The impact of Russian on GPS signal jamming in the Scandinavian Region

Atınç Pırtı (atinc@yildiz.edu.tr)
Yıldız Technical University
Mehmet Ali Yücel
Çanakkale Onsekiz Mart University

Research Article

Keywords: GPS, Jamming, Scandinavian region, Accuracy

Posted Date: July 27th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1856904/v1

Abstract

GPS's dependability and precision are crucial because it supports infrastructure assets that are essential to the operation of the power grid, transportation, communication, and national and international financial operations. Worldwide productivity is rising thanks to GPS, which has also had a significant impact on military operations. Despite their significance, GPS signals are vulnerable to interference because of their relative weakness. This weakness gives terrorists and state actors that utilize GPS jamming devices a wide range of options. Although different types of jammers can cause varying degrees of interference, the use of powerful military jammers is becoming more and more common. The Russian military is deploying jammers to obstruct GPS satellite signals, which are essential for navigation, mapping, and other purposes. Considering that there are jammers in the region that prevent them from getting any usable signal, Scandinavian nations may not be able to use GPS on some days. In this study, how the jamming effect on the GPS satellites in the Scandinavian regions affects the position accuracy obtained and the performance of the GLONASS, Galileo, Beidou, and QZSS satellites that are used to eliminate this situation was investigated.

Introduction

Recently, GNSS signal jamming has been considered a serious hazard to GNSS users. Given the widespread use of GPS-like systems in daily life and the strong faith that users have in the veracity of device indicators, it is particularly risky. Even though it is illegal to use jammers, they are frequently available, particularly online. The last several years have nevertheless demonstrated that certain governments have created this danger on deliberately, as is seen in armed wars and military drills. Naturally, if there are any civilian users nearby, this poses a serious hazard to them. In order to increase the noise level or overburden the receiver electronics and induce a loss of lock, jamming is the broadcast of a noise signal across one or more of the GPS frequencies. Jammer power and capabilities vary, and they are elements that influence end-user intents. Jamming frequently creates indiscriminate, cross-border, system- and wall-penetrating disruption that is both purposeful and unintended. As a result, interference with the GPS system is a problem that worries a variety of parties, including the military, the owners of critical infrastructure, and the sectors of aerial, maritime, and land transportation, with potential repercussions for the economy and politics as well as a threat to human life. It is a crucial issue for national security as well as for ties internationally. Risk and vulnerability assessments will be influenced by an understanding of a state's deliberate decision to employ electronic warfare as a form of border harassment and intimidation (Gorski 2018; Martini 2016; Mizokami 2016; Dunnigan 2013; Staalesen 2018; Goward 2017). Up to 10 kilometers away from Norway, Russia conducts its Zapad military exercises, which feature hundreds of soldiers. Jamming has also been brought on by Russian military exercises in Finland. Thus, GPS interference is now a problem that may occur everywhere and is no longer just a problem in war areas or nearby regions. A slightly stronger jamming signal can completely disrupt signals from all satellites in range. The generation of a false GNSS signal that seems authentic to the GNSS receiver is known as GNSS signal spoofing. Because signal spoofing is harder to detect than jamming, it is more dangerous. The spoofing signal can fool the receiver, which has an impact on its navigation solution. Furthermore, unlike signal jamming, utilizing correlation techniques to identify spoofing is not possible because the received signal is statistically associated with the legitimate GNSS signal. Signal spoofing's influence on deteriorating navigation solutions can have major consequences in both military and civilian applications, particularly those involving safety-of-life services. Russia is specifically targeting the GPS satellite system, which is used by the United States and made freely available to numerous countries across the world. (Russia has its own separate satellite navigation system, GLONASS, whereas Europe has Galileo and China has Compass or Beidou). Russian forces occupying the country are using jammers to disrupt GPS satellite signals, which are needed for navigation, mapping, and other functions. GPS transmits on a standard set of radio frequencies that GPS receivers, such as automotive navigation systems or cell phones, can detect. Changing or widening the frequency of transmissions to make it more difficult for jamming equipment to obstruct the signal is one technique to avoid jamming. There has been a lot of work in general on the mixing of GPS signals (Gorski 2018; Martini 2016; Mizokami 2016; Dunnigan 2013; Staalesen 2018; Goward 2017; The University of Nottingham 2016; CRFS 2019; Fernholz 2017; Faria et al. 2016; Borio and Closas 2017; Borio et al. 2016; Stopienski 2020; Westbrook 2019; Trevithick 2018). In these papers, the power of jammers to affect GPS signals and the suggestions to be made to prevent the distortions were examined. Russia, especially against NATO, has carried out its efforts to disrupt GPS signals for military purposes before and during NATO exercises in Norway, Sweden and Finland. Today, efforts to disrupt the GPS signals in the Ukraine-Russia war continue. The aim is purely to prevent the localization of military and civilian targets. It is known that Russia has interfered with GPS satellites. However, before the study by Center for Advanced Defense Studies (C4ADS), no one looked at Russia's practices from a scientific point of view. In order to do this, C4ADS examined approximately 10 thousand fake global navigation signals that have been detected from the Russian Federation and regions where Russia is in conflict, such as Crimea and Syria, since 2016, with the equipment placed on the International Space Station by the University of Texas. C4ADS does not formally accuse the Russian government of sending false signals. It is impossible to make such a determination from the space station. However, fake signals often serve Russia's national interests. Fake signals involving Russia often appear to provide incorrect information about a location rather than changing the timing. However, C4ADS reports show that NATO and Russian military exercises are also affected by the changed timing information. This also affects Finnish and Norwegian GSM networks. Norway and Finland have in the past accused Russia of disrupting GPS signals in their airspace. Satellites are considered one of the critical components of military power in the twenty-first century. Today, Russia interferes with GPS signals not only over Ukraine but also over the Scandinavian countries. This is especially true when NATO exercises will be held in the North Sea. In this study, it has been revealed that when the NATO exercise is approaching, Russia's interference with the GPS signals in the Scandinavian countries, especially on January 8, 2022 (between 19:00:00–24:00:00) peaked. Not only the date of January 8, 2022 was examined, but also the cases of January 9, 2022 and January 10, 2022 were investigated for GPS jamming.

Scandinavian Region

In these investigations, the processes of three IGS points (SOD3, KIRU and TOR1) located in Scandinavian countries were carried out. From these three points, Point TRO1 was located in Norway, Point KIRU was in Sweden, and Point SOD3 was in Finland (Fig. 1 and Table 1). The jamming effects of Russia on GPS signals can be clearly seen on January 8, 2022, between 19–24 hours (Fig. 2). This effect affects GPS positioning accuracy between these hours. Considering the date of January 9, 2022, there is no jamming effect of the GPS signals between 19–24 hours on January 8, 2022. Figure 3a shows the skyplot and Fig. 3b shows general GPS satellite visibility values at the SOD3 point of these effects. When the satellite visibility of the SOD3 point was investigated on January 10, 2022, between 19:00:00–24:00:00 hours, no signal degradation or jumping was found. In general, the jumps of GPS and other satellite signals occur at the beginning and end of the time of observation of the satellites (taking into account the elevation angle and horizon planes).

