Atinç PIRTI[1], Mehmet Ali YÜCEL[2]

[1*] Yıldız Technical University, Department of Geomatics Engineering, 34220 Esenler, Istanbul, Turkey
[2] Çanakkale Onsekiz Mart University, Department of Geomatics Engineering, 17100, Çanakkale, Turkey
*Corresponding Author: atinc@yildiz.edu.tr, http://orcid.org/0000-0001-9197-3411

https://doi.org/10.23939/istcgcap2023.98.005

GPS SIGNAL JAMMING EFFECT IN SVALBARD ISLAND AND ITS ELIMINATION BY USING GLONASS, GALILEO AND BEIDOU SATELLITES

The Svalbard Islands are located in the Arctic Ocean, halfway between Norway and the North Pole. Because of this, the Svalbard Islands exhibit a number of special properties that make it an interesting region for studying interactions between the atmosphere, sea ice, and ocean. In this study, satellite signals of three points (NABG, NYA2 and NYAL) on the island of Svalbard in the Barents Sea were examined. On January 8, 2022, signal jamming effects appeared at all three points. From these two points (NYA2, NYAL), it was obvious that GLONASS, Galileo and Beidou satellites were also recorded in the receivers as well as GPS satellites. For this reason, the effect of the jamming effect on the GPS signals on the position accuracy was investigated using both static and kinematic methods. In addition, both static and kinematic processing at these two points was performed with GLONASS-Galileo-Beidou satellite combinations in order to eliminate the GPS jamming effect. Although the GPS jamming effect is not obtained in large values in the static process, when only GPS satellites are used in the kinematic process, it reaches approximately 5 meters as the maximum horizontal coordinate difference. The maximum height difference recorded was approximately 15 meters. The difference in coordinates between the kinematic and static processes, as determined through the use of GLONASS, Galileo, and Beidou satellites, was around 5 cm. However, in terms of height values, it reached up to about 10 cm. In the Svalbard Islands, when GPS signals are exposed to interference, satisfactory results were obtained by using GLONASS-Galileo-Beidou satellites.

Key words: GPS, GLONASS, Galileo, Beidou, Signal Jamming, Svalbard Islands, Accuracy

Introduction

Electronic attacks are not always precise. During an attack, jamming signals radiate outward from a central source, and can affect any device that is within both range and line of sight. Often, only high-profile jamming occurrences affect larger entities, such as governments, large commercial airlines, or media organizations. They are usually reported in the media or by government agencies. Therefore, discrete points presented on the maps do not necessarily represent the full scope signal loss of jamming-affected areas. Jamming of GPS signals is not only a matter for the military but even more so for the civilian part of society. In case of an emergency on land, at sea, or in the air, loss of GPS may lead to a higher risk of navigation error, causing much longer time to locate a person or a group of people in distress (Nilsen 2019). Both military and civilian entities make regular use of satellite-enabled Global Positioning System (GPS) and communication technology via signals transmitted over various radio frequencies. However, reliable transmission of this information can be disrupted through electronic counter-space attacks, including jamming and spoofing. Without GPS, aircraft pilots and ship captains can lose the ability to verify their precise position, especially if it is not obvious to them that service has lapsed, Aerospace Security (2022). In general, a lot of research has been done on blocking GPS signals. The effect of GPS/GNSS jammers on receivers has been shown by Borio et al. (2016), Borio and Groia (2021), Pinker and Smith (1999), Fu et al. (2003), Fariu et al. (2016), Faria et al. (2016), and Marcus (2014). It has been shown by Gorski (2018) and Westbrook (2019) that GPS jammers disrupt military operations. GPS signal jamming has been shown by researchers Goward (2017), Mizokami (2016), Stanlesen (2018), Glomsvoll and Bonenberg (2017), and Trevithick (2018) in the Black Sea, North Korea, Norway, Northern Sea, and Syria, respectively. According to Hu et al. (2018), GNSS spoofing detection is based on a novel model for evaluating signal quality. Martini (2016) has shown that China can block GPS satellite signals. This anti-jamming solution for GPS receivers has been shown by Mosavi et al. (2017), Moussa et al. (2017), Stopienski (2020), Aghadadasfam et al. (2020), CRFS (2019), and Wang et al. (2021). In this study, the effect of signal jamming on the island of Svalbard on GPS and other satellite systems was investigated.

The ability of jammers to impact GPS signals, as well as solutions for preventing distortions, was investigated in this research. Jamming with GPS signals in the Svalbard Islands peaked on January 8, 2022 (between 00:00:00 and 24:00:00). Not only the data from January 8, 2022 but also the instances from January 8, 2022, were analysed.

Materials and Methods

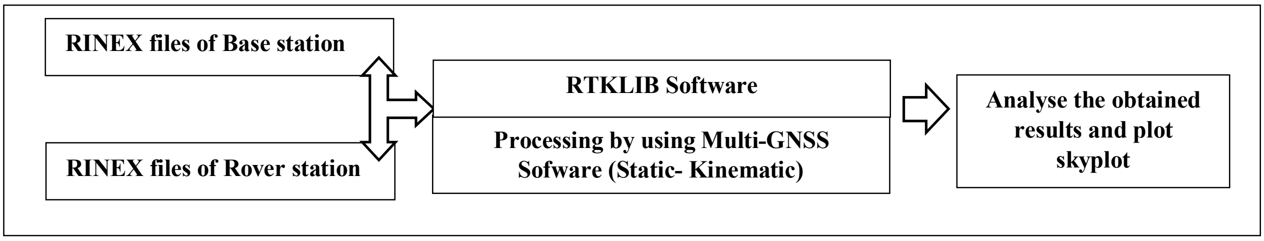
The use of Global Navigation Satellite Systems (GNSS) in the field of earth sciences has grown widely prevalent. GNSS data has the capability to provide measurements with a high level of accuracy and resolution within widely accepted reference frames. Static GNSS techniques use extended periods of data collection to provide precise measurements and time-series data acquisition. This enables the detection and analysis of many phenomena, including tectonic deformation, earthquakes, groundwater depletion, and the gradual movement of landforms. The primary objective of this course is to explore the principles and practices involved in designing and implementing basic static surveys. The emphasis will be placed on understanding the advantages and constraints associated with this particular method. Students will acquire knowledge on the specific domains in which the methodology is best suitable, along with the conventional methods used for data processing. Furthermore, students enhance their comprehension of GNSS systems by analysing field data obtained from static surveys and public data sets of continuously-operating stations. This section provides students with the necessary skills to create and execute their own survey by offering practical education and demonstrating both rapid-static and static approaches in a real-world environment.

