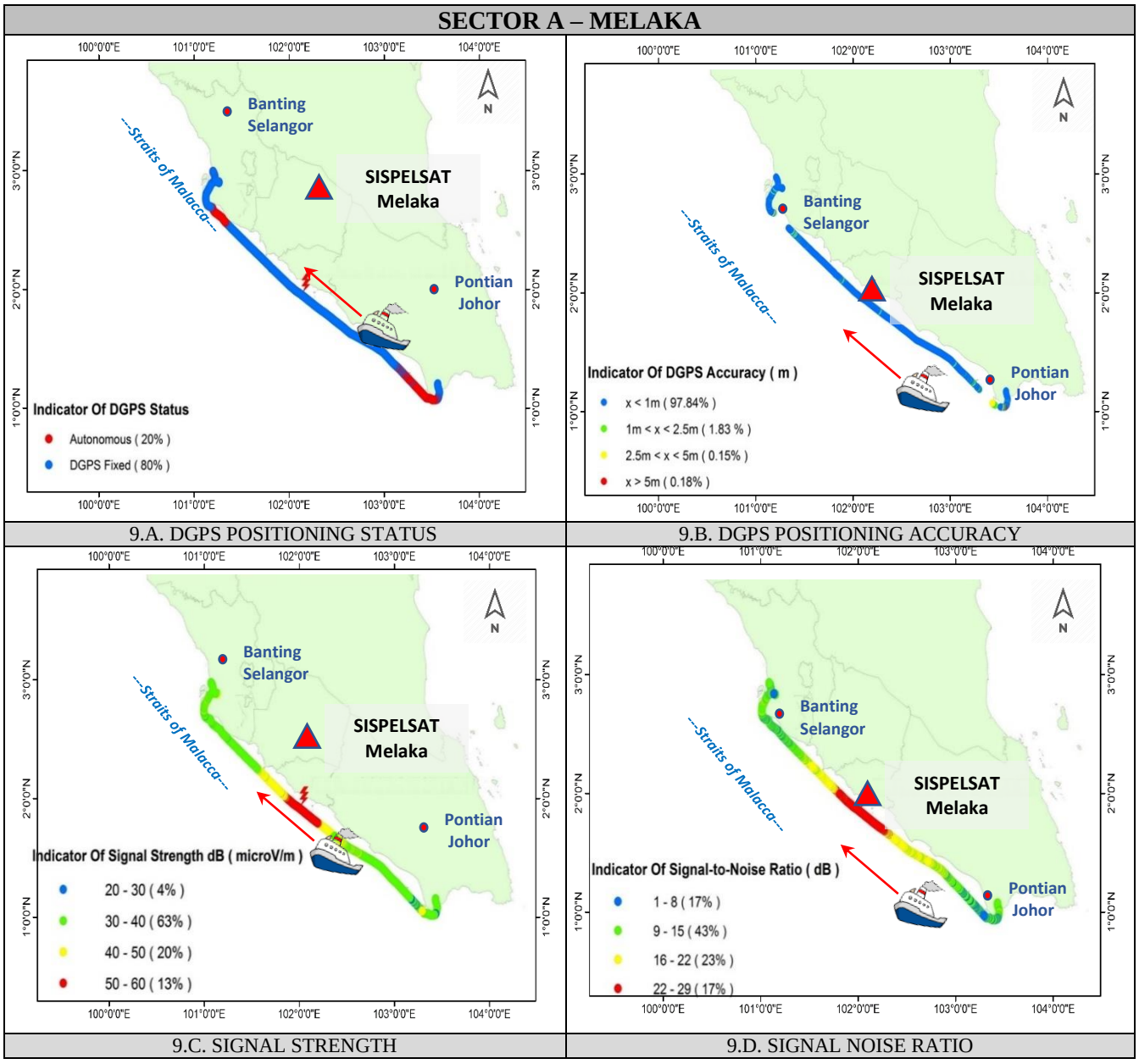

Figure 9. Result map of sector A – SISPELSAT Melaka

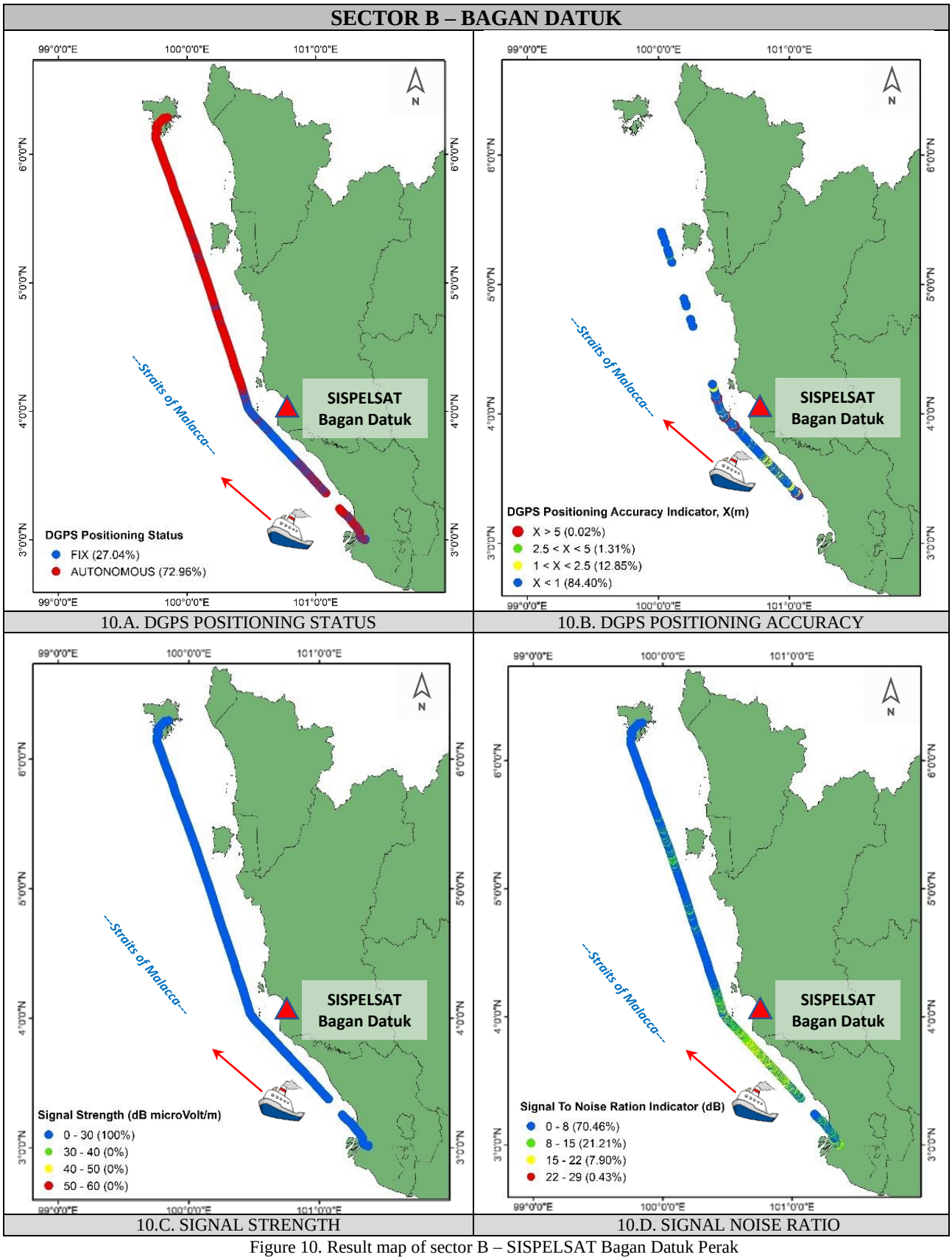

Figure 10. Result map of sector B – SISPELSAT Bagan Datuk Perak

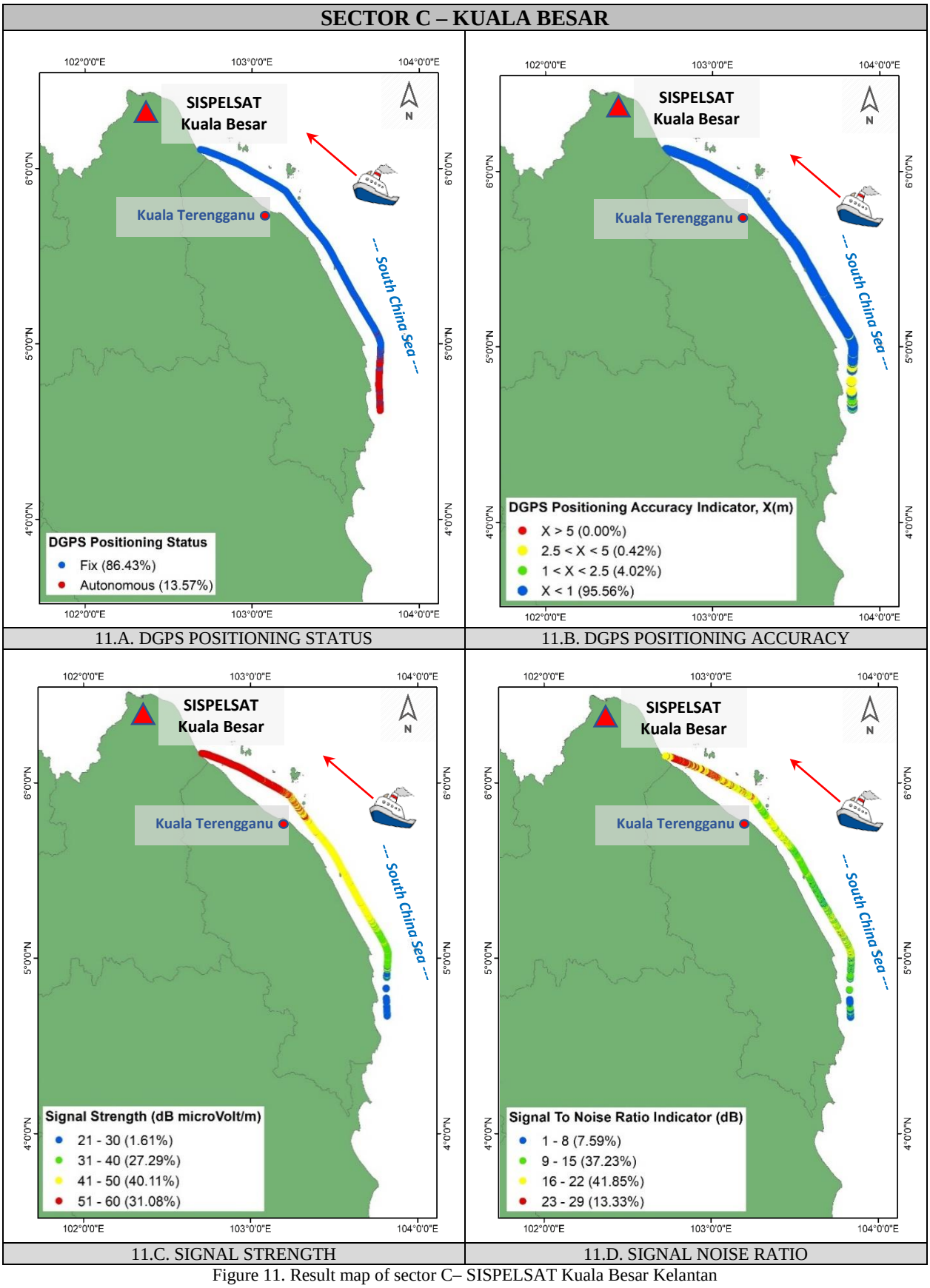

Figure 11. Result map of sector C– SISPELSAT Kuala Besar Kelantan

4.2 Sector B – SISPELSAT Bagan Datuk Perak (Refer Figure 10)

According to map 10.A, 27% of data collections in DGPS fix positioning with 84% less than 1-meter accuracy. It also highlights that SS remain 100% constant between 0-30 dB follow by 70% for SNR between 0-8 dB from map 10.B and 10.C. From the result, its shows that the performance of SISPELSAT Bagan Datuk is getting poorer even though the location of station is facing the Melaka strait. On top of that, further investigation found that the radio transmitter is almost 10 years old and considered to replace with a new transmitter.

