Alternative navigation systems use for satellite positioning in Russia

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Abstract. The article provides a comparative analysis of the joint application and accuracy of determining the locations by GLONASS, Galileo, BeiDou satellites, obtained from the navigation messages and available forecasting algorithms.

Nowadays the high-precision satellite definitions are based not only on the two-frequency measurement mode use, but also on the information inclusion from various existing satellite systems in processing [1,2]. Practical experiments performed in 2016 at latitude $B=47^\circ$ and presented in [3], confirmed the advantages of the GPS and GLONASS satellite systems’ joint use. To date, alternative GNSSs have appeared – the European “Galileo” and the Chinese “BeiDou”, the capabilities’ studies of which are not given due attention to. Therefore, we will try to compare the location determination accuracy by GLONASS, Galileo, BeiDou satellites received by the navigation messages, by comparing them with the exact data provided by the International GNSS Service (IGS), as well as with the available GNSS prediction algorithms available on the satellite observation equipment manufacturer Trimble site.

Introduction

The possibilities study of using GNSS GLONASS, Galileo, BeiDou was conducted for a single observer location point. The point parameters for a fixed longitude are selected as the observer placement $L = 38^\circ$ e.l. and more north latitude observation points $B = 67^\circ$n.l. [4]. Geodesic height of the observation point above the Earth ellipsoid is $H = 50$ m. For the intended purpose, the following were used: 24 SC (Spacecraft) – GNSS GLONASS; 27 SC – GNSS Galileo, GNSS BeiDou - 35 SC. Clipping mask angle is $\beta = 10^\circ$. The observation time was chosen from 00 h 00 min 00 sec till 23 h 59 min 59 sec on the date 08.10.2019. The observation time discreteness is $\Delta t = 5$ min.

The first analysis was performed for the domestic GNSS GLONASS.

According to Figure 1, it is obvious that the maximum number of satellites did not exceed 11, the minimum number was 7.
Figure 1. Display of the number of satellites GNSS GLONASS

Figure 2 shows a graph of the instantaneous values of the geometric factor coefficients GDOP GNSS GLONASS on the measurements date. The results analysis showed:

- minimum daily value of the geometric decrease coefficient in accuracy by location and time GDOP GNSS GLONASS 1.46, - maximum value 3.0;
- minimum daily value of the geometric decrease coefficient in accuracy by location PDOP GNSS GLONASS 1.33, - maximum value 2.6;
- the minimum daily value of the decrease coefficient in accuracy in the horizontal plane HDOP GNSS GLONASS 0.82, - maximum value 1.4.

Figure 2. Display of minimum and maximum accuracy GNSS GLONASS reduction factors

For the European GNSS Galileo Figure 3 shows that the maximum number of satellites did not exceed 10 SC, - the minimum was 5 SC.

Figure 3. Display of the number of satellites GNSS Galileo
Figure 4 shows a graph of the GNSS Galileo geometry coefficients instantaneous values. The results analysis shows:

– minimum daily value of the geometric decrease coefficient in accuracy by location and time GDOP GNSS Galileo 1.66, - maximum value 3.1;
– minimum daily value of the geometric decrease coefficient in accuracy by location PDOP GNSS Galileo 1.53, - maximum value 2.8;
– the minimum daily value of the decrease coefficient in accuracy in the horizontal plane HDOP Galileo 0.81, - maximum value 1.6.

![Figure 4. Display of minimum and maximum accuracy reduction factors GNSS Galileo](image)

For the Chinese GNSS BeiDou Figure 5 shows that the maximum number of visible satellites did not exceed 21 SC, - the minimum was 14 SC.

![Figure 5. Display of the GNSS BeiDou satellites number](image)

Figure 6 shows a graph of the geometry coefficients instantaneous values GDOP GNSS BeiDou. The graph is built according to the measurements. The results analysis shows:

– minimum daily value of the geometric decrease coefficient in accuracy by location and time GDOP GNSS BeiDou 1.12, maximum value – 1.6;
– minimum daily value of the geometric decrease coefficient in accuracy by location PDOP GNSS BeiDou 1.01, maximum value – 1.5;
– the minimum daily value of the decrease coefficient in accuracy in the horizontal plane HDOP GNSS BeiDou 0.57, maximum value – 0.8.

![Figure 6. Display of minimum and maximum accuracy reduction factors GNSS BeiDou](image)
As it can be seen from the above-showed graphs, the minimum values of the accuracy decrease coefficients and the maximum number of visible satellites are shown by the Chinese GNSS BeiDou, which is achieved by high technical equipment and the total number of spacecrafts. However, in order to improve the data quality received from the GNSS comparative analysis of sharing GNSS GLONASS-Galileo, GLONASS-BeiDou, BeiDou-Galileo, as well as all the above-mentioned systems at the same time.

Figure 7. Display of the satellites number when sharing GNSS GLONASS-Galileo

Figure 7 shows that the maximum number of satellites when GNSS GLONASS- Galileo joint use did not exceed 19 SC.

