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SENSORS II SESSION

Improving GNSS Sensor Reliability

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Abstract

The GNSS sensor provides a real-time position feed to the DP system and is essential for safe and reliable operations on a global basis. This paper will look at how the reliability of the GNSS sensor as a PME (Position Measuring Equipment) can be improved through various approaches as outlined below.

It will examine the impact of new GNSS satellite signals and constellations, focusing on the potential signal combinations and the benefits that will bring in terms of positioning resilience and robustness. This will also have an impact in the augmentation data required to be generated and subsequently sent to users.

Delivery of data to the user is also considered with particular focus on providing augmentation to vessels operating at high latitudes where reception of data from the L-band geo-stationary satellites can become problematic because of visibility to the satellite. In addition, extending the validity of the correction data can help maintain reliable GNSS positioning.

Reliability can be improved by integrating a complementary sensor with the GNSS such as an INS. This paper will look at the results from the VERIPOS Axiom system in an operational environment which has helped in facilitating further development of the system with particular focus on the particular information provided to the DP system and DP operator in terms of data interface and visualization.

Introduction

The GNSS sensor provides a real-time position feed to the DP system and is essential for safe and reliable operations on a global basis. The ideal GNSS sensor or surface positioning system should provide a reliable position that is constant, stable, accurate and repeatable, however, vessels and GNSS sensors don’t operate in the ideal world. GNSS signals need line of site to the satellite plus the signals have to travel over 20,000km meaning they are weak by the time they arrive at the user’s antenna and making them susceptible to degradation through interference. This can result in unreliable positioning.

There is always a constant evolution of GNSS technology to improve performance and reliability of positioning. Reliability is not just about making the position better but also understanding when positioning is non-optimal and informing the user that the sensor is out of specification to allow appropriate action to be taken.

This paper will examine how the reliability of the GNSS sensor can be improved by examining the following aspects:

- Satellite Constellation
- Antennas
- Data Delivery
- Sensor Integration
- Visualisation
- Interfacing

Satellite Constellations

It is well know that the landscape of satellite navigation is gradually changing with the modernisation of the GPS and GLONASS satellite constellations and the addition of Galileo and Beidou. Ths will mean that the user will have the ability to track more satellites and use a larger number of signals broadcast by all constellations. Figure 1 shows the number of satellites for all constellations that will become available over the next ten years providing more redundancy through satellite availability.