4.3 Sector C – SISPELSAT Kuala Besar Kelantan (Refer Figure 11)

Map 11.A shows 86% of data in Fix DGPS position correspondingly with 96% accuracy less than 1-meter in map 11.B. This also influenced by higher SS (map 11.C) and SNR (map 11.D) values when nearer to the broadcasting station. The performance of SISPELSAT Kuala Besar were satisfying since it still can cover around 150km± and above on coastal area.

5. ANALYSIS

5.1 Sector A – SISPELSAT Melaka (Refer Figure 9)

Case 1. It was found that at the area of Pontian Johor, DGPS status is in Autonomous mode while Signal Strength and SNR recorded low. These is due to massive blockage of signal at the area, which are Pulau Kukup and Pulau Pisang. Furthermore, the distance to the SISPELSAT broadcasting station Melaka were far, around 180km which is the signal strength and SNR is weak.

Case 2. A problem found in Banting Selangor area whereby the DGPS status suddenly lose at the area. The Signal Strength and SNR also recorded low, showing high noise in data transmission and low signal from broadcasting station than it should be. Further investigation at the area observed no massive obstruction which can cause the signal to be affected. Besides that, there also no any radio transmitter at the area except aviation radar at the Jugra Hill. Supplementary study needs to be done at the area to investigate for any signal that could interfere with SISPELSAT broadcasting signal.

Based on simulation as shown in Figure 12, it shows that Case 1 having identical simulation result whereby low Signal Strength at Pontian Area were observed. While Case 2 shows different conditions with simulations which indicate that the signal should