Table 1
KIRU, SOD3 and TRO1 IGS points coordinates.

Name	Latitude (°)	Longitude (°)	Ellipsoidl Height (m)	Std (N) (m)	Std (E) (m)	Std (h) (m)
KIRU	67°51'26,47371"N	20°58'06,43422"E	391,071	0,002	0,002	0,008
SOD3	67°25'14,83600"N	26°23'21,44039"E	300,882	0,002	0,002	0,008
TRO1	69°39'45,79363"N	18°56'22,75106"E	138,131	0,002	0,002	0,008

Results

All figures were performed by using RTKLIB v.2.4.2 software. Figure 2a depicts the visibility of several satellites in an open sky simulation scenario. Figure 2b depicts the discontinuity (the highlighted rectangle) in satellite availability for the same scenario but with a jamming signal inserted. In particular, it is seen that the SOD3 point was exposed to the effect of jamming the GPS signals between 19-24 hours on January 8, 2022 (Figure 2b). However, these effects do not appear for the SOD3 point at the same time interval on January 9 and 10, 2022 (Figures 3b and 4b).

Figure 5a depicts the visibility of several satellites in an open sky simulation scenario. Figure 5b depicts the discontinuity (the highlighted rectangle) in satellite availability for the same scenario but with a jamming signal inserted. In particular, it is seen that the KIRU point was exposed to the effect of jamming the GPS signals between between 19:00:00–24:00:00 hours on January 8, 2022 (Fig. 5b). However, such an effect does not appear for the KIRU point at the same time interval on January 9 and 10, 2022 (Figs. 6b and 7b).

In the GPS observations at TRO1 in Norway on January 8, 9 and 10, 2022, the disruptive effects of GPS signals appeared on all three days (between 19:00:00–24:00:00), see Figs. 8, 9 and 10. As can be seen from the figures, Point TRO1 was exposed to the greatest jamming for GPS signals within three days. For this reason, the effect of the jamming in the GPS signals on the position accuracy was also investigated for these three points.

The obtained results from the process of KIRU point for three days by using GPS-only satellites are shown in Fig. 11a. The three-dimensional coordinate differences of KIRU point between the hours of 19:00–24:00 on January 8, 2022, reached about 2 meters. Integer ambiguity could not be resolved due to jamming in the GPS signal at certain time intervals. The standard deviation values of the coordinate differences of KIRU point, obtained on January 8, 2022, between 19–24 hours, are 13–17 cm, and the average values are 8-17.1 cm. For Point TRO1, the strength of the GPS signal jamming effects on January 8, 9, and 10 in 2022 differs. This effect on the values of the coordinate differences is in the range of ± 2 m between 19 and 24 hours on January 8, 2022, in the range of ± 0.5 m between 19:00 and 24:00 hours on January 9, 2022, and in the range of ± 1 m between 19:00:00–24:00:00 on January 10, 2022, were obtained. For Point TRO1, the standard deviation values of the coordinate differences between 19:00 and 24:00 hours on January 8, 2022 are 11.1–20.8 cm and the mean values are 8.7–9.7 cm. On January 9, 2022, the standard deviation values were 0.9-4.0 cm, and the mean values were 0.9-3.0 cm. On January 10, 2022, standard deviation values were 3.9–17.9 cm, and mean values were 2.2–9.1 cm. Figure 11 shows that the standard deviation and mean values for the coordinate differences led to a ten-fold decrease in accuracy.

Investigation of Signal Jamming on GLONASS, Galileo, Beidou, and QZSS Satellites

As seen in Fig. 12, GLONASS, Galileo, and Beidou satellites, except for the QZSS satellite, were not affected by signal jammers between 19:00–24:00 hours on January 8, 2022. During this period, only one QZSS satellite was affected by this disturbance (Fig. 12d). GLONASS, Galileo, and Beidou satellite signals are also more resistant to interference and jamming. In addition, three base lengths (among KIRU, SOD3, and TRO1 points) were examined in order to make this effect more evident and to eliminate it. As seen in Table 1, the lengths obtained by using the process of GPS-only satellites on January 8, 9, and 10, 2022 (between 19:00 and 24:00 hours) are shown. The obtained baseline lengths by processing the signals of GLONASS, Galileo, and Beidou satellites on January 8, 9, and 10, 2022 (between 19:00–24:00 hours) were compared with the other processed values. Differences between the three baselines were obtained in the range of 1–31 cm, as seen in Table 2.

Table 2
Comparison of the three baselines on three days

Baseline	$S_{Bernese}$	$S_{(GPS/08.01.2022)}$ $S_{(GPS/09.01.2022)}$ $S_{(GPS/10.01.2022)}$	$S_{(GLONASS-Galileo-Beidou/08.01.2022)}$ $S_{(GLONASS-Galileo-Beidou/09.01.2022)}$ $S_{(GLONASS-Galileo-Beidou/10.01.2022)}$
KIRU-SOD3	235.244102 km	235.244220 235.244108 235.244113	235.244196 235.244107 235.244109
KIRU-TRO1	217.427949 km	217.428238 217.427953 217.428130	217.428163 217.428011 217.428007
SOD3-TRO1	393.339312 km	393.339563 393.339318 393.339625	393.339584 393.339320 393.339326

On January 8, 2022, the number of GPS satellites observed for three points between 19:00 and 24:00 hours was 25–26, and PDOP values were obtained in the range of 1.653 and 1.677. On January 8, 2022, the number of GLONASS/Galileo/Beidou satellites observed for three points between 19 and 24 hours was 18–19, 17, 17–22, and PDOP values were obtained in the range of 1.371 and 1.402. On January 9, 2022, the number of GPS satellites observed for three points between 19 and 24 hours was 14, and PDOP values were obtained in the range of 1.310 and 1.323. On January 9, 2022, the number of GLONASS/Galileo/Beidou satellites observed for three points between 19:00 and 24:00 hours was 12, 12–13, and 11–15, respectively, and PDOP values were obtained in the range of 1.310 and 1.323. On January 10, 2022, the number of GPS satellites observed for three points between 19:00 and 24:00 hours was 14, and PDOP values were obtained in the range of 1.279 and 1.296. On January 10, 2022, the number of GLONASS/Galileo/Beidou satellites observed for three points between 19:00 and 24:00 hours was 11, 8–9, and 11–16, respectively, and PDOP values were obtained in the range of 1.279 and 1.296. The results among the three baselines of the process by using GPS satellites on 8, 9 and 10 January 2022 between 19 and 24 hours were compared with the results of the base lengths obtained from the process by using GLONASS/Galileo/Beidou satellites (Table 1). According to the obtained results from this comparison, an improvement in the base lengths of between 1 cm and 30 cm was obtained.

