THE DEVELOPMENT OF A NETWORK AUTONOMOUS INTEGRITY MONITORING POSITIONING SYSTEM IN MALAYSIA

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DEDICATION

In the Name of Allah, The Most Gracious, The Most Merciful

To my beloved parents, *Abah* and *Mama,*

Ab Razak Bin Mamat & Ramlah Binti Abdul Latif,

Thank you for the love, support, Doa' and encouragements.

I will always pray for your health and happiness of our family.

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ABSTRACT

Global Positioning System (GPS) is a space-based positioning, navigation and time distribution system designed for world-wide positioning and navigation applications. Accuracy of the GPS solution can be improved through Differential GPS (DGPS) technique that reduces errors in the GPS satellite signal. These errors are determined by Continuously Operating Reference Station (CORS) at precisely known station coordinates which will be transmitted in real-time as corrections to the user thus improving their position accuracy. To maintain the CORS system, the service provider needs to have a comprehensive quality and integrity monitoring mechanism in real time to ensure reliability of the system that would provide better service to users. The study provided a network based autonomous integrity monitoring (NAIM) system within the GPS National Research and Development CORS Network (NRC-net) area. A prototype of NAIM system in a web-based platform was developed to provide integrity monitoring for all CORS including information on CORS status, system level monitoring, user level monitoring and ground level monitoring. The web can be accessed by user via internet to check real-time status and integrity information of each NRC-net station. Besides, the user can monitor the accuracy of the station in term of DGPS fix rover precision shown in standard deviation in northing, easting and up component, thus increasing the confidence of users utilizing CORS data in real-time application. Two radio beacon stations of Sistem Pelayaran Satelit (SISPELSAT), namely Bandar Hilir Melaka (JLML) and Kuantan Pahang (JLKU) owned by the Marine Department of Malaysia were integrated into the NAIM system. By utilizing this system, the GPS data from JLML station were recorded for data accuracy and validation analysis continuously for 7 days. It was found that the accuracy of the JLML station for the north component was less than 1-meter, whereas the east component was less than 2-meters, and the up component had less than 3-meters. The data analysis proved that the station was in a good condition as it provided 100 percent DGPS fix and 2-meter accuracy on average. Based on the analysis, several tests and assessments were conducted towards NAIM system to evaluate the performance of SISPELSAT DGPS radio beacon services at the offshore and coastal areas of Peninsular Malaysia. At the offshore area, SISPELSAT stations, Melaka and Kuala Besar Kelantan had good conditions of more than 96 percent less than 1-meter accuracy and 80 percent of DGPS fix. However, Station Bagan Datuk had only 84 percent less than1-meter accuracy with 27 percent of DGPS fix. At the coastal area, the accuracy of DGPS fix observation at 21 reference stations was less than 2-meters which are directly proportional to the distance of the SISPELSAT stations. The study concludes that the factor of distance-dependent is significant towards the accuracy of the DGPS and influences the radio signal strength and Signal to Noise Ratio of SISPELSAT stations. Overall, the NAIM system has been shown to be capable of providing integrity monitoring mechanism and can be an alternative system for SISPELSAT.