be in good condition. Therefore, further study suggested to be conducted at the area of Banting Selangor to determined the real problem.

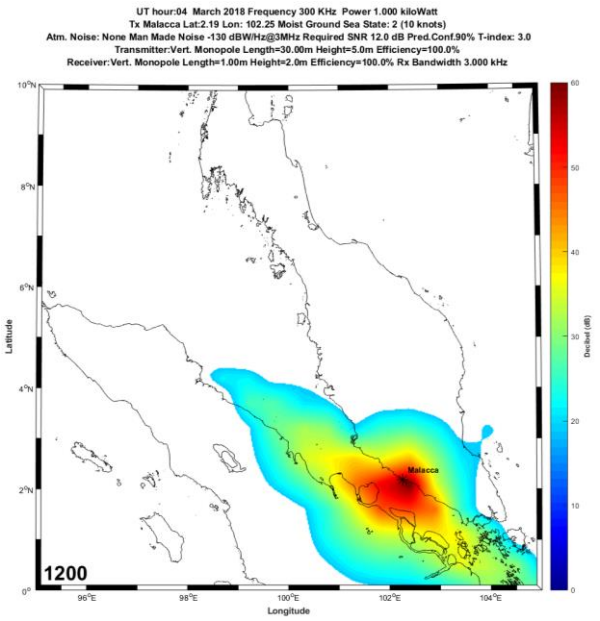

Figure 12. Simulation of SISPELSAT Melaka signal coverage

Overall, SISPELSAT Melaka showing good performance as a broadcasting station covering the southern area of the Straits of Malacca although the age of Station is almost 10 years. This is due to well-maintained and periodically maintenance work by Marine Department. High Signal Strength and SNR values have been recorded around Melaka waters showing that Signal Strength and SNR are influenced by the distance from the broadcasting station. On top of that, based on simulation result, SISPELSAT Melaka should give more better performance in term of signal coverage if the radio transmitter can boost into 100 percent of power.

