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GNSS RTK PERFORMANCE IMPROVEMENTS USING GALILEO SATELLITE SIGNAL

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Two factors of the existing GNSS Real-Time Kinematic (RTK) positioning are as follows: distance-dependence and unreliable ambiguity resolution under bad observation conditions in cities or forests. Use of multi-frequency GNSS signals and systems could possibly redefine RTK services in LatPos, regionally and globally, and more redundant measurements from multiple satellite systems, such as NAVSTAR, Galileo, Glonass and BeiDou, can improve the performance of RTK measurement results in terms of accuracy, availability, reliability and time to fix. The benefits of multiple systems of GNSS services are as follows: 1) savings in the reference station infrastructure costs, and 2) improvement on RTK preciseness and reliability for the professional users. The paper aims at studying how the RTK system, using multiple satellite constellations, performs, adding Galileo signal measurements. Galileo measurements are observed using a field receiver and corrections received from LatPos base station network. Numerical analysis is performed using real-time corrections in field receivers, and results from collected RINEX data are compared by various computing schemes, such as L1/L2 and wide lane signals, NAVSTAR and NAVSTAR with Galileo measurements. The results have preliminary demonstrated the significant improvement using both GNSS satellite signals. Further improvements on the LatPos system have been introduced and the planned improvements shown.

Keywords: *Galileo, global navigation satellite system, satellite signal*

1. INTRODUCTION

Real-Time Kinematic (RTK) measurements with centimetre accuracy are used in all areas of economy.

Surveying measurements are done in cities and wooden areas with poor visibility. More than 5 satellites are needed to proceed with RTK measurements.

If multiple signals from navigation systems can be received by the GNSS RTK equipment, then there is a chance that satellite signals at least from five satellites will be received. Multi-constellation and multi-frequency GNSS RTK is a complex real-time process that aims at providing cm-level positioning accuracy with as few as possible data epochs for variable user kinematics and even in difficult measuring environments. RTK performance characteristics need to be carefully selected to be able to evaluate the system and users could use services for all they need in their applications.

The receiver parameters are used in the article to assess the benefits of Galileo for RTK:

1. Satellite usage. Number of satellites used in RTK fixed solutions with an elevation cut-off angle of 15°.
2. Availability. RTK fixed positions in clear sky visibility.
3. Accuracy. Deviation differences of RTK fixed positions between two receivers – with Galileo signal reception and without Galileo system. Both receivers running simultaneously.
4. Reliability. Percentage that the position error (with respect to ground truth) is less than 3 x coordinate quality (CQ) indicator.
5. Time to Fix. Time needed to reach the RTK fixed solution after each instrument restart [1].

In Latvia, RTK correction provider is the Latvian Positioning System (LatPos) maintained by LGIA.

In the territory of Latvia, the State Land Service has started to develop a real-time correction system since 2005 by creating the Latvian positioning system – LatPos, which was based on GNSS available at that time. Since 2006, the Latvian Geospatial Information Agency has been responsible for maintenance and development of LatPos [2]. As a state geodetic system, LatPOS is maintained and developed on a regular basis, so the possibility is created to ensure coordinate precision real-time corrections anytime, anywhere for spatial measurements of different kind. Originally, it was planned to use LatPOS real-time correction system in surveying and geodesy for determination of precise coordinates in real time of the measurement. As GNSS technologies developed, their usage also improved in various other branches of economics.

Research is conducted using statistical methods, comparing different measurement conditions to display the contribution of the Galileo GNSS system on the improvement of measurement accuracy.

The change in the number of satellites can be compared to the planned number. Let us consider the situation on 23 July for GNSS systems. Measurements were taken in the open, providing complete satellite signal reception. The present article studies the increase in measurement accuracy and measurement stability using Galileo system signals. The number of satellites at observation time (Fig. 1) has been considered.