ABSTRAK

Sistem Penentududukan Sejagat (GPS) adalah sistem penentududukan berasaskan angkasa, navigasi dan pengedaran masa yang direka untuk aplikasi penentududukan dan navigasi sejagat. Ketepatan penyelesaian GPS boleh ditingkatkan melalui teknik Pembezaan GPS (DGPS) dengan mengurangkan ralat pada isyarat satelit GPS. Ralat ini ditentukan oleh Stesen Rujukan Berterusan (CORS) pada koordinat stesen yang diketahui ketepatannya yang akan dihantar secara masa-hakiki sebagai pembetulan kepada pengguna seterusnya meningkatkan ketepatan kedudukan mereka. Bagi mengekalkan sistem CORS, pembekal perkhidmatan perlu menyediakan mekanisma pengawasan kualiti dan integriti secara menyeluruh dalam masa-hakiki bagi memastikan kebolehpercayaan sistem yang akan memberi perkhidmatan yang lebih baik terhadap pengguna. Kajian ini menyediakan rangkaian sistem pemantauan integriti berautonomi (NAIM) dalam Rangkaian Penyelidikan dan Pembangunan CORS Nasional (NRC-net) GPS. Satu prototaip sistem NAIM dalam platform berasaskan laman sesawang telah dibangunkan bagi penyediaan pemantauan integriti untuk semua CORS termasuk infomasi status CORS, pemantauan tahap sistem, pemantauan tahap pengguna, dan pemantauan tahap bawah. Laman tersebut boleh diakses oleh pengguna melalui internet untuk menyemak status masa-hakiki dan maklumat pemantauan integriti setiap stesen NRC-net. Selain itu, pengguna boleh memantau ketepatan stesen melalui kejituan DGPS perayau yang ditunjukkan dalam komponen sisihan piawai utaraan, timuran dan atas, seterusnya meningkatkan keyakinan pengguna menggunakan data CORS dalam aplikasi masa-hakiki. Dua stesen radio suar Sistem Pelayaran Satelit (SISPELSAT) iaitu Bandar Hilir Melaka (JLML) dan Kuantan Pahang (JLKU), yang dimiliki oleh Jabatan Laut Malaysia telah diintegrasi ke dalam sistem NAIM. Dengan menggunakan sistem ini, data GPS dari stesen JLML direkodkan untuk ketepatan data dan analisis pengesahan berterusan selama 7 hari. Didapati bahawa ketepatan stesen JLML untuk komponen utaraan adalah kurang daripada 1-meter manakala komponen timuran kurang daripada 2-meter dan komponen atas kurang daripada 3-meter. Analisis data membuktikan bahawa stesen itu berada dalam keadaan yang baik kerana ia menyediakan 100 peratus penetapan DGPS dan 2-meter ketepatan secara purata. Berdasarkan analisis, beberapa ujian dan penilaian dilaksanakan ke arah sistem NAIM bagi menilai prestasi perkhidmatan radio suar DGPS SISPELSAT di kawasan luar pesisir dan pantai Semenanjung Malaysia. Di kawasan luar pesisir, stesen SISPELSAT Melaka dan Kuala Besar Kelantan berada dalam keadaan yang lebih baik daripada 96 peratus ketepatan kurang daripada 1-meter dan 80 peratus daripada tetapan DGPS. Walau bagaimanapun, Stesen Bagan Datuk hanya mempunyai 84 peratus ketepatan kurang daripada 1-meter dengan 27 peratusan tetapan DGPS. Di kawasan pantai, cerapan ketepatan tetapan DGPS terhadap 21 stesen rujukan adalah kurang daripada 2-meter yang berkadar langsung dengan jarak stesen SISPELSAT. Kajian ini menyimpulkan bahawa faktor kebergantungan-jarak adalah signifikan terhadap ketepatan DGPS dan mempengaruhi kekuatan isyarat radio dan nisbah isyarat kepada selisih stesen SISPELSAT. Secara keseluruhan, sistem NAIM telah terbukti mampu menyediakan mekanisme pemantauan integriti dan boleh menjadi sistem alternatif untuk SISPELSAT.

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2D	Two dimensions
2DRMS	Twice-Distance Root Means Square
3D	Three-dimensional
ANGKASA	National Space Agency Malaysia
BKG	German Federal Agency for Cartography and Geodesy
CEP	Circular Error Probability
com	Communication
CORS	Continuously Operating Reference Stations
DGPS	Differential Global Positioning System
DSMM	Department of Survey and Mapping Malaysia
EPN	EUREF Permanent GNSS Network
ETR89	European Terrestrial Reference System
EUREF	European Reference Frame
FTP	File Transfer Protocol
GDM2000	Geocentric Datum Malaysia 2000
GEONET	GNSS Earth Observation Network
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPS	Global Positioning System
GWPS	Ground Wave Prediction System
HTPP 1.1	Hypertext Transfer Protocol
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IHO	International Hydrographic Organization
IMO	International Maritime Organization
IP	Internet Protocol
ITRF	International Terrestrial Frame
JLKU	SISPELSAT Kuantan
JLML	SISPELSAT Melaka
kHz	kilohertz
km	kilometer

kW	Kilo Watt
m	meter
MF	Medium Frequency
MOSTI	Ministry of Science, Technology and Innovation
MSK	Minimum Shift-Keying
MV	Malaysia Vessel
MyRTKnet	Malaysia Real Time Kinematic GPS Network
MySQL	My Structured Query Language
NAIM	Network Autonomous Integrity Monitoring
NANU	Notice Advisory to NAVSTAR Users
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration's
NRC-net	National Research and Development CORS Network
NRTK	Network Real Time Kinematic
NTRIP	Networked Transport of RTCM via Internet Protocol
PHP	Hypertext Preprocessor
PNT	positioning, navigation, and timing
PRC	pseudo-range corrections
RINEX	Receiver Independent Exchange Format
RTCM	Radio Technical Commission for Maritime
RTK	Real Time Kinematic
RTKlib	Real Time Kinematic Library
SiRENT	Singapore Satellite Positioning Reference Network
SISPELSAT	Sistem Pelayaran Satelit
SLA	Singapore Land Authority
SNR	Signal to Noise Ratio
SS	Signal Strength
TCP	Transmission Control Protocol
USAF	United States Air Force
USCG	U.S. COAST GUARD NAVIGATION CENTER (USCG)
VRS	Virtual Reference Station
XAMPP	Cross-Platform (X), Apache (A), MySQL (M), PHP (P) and Perl (P)