5.2 Sector B – SISPELSAT Bagan Datuk Perak (Refer Figure 10)

Case 1. It was observed that when the ship leading north and toward south, the positioning status recorded Autonomous while SNR getting weaker and signal strength keep constant low from beginning of data observation. These is due to low power of transmitter radio at Broadcasting Station. Besides, location of broadcasting station at the bay may exposed the signal to getting worse because of obstruction at coast toward south, Pulau Pangkor and Pulau Pinang towards north. When vessel approaches nearer the station, Signal Strength and SNR recorded getting better but still low.

Based on simulation as shown in Figure 13, signal coverage of SISPELSAT Bagan Datuk supposed to be wider and cover till northern of Langkawi. It shows that the performance of SISPELSAT Bagan Datuk is unsatisfactory since its coverage is not widespread in the Straits of Malacca.

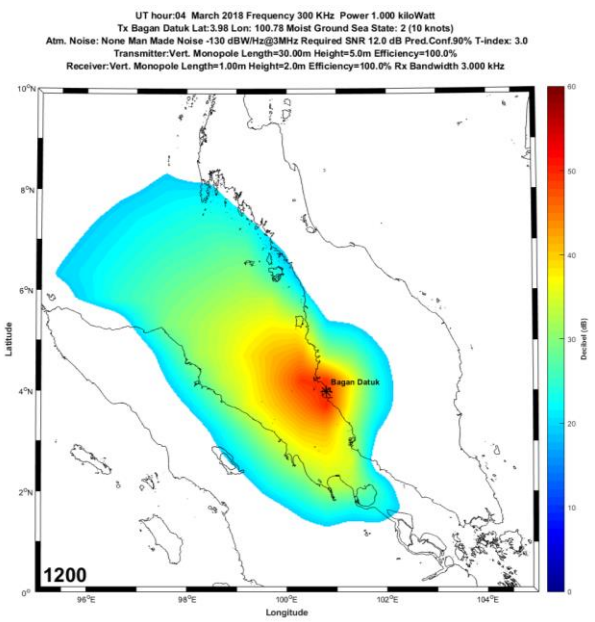

Figure 13. Simulation of SISPELSAT Bagan Datuk signal coverage

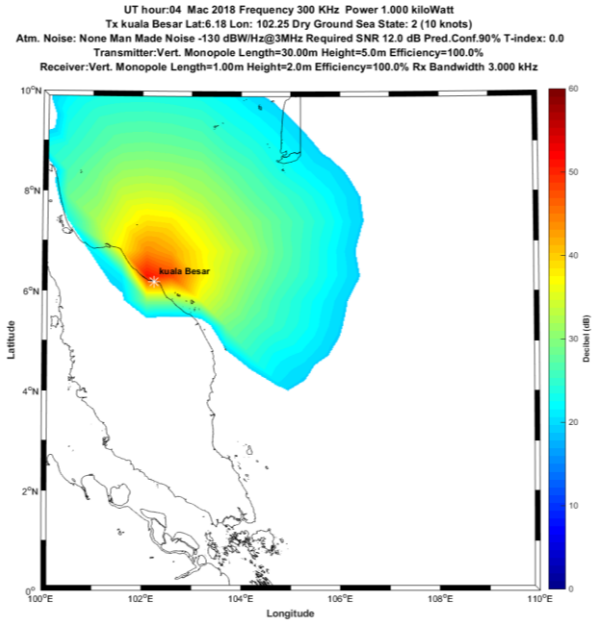

Figure 14. Simulation of SISPELSAT Bagan Datuk signal coverage

Overall, SISPELSAT Bagan Datuk Perak showing deteriorating performance as broadcasting station due to low power of radio transmitter. The radio transmitter is suggested to be replace to new one since SISPELSAT Bagan Datuk play an important role in navigation for marine user especially in port harbour.