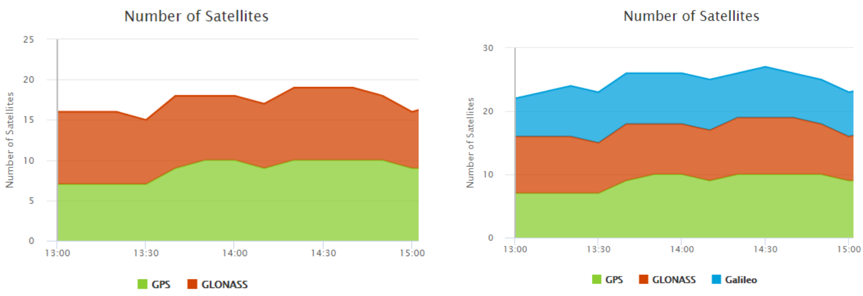


Fig. 1. Number of satellites in view (Trimble Online Planning).

Making measurements only with NAVSTAR and Glonass systems, the number of satellites is not more than 20 space vehicles. Adding Galileo GNSS signal, eight satellites will be added. It will significantly increase the number of available satellites.

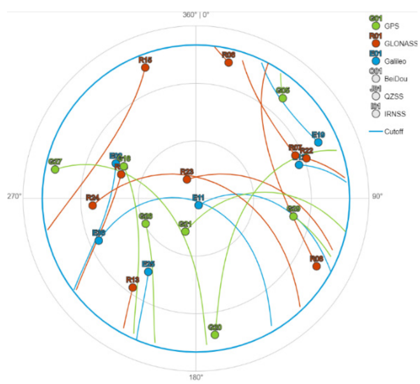


Fig. 2. Satellite sky plot.

As it can be observed (Fig. 2), Galileo satellites are in good constellation and this situation is proven by Position Dilution of Precision (PDOP), PDOP value of which (Fig. 3) must be near 1, then it is the best satellite constellation.

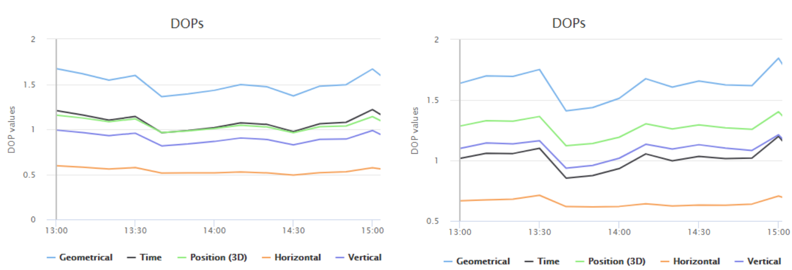


Fig. 3. Dilution of precision.

Without Galileo satellite signals, PDOP is 1.23, but the instrument with Galileo satellite signals PDOP is 1.04.

Ionosphere impact is small as Total Electron Content (TEC) is low and Ionospheric Index is also low (Fig. 4).

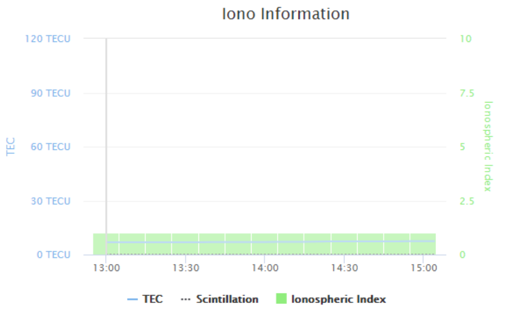


Fig. 4. Ionospheric information.

2. EXPERIMENTAL PART

When measurements are carried out under good conditions, with many satellites with good PDOP and a low ionosphere index, we can assume that these values have no effect. Further experiments are carried out to determine the accuracy of the measurements, the time to the FIX depending on the distance of the rover from the LatPos base station. Only a few stations on the LatPos system provide Galileo signal reception. Consequently, one base station, OJAR, has been used.

Two receivers have been used simultaneously for data acquisition and calculations. By placing two rover receivers side by side and measuring simultaneously, the same conditions are ensured: satellite positioning, ionosphere, satellite visibility, PDOP, and other conditions. Correction data are received from LatPos system in the same way. This ensures that the exact differences that result from measurements with and without Galileo satellite signals will be displayed.