Figure 8 shows a graph of the geometry coefficients’ instantaneous values for GNSS GLONASS-Galileo joint use. The graph is built according to the measurements. The results analysis shows:

- the minimum daily value of the geometric decrease coefficient in accuracy by location and time GDOP with GNSS GLONASS-Galileo joint use is 1.19, the maximum value – 2.4;
- the minimum daily value of the geometric decrease coefficient in accuracy by location PDOP with GNSS GLONASS-Galileo joint use is 0.97, the maximum value – 1.6;
- the minimum daily value of the decrease coefficient in accuracy in the horizontal plane HDOP with GNSS GLONASS- Galileo joint use is 0.57, the maximum value – 0.8.

Figure 8. The accuracy reduction factors’ values with GNSS GLONASS-Galileo joint use

The data of the joint use analysis GNSS GLONASS- BeiDou are presented below.

Figure 9 shows that the maximum number of satellites with GNSS GLONASS- BeiDou joint use did not exceed 31 SC.
Figure 9. Display of the satellites number with GNSS GLONASS- BeiDou joint use

Figure 10 shows a graph of the geometry coefficients’ instantaneous values for the joint use GNSS GLONASS - BeiDou. The graph is built according to the measurements. The results analysis shows that:

– the minimum daily value of the geometric decrease coefficient in accuracy by location and time GDOP with GNSS GLONASS-BeiDou joint use is 1.06, the maximum value – 1.5;
– the minimum daily value of the geometric decrease coefficient in accuracy by location PDOP with GNSS GLONASS-BeiDou joint use is 0.85, the maximum value – 1.2;
– the minimum daily value of the decrease coefficient in accuracy in the horizontal plane HDOP with GNSS GLONASS-BeiDou joint use is 0.47, the maximum value – 0.6.

Figure 10. Display of the decrease minimum and maximum coefficients in accuracy with GNSS GLONASS-BeiDou joint use

For the next pair GNSS Galileo and BeiDou Figure 11 shows that the maximum number of satellites with GNSS Galileo – BeiDou joint use reaches 31SC.

Figure 11. Display of the satellites number with GNSS Galileo – BeiDou joint use

Figure 12 shows a graph of the geometry coefficients’ instantaneous values for the GNSS Galileo -
BeiDou joint use. The graph is built according to the measurements. The results analysis shows:
- the minimum daily value of the geometric decrease coefficient in accuracy by location and time GDOP with GNSS Galileo – BeiDou joint use is 1.03, the maximum value – 1.6;
- the minimum daily value of the geometric reduction coefficient in accuracy by location PDOP with GNSS Galileo – BeiDou joint use is 0.84, the maximum value – 1.24;
- the minimum daily value of the decrease coefficient in accuracy in the horizontal plane HDOP with GNSS Galileo – BeiDou joint use is 0.46, the maximum value – 0.69.

![Graph](image)

**Figure 12.** Display of the decrease minimum and maximum coefficients in accuracy with GNSS Galileo – BeiDou joint use

As mentioned above, the satellites number analysis, as well as the accuracy reduction coefficients’ minimum values was also carried out for the simultaneous GNSS GLONASS- Galileo – BeiDou joint use. The data obtained are presented below.

Figure 13 shows that the maximum number of satellites with GNSS GLONASS-Galileo-BeiDou joint use makes up 40 SC.

![Satellite Graph](image)

**Figure 13.** Display of the satellites number with GNSS GLONASS-Galileo- BeiDou joint use

Figure 14 shows a graph of the geometry coefficients instantaneous values with GNSS GLONASS-Galileo- BeiDou joint use. The results analysis shows:
- the minimum daily value of the geometric decrease coefficient in accuracy by location and time GDOP with GNSS GLONASS - Galileo – BeiDou joint use is 1.07, the maximum value – 1.4;
- the minimum daily value of the geometric decrease coefficient in accuracy by location PDOP with GNSS GLONASS – Galileo - BeiDou joint use is 0.75, the maximum value – 1.0;
- the minimum daily value of the decrease coefficient in accuracy in the horizontal plane HDOP with GNSS GLONASS - Galileo – BeiDou joint use is 0.41, the maximum value – 0.52.
Figure 14. Display of minimum and maximum accuracy reduction factors with GNSS GLONASS - Galileo – BeiDou joint use

Summary
The data obtained indicate that when it becomes necessary to use only two GNSS systems, the lowest values of accuracy reduction coefficients, which means that the ability to obtain the location and altitude data with high accuracy, a pair GNSS Galileo – BeiDou shows. This is due to both qualitative NSC differences, and their total number.

However, to obtain the most reliable and complete data on the observer’s location coordinates it is necessary to simultaneously use GNSS GLONASS – Galileo - BeiDou.

As it can be seen from the above-shown graphs, the maximum number of simultaneously observed satellites with a single use GNSS GLONASS-Galileo-BeiDou is almost 4 times higher (11 satellites in the GNSS GLONASS system, versus 40 satellites), as well as the minimum accuracy reduction factors with GNSS GLONASS-Galileo- BeiDou joint use is 2.2 times lower on average than using a single GNSS GLONASS system.

The use of alternative satellite systems is not inferior in SC quantity and geometrical factors of the systems used in Russia, but requires further practical confirmation of the results on the actual positioning accuracy.

References
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