5.3 Sector C – SISPELSAT Kuala Besar Kelantan (Refer Figure 11)

Case 1. It was observed that at the area of starting of observation at Kemaman Terengganu, Autonomous DGPS positioning status recorded and also low in signal strength and SNR. This is due to the distance from starting point to broadcasting station around 200km. But when heading to the north, constant FIX recorded with rising up in Signal Strength and SNR due to closer distance towards Broadcasting station. SISPELSAT Kuala Besar also expose to massive blockage of signal, which is Pulau Perhentian Besar and Pulau Redang, as experienced in the area of Kuala Terengganu, Terengganu where its recorded medium Signal Strengh and SNR.

Based on simulation result on Figure 14, there is no signal coverage at Kemaman area and its identical with Case 1. Simulation also show that the obstacle from Pulau Perhentian Besar and Pulau Redang make signal towards south getting weaker.

Overall, SISPELSAT Kuala Besar also showing good performance as Melaka. High power radio transmitter is a contributing factor of large signal coverage cover Northern area South China Sea of Peninsular Malaysia and can be wider if the radio transmitter can boost to 100 percent power.

6. CONCLUSION

SISPELSAT provide a lot of benefit to the user in supporting critical positioning and navigation applications such as hydrography survey and maritime activities.

All stations play a very important role especially in busiest Malaysia's main ports such as Port Klang, Penang, Kuantan and Kemamam. The absence of SISPELSAT Kuantan Station due to maintenances on going has caused the southern area of South China Sea of Peninsular Malaysia lack of SISPELSAT coverage which is needed for shipping community.

Latest upgrade of SISPELSAT equipment and system was in 2008, thus upgrading and regular maintenance on the SISPELSAT station is highly recommended to ensure the optimum performance of station and sustainability of the services as suggest by IALA and IMO. Additional station install is recommended especially for in one of busiest strait in the world, Strait of Malacca for widen the area cover of SISPELSAT and increase its efficiency in providing positioning corrections.

IALA and IMO also suggest and recommended DGPS broadcasting station such as SISPELSAT need to be integrated with satellite communication in the future as it can cover wider areas and continuous DGPS positioning.

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REFERENCES

IALA, 2015. IALA Recommendation R-121 on the Performance and Monitoring of DGNSS Services in the Frequency Band 283.5 – 325 kHz. International Association of Marine Aids to Navigation and Lighthouse Authorities IALA-AISM, France.

Hasan, R. C. and Mahmud, M. R. 2005. Free Broadcast DGPS Service in marine: How good is it?. International symposium and exhibition on Geoinformation.

Subari, M. D. and Che Awang, M. S. 2004. GNSS radiobeacon service availability study: The SISPELSAT. In: 3rd FIG Regional Conference, 3-7 Oct 2004, Jakarta, Indonesia.

Ooi Wei Han, Moslin S.I., Ahmad N., Subari M.D., Musa T.A., Othman R., Omar A.H., Musliman I.A. 2013. Integrity Monitoring System for Space-Based Navigation and Positioning in Malaysia. Geospatial World Forum 13-16 May 2013, Beurs-World Trade Centre Rotterdam.

Yusup, A., Othman,R., Musliman,I.A., and Han, W. O. 2014. Iskandarnet CORS Network Integrity Monitoring.

AMSA 2016. Differential Global Positioning System (DGPS). FACT SHEET - Australian Maritime Safety Authority