Conclusion

The jamming of GPS signals, which is thought to be caused by Russia and includes the Scandinavian countries of Norway, Sweden, and Finland, was investigated in this study by processing three-day GPS observations using three points (KIRU, SOD3, and TOR1). These distortion effects created in GPS signals affect the accuracy of position. The fluctuations of the coordinate differences at KIRU, SOD3 and TRO1 points, especially between 19:00 and 24:00 hours on January 8, 2022, when the GPS signals were exposed to the most intense jamming effect, reached 2 meters. In addition, in the process data on 9 and 10 January 2022, by using the same time interval, the fluctuations of the coordinate differences were obtained in the range of 0.2–0.5 m. At TRO1 point in Norway, on January 8, 9 and 10, 2022, there were always fluctuations in the coordinate differences depending on the effect and distance of the system that jammed the GPS signals. In addition, when the three baseline lengths were examined over three days, improvement of between 1 cm and 30 cm was obtained in some baseline lengths. When the GPS signal is exposed to interference, the accuracy of the position determination with GLONASS/Galileo/Beidou signals has been obtained at a satisfactory level. For Scandinavian countries, it is recommended that the jamming that may occur in GPS signals be solved with GLONASS/Galileo/Beidou combinations.

Declarations

Acknowledgments

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

Data availability

The IGS provides GNSS data, which may be obtained via igs.org.

Conflict of interest

There is not any conflict of interest with the manuscript.

Author Contributions Statement

Atınç PIRTI and Mehmet Ali Yücel wrote the main manuscript text. Mehmet Ali Yücel prepared figure 1. Atınç PIRTI prepared figures 2-12. Atınç PIRTI and Mehmet Ali Yücel reviewed the manuscript.

Founders

The manuscript does not have a founder.

References

1. Borio D, Closas P (2017) A fresh look at GNSS anti-jamming. Inside GNSS 12:54–61
2. Borio D, Dovis F, Kuusniemi H, Lo Presti L (2016) Impact and detection of GNSS jammers on consumer grade satellite navigation receivers. Proceedings of the IEEE 104(6):1233–1245

3. 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/.
4. Dunnigan J (2013) A Solution for the Jammer Threat. Strategy Page, November 21, https://www.strategypage.com/dls/articles/A-Solution-For-The-GPS-Jammer-Threat-11-21-2013.asp.
5. Faria LA, Silvestre CAM, Correia MAF (2016) GPS-dependent systems: vulnerabilities to electromagnetic attacks. J Aerosp Technol and Manag 8(4):423–430. https://doi.org/10.5028/jatm.v8i4.632
6. Fernholz T (2017) The entire global financial system depends on GPS, and it's shockingly vulnerable to attack. Quartz, October 22, https://qz.com/1106064/the-entire-globalfinancial-system-depends-on-gps-and-its-shockingly-vulnerable-to-attack/.
7. 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.
8. 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
9. 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/.
10. Mizokami K (2016) North Korea Is Jamming GPS Signals. Popular Mechanics, April 5, https://www.popularmechanics.com/military/weapons/a20289/north-korea-jamming-gpssignals/
11. 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.
12. Stopienski P (2020) Opportunity to elimination Jamming by the adequate formation of the antenna beam of the GNSS receiver (in Polish: Możliwości eliminacji Jammingu poprzez adekwatne kształtowanie wiązki antenowej odbiornika GNSS). Master Thesis, PNA, Gdynia.
13. The University of Nottingham (2016) GPS jamming: keeping ships on the 'strait' and narrow. July 21, https://www.nottingham.ac.uk/news/pressreleases/2016/july/gps-jamming-keepingships-on-the-strait-and-narrow.aspx.
14. 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.
15. Westbrook T (2019) The Global Positioning System and Military Jamming: The geographies of electronic warfare. J Strateg Secur 12(2):1–16. https://doi.org/10.5038/1944-0472.12.2.1720