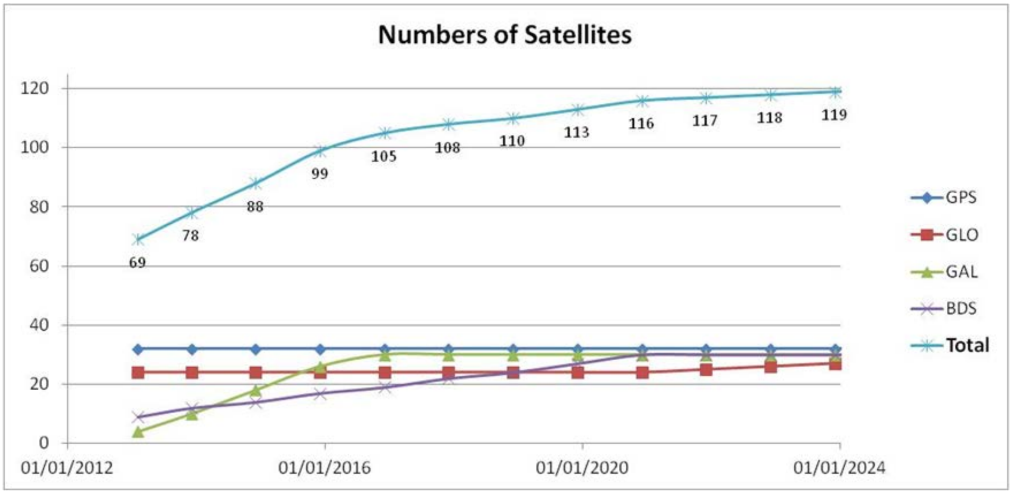

Figure 1 - Number of Available Satellites

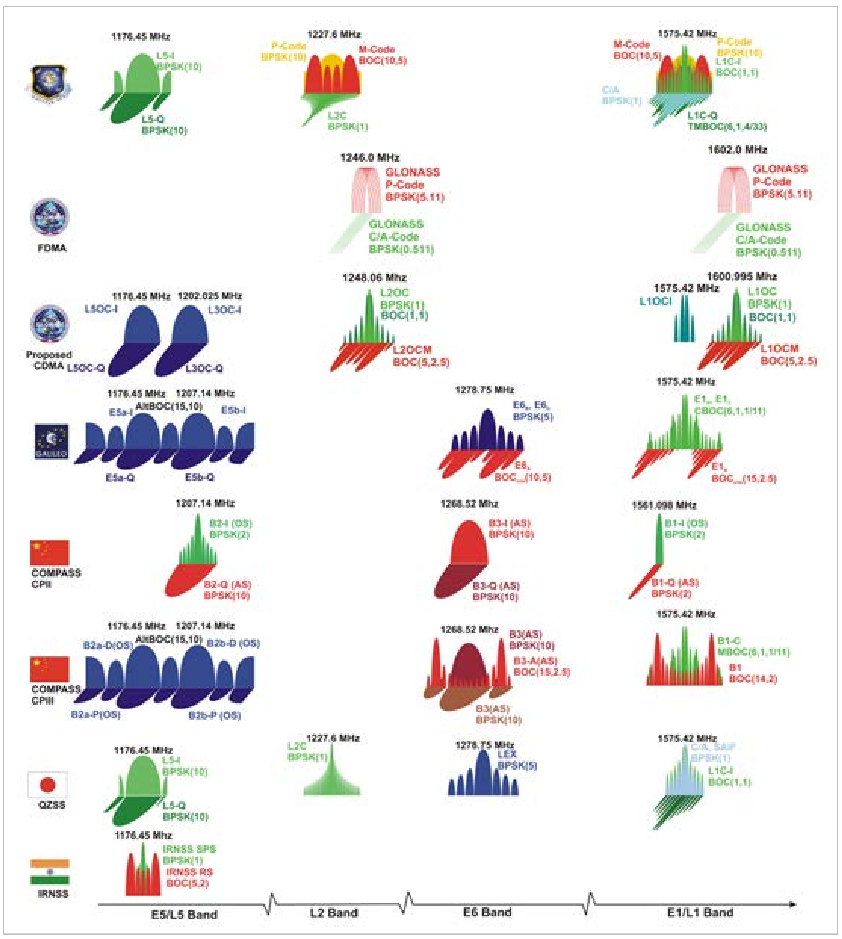

Figure 2 - GNSS Signal Structure (All Constellations) [source: Stefan Wallner]

The signal structure and transmission frequency for all GNSS constellation including the Japanese and Indian regional systems is shown in Figure 2. It shows that the four global GNSS systems will all be transmitting signals on three different frequencies and with different signals structures.

The design of the new and modernised signals allows for improved signal tracking and also broadcast at a slightly higher power level which provides additional resilience to interference. Resilience is also provided through redundancy due to the number of signals available. The signals are still susceptible to degradation through interference particularly if the GNSS antenna is located close to a local transmitter.

One of the advantages of having extra satellites and observations will be the ability to exclude or reject satellites from the solution to improve the reliability and robustness of the calculated position while still maintaining redundant satellites/observations.

Figure 3 demonstrates how using Receiver Autonomous Integrity Monitoring (RAIM) algorithms with a better rejection threshold can exclude observations affected by scintillation or interference. This is only possible with extra observation redundancy in order to maintain the required number of satellites to generate a position solution.

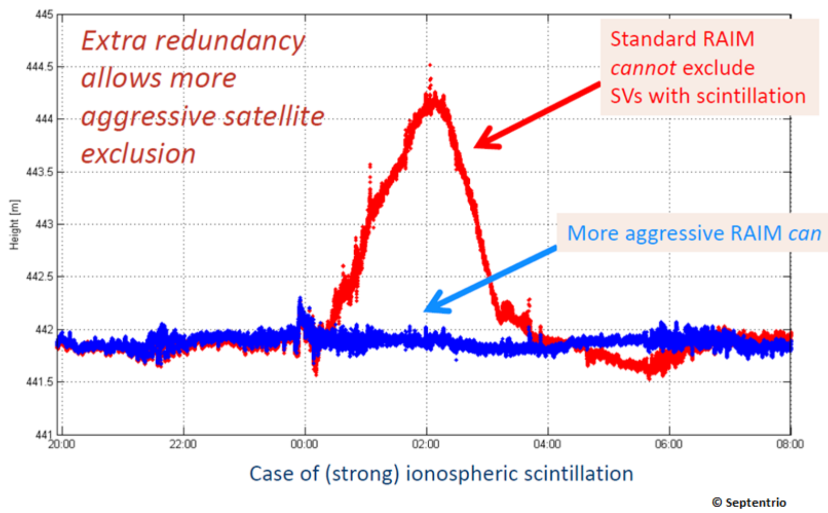

Figure 3 - Improved Position Robustness through Satellite Rejection

Additional satellites and observations provides an opportunity to develop new strategies for generating a position solution through the rejection of questionable observations but still maintaining a good number of satellites to provide a reliable position solution.

