DEVELOPMENT OF GNSS AND DGPS INTEGRITY MONITORING SYSTEM IN MALAYSIA

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Abstract

In Malaysia, navigation technology has become an essential tool in various applications across military as well as in civilian sectors. With the technology upgrading of US's GPS and the comprehensive full operational constellation of Russian's GLONASS, the positioning accuracy has been definitely improved. Basically, the integrity of the navigation system is as vital as accuracy. It was a number of different signals in failure modes that resulted significant position errors, and there is a need to authenticate and monitor the integrity on received signals in order to detect any anomalous signals from time to time. The National Space Agency (ANGKASA) is intended to establish the GNSS and DGPS integrity monitoring system for local used purpose. In the end of the research, a system with the capability of displaying the satellite integrity and availability analysis will be developed. It will identify the each satellite range errors as well as to show the signal quality statistics in the system. User notification alert will be made if the monitored parameters exceed specified thresholds.

Keywords: GNSS, Integrity, monitoring, availability

1.0 INTRODUCTION

Nowadays, the Global Navigation Satellite System or GNSS has become essential tool in various applications and sectors in the world as well as in Malaysia. The user reliance on high positional, navigational and timing data is growing, therefore the U.S government has upgraded its GPS satellites and launched new and better civilian signals; while Russian government has managed to complete the GLONASS satellites constellation in year 2010 and start providing the services to the global users. Nevertheless, the China and European Union are in the midst of expanding their own navigation systems and target to be fully operational in the coming few years.

The positioning accuracy was greatly improved accordingly due to multiple available GNSS signals could be received by users. However, it was a number of incidents indicated that the signals in failure mode at particular time which it was resulted significant position errors. The signals were affected by different types of errors that occurred at various stages during the transmission between satellites and users. Several types of error above are satellite clock and orbit errors, invalid broadcast PRN code, the ionospheric and tropospheric delays, receiver clock error, possible cycle slips, multipath errors and etc.

To ensure the safety of used on the system, there is a need to authenticate and monitor the integrity of the received signals in order to detect the anomalous signals at all time. In United States, the U.S. Coast Guard Navigation Centre (NAVCEN) is provides quality navigation services of GPS with the information on timely operational status. The Coast Guard's DGPS service serves to monitor marine radio beacon broad-cast signals as well as the accuracy of DGPS Reference Station-generated corrections. The centre is intended to promote the safe transportation as well as to support the commerce of country. In addition, the Federal Space Agency in Russia also set up an Information Analytical Centre to monitor and evaluate the status of GLONASS satellite every day. Users could be able to obtain such information through dedicated website.

In Malaysia scenario, there is a need to set up mechanism to monitor the GNSS signals throughout the country since the popularity and usage of GNSS is increasing yearly. The National Space Agency or ANGKASA has responsibility and intended to establish the GNSS and DGPS integrity monitoring system for local used purpose. This project has been approved by MOSTI Science Fund for the duration of 18 months and target to be completed by end of year 2013, with the expected output of developed system to monitor the satellite integrity and availability analysis, identify the each satellite range errors as well as to indicate the signal quality statistics. It believes could be able to benefit to all relevant sectors from the develop systems.

2.0 LITERATURE REVIEW

Integrity is a measure of the trust that can be placed in the correctness of the information supplied by the total system with the ability to provide timely and valid warnings to the user when the system must not be used for the intended operation (Bhatti, 2007). It could be called as reliability measurement for users and is an important parameter to guarantee the users security.

Numerous incidents on signal anomalous were detected based on data collected from IGS stations worldwide and the main caused was from satellite clock and ephemeris anomalies. There were satellite clock anomaly on SV22 in 28 July 2001, SV27 in 14 Nov 2008 (4 hours), SV25 in 26 Jun 2009 (45 minutes), SV08 in 5 Nov 2009 (30 minutes), SV06 in 24 Jun 2010 (2 hours); ephemeris anomaly on SV24 in 26 September 2006 (3 hours), SV15 in 20 May 2007 (15 minutes) and SV09 in 25 April 2010 (15 minutes) and etc. (L.Heng et. al., 2010). Table 1 shows further the potential SIS anomalies between years 2004 to 2010.