Figures

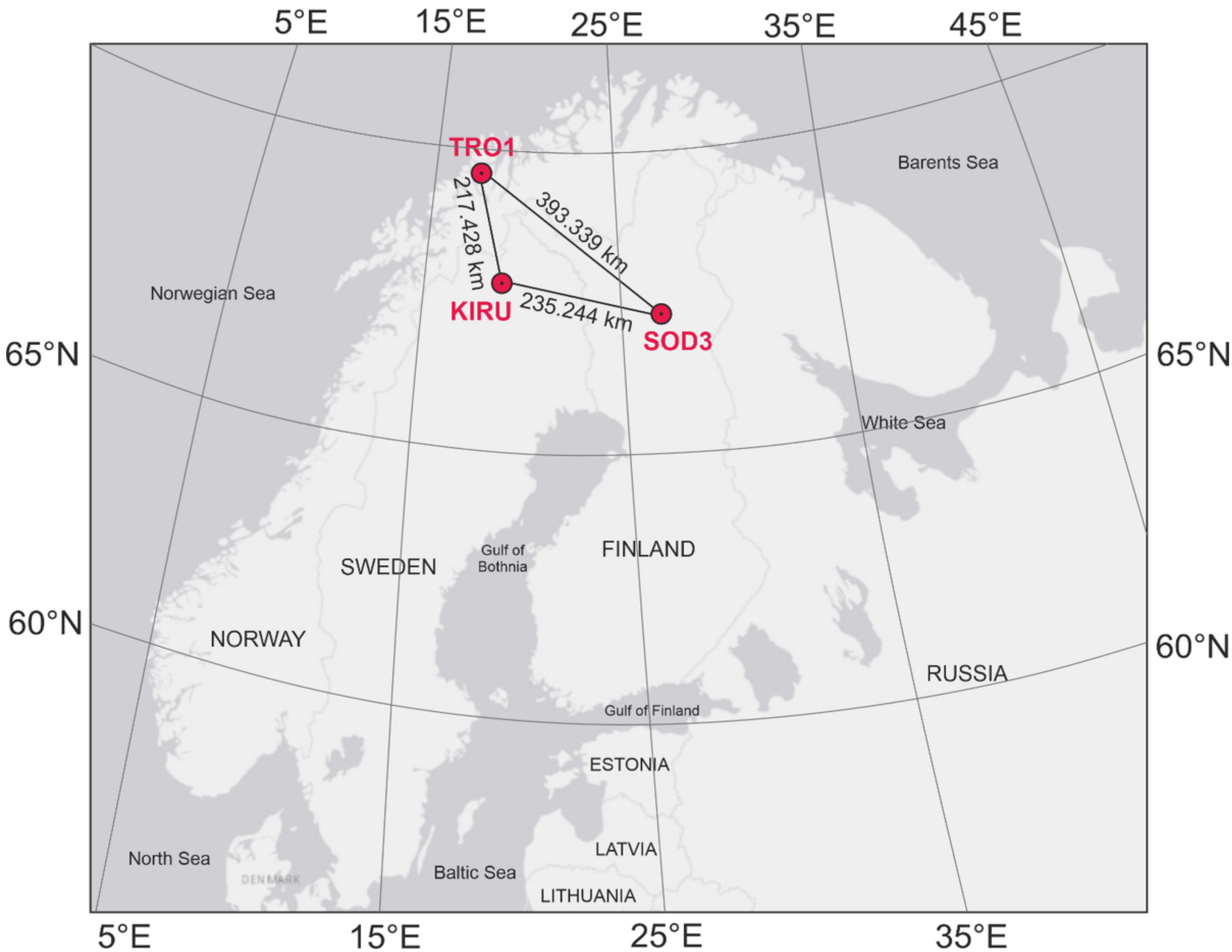


Figure 1

KIRU, SOD3 and TRO1 IGS points located in the Scandinavian region

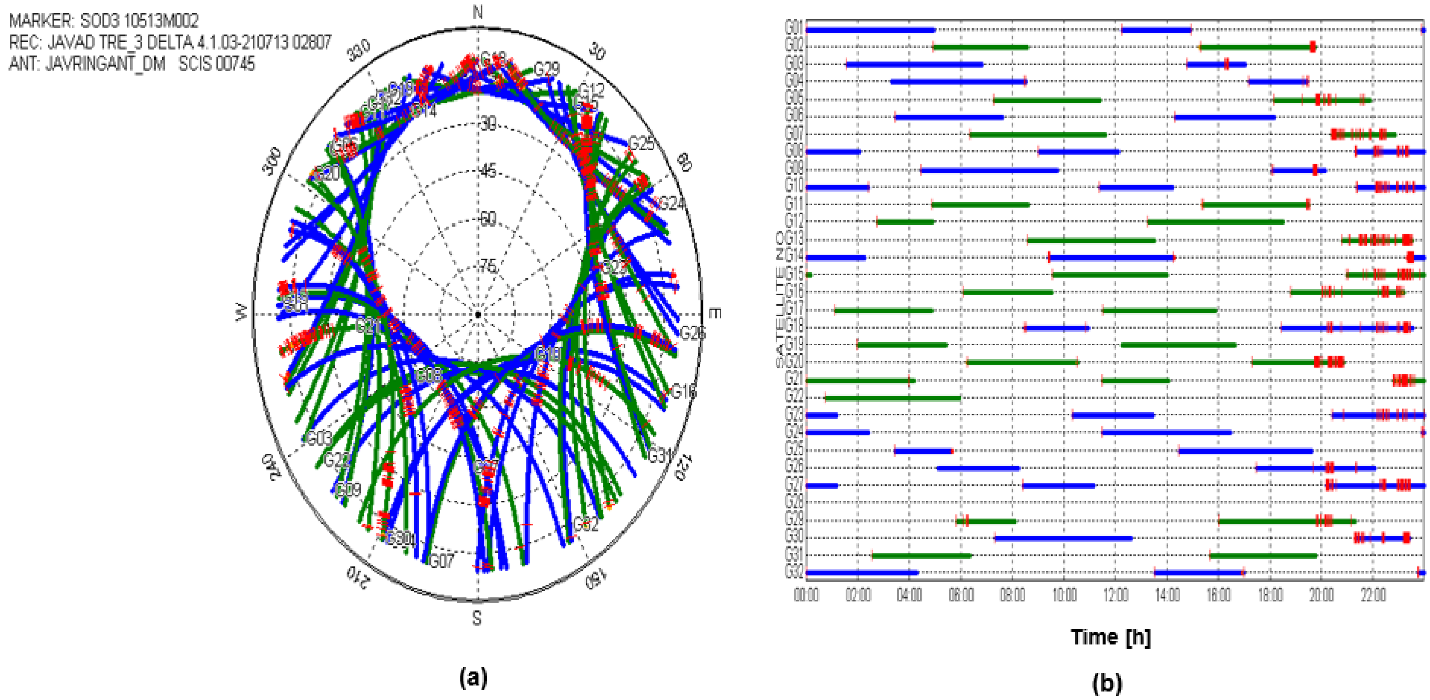


Figure 2

Skyplot (a) and GPS satellite visibility plot of SOD3 point in Finland during the presence of jamming signals (8 January 2022-24 h, (b))