Kinematic GNSS surveys are used for the efficient acquisition of a substantial quantity of survey locations with a high level of accuracy. These positions are then subjected to post-processing procedures by comparing them against a stationary base station. The system consists of three main components: a base station, a rover, and, optionally, a radio system. The fundamental component of the kinematic system comprises a mobile rover, responsible for acquiring starting positions, and a base station, which facilitates the adjustment of the rover's location. The rover is transported to each designated measurement location and is thereafter stabilized for a brief period, generally ranging from 5 to 30 seconds, in order to get an initial position. The location of the rover is compared to the position of the static base station in order to eliminate various sources of inaccuracy, such as integer ambiguity and atmospheric delays. As a consequence, the rover achieves a location with a high level of accuracy, often within the range of a few millimetres. The correction may be implemented either at the post-processing stage or in real-time if the rover gets correction data over a radio or cellular link.

A flowchart of this research is illustrated in Table 1.

Table 1

A flowchart of the research



Svalbard Island Region

Svalbard, also known as Spitsbergen, or Spitzbergen, is a Norwegian archipelago in the Arctic Ocean. North of mainland Europe, it is about midway between the northern coast of Norway and the North Pole. The islands of the group range from 74° to 81° north latitude and from 10° to 35° east longitude. The largest island is Spitsbergen, followed by Nordaustlandet and Edgeøya. The largest settlement is Longyearbyen (Wikipedia (2022), World Wildlife Fund (2008)). Many polar expeditions have made Svalbard their base for scientific purposes. The first polar exploration was conducted by British Captain C.J. Phipps in 1773, followed by Norwegian, Swedish, and German groups in the 19th century. Mapping, polar flights, and geologic surveys continued through the first half of the 20th century. The Norwegian Polar Institute, headquartered in Oslo, furthers the work begun by earlier expeditions. The population (there are no indigenousinhabitants) changes seasonally but generally numbers about 3,000. Longyearbyen is the administrative centre. During the summer months, tourists arrive by boat at Hotellneset, on Advent Fjord.

The island of Svalbard in the Barents Sea was chosen as the study area (Fig. 1). The use of GNSS in the Arctic has recently gained importance, due to the growth of human activities such as oil drilling, shipping, and tourism. Much attention was also given to risks related to decreased accuracy and reliability of the navigation solution. Furthermore, high-latitude regions are generally characterized by poor satellite geometry and high GDOP values, further reducing the positioning quality. Satellite signals on 8 January 2022 of three points (NABG, NYAL, NYA2) in this island were analysed. In addition to GPS satellites, GLONASS-Galileo-Beidou satellites are also recorded at only two of the three points (NYA2, NYAL). Satellite data of these three points on January 8, 2022 have been downloaded from the web page of IGS. The Norway-EUREF89 NTM5 coordinates obtained as a result of the static processing of these data of the three points are shown in Table 2.

Results

As mentioned above, the reason for using NYAL and NYA2 points in this study is that these two points record GLONASS, Galileo and Beidou signals. The total satellite numbers with account of NYA2 and NYAL receivers and elevation masks were between 22 and 54 (Fig. 2).

Figs 3,4 and 5 were performed by using RTKLIB v.2.4.3 software. Fig. 3 (left) depicts the visibility of several satellites in an open-sky simulation scenario. Fig. 3 (right) shows the discontinuity (Pirti and Yucel 2022).

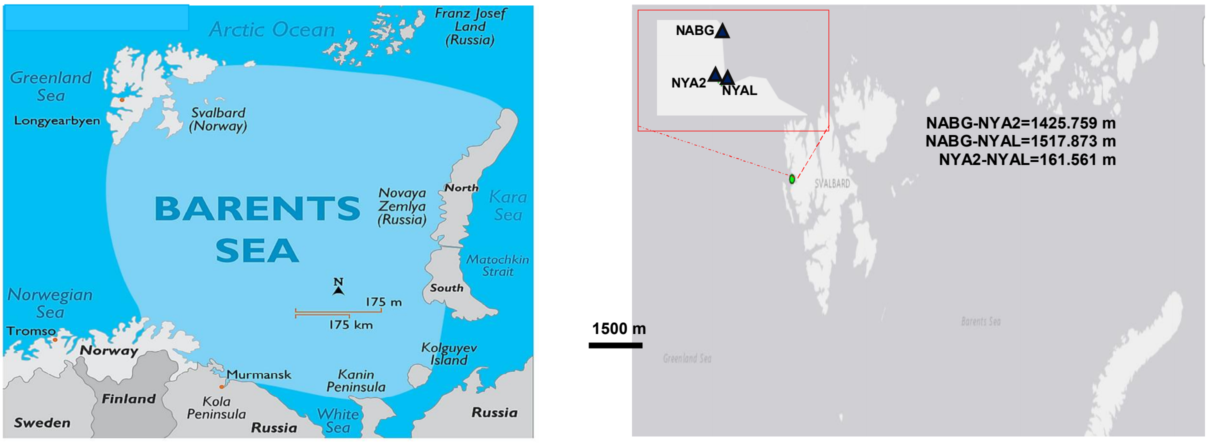


Fig. 1. Project area and NABG, NYA2 and NYAL IGS points located in the Svalbard Island

Table 2

IGS Points NABG, NYA2 and NYAL coordinates (Norway-EUREF89 NTM5) in the Svalbard Islands (static process, using GPS, GLONASS, Galileo, Beidou satellites)

Name	Grid Northing (m)	Grid Easting (m)	Elevation (m)	Std (N) (m)	Std (E) (m)	Std (h) (m)
NABG	3343255,159	235905,11	43,004	0,002	0,002	0,010
NYA2	3341841,418	236088,194	81,506	0,002	0,002	0,010
NYAL	3341773,631	236234,858	78,711	0,002	0,002	0,010