An issue that needs to be addressed with multiple constellations is what combinations of constellations and signals will be used to maximise reliability. There are various combinations possible is something that receiver hardware manufacturers and service providers are working to see what the best combination will be. Various factors need to be accounted for including the receiver design in order to track all the satellites and signals which adds complexity and cost.

For the service provider, their reference station networks have to be upgraded (receiver and antenna) in order to track all the satellites but this adds a significant burden to the data communication bandwidth due to number of additional observations. This is important when considering the augmentation corrections that are broadcast over the satellites links as this is fixed bandwidth so adding more corrections will result in latency increases.

Another factor for consideration is the operation implementation and user expectations with what combinations of constellations to use in a position solution (Figure 4). It’s possible to have a single solution using all constellations while monitoring the individually generated position solutions from each constellation. Alternatively, a vessel could have two independent position solutions using a combined GPS/GLONASS solution and a combined Galileo/Beidou solution.

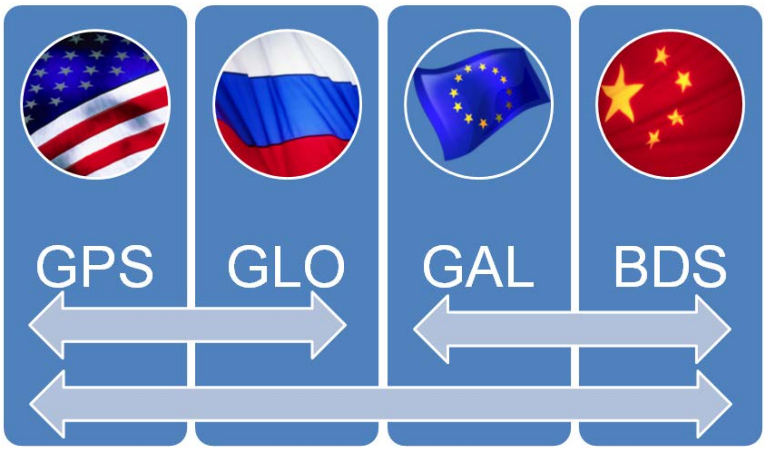

Figure 4 - What Constellation Combination to Use?

Despite the issues faced with utilising additional satellite constellations and signals, it is clear that the reliability of GNSS will be improved through their use. The issues can all be addressed but some work will be required to integrate the constellation in order to maximise performance and reliability.

Data Delivery

Augmentation services are used to improve the accuracy of the position solution but also indirectly provide integrity information about the GNSS constellations based on the generated correction data. This data is delivered to the user via geo-stationary L-band communication satellites on dedicated channels. This point to multipoint (PMP) service has been successfully used for a long time providing good coverage.

The major limitation of the PMP service is that it can only operate up to 74° latitude (North or South) which makes it unsuitable for high latitude operations that are becoming more commonplace. Therefore, alternative delivery systems are required to get the augmentation to the user in these areas of operation.

An alternative method is delivering the data to the user via the internet either through the vessel’s internet connection (e.g. VSat) or via the Iridium satellite network (Figure 5). The data is made available using the NTRIP (Networked Transport of RTCM via Internet Protocol) format which is a RTCM SC-104 standard.

With internet delivery the inability of the service provider to monitor the data is a major limitation unlike the PMP service. The service provider can ensure that the data is available from a connection but has no way of monitoring the data once it is out on the internet and thus cannot guarantee delivery.

As with any internet connection, real time data can be delayed due to network bandwidth and the amount of traffic. This is especially true with a vessel’s intranet link as it will be VSat based and have limited bandwidth, so when high email/telephone traffic or video streaming is present, data may be delayed or stopped. Compression equipment is also used to try and maximise the Internet bandwidth and this can also introduce delays.