Table 1: List of potential SIS anomalies 1/1/2004-31/8/2010 (source: *L.Heng et. al., 2010*)

Date/time	PRN	Duration	Anomaly	URA UB (m)	References
2004-05-03 11:00	08	30 minutes	clock −30.8 m	3.4	IGS
2004-06-14 11:15	29	2.75 hours	ephemeris −10.8 m	2.4	IGS
2004-06-17 11:15	29	1.5 hours	ephemeris 12.5 m	2.4	IGS
2004-07-20 07:15	23	45 minutes	ephemeris 13 m	2.4	IGS
2004-08-29 00:45	27	1 hours	clock 69.5 m	3.4	IGS
2005-05-14 20:15	27	15 minutes	clock 27.6 m	2.4	IGS
2005-06-09 03:45	26	15 minutes	clock −38 m	3.4	IGS
2005-12-25 21:15	25	30 minutes	clock −129 m	2.4	IGS
2006-06-02 20:30	30	30 minutes	clock −1045 m	2.4	NGA
2006-06-27 04:45	06	30 minutes	clock −10.2 m	2.4	IGS, NGA
2006-07-31 22:15	03	1 hour	clock −12.7 m	2.4	IGS, NGA
2006-08-25 12:30	29	1.5 hours	clock −11.6 m	2.4	IGS, NGA
2006-09-22 19:45	24	2.75 hours	ephemeris 41.2 m	2.4	IGS, NGA
2006-11-07 01:45	05	3.75 hours	clock −30.7 m	2.4	IGS, NGA
2007-03-01 14:45	29	2.5 hours	clock −42.3 m	2.4	IGS, NGA
2007-04-10 16:00	18	1.75 hours	ephemeris 688 m	2.4	IGS, NGA
2007-04-22 10:30	25	45 minutes	clock −29.4 m	6.85	NGA
2007-05-20 03:45	19	15 minutes	ephemeris −13.3 m	2.4	IGS, NGA
2007-08-17 07:30	07	30 minutes	clock −14.3 m	2.4	IGS, NGA
2007-10-08 09:45	12	2.25 hours	clock −86 km	2.4	NGA
2007-10-08 23:00	14	1.5 hours	clock −112 km	2.4	NGA
2007-10-09 09:45	23	1 hour	clock 27 km	6.85	NGA
2007-10-09 13:15	16	15 minutes	clock −18 km	4.85	IGS, NGA
2007-10-10 08:45	20	1.25 hours	clock 48 km	2.4	IGS, NGA
2008-11-14 05:45	27	3.75 hours	clock −70 km	2.4	NGA
2009-06-26 09:30	25	45 minutes	clock −22.3 m	2.4	NGA
2009-11-05 18:45	08	30 minutes	clock −18.5 m	2.4	IGS
2010-02-22 21:00	30	30 minutes	clock −42.9 m	3.4	NGA
2010-04-25 19:45	09	15 minutes	ephemeris 11 m	2.4	IGS, NGA
2010-06-24 18:30	16	2 hours	clock 374 m	2.4	NGA

GNSS integrity monitoring system could be staged as system-level, monitoring station-level and user-level. The system-level integrity monitoring is based on existing satellite and mainly process satellite orbit errors and clock errors. The system-level integrity monitoring does not concern with whether the navigation system is enhanced, and its research target is satellite. The station-level integrity monitoring is mainly process and enhanced signal data on the ground monitoring station, and its research target is monitoring station. GNSS user-level integrity monitoring combines the signal of enhanced system and observation data of satellite system signals, realize receiver integrity monitoring according to redundancy measurement.

There have two common practices to provide integrity information about the signals which are the use of special augmentation systems or Receiver Autonomous Integrity Monitoring (RAIM). Special augmentation systems consist of ground based stations that receive signals from GPS satellites and generate information to enhance the performance of GPS signals, and ground based or satellite based transmitters to broadcast this information to the users. (Ochieng et al., 2003). RAIM takes the form of a computer algorithm which checks the consistency of measurements received by exploiting measurement redundancy, the geometrical configuration of the satellites relative to the user, knowledge of nominal error behaviour and the user requirements (Brown and McBurney, 1988).

3.0 METHODOLOGY

The project is target to establish two new operating ground infrastructure at the primarily stage mainly for the purpose of collecting the GPS and GLONASS multiple signal frequencies. The stations will equip with the GNSS Continuously Operating Reference Station (CORS) high geodetic receivers and antennas, a workstation with the database management system and well internet communication. Meanwhile, a system plans to be linked with marine DGPS data in order to receive the data correction from time to time. The main control centre will be set up in ANGKASA's National Space Centre at Banting Selangor.