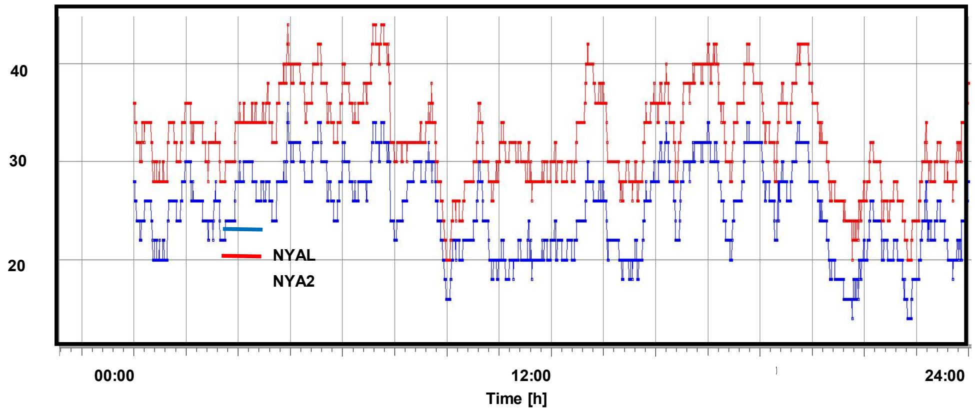


Fig 2. Total satellites number with account of receiver and elevation mask

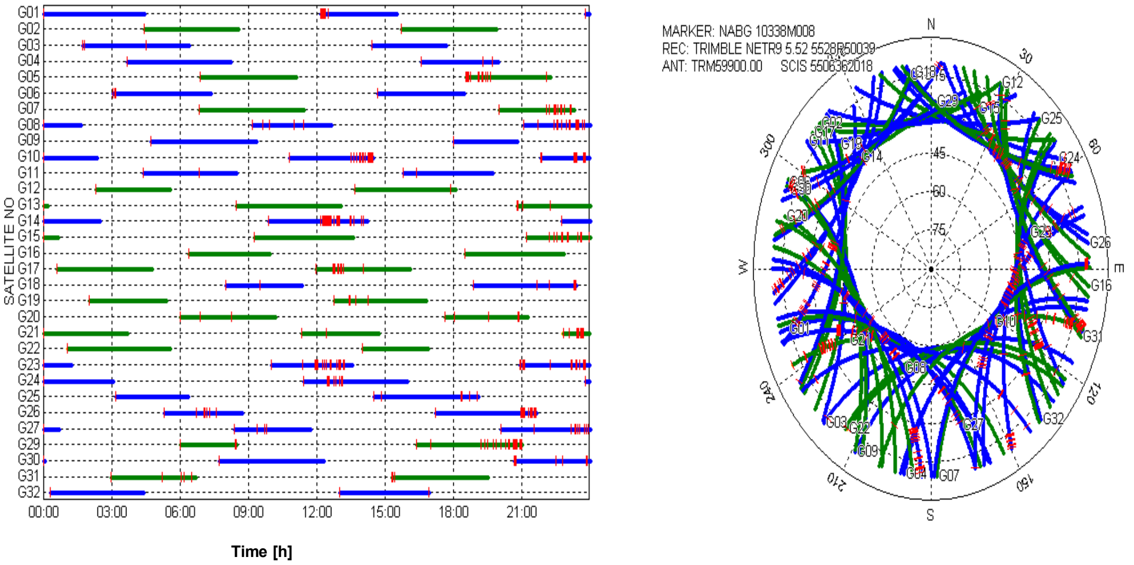


Fig. 3. Skyplot (left) and GPS satellite visibility plot of NABG point of the island of Svalbard during the presence of jamming signals during January 8, 2022, (right)

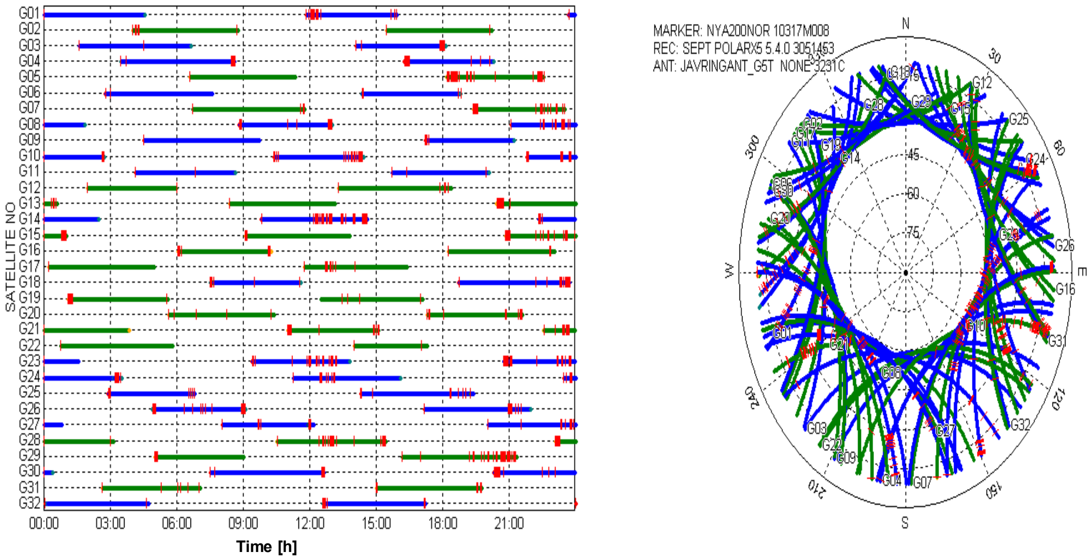


Fig. 4. Skyplot (left) and GPS satellite visibility plot of NYA2 point of the island of Svalbard during the presence of jamming signals during January 8, 2022, (right)

