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Sensors

Experiences with Fugro's Real Time GPS/GLONASS Orbit/Clock Decimeter Level Precise Positioning System

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Abstract

Fugro has introduced a new satellite based precise positioning service called G2. This high performance navigation service combines the navigation satellites of both the American GPS constellation and the Russian GLONASS constellation, to produce a composite GPS/GLONASS position solution. With the full GLONASS constellation of 24 satellites expected in a couple of years, GPS and GLONASS can also be used as independent systems. The service utilizes Fugro's own network of dual system reference stations to calculate 'orbit and clock' corrections on a satellite by satellite basis for all 50 satellites of the two global navigation satellite systems, thus providing consistent decimetre level accuracy positioning on a world wide basis. By using the full range of satellites from both the American and Russian systems, best possible service can be ensured when satellite visibility is partially obstructed. This can occur in equatorial regions when severe scintillations tend to make it difficult to track satellites. The scintillations tend to affect parts of the sky, making it more likely to track enough good satellites when using both GPS and GLONASS.

G2 is the first real-time, precise, orbit and clock service using GLONASS. The development of G2 has benefited from the close cooperation between Fugro and ESOC (European Space Operation Centre), an establishment of ESA (European Space Agency).

The system comprises about 40 dual frequency GPS/GLONASS reference stations evenly distributed around the world. Raw range data for all satellites are transmitted to processing centres for calculation of the orbit and clock error of each GPS and GLONASS satellite. Correction data is then broadcast to the user via geostationary communications satellites, providing close to global coverage. In the mobile equipment, the orbit and clock correction data is used to improve the ephemeris information read from the GPS and GLONASS satellites providing decimeter accuracy. This is also known as Precise Point Positioning (PPP). Fugro utilizes a proprietary software engine for the mobile position calculations. This software is embedded in GNSS receiver manufacturer's hardware and Fugro's own range of products.

The paper presents the elements of the complete G2 system from the reference station network to the user end. Series of test results are presented both from benign and challenging environments, both static and dynamic. Even results from GLONASS-only precise orbit and clock real-time navigation are presented showing the full potential of GLONASS as an independent positioning source for DP applications.

Biography

Ole Ørpen is Senior Scientist at Fugro Seastar in Oslo, Norway. He received his Master of Science from the Norwegian Institute of Technology (NTH) in 1974 in electrical engineering. Mr. Ørpen has worked in the field of radio-navigation from before the days of GPS, initially at the Norwegian Defence Research Establishment, and since 1987 in private industry.

Tor Egil Melgård is R&D Manager at Fugro Seastar in Oslo. He received his Master of Science degree in electrical engineering from the Norwegian Institute of Technology (NTH) in 1994. He wrote his thesis as a visiting student at the Department of Geomatics at the University of Calgary in 1993-1994, and has worked in the field of satellite navigation since then.

Introduction

Fugro has introduced a new satellite based precise positioning service called G2. This high performance navigation service combines the navigation satellites of both the American GPS constellation and the Russian GLONASS constellation, to produce a composite GPS/ GLONASS position solution.

G2 is the first real-time, precise, orbit and clock service using GLONASS. It provides consistent decimetre level accuracy Precise Point Positioning (PPP) on a world wide basis.

The paper presents the elements of the complete G2 system from the reference station network to the user end. It shows detailed accuracy analysis of the real-time orbits and clocks compared to IGS (International GNSS Service) products for both GPS and GLONASS. Series of test results are presented both from benign and challenging environments, both static and dynamic. It is shown that even GLONASS-only measurements from the G2 service are capable of providing precise real-time navigation.

G2 System Elements

The G2 service utilizes Fugro's own network of dual system GNSS reference stations to calculate precise orbits and clocks on a satellite by satellite basis for all 50 satellites of the two global navigation satellite systems. The system comprises about 40 dual-frequency GPS and GLONASS reference stations evenly distributed around the world. Raw GNSS measurement data for all satellites are transmitted to the processing centres for calculation of the precise orbit and clock of each GPS and GLONASS satellite. There are two geographically separated processing centres running independent calculation servers in order to ensure redundancy. An automatic process selects the preferred server to use at any time. The generated precise orbit and clock data is broadcast to the user via geostationary communications satellites, providing close to global coverage. Inside the end user equipment a dual-frequency carrier-phase based PPP solution gives horizontal positioning accuracy at the decimetre level. The PPP calculation module is provided by Fugro and is embedded in multiple GNSS receiver manufacturer's products as well as in Fugro's own product line.