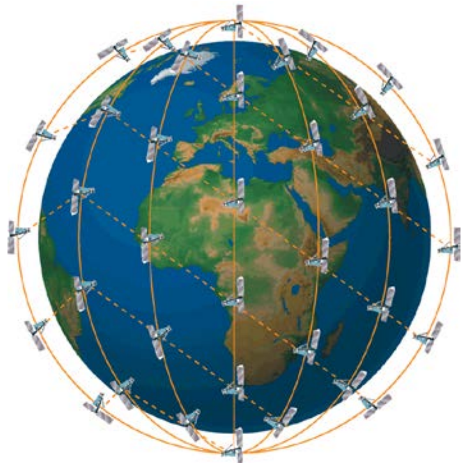

Figure 5 - Iridium Satellite Constellation

Iridium is a network of 66 low Earth orbiting (LEO) satellites providing global coverage including over the Polar regions where the PMP service has no coverage. The transmission power of the LEO permits the use of an omnidirectional antenna to receive the data rather than a stabilised dish making the system ideal for operations at high latitudes.

Experience of using Iridium has shown that one of the major challenges with using the system is the fact that the user will be switching satellites on a regular basis which introduces breaks into the correction data resulting in increased latency. This can impact the position solution as increased latency will cause the solution to time out and revert to standalone positioning and this will likely be rejected by the DP system. To counteract this, it is possible to extend the latency thresholds in the position solution to extend the validity of the correction data. The effect on a position is shown in Figure 6 were a test was conducted to look at the impact on position accuracy after the correction data was removed.

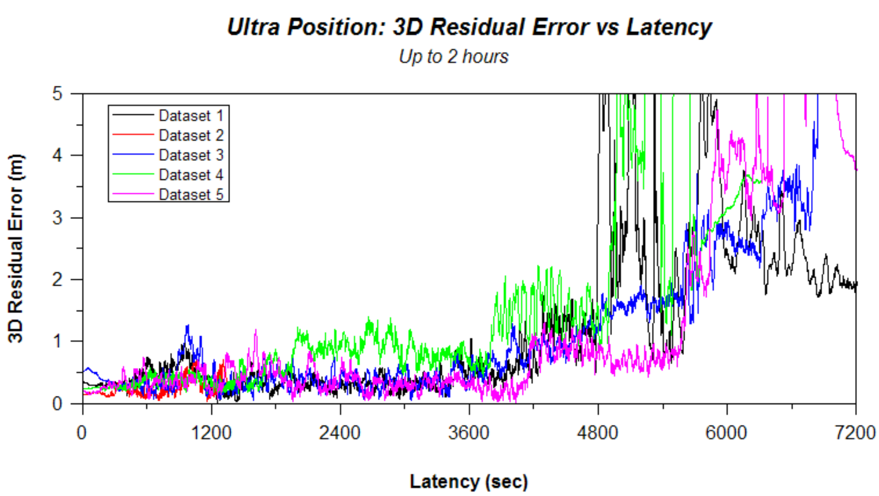

Figure 6 - Effect of Latency on Positioning (High Accuracy PPP)

The result in Figure 6 indicates that the high accuracy PPP solution can maintain reliable positioning for a significant period of time although not at the 10cm level which is the typical level of accuracy of the PPP solution. It is also worth noting that this test was conducted in a static environment. However, it does demonstrate that for working with Iridium the validity of the corrections can be extended to maintain reliable positioning.

In the future, the Galileo GNSS constellation has a dedicated channel with bandwidth that will support a commercial service. As yet details on what information will be transmitted over the commercial service are undefined.

Antennas

An integral and important part of any GNSS system is the antenna which is used to receive the signals transmitted by the satellites. The design of the antenna is crucial for reception of the weak signals and various factors needs to be taken into account when designing and selecting any antenna. These factors include frequency coverage, gain pattern, multipath, and interference suppression with appropriate filters and notches. Many aspects of antenna design are inter-dependent and by changing one area of the design can negatively impact another aspect. Figure 7 illustrate the different antenna elements used in antennas used for positioning.