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

In modern positioning, use of Global Positioning System (GPS) or Global Navigation Satellite System (GNSS) has gain popularity and the trend are increasing, demanded by location-based industry worldwide since it provides fast and efficient data collection. Several techniques of real-time positioning have been introduced, such as Real-Time Kinematics (RTK), Network Real-Time Kinematics (NRTK), Differential Global Positioning System (DGPS) and others to support critical positioning and navigation applications. Therefore, in order to support the implementation of these real-time positioning technique, establishment of Continuous Operating Reference Station (CORS) is required.

CORS is a facility to continuously collect and record the GPS/GNSS data in an automated manner, at specific location 24 hours per day. Each CORS equipped with GPS/GNSS receiver and the antenna has been installed at a very stable monument with proper electricity and communication. All the data are transmitted in real-time via internet to a control center before being distributed back to users. The data are also being stored locally at the station and transferred to a control center in hourly and daily data sequence for archiving and post-process purposes.

The CORS has been established in many areas around the world by numerous service providers, such as in the Australian states of Victoria (GPSnet), New South Wales (CORSnet) and Queensland (SunPOZ), Denmark (REFDK), Germany (SAPOS), Japan (GEONET), Hong Kong (SatRef), Singapore (SiReNT), and in Malaysia (MyRTKnet) (Shariff *et al.*, 2010). In order to maintain the CORS system, it is indispensable for the service providers to have a comprehensive quality and integrity

monitoring mechanism in various aspects, such as communication link, data transfer, and CORS health status in real time (Lim *et al.*, 2008).

This study has been carried out to implement a comprehensive mechanism of quality and integrity monitoring system known as Network Autonomous Integrity Monitoring (NAIM) system. With these mechanisms, it will ensure the reliability of the CORS system in providing better services to users and able to monitor the data qualities in real time. A CORS network called National Research and Development CORS Network or NRC-net has been used as a prototype for this study. The NRC-net consist of multiple CORS around Malaysia, a control center that equipped with data storage and communication links for data streaming and broadcasting via internet.

A DGPS service by Marine Department of Malaysia known as Sistem Pelayaran Satelit (SISPELSAT) is currently applying the concept of CORS in their DGPS beacon. It provides shore-to-ship DGPS correction services to user via radio. Two of the broadcasting beacon stations transmitted the data into NRC-net system, which then used as testing and assessment of NAIM. Other than that, the performance of SISPELSAT towards the accuracy of broadcast, signal strength and signal to noise ratio have also been evaluated offshore and at coastal areas of Peninsular Malaysia. Overall, the implementation of NAIM prototype in NRC-net have yielded valuable experience in providing a real-time integrity monitoring of CORS to facilitate the user and can be an alternative method for integrity monitoring of SISPELSAT.

1.2 Statement of the Problem

Communication is one of the major concern for CORS service providers in providing a quality service to users. Fault in internet communication between CORS station and control center can cause inconsistency and degradation of real-time GPS data to user. Thus, it is very important for communication of CORS being monitored and the status being informed directly to user in real-time manner from service provider. Therefore, NAIM can be an alternative system for monitoring CORS system in real-time.

The position accuracy of user in real-time application are dependent on the quality of CORS data used. The degradation in data quality can be due to several contributing factors, such as multipath effect, satellite availability and communication itself. Thus, it will affect the accuracy of real-time positioning. Therefore, a comprehensive mechanism of data quality checking in real-time is crucial to be undertaken.

The position accuracy of user using the DGPS beacon are depending on the correction data determine by DGPS radio beacon station at a precisely known coordinate. Distance from user towards DGPS radio beacon also affect the accuracy of DGPS position. Thus, quality of data needs to be monitored and analyzed further. Therefore, NAIM can be an alternative system for SISPELSAT for integrity monitoring system.