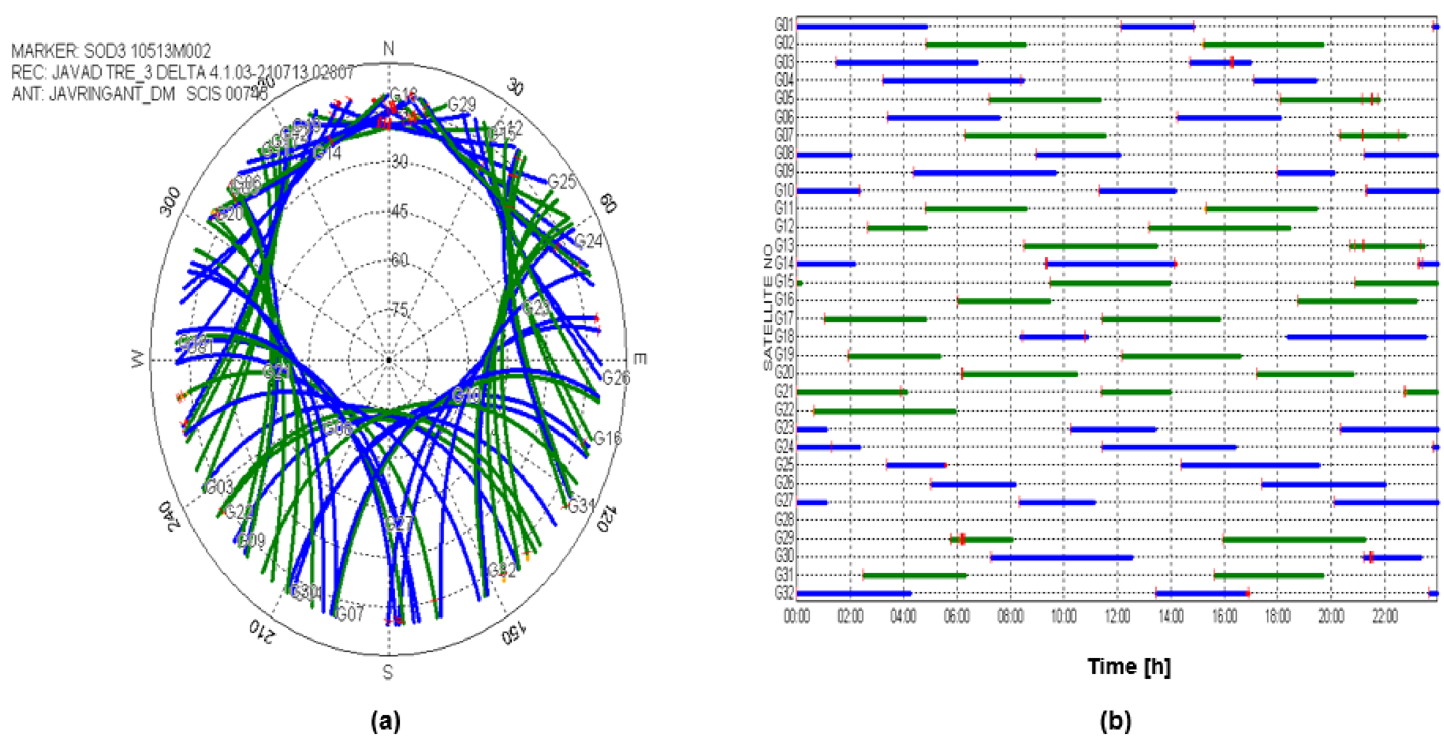
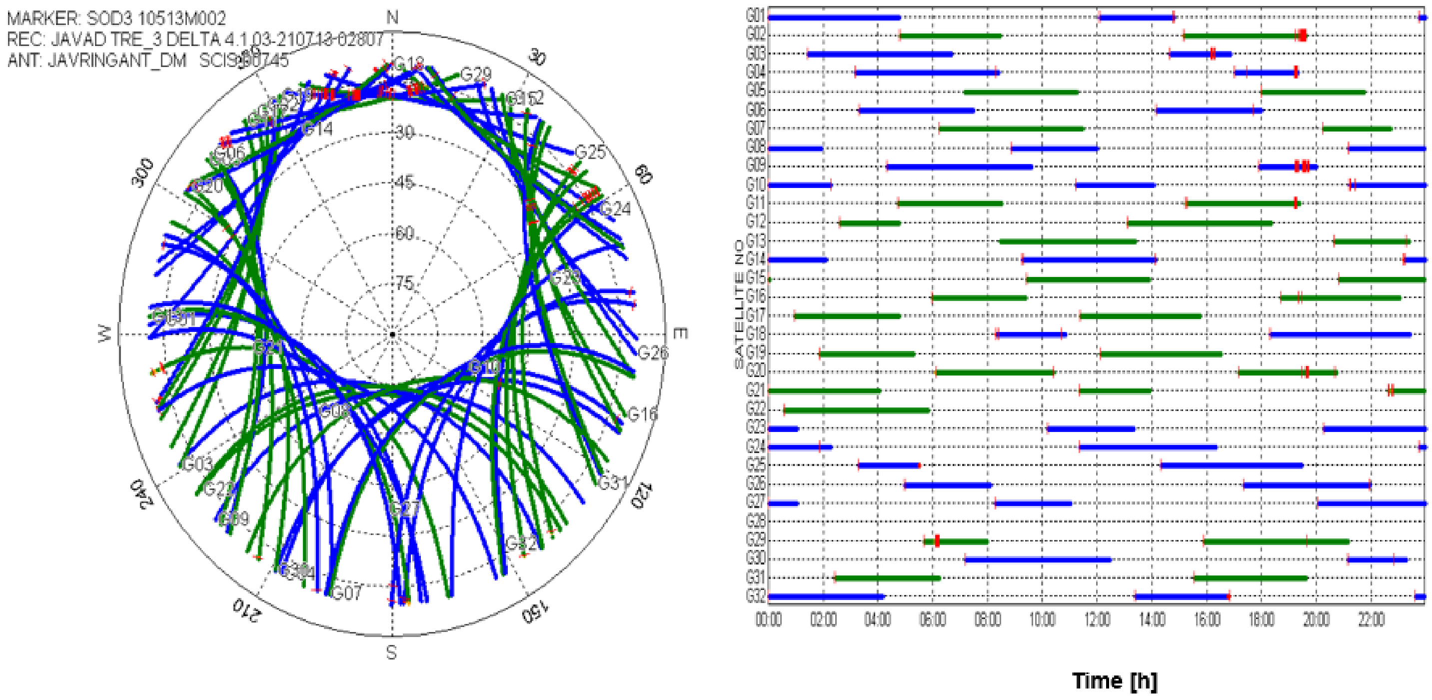


Figure 3

Skyplot (a) and GPS satellite visibility plot of SOD3 point in Finland during the presence of signals (9 January 2022-24 h, (b))



(a)

(b)

Figure 4

Skyplot (a) and GPS satellite visibility plot of SOD3 point in Finland during the presence of signals (10 January 2022-24 h, (b))