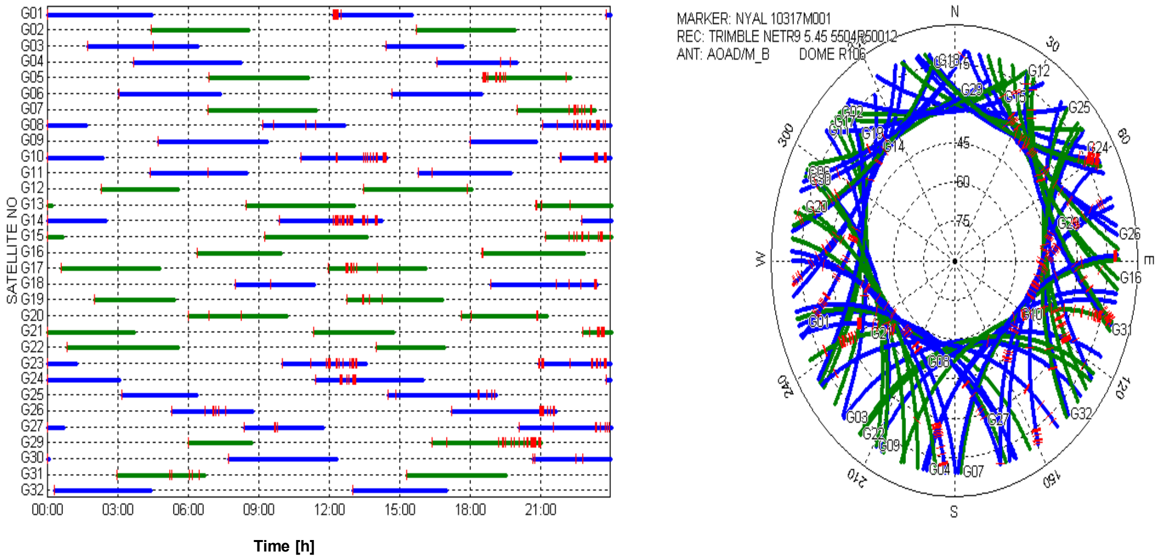


Fig. 5. Skyplot (left) and GPS satellite visibility plot of NYAL point in of the island of Svalbard during the presence of jamming signals during January 8, 2022, (right)

Fig. 4 (left) demonstrates the visibility of several satellites in an open sky simulation scenario. Fig. 4 (right) depicts the discontinuity (Pirti and Yucel 2022).

Fig. 5 (left) illustrates the visibility of several satellites in an open sky simulation scenario. Fig. 5 (right) depicts the discontinuity (Pirti and Yucel 2022). Figs 3, 4 and 5 clearly show the jamming effect of the GPS signals.

Investigation of Signal Jamming Effect on GPS and GLONASS, Galileo, and Beidou Satellites especially for static and kinematic processing

Static Processing

It seems quite difficult to obtain the jamming effect from the static processing results. Table 2 shows the distances between NYA2 and NYAL obtained by using the static processing of GPS-only satellites on January 8, 2022, (between 00:00 and 24:00 hours). On January 8, 2022, between 00:00-24:00 hours, the baseline lengths (NYA2-NYAL) were measured using static processing of signals from GLONASS, Galileo, and Beidou satellites. These values were then compared with GPS-only processed values. The comparison showed an improvement in the base length of 1 mm. The obtained baseline lengths (NYA2-NYAL) by using static processing the signals of GLONASS, Galileo, and Beidou satellites on January 8, 2022, (between 00:00-24:00 hours) were compared with GPS-only processed values. According to the obtained results from this comparison, an improvement in the base length of 1 mm was obtained (Pirti and Yucel 2022).

As seen in Fig. 6, the number of GPS satellites seen for NYA2 and NYAL points was obtained in the range of 9 to 14. However, for the GLONASS, Galileo and Beidou satellites, this number remains in the range of 7-11 (Fig. 6a), 7-13 (Fig. 6b) and 6-14 (Fig. 6c), respectively. On January 8, PDOP values of GPS satellites between NYA2 and NYAL points were obtained in the range of 0.50 and 1.550. On January 8, 2022, PDOP values of GLONASS, Galileo and Beidou satellites between NYA2 and NYAL points were obtained in the range of 0.50 and 1.650.

Table 2

Comparison of the obtained baseline values among the different satellite configurations (static processing) by using Software (Topcon Magnet Tools 7.3.0)

Baseline	S **(GPS/08.01.2022)**	S **(GLONASS-Galileo-Beidou/08.01.2022)**
NYA2-NYAL	161.562 m	161.561 m

Kinematic Processing

Coordinate differences (between kinematic and static processing) were compared in order to make this jamming effect more evident and to eliminate it. Since the kinematic process includes real-time position determination and broadcast ephemeris information is used, the jamming effect on the GPS signal becomes clear from the coordinate differences in the kinematic processing results (Fig. 7a). When analyzing satellite data for kinematic processing in a jamming situation, GLONASS, Galileo, and GPS satellites showed significant improvements in standard deviation and mean values, except for Beidou-only. (Figs 7b and 7c). This study presents the advantages of selecting GLONASS, Galileo and Beidou (GGB) processing as an alternative method in the regions with GPS jamming effects.