1.3 Objective

This research aims to provide a network-based autonomous integrity monitoring system within the NRC-net area coverage. This aim embarks three objectives:

I. To develop a framework of NAIM for NRC-net.

An attractive web base is designed for integrity monitoring of NRC-net.

II. To implement NAIM in SISPELSAT stations.

NAIM systems is implemented for integrity monitoring of SISPELSAT stations.

III. To assess the performance of SISPELSAT system.

The assessments are conducted in the offshore and coastal area to validate the performance of SISPELSAT.

1.4 Scope of the Study

The scopes of this study are described as follows:

1. Research studies have been selected within NRC-net area which included 17 CORS around Peninsular Malaysia and Sabah Sarawak.

2. Only the GPS satellite constellation have been used in this study even though multi GNSS receivers were installed in few CORS in NRC-net stations. L1, L2 carrier phase and code measurement from all NRC-net CORS are collected and are stored in Receiver Independent Exchange Format (RINEX). Meanwhile, real-time data are broadcasted in Radio Technical Commission for Maritime Services (RTCM) data format.

3. Internet communication has been used for entire data streaming in the NAIM system. Transmission Control Protocol / Internet Protocol (TCP/IP) is used to interconnect between the CORS and control center. Meanwhile, user will utilize mobile cellular data such as GPRS, 2G, 3G, and 4G or through Wi-Fi connection for communication with control center.

4. The assessment of SISPELSAT in support of NAIM system are performed by comparing the results gathered using radio (with correction) and post process static technique.

5. The user's positions accuracy are analyzed by comparing user DGPS position with the known coordinate points from static positioning technique.

1.5 Significant of the Study

Real time positioning is very useful since it provides result almost instantly. The NAIM system as centralized system that is going to be implemented in NRC-net will enable service providers and the users to monitor data quality and status of CORS. The NAIM system will provide a comprehensive mechanism for the system integrity that involves many aspects of ground and space segment.

Implementation of NAIM in SISPELSAT system also has a huge impact on consumers, especially in the shipping sector where the availability of the system can be known by accessing the NAIM web page. In addition, the accuracy of the beacon station also can be monitored in real-time and thus to provided confidence for users. Therefore, NAIM system can be an alternative system in providing comprehensive integrity and monitoring system for SISPELSAT.

The NAIM system may deliver positive effects to the users, particularly for implementation of high precise application in the NRC-net coverage. For instance, the system can be upgrade to provide more services in the future. This study will ease the integrity monitoring of positioning solution for future study.

1.6 Research Methodology Approach

In order to achieve the aim and objectives of this study, there are four (4) main phases that have been carried out as below and shows in Figure 1.1:

Phase 1 – Literature Review

- Overview of CORS establishment and brief review on fundamental GPS will also be emphasized in this chapter. NRC-net and SISPELSAT stations infrastructures are highlighted as well in this phase.

Phase 2 – Development of NAIM system

- GPS data from all NRC-net CORS are streamed into server for analysis. The output result are stored into a database.
- The website has been designed and all the data stored in database will be retrieved for implementation of CORS integrity monitoring.
- First research objective is accomplished upon the completion of this phase.

Phase 3 – Implementation of NAIM in SISPELSAT

- GPS data from SISPELSAT station are streamed to NRC-net CORS and then to the NAIM system for integrity monitoring.
- The second research objective is achieved upon the completion of this phase.

Phase 4 – System Analyses base on SISPELSAT

- Data from SISPELSATs station have been utilized to validate the performance of the system.
- Assessment offshore and coastal areas have been conducted by observing SISPELSAT radio signal and the accuracy of the system were analyzed.
- Result and analysis are presented.
- This phase fulfilled the third research objective.