The developed system will track and monitor the GNSS signals behaviour in real time based on data collection from ground stations. There will undergo a process to compute the precise theoretical distance from the antenna to the satellite and to compare the result with the observable. A large difference between the computed and the observed distance indicates possible errors and the system will distinguish further between the actual observed distance with the local anomalies. This particularly in favour of extracting the signal's multipath effect, ionospheric and troposheric delays, receiver clock error, possible cycle slips, and any errors included in the broadcast ephemeris. Besides to identify the satellite range errors, a signal quality statistics also will be displayed in real time.

Additionally, the integrity system is plans to verify DGPS reference station generated pseudorange corrections by making GPS pseudorange measurements and correcting the GPS pseudorange measurements with received RTCM corrections as well as compare the corrected pseudorange with data computed using the known position.

As output of the project, the system will generate info of GNSS status message which consists of satellite constellation status as well as reporting on any outages and anomalies to the local users. Besides that, it also will predict on expected behavior of signal by retrieves and integrates official satellite health information published in Notice Advisory for Navstar (GPS) and GLONASS Users (NANUs/NAGUs). All the integrity results will disseminate in data and graphical formats through ANGKASA's website or emails. When monitored parameters exceed specified thresholds, the integrity monitor system will automatically generate appropriate alert and notification to local GNSS users.

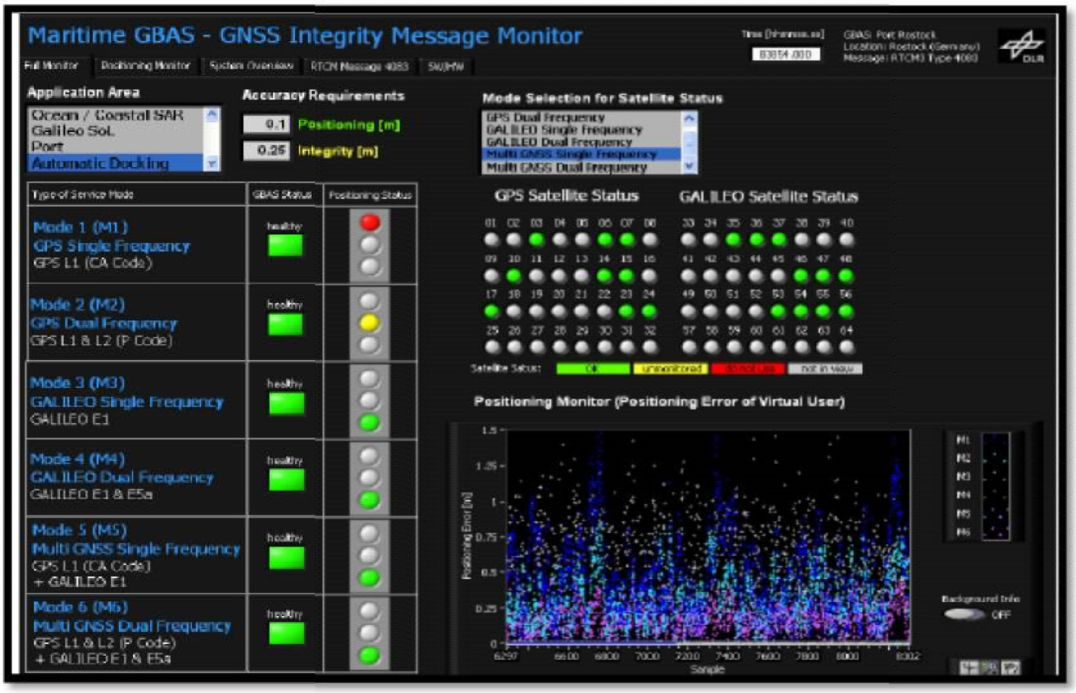

Figure 1: Sample of GNSS Integrity system (source: DLR)

4.0 CONCLUSIONS

The usage of GNSS technology is growing in fast mode in Malaysia. Thus, the GNSS integrity monitoring system is developed mainly to ensure the secure and safety use of GNSS technology and application in Malaysia since it will provides reliable navigation information. The system is need and essential in positioning and navigation areas especially for safety critical sectors like marine, aviation and military, where stringent integrity performance requirement must be met. The local users are much trust, reliable and confident on the technology and indirectly the usage and demand in variety of areas will definitely increase.

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