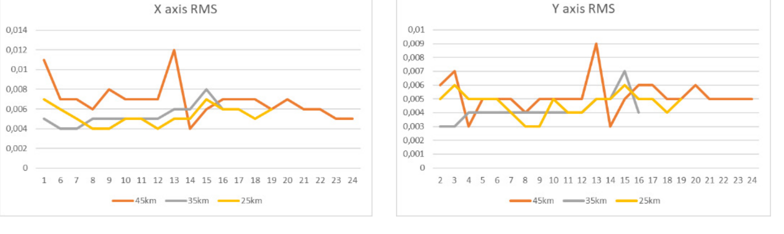
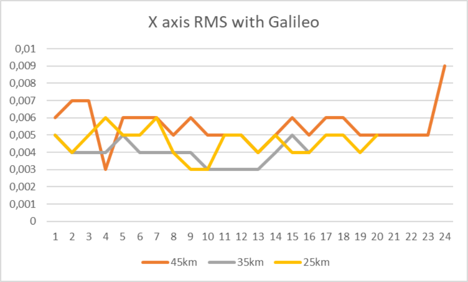


Fig. 5. X and Y coordinate RMS with different baseline length.

Taking into account the general assumption that correction errors up to 10 km from the base station are identical in both the rover receiver and the base station and the assumption that the baseline should not exceed 35 km to provide real-time online measurements, the following distances to the base station have been selected: 25 km, 35 km and 45 km [4]. The longest baseline has been selected over 35 km to ensure that measurements with baselines above 35 km could be performed using the Galileo signal. X and Y coordinate RMS measurements without Galileo satellite signal (Fig. 6) are increasing only few millimetres with a longer baseline (Fig. 5).



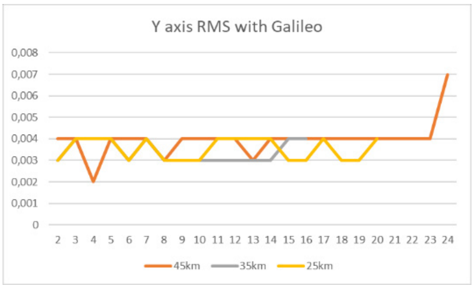


Fig. 6. Coordinate RMS using Galileo signal in calculations.

The instrument receiving the Galileo signal reduces the mean quadratic error of the measurements and is more stable. This means that the Galileo signal provides increased accuracy and stability of measurements. As measurement weights fall within the error limits, measurement stability is a major consideration.

The additional reception of Galileo satellites increases the number of satellites, resulting in a more homogeneous distribution and lower PDOP. As it is shown in Fig. 7, PDOP value decreases by about 20 % and it ensures an increase in measurement accuracy.

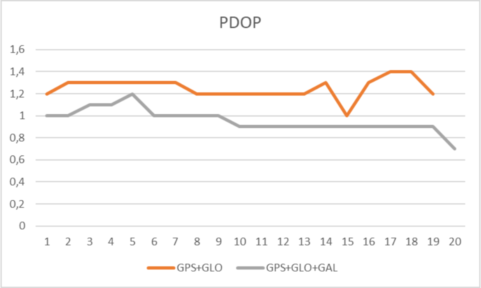


Fig. 7. Satellite PDOP changes in time.

As the distance from the base station to longer baselines increases, the time to the FIX position should increase as the rover instrument has other measurement conditions – the ionosphere and the troposphere.

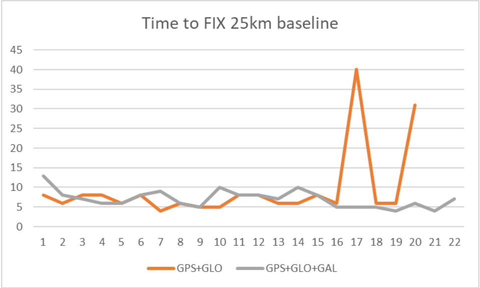


Fig. 8. Time to FIX on 25 km baseline.

Only by increasing the distance from 25 km to 35 km it can be observed that the average size does not change for 9 seconds. Measuring 45 km from the base station, the fixation time is even reduced (Figs. 9 and 10).