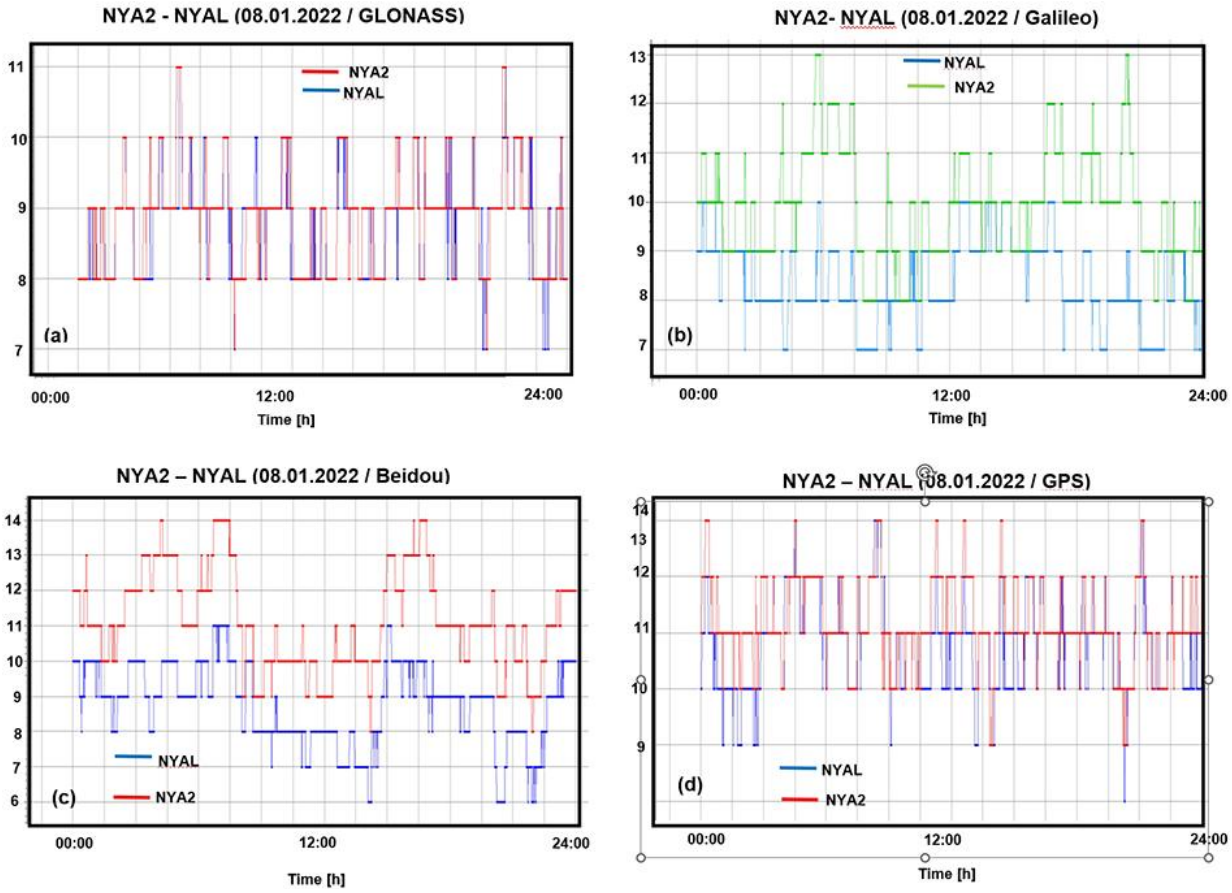
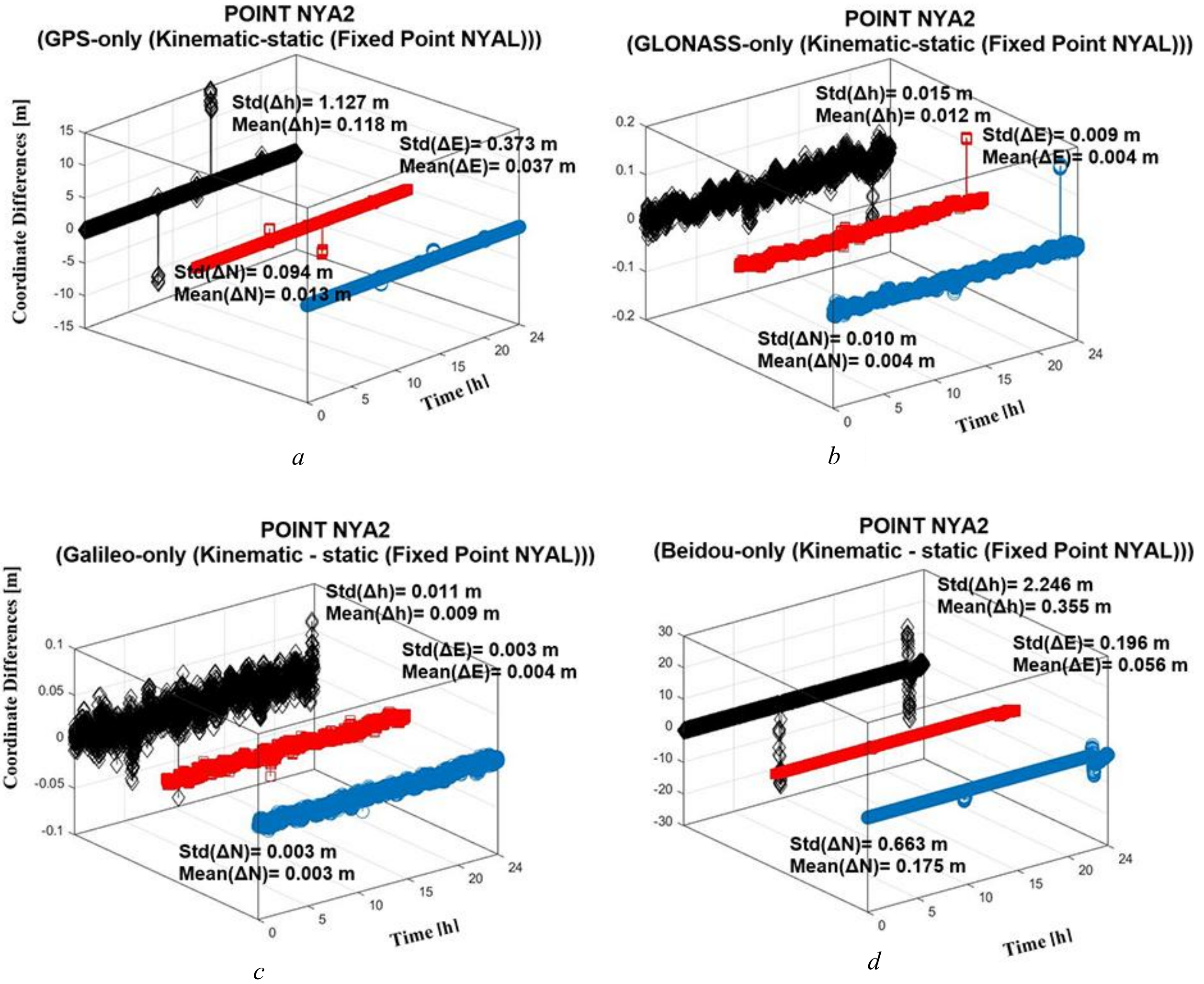