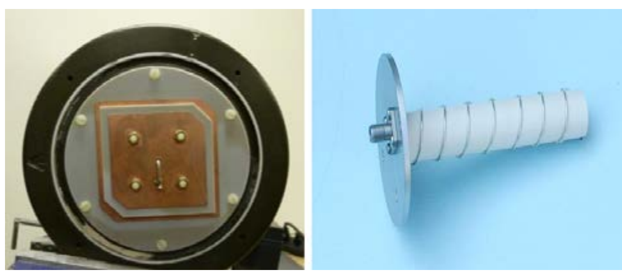

Figure 7 - Antenna Elements (Left - GNSS Patch Element, Right - L-Band Helix Element)

The actual physical installation of the antenna is very critical as a badly installed antenna will degrade to performance of the GNSS sensor. The location of the antenna on the mast must provide clear line-of-site to sky in order to receive the GNSS signals. It should also be installed away from any systems that may cause interference and degradation of the GNSS system or introduce multipath into the system. Information about the installation and maintenance of GNSS positioning system is available in [1] and more information on antennas is available in [2].

Preventative Maintenance

Planned preventative maintenance should be an on-going task for any GNSS sensor installation as it will deteriorate over time particularly affecting the parts exposed to the elements. This is irrespective of how good the quality of the GNSS installation is.

The key parts of the system that should be inspected would include the antenna, its connections, cable integrity, condition of all components and upgrading the system to use the latest version of software and firmware.

Sensor Integration

Integrating sensors can help to provide a robust position solution. INS and GNSS are complementary sensors and when combined can deliver constant, stable, accurate and repeatable positioning. The integration of GNSS and inertial technologies exploits the long term accuracy and precision characteristics of GNSS positioning with the continuous availability and fast update rate of inertial sensors.

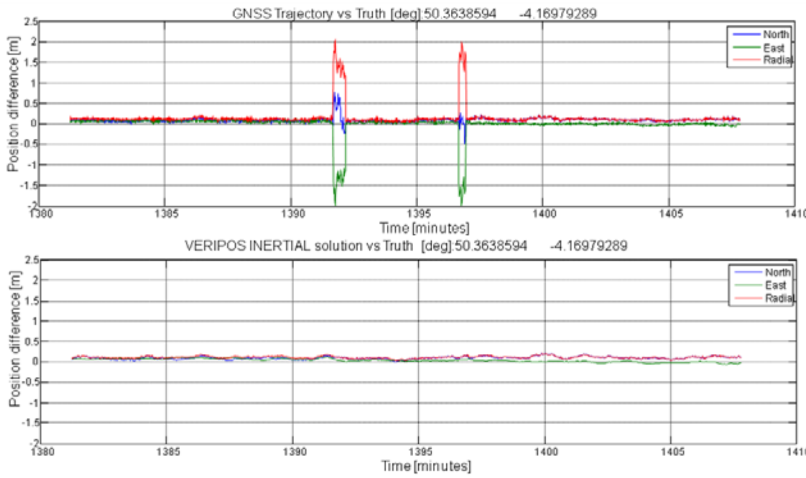

Figure 8 - INS and GNSS Performance

The resulting integrated system can bridge GNSS disruptions (e.g. ionosphere scintillation, physical obstructions, etc.) as well as detecting position outliers due to common mode failures which can affect vessel GNSS systems simultaneously which are particularly advantageous for DP operations. The performance of an integrated INS/GNSS solution is shown in Figure 8 illustrating how the integrated solution (bottom graph) maintains good positioning performance when the GNSS solution has a problem (top graph).

With an integrated solution, it is important to know what state the solution is in, whether, GNSS, INS or and GNSS/INS solution.

Visualization

With additional satellite constellations, integration of other sensors the visualisation of the position solution needs to change to provide relevant information to the user to allow the correct interpretation. This should provide the user with visibility on performance and independence of solutions as well as any integrated solutions.

Figure 9 - Visualization Software

Data Interfacing

Transporting the data from the GNSS senor or positioning system to the DP relies on a data interface which is typically, the NMEA 0183 GGA telegram. This provides limited status information on the reliability of the position and hasn't been designed to work with multi-constellations or with a sensor integrated solution. There is also a requirement to provide additional information about the position quality and it is clear that the existing industry standards and guidelines are out of date and need to be updated to reflect the changes in positioning. Therefore an appropriate interface standard is needed so that it is possible to unlock the full potential of an integrated solution and ensure compatibility between all systems and the provision of appropriate information for the user.

References

[1] IMCA, 2009. *Guidelines on Installation and Maintenance of DGNSS-Based Positioning Systems.* IMCA M 199/ IMCA S 012, August 2009.

[2] Russell, D., 2011. *Location, Location, Location* - *Antenna Installation.* Proc. of MTS Dynamic Positioning Conference, Houston, 2011.