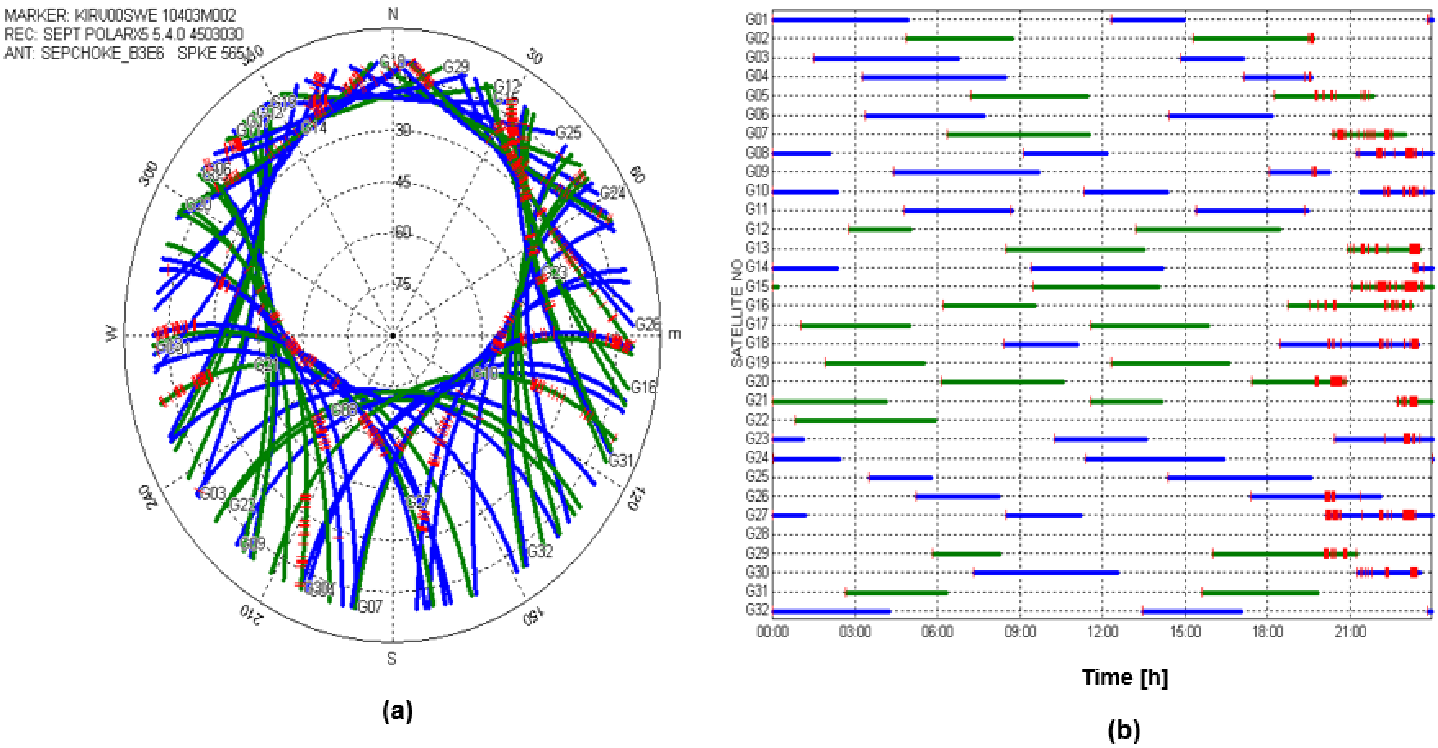


Figure 5

Skyplot (a) and GPS satellite visibility plot of KIRU point in Sweden during the presence of jamming signals (8 January 2022-24 h, (b))

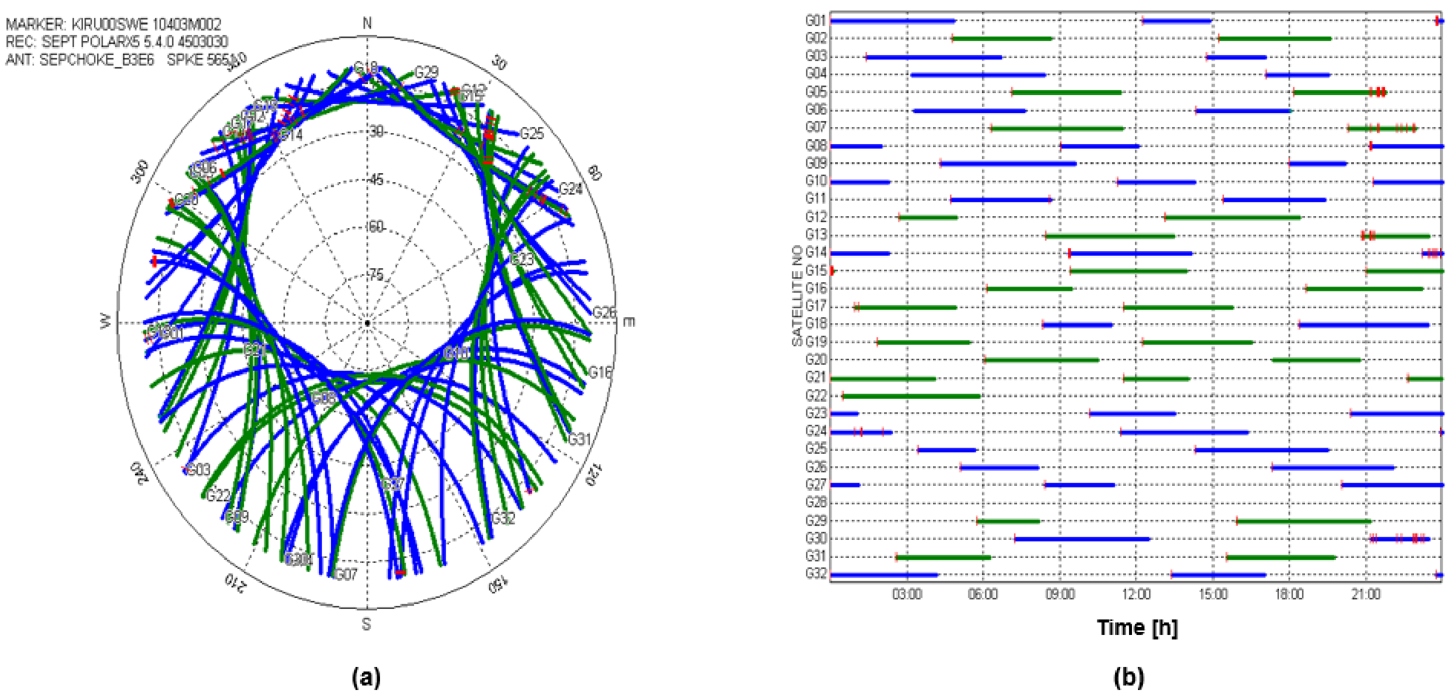


Figure 6

Skyplot (a) and GPS satellite visibility plot of KIRU point in Sweden during the presence of jamming signals (9 January 2022-24 h, (b))