Fig. 6. Satellites numbers (GLONASS, Galileo, Beidou and GPS) of baseline NYA2-NYAL on January 8, 2022, between 00:00 and 24:00 hours

The obtained results between the kinematic processing and static processing of NYA2 point on 8 January 2022 by using GPS-only satellites and fixing point NYAL are shown in Fig. 7. The three-dimensional coordinate differences of NYA2 point between the hours of 00:00-24:00 on January 8, 2022, reached about 5 meters. Integer ambiguity could not be resolved with enough accuracy due to jamming in the GPS signal at certain time intervals. The standard deviation values of the coordinate differences of NYA2 point, obtained on January 8, 2022, between 00:00-24:00 hours, are 0.094-1.127 m, and the mean values are approximately 0.013-0.118 m, see Fig. 7a. Figs 7b and 7c show that the standard deviation and mean values of the coordinate differences led to increase in accuracy level (Pirti and Yucel 2022).

Additionally, processing of GLONASS/Galileo, GLONASS/Beidou, Galileo/Beidou, and GLONASS/Galileo/Beidou satellite configurations was performed. Fig. 8 compares the coordinates of the NYA2 point obtained by kinematic processing and the coordinates obtained by static processing. As seen in Fig. 8, the standard deviation and mean values of the coordinate differences were obtained in the range of 2 mm to 11 mm. The obtained results in which GPS satellite processing is disabled seem to be satisfactory.


POINT NYA2 (GPS-only (Kinematic-static (Fixed Point NYAL)))

a

POINT NYA2 (GLONASS-only (Kinematic-static (Fixed Point NYAL)))

b

POINT NYA2 (Galileo-only (Kinematic - static (Fixed Point NYAL)))

c

POINT NYA2 (Beidou-only (Kinematic - static (Fixed Point NYAL)))

d

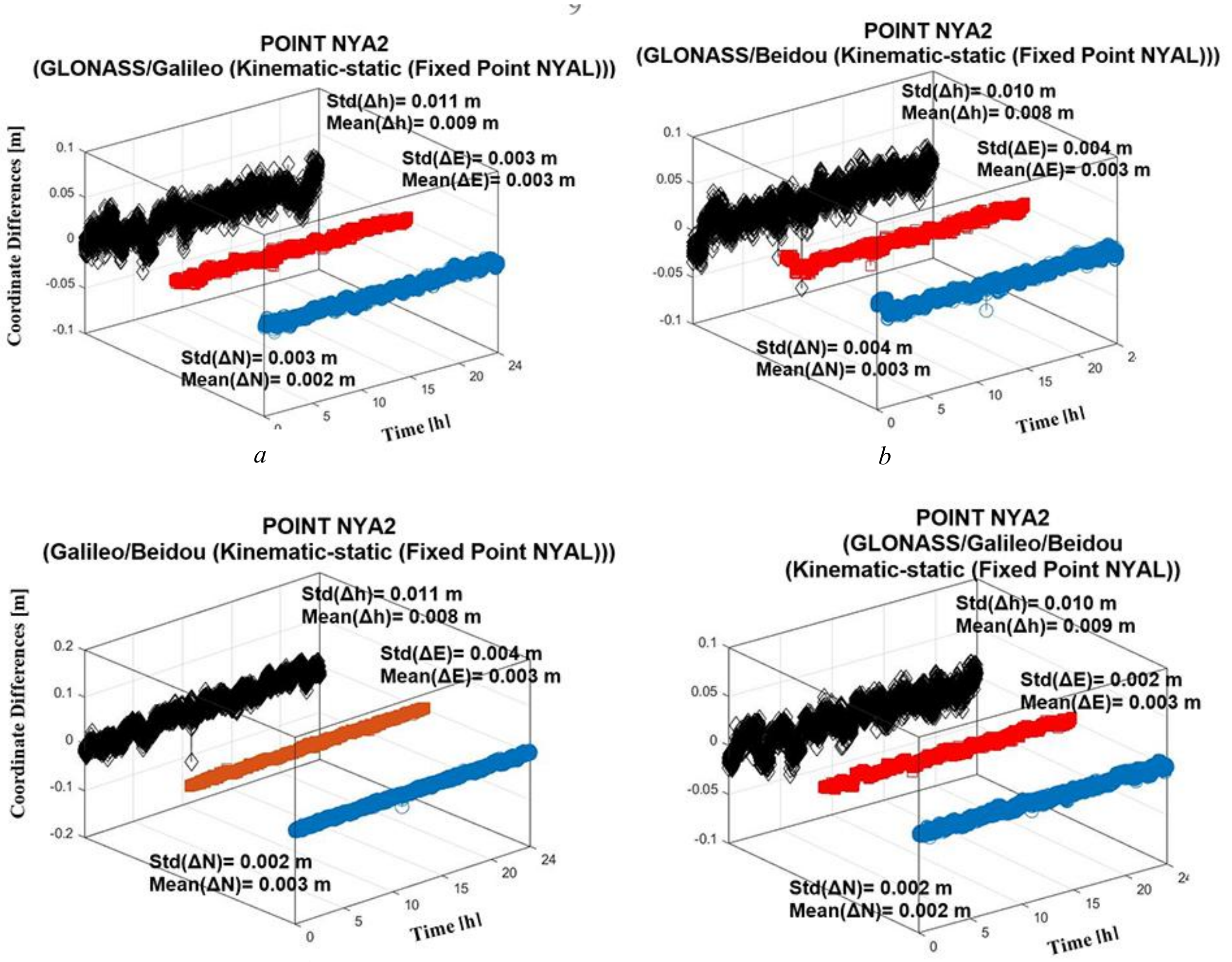
Fig. 7. Grid Northing, Easting and height coordinate differences, standard deviation and mean values of Point NYA2 ((a) processed GPS-only (kinematic method) by fixing NYAL coordinates; (b) processed GLONASS-Galileo-Beidou (kinematic method) by fixing NYAL coordinates) in Svalbard Island on 08.01.2022

GLONASS, Galileo satellites, were not affected by signal jammers between 00:00-24:00 hours on January 8, 2022. GLONASS, Galileo satellite signals are also more resistant to interference and jamming (Pirti and Yucel 2022).