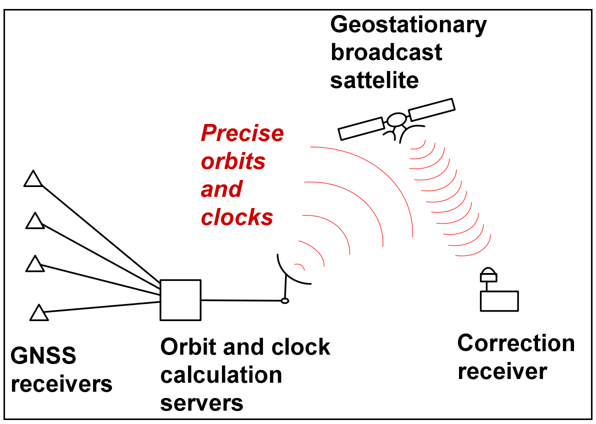

Figure 1: G2 data flow overview

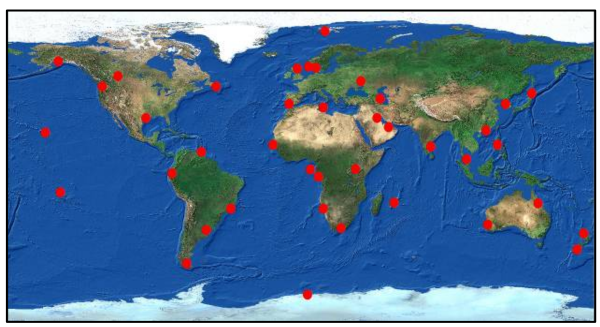

Figure 2: G2 reference station network

PPP Optimal For GNSS Augmentation

The development of the G2 system presented in this paper is a big step towards the preparations for future GNSS as well. PPP stands out as an optimal approach for providing global augmentation services for current and coming GNSS constellations. PPP requires fewer reference stations globally than conventional differential approaches; one set of precise orbit and clock data is valid for all users everywhere, and the solution is generally unaffected by individual reference station failures. There are always many reference stations observing the same satellite because the precise orbits and clocks are calculated from a global network of reference stations. As a result PPP gives a highly redundant and robust position solution.

GLONASS Improves Availability

Like any other GNSS technique, PPP is adversely affected by the satellite line-of-sight obstructions. Even the most precise orbit and clock data is useless if the user does not track particular satellites. By using the full range of satellites from both the GPS and GLONASS systems, a best possible service can be ensured when satellite visibility is partially obstructed. This can occur during a survey of a dense urban environment and for urban positioning in general, it can occur under heavy tree cover, when a cruise ship is in a high sided fjord, when an offshore vessel is close to an oil rig or platform, and during ionospheric disturbances.

The increase in the number of available GNSS satellites is an ongoing trend and there are numerous studies predicting the future benefits of combining the GPS and Galileo constellations. However, as this paper clearly demonstrates, there is no need to wait for future constellations like Galileo to gain the benefits of having access to additional GNSS satellites. The current GLONASS constellation may not have all the features of future GNSS systems, but it is available here and now. And over the last years the Russian government has proved its commitment to follow its launch plan for enhancing the GLONASS constellation. Most GNSS receiver manufacturers have also acknowledged this fact and provide combined GPS and GLONASS receivers.

Static Test Results

Fugro Seastar continuously monitors the performance of the G2 service. Figure 3 shows the horizontal position error (top) and the number of satellites used in the solution (bottom) of a combined GPS and GLONASS position solution on 28 March 2009 in Oslo. The position is for a static antenna in a known location with the navigation filter in dynamic solution mode. The position error is within about 10 cm and the blue reference line is at 20 cm.

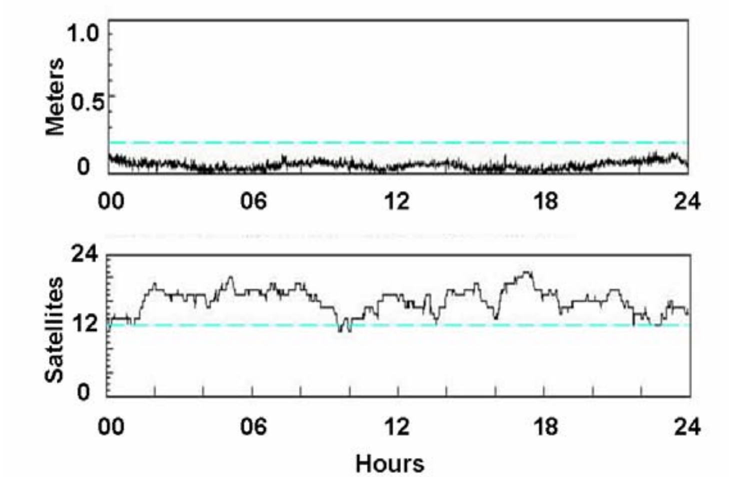

Figure 3: Position performance using GPS and GLONASS on 28 March 2009. The top plot is horizontal position error, and the bottom plot the number of satellites used in the solution.

Challenging Environment Test

In order to observe the benefits of adding GLONASS, tests were performed where an antenna was placed on a tripod next to a structure obstructing a large part of the sky (see Figure 4). During some periods this resulted in situations when there were only 2 or 3 GPS satellites available, and GLONASS satellites were required to get a solution.

Figure 5 shows results from such a test performed on 16 January 2009. In the bottom graph the number of GPS satellites is in black and the number of GLONASS satellites is in red. In the upper plot it can be seen that during periods with 2-3 GPS satellites, the system still produces an accurate solution to within about 0.2 metres.

Figure 4: Test in challenging environment, antenna on tripod next to obstruction.