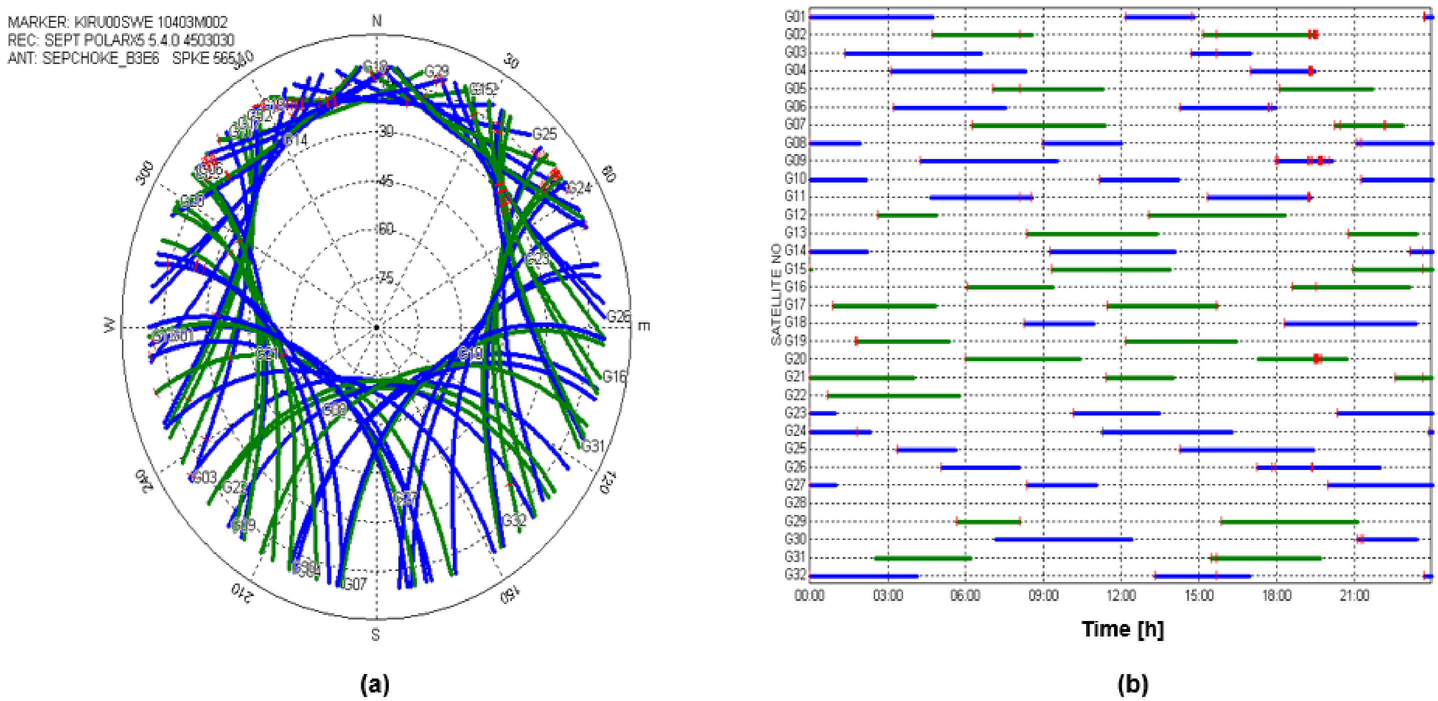
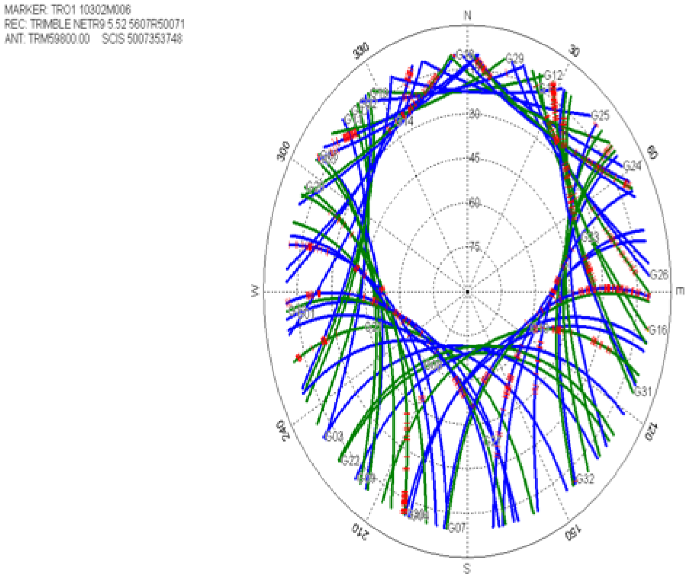
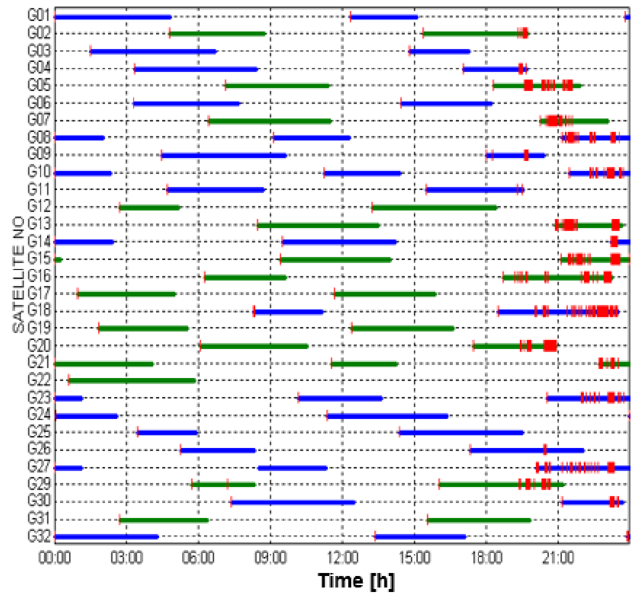


Figure 7

Skyplot (a) and GPS satellite visibility plot of KIRU point in Sweden during the presence of jamming signals (10 January 2022-24 h, (b))



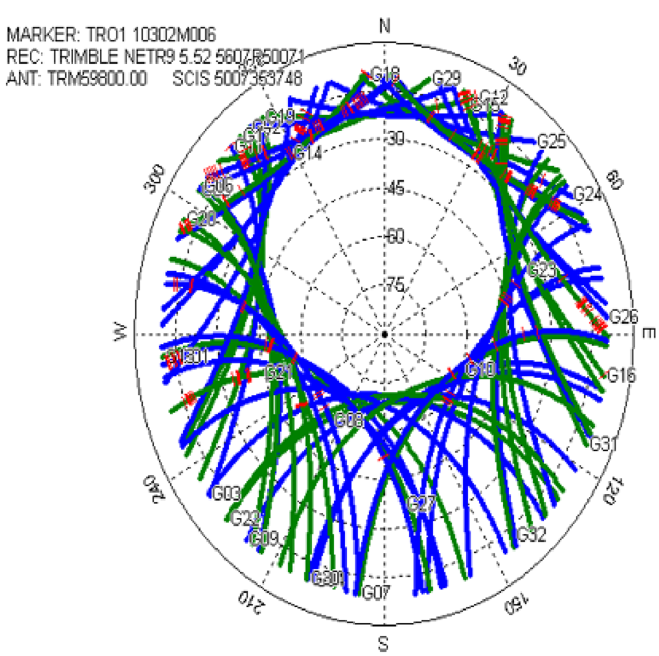
(a)



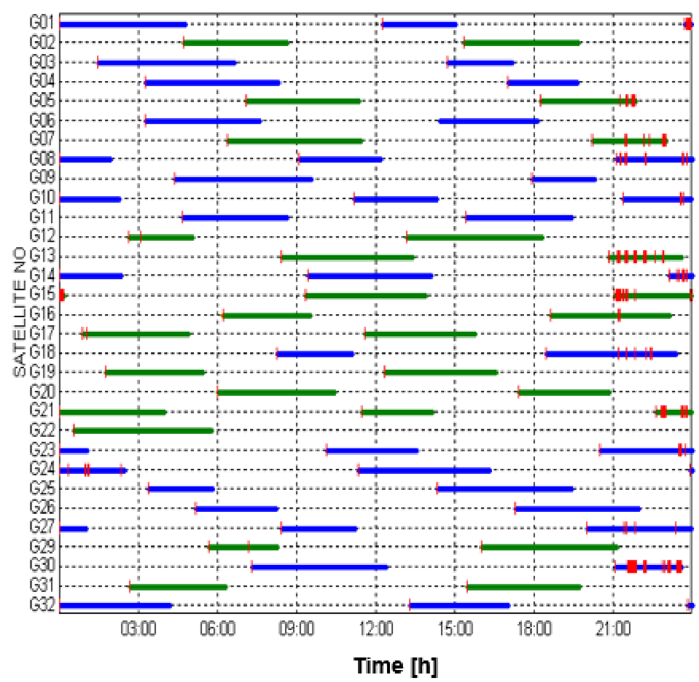
(b)