In the kinematic process where only Beidou satellites were used, the observation of 6-14 Beidou satellites (Fig. 6c) did not allow us to obtain sufficient accuracies for the processing. As seen in Fig. 7d, the standard deviation and mean values are larger than the standard deviation and mean values obtained from other processes (with GLONASS-only and Galileo-only). As can be seen in Fig.7a, through the use of GPS satellites alone, the standard deviation and mean values for both horizontal and vertical components were found to be significant. Comparatively, in Figs 7b and 7c, utilizing only GLONASS and Galileo satellites resulted in standard deviation and mean values that were much closer to each other. However, the results obtained in the processing with only Beidou in Fig. 7d are close to Fig. 7a. Thus, GPS and Beidou satellites respond to the signal jamming effect with greater coordinate differences.

Discussions

In this study, the position accuracies obtained as a result of the jamming effect of the GPS signals were investigated for three points on the island of Svalbard. Furthermore, this study calculated the accuracy values achieved when the GPS satellites of other satellite systems were disabled. The results obtained are in line with those reported by other researchers who have also investigated this topic (Gao et al. 2012), (Jensen and Sicard 2010), (Linty et al. 2018).



a *b*

c *d*

Fig. 8. Grid Northing, Easting and height coordinate differences, standard deviation and mean values of Point NYA2 ((a) processed GPS-only (kinematic method) by fixing NYAL coordinates; (b) processed GLONASS-Galileo-Beidou (kinematic method) by fixing NYAL coordinates) in Svalbard Island on 08.01.2022

Conclusion

This research analysed GPS signal jamming, which is supposed to occur in Svalbard Island. The study utilized static-kinematic processing GPS measurements from two points, NYA2 and NYAL. These jamming effects in GPS signals have an impact on location accuracy, particularly for kinematic processing. The changes in coordinate discrepancies at position NYA2 between 00:00 and 24:00 on January 8, 2022, when GPS signals were subjected to the most significant jamming impact, reached around 5 meters. If the GPS signal is interfered with, we modify the path. To achieve satisfactory precision in three-dimensional location, GLONASS/Galileo/Beidou signals were employed. It is recommended that the jamming that may occur in Svalbard Island should be avoided, and the use of GLONASS/Galileo/Beidou satellite combinations can eliminate the jamming that may occur in GPS signals.

Acknowledgments

We would like to special thanks to Yildiz Technical University GNSS Laboratory. We also thank the IGS for sharing the GNSS dataset.

REFERENCES

Aerospace Security (2022) Arctic Circle GPS Jamming, https://aerospace.csis.org/data/gps-jamming-in-the-arctic-circle/#:~:text=GPS%20signal%20loss%20was %20reported,January%209%20and%2010,%202019.&text=In

Aghadadashfam, M., Mosavi, M. R., & Rezaei, M. J. (2020). A new post-correlation anti-jamming technique for GPS receivers. *GPS solutions*, *24*, 1-16. https://doi.org/10.1007/s10291-020-01004-y

Borio, D., Dovis, F., Kuusniemi, H., & Presti, L. L. (2016). Impact and detection of GNSS jammers on consumer grade satellite navigation receivers. *Proceedings of the IEEE*, *104*(6), 1233-1245. https://doi.org/10.1109/JPROC.2016.2543266

Borio, D., & Gioia, C. (2021). Interference mitigation: impact on GNSS timing. *GPS Solutions*, *25*(2), 37. https://doi.org/10.1007/s10291-020-01075-x

CRFS. (2019). How to deal with GPS jamming and spoofing. CRFS, February 21, https://www.crfs.com/blog/how-to-deal-with-gps-jamming-and-spoofing/.

Dunnigan, J. (2013). A Solution for the Jammer Threat. Report Page, November 21, https://www. strategypage.com/dls/articles/A-Solution-For-The-GPS-Jammer-Threat-11-21- 2013.asp.

Faria, L. D. A., Silvestre, C. A. D. M., & Correia, M. A. F. (2016). GPS-dependent systems: Vulnerabilities to electromagnetic attacks. *Journal of Aerospace Technology and Management*, *8*, 423-430. https://doi.org/ 10.5028/jatm.v8i4.632

Fu, Z., Hornbostel, A., Hammesfahr, J., & Konovaltsev, A. (2003). Suppression of multipath and jamming signals by digital beamforming for GPS/Galileo applications. *GPS solutions*, *6*, 257-264. https://doi.org/10.1007/s10291-002-0042-2

Gao, G. X., Heng, L., Walter, T., & Enge, P. (2012). Breaking the ice: Navigation in the Arctic. In *Global Navigation Satellite Systems: Report of a Joint Workshop of the National Academy of Engineering and the Chinese Academy of Engineering* (pp. 229–238). National Academies Press.

Glomsvoll, O., & Bonenberg, L. K. (2017). GNSS jamming resilience for close to shore navigation in the Northern Sea. *The Journal of Navigation*, *70*(1), 33-48. https://doi.org/ 10.1017/S0373463316000473

Gorski, A. (2018). When GPS jammers interfere with military operations. AGI, April 10, https://www.agi.com/news/blog/april-2018/when-gps-jammers-interfere-with-militaryoperation.

Goward, D. (2017). Mass GPS Spoofing Attack in Black Sea? *The Maritime Executive*, November 7. https://www.maritime-executive.com/editorials/mass-gps-spoofing-attack-in-black-sea

Hu, Y., Bian, S., Cao, K., & Ji, B. (2018). GNSS spoofing detection based on new signal quality assessment model. *GPS Solutions*, *22*, 1-13. https://doi.org/10.1007/s10291-017-0693-7

Jensen, A. B., & Sicard, J.-P. (2010). Challenges for positioning and navigation in the Arctic. *Coordinates: A resource on positioning, navigation, and beyond, 6(10), 10-13. https://www.unoosa.org/documents/pdf/psa/activities/2015/RussiaGNSS/Presentations/52.pdf*

Linty, N., Minetto, A., Dovis, F., & Spogli, L. (2018). Effects of phase scintillation on the GNSS positioning error during the September 2017 storm at Svalbard. *Space Weather*, *16*(9), 1317-1329. https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2018SW001940

Marcus, M. J. (2014). Growing consumer interest in jamming: spectrum policy implications [Spectrum Policy and Regulatory Issues]. *IEEE wireless communications*, *21*(1), 4-4. https://doi.org/10.1109/MWC.2014.6757888

Martini, P. (2016). China Jamming US Forces' GPS. Resilient Navigation and Timing Foundation, September 26, https://rntfnd.org/2016/09/26/china-jamming-us-forces-gps/.