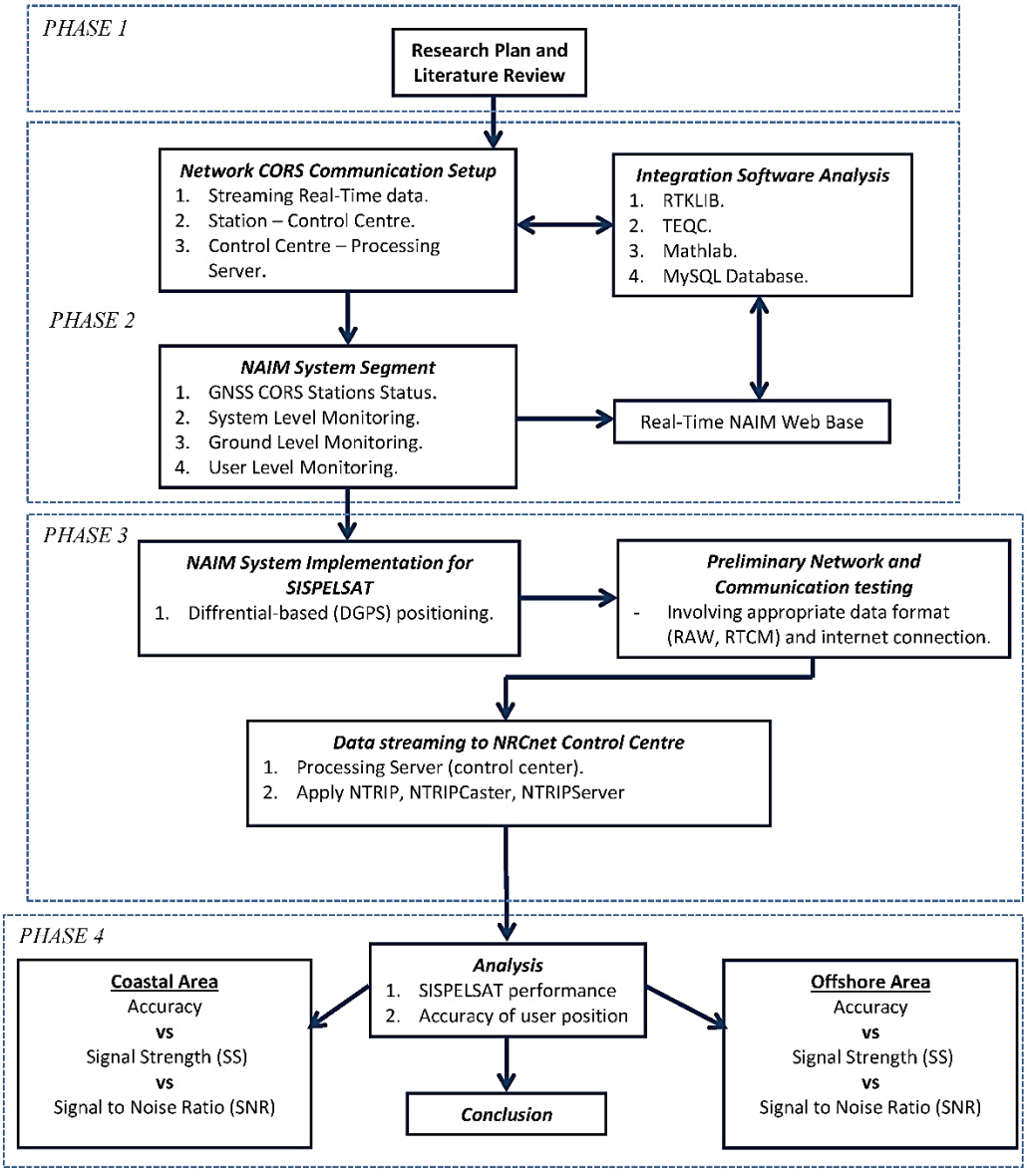

Figure 1.1: Methodology of this study.

REFERENCE

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

BROWN, N., Kealy, A., MILLNER, J., RAMM, P. and WILLIAMSON, I., (2002). Quality control and integrity monitoring of the Victorian GPS reference station network.

Carroll, J. (2003). Vulnerability Assessment of the U.S. Transportation Infrastructure that Relies on the Global Positioning System. Journal of Navigation, 56(2), 185-193. doi:10.1017/S0373463303002273

DoD (2008). Global Positioning System Standard Positioning Service Performance Standard. 4th Edition. ASD(NII)/DASD (C3, Space and spectrum)

EL-Rabbany, A. (2006). Introduction to GPS the Global Positioning System, Second Edition. Boston, London: Artech House, Inc

Estey, L.H. and Meertens, C.M., (1999). TEQC: the multi-purpose toolkit for GPS/GLONASS data. GPS solutions, 3(1), pp.42-49.

Fuller S., Collier P.A., and Seager J. (2007). Real-Time Quality Control for CORS Networks and Mobile Users. Proceedings of IGNSS Symposium 2007, Sydney, Australia.

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.