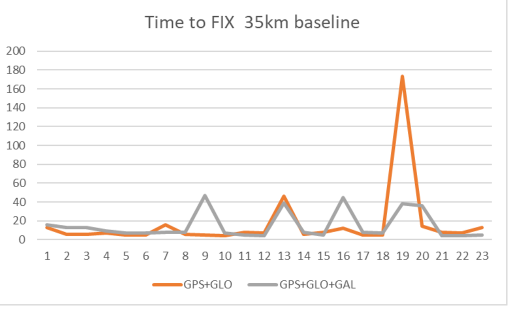


Fig. 9. Time to FIX on 35 km baseline.

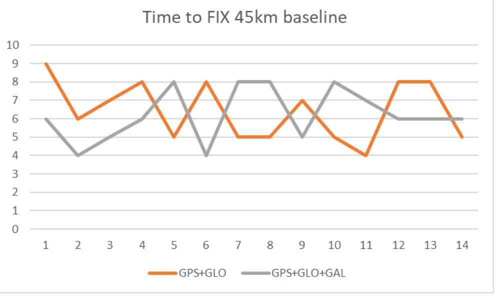


Fig. 10. Time to FIX on 45km baseline.

3. CONCLUSIONS

Having conducted the research, the following conclusions can be drawn:

- Galileo satellite system signal increases the number of satellites providing multiple measurements to satellites;
- The number of satellites increases by adding Galileo satellites, the PDOP improves by at least 20 %;
- Coordinate accuracy improves within error limits and remains independent of distance to base station, even when measuring on baseline longer than 35 km;
- Using Galileo satellite signals, the RMS of the measurements is reduced and becomes more stable. This increases the reliability of the measurements;
- When moving away from the base station, the time to fix increases by only 10 %. This means that the biggest factor for fixation time is the continuous and uninterrupted flow of correction data. Even on the longest baseline – 45 km, time to fix is shortest.

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GNSS RTK VEIKTSPĒJAS UZLABOJUMI, IZMANTOJOT GALILEO SATELĪTA SIGNĀLU

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Kopsavilkums

Divi GNSS reālā laika kinemātiskās (RTK) pozicionēšanas faktori ir atkarība no attāluma līdz bāzes stacijai un slikti novērošanas apstākļi pilsētās vai mežā. Daudzfrekvences GNSS signālu un sistēmu izmantošana, iespējams, varētu uzlabot RTK pakalpojumus LatPos sistēmā, reģionālā un globālā mērogā. Precīzāki mērījumi no vairākām satelītu sistēmām, piemēram, NAVSTAR, Galileo, Glonass un BeiDou, var uzlabot RTK mērījumu rezultātu veikšanu attiecībā uz precizitāti, pieejamību, uzticamību un laiku līdz fiksācijai. Ieguvumi no vairākām GNSS pakalpojumu sistēmām ir šādi: 1) stacijas infrastruktūras izmaksu samazinājums; 2) RTK precizitātes un uzticamības uzlabošana profesionāliem lietotājiem. Darba mērķis ir izpētīt kā darbojas RTK sistēma, izmantojot vairākas satelīta sistēmas, pievienojot Galileo signāla mērījumus. Galileo mērījumi tiek novēroti, izmantojot lauka uztvērēju un korekcijas, kas saņemtas no LatPos bāzes staciju tīkla. Skaitliskā analīze tiek veikta, izmantojot reāllaika korekcijas lauka uztvērējos, un iegūtos RINEX datu rezultātus salīdzina dažādas skaitļošanas shēmas, piemēram, L1 / L2 signālus, NAVSTAR un NAVSTAR, ar Galileo mērījumiem. Rezultāti provizoriski parādīja būtisku uzlabojumu, izmantojot abus GNSS satelīta signālus. Darbā ieviesti turpmāki LatPos sistēmas uzlabojumi un parādīti plānotie uzlabojumi.

Atslēgas vārdi: *Galileo, globālā satelītu navigācijas sistēma, satelīta signāls*