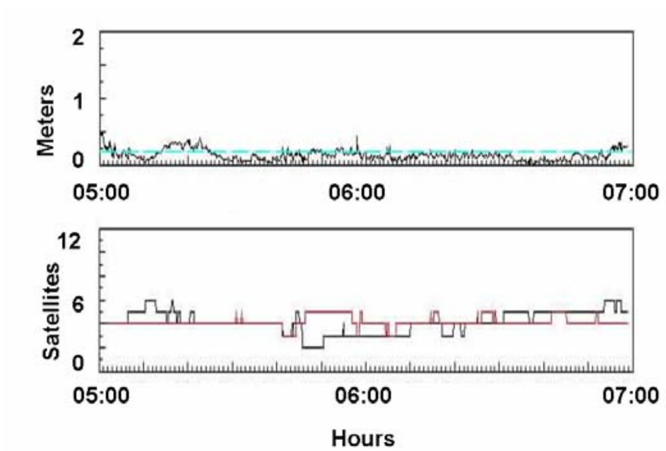

Figure 5: Errors during a two hours test next to an obstruction. The top plot shows horizontal position error and the bottom plot shows the number GPS (black) and GLONASS (red) satellites,

Figure 6: Bourbon Topaz.

Figure 7: Area offshore mid Norway served by Bourbon Topaz.

Figure 8: Antenna movement on Bourbon Topaz offshore due to wave motion.

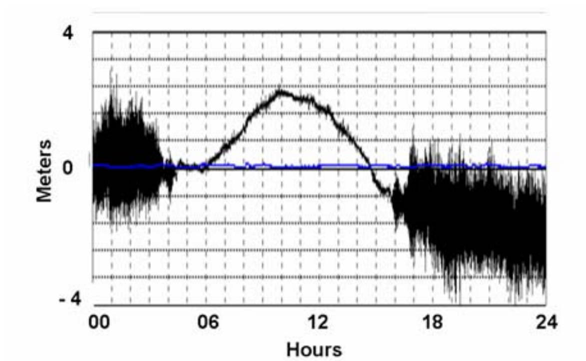

Figure 9: Relative height during 24 hours on Bourbon Topaz 16 October 2008. The vessel is at harbor between 0400 and 1600 where the tidal variation can be seen.

Dynamic Tests

A mobile system was placed on the supply vessel Bourbon Topaz (Figure 6) while working offshore mid Norway (Figure 7). Figure 8 shows the motions of the antenna on the vessel due to waves while supporting an offshore installation. The plot in Figure 9 shows the calculated height relative to the mean during a period of 24 hours. The vessel was at sea until 0400 where the waves make the height vary by 3-4 metres. During the period at harbour from 0400 to 1600, it is seen that the height varies with the tide. At 1600 the vessel departed the port. These tests show that the system also works in a typical offshore environment.

GLONASS Only Positioning Test

Traditionally it has been difficult to do tests where only GLONASS satellites are used in the solution because of low availability, and the test results have often suffered from this. Because the GLONASS constellation has increased to 20 satellites, we are now able to show full day plots with continuous high quality solutions using GLONASS only. Figure 10 shows the results from a GLONASS-only solution for 28 March 2009 for a receiver located in Oslo, Norway. However, due to too few available GLONASS satellites, most days there will not be 24 hour availability using only GLONASS.

The potential of using GLONASS, with G2 corrections, as a sole means positioning system to achieve decimetre level accuracy is clearly demonstrated. It is seen that the periods with the larger errors are due to poor geometry of the satellites, i.e. high HDOP (Horizontal Dilution of Precision). The accuracy of the GLONASS only solution is continually improving as the G2 system is being tuned.

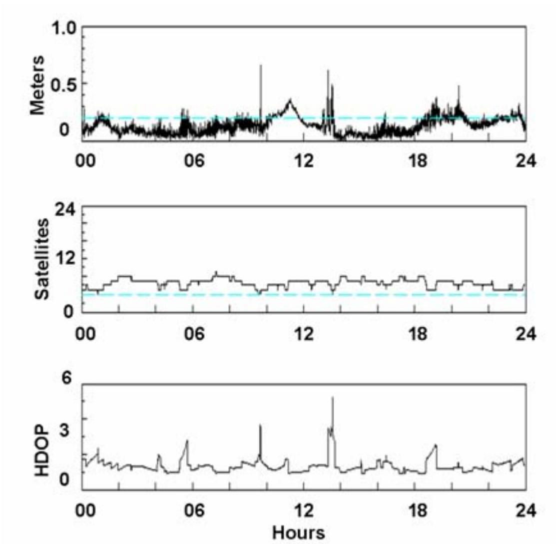

Figure 10: Static performance using GLONASS-only data on 28 March 2009. The top plot is horizontal position error, the middle plot the number of satellites used in the solution and the bottom plot HDOP.

Conclusions

The principal elements of Fugro's G2 system have been presented. Accuracy analyses in the satellite and user domains demonstrate decimetre level system accuracy achievable by PPP solutions, even for a sole means GLONASS user. It has further been shown that GLONASS is a good complement to GPS when satellite visibility is limited, and a high quality PPP solution may be maintained when GPS availability is too low.