Mizokami, K. (2016). North Korea Is Jamming GPS Signals. *Popular Mechanics*, April 5, https://www.popularmechanics.com/military/weapons/a20289/north-korea-jamming-gpssignals/

Mosavi, M. R., Rezaei, M. J., Pashaian, M., & Moghaddasi, M. S. (2017). A fast and accurate anti-jamming system based on wavelet packet transform for GPS receivers. *GPS solutions*, *21*, 415-426. https://doi.org/10.1007/s10291-016-0535-z

Moussa, M. M., Osman, A., Tamazin, M., Korenberg, M., Noureldin, A., & NavINST Research Group. (2017). Enhanced GPS narrowband jamming detection using high-resolution spectral estimation. *GPS solutions*, *21*, 475-485. https://doi.org/10.1007/s10291-016-0528-y

Nilsen, T. (2019). GPS jamming jeopardizes public safety in Norway's northernmost region, The Barents Observer. https://thebarentsobserver.com/en/security/2019/01/gps-jamming-jeopardizes-public-safety-norways-northernmost-region

Pırtı, A, & Yucel M. A. (2022). The impact of Russian on GPS signal jamming in the Scandinavian Region, https://www.researchsquare.com/article/rs-1856904/v1

Pinker, A., & Smith, C. (1999). Vulnerability of the GPS Signal to Jamming. *GPS Solutions*, *3*, 19-27. https://doi.org/10.1007/PL00012788

Staalesen, A. (2018). Norway requests Russia to halt GPS jamming in borderland. The Barents Observer, April 27, https://thebarentsobserver.com/en/ security/2018/04/norwayrequests-russia-halt-gps-jamming-borderland.

Stopienski, P. (2020). *Opportunity to elimination Jamming by the adequate formation of the antenna beam of the GNSS receiver* (Doctoral dissertation, in Polish: Możliwości eliminacji Jammingu poprzez adekwatne kształtowanie wiązki antenowej odbiornika GNSS). Master Thesis. PNA, Gdynia 2020.

Trevithick, J. (2018). American General Says 'Adversaries' Are Jamming AC-130 Gunships in Syria. *The Drive,* April 25. https://www.thedrive.com/the-war-zone/20404/americangeneral-says-adversaries-are-jamming-ac-130-gunships-in-syria.

Wang, C. Z., Kong, L. W., Jiang, J., & Lai, Y. C. (2021). Machine learning-based approach to GPS antijamming. *GPS Solutions*, *25*(3), 115. https://doi.org/10.1007/s10291-021-01154-7

Westbrook, T. (2019). The global positioning system and military jamming. *Journal of Strategic Security*, *12*(2), 1-16. https://doi.org/10.5038/1944-0472.12.2.1720

Wikipedia. (2022) Barents Sea, https://en.wikipedia.org/wiki?curid=44060

World Wildlife Fund. (2008). Barents Sea environment and conservation.

Атінч ПІРТІ[1], Мехмет Алі ЮДЖЕЛ[2]

1* Технічний університет Йилдиз, кафедра геоматичної інженерії, 34220 Есенлер, Стамбул, Туреччина
2 Університет Онсекіз Март, кафедра інженерної геоматики, 17100, Чанаккале, Туреччина
*Автор для кореспонденції: atinc@yildiz.edu.tr, http://orcid.org/0000-0001-9197-3411

ВПЛИВ ГЛУШІННЯ СИГНАЛУ GPS НА ОСТРОВІ ШПІЦБЕРГЕН І УСУНЕННЯ ЦЬОГО ГЛУШІННЯ ЗА ДОПОМОГОЮ СУПУТНИКІВ ГЛОНАСС, GALILEO ТА BEIDOU

Острови Шпіцберген розташовані в Північному Льодовитому океані, посередині між Норвегією та Північним полюсом. Через це Шпіцберген має низку особливих властивостей, які роблять його цікавим регіоном для вивчення взаємодії між атмосферою, морським льодом і океаном. У цьому дослідженні оцінювались супутникові сигнали трьох ГНСС-пунктів (NABG, NYA2 і NYAL) на острові Шпіцберген у Баренцевому морі. 8 січня 2022 року у вимірюваннях на цих трьох ГНСС-пунктах було помічено ефекти глушіння сигналу. З вимірювань на двох ГНСС-пунктах (NYA2, NYAL) було очевидно, що супутники ГЛОНАСС, Galileo та Beidou також були записані в приймачі, а також супутники GPS. З цієї причини вплив ефекту глушіння сигналів GPS на точність позиціонування було досліджено як статичним, так і кінематичним методами. Крім того, як статична, так і кінематична обробка в цих двох ГНСС-пунктах була виконана за допомогою супутникових комбінацій ГЛОНАСС-Галілео-Бейдоу, щоб усунути ефект перешкод GPS. Хоча ефект перешкод GPS не досягається у великих значеннях у статичному процесі, коли в кінематичному процесі використовуються лише супутники GPS, цей ефект досягає приблизно 5 метрів як максимальна різниця горизонтальних координат. У значеннях перепаду висот максимальний перепад становив близько 15 метрів. У той час як отримані різниці координат між кінематичним процесом і статичним процесом, виконаними за допомогою супутників GLONASS-Galileo-Beidou, становили близько 5 см, значення висоти досягали приблизно 10 см. На островах Шпіцберген, коли сигнали GPS піддаються перешкодам, задовільні результати були отримані за допомогою супутників ГЛОНАСС-Galileo-Beidou.

Ключові слова: GPS, ГЛОНАСС, Galileo, Beidou, глушіння сигналу, острови Шпіцберген, точність.

Received 28.08.2023