Figure 8

Skyplot (a) and GPS satellite visibility plot of TRO1 point in Norway during the presence of jamming signals (8 January 2022-24 h, (b))



(a)



(b)

Figure 9

Skyplot (a) and GPS satellite visibility plot of TRO1 point in Norway during the presence of jamming signals (9 January 2022-24 h, (b))

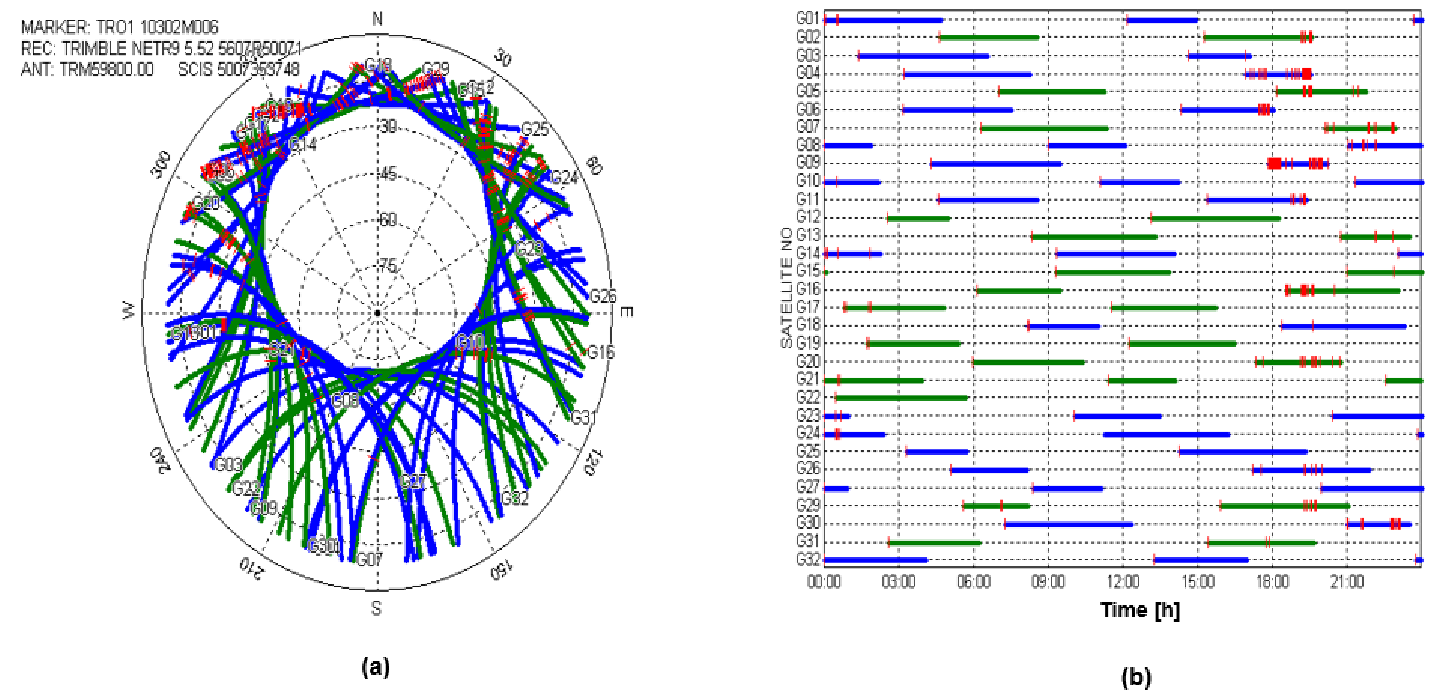


Figure 10

Skyplot (a) and GPS satellite visibility plot of TRO1 point in Norway during the presence of jamming signals (10 January 2022-24 h, (b))

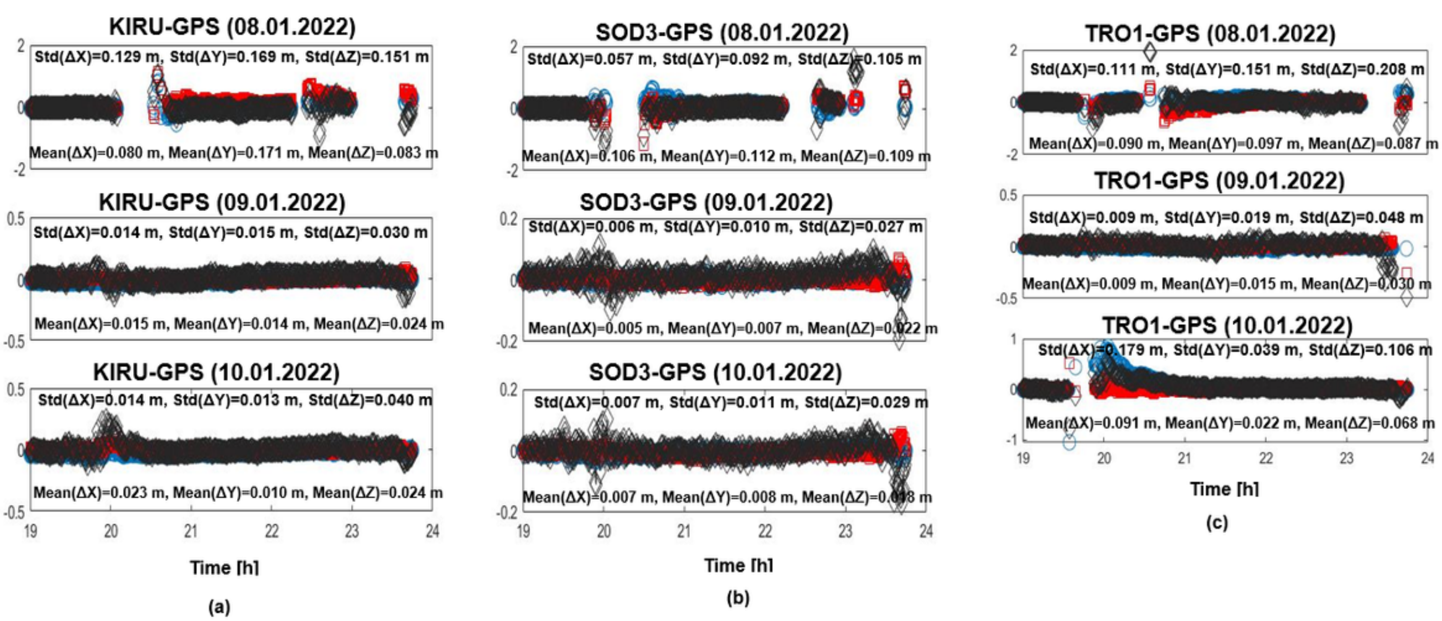


Figure 11

Coordinate differences, standard deviation and mean values of three points (processed GPS-only) in Scandinavian region on three days