ICSM (2014). Guideline for Continuously Operating Reference Stations. Special Publication 1, Version 2.1. Intergovernmental Committee on Survey and Mapping (ICSM) Permanent Committee on Geodesy (PCG) 24 September 2014

IGS (2017). Current IGS Site Guidelines. Accessed via https://kb.igs.org/hc/en-us/articles/202011433-Current-IGS-Site-Guidelines. Accessed: 11 March 2018

Lenz, E. (2004) Networked Transport of RTCM via Internet Protocol (NTRIP) – Application and Benefit in Modern Surveying Systems. FIG working week, Athens, Greece, May 22-27, 2004

Lim, S., Heo, Y. and Rizos, C., (2008). A web-based real-time monitoring system for GNSS data quality and integrity. In FIG Working Week–Integrating Generations. Stockholm, Sweden Stockholm, Sweden.

Magee, J., and Janssen, V. (2008). Comparison of community and commercial DGPS correction sources in Tasmania, Australia. Journal of Geospatial Engineering, 10(1-2), 28-40.

MyRTKnet (2005). Garis Panduan Mengenai Penggunaan Perkhidmatan Malaysian RTK GPS Network (myrtknet). PEKELILING KETUA PENGARAH UKUR DAN PEMETAAN BIL. 9 TAHUN 2005

NGS (2018). Guidelines for New and Existing Continuously Operating Reference Stations (CORS). National Geodetic Survey National Ocean Survey, NOAA Silver Spring, MD 20910

NovAtel (2012). White Paper, Mitigating The Threat of GPS Jamming http://www.novatel.com/assets/gajt/pdf/gajt-white-paper.pdf

Ochieng, W. Y., and Sauer, K. (2002). Urban road transport navigation: performance of the global positioning system after selective availability. Transportation Research Part C: Emerging Technologies, 10(3), 171-187.

Ooi Wei Han., Moslin S.I1., Ahmad N., Subari M.D.,Musa T.A., Othman R., Omar A.H., Musliman I.A. (2014). Integrity Monitoring System For Space-Based Navigation And Positioning In Malaysia. Geospatial World Forum 13-16 May 2013, Beurs-World Trade Centre Rotterdam.

Rizos, Chris and Satirapod, Chalermchon. (2011). Contribution of GNSS CORS infrastructure to the mission of modern geodesy and status of GNSS CORS in Thailand. Engineering Journal; Vol 15, No 1 (2011): Geo-Informatics; 25-42. 15. 10.4186/ej.2011.15.1.25.

Rizos, Chris. (2007). Alternatives to current GPS-RTK services and some implications for CORS infrastructure and operations. GPS Solutions. 11. 151-158. 10.1007/s10291-007-0056-x.

Rizos, Chris. (2008). Multi-Constellation GNSS/RNSS from the Perspective of High Accuracy Users in Australia. Journal of Spatial Science. 53. 10.1080/14498596.2008.9635149.

Rubinov, Eldar., Fuller Simon., Collier, Philip., and Seager, James. (2010). Implementation of Real-Time Quality Control Procedures for Network RTK GNSS Positioning.

Schwieger, V., Lilje, M., and Sarib, R. (2009). GNSS CORS–reference frames and services. In 7th FIG Regional Conference, Hanoi, Vietnam (Vol. 19, No. 22.10, p. 2009).

Shariff, N. S. M., Musa, T. A., Omar, K., Ses, S. and Abdullah, K. A.(2010) Performance of Research-Based N-RTK Positioning System in ISKANDAR Malaysia. 2010 International Symposium on GPS/GNSS Taipei, Taiwan. October 26-28, 2010.

Sickle, V. J. (2008) GPS for land surveyors. Third Edition. Boca Raton: CRC Press.

SLA (2015). SINGAPORE SATELLITE POSITIONING REFERENCE NETWORK (SiReNT) - User Guide Version 2

Snay, Richard and Soler, Tomas. (2008). Continuously Operating Reference Station (CORS): History, Applications, and Future Enhancements. Journal of Surveying Engineering. 134. 95-104. 10.1061/(ASCE)0733-9453(2008)134:4(95).

Subari, MD. and Che Awang, M.S., (2004), GNSS Radiobeacon Service Availability Study: The SISPELSAT, Proceedings of 3rd. FIG Regional Conference, Jakarta, Ocktober, 2004.

Weber, Georg and Dettmering, Denise and Gebhard, H. (2005). Networked Transport of RTCM via Internet Protocol (NTRIP). 60-64. 10.1007/3-540-27432-4_11.

Yusup, A., Othman, R., Musliman, I. A., Han, W. O. (2014). ISKANDARnet CORS Network Integrity Monitoring. Jurnal Teknologi (Sciences and Engineering) 71:4 (2014) 11–19 Jakarta, Indonesia, October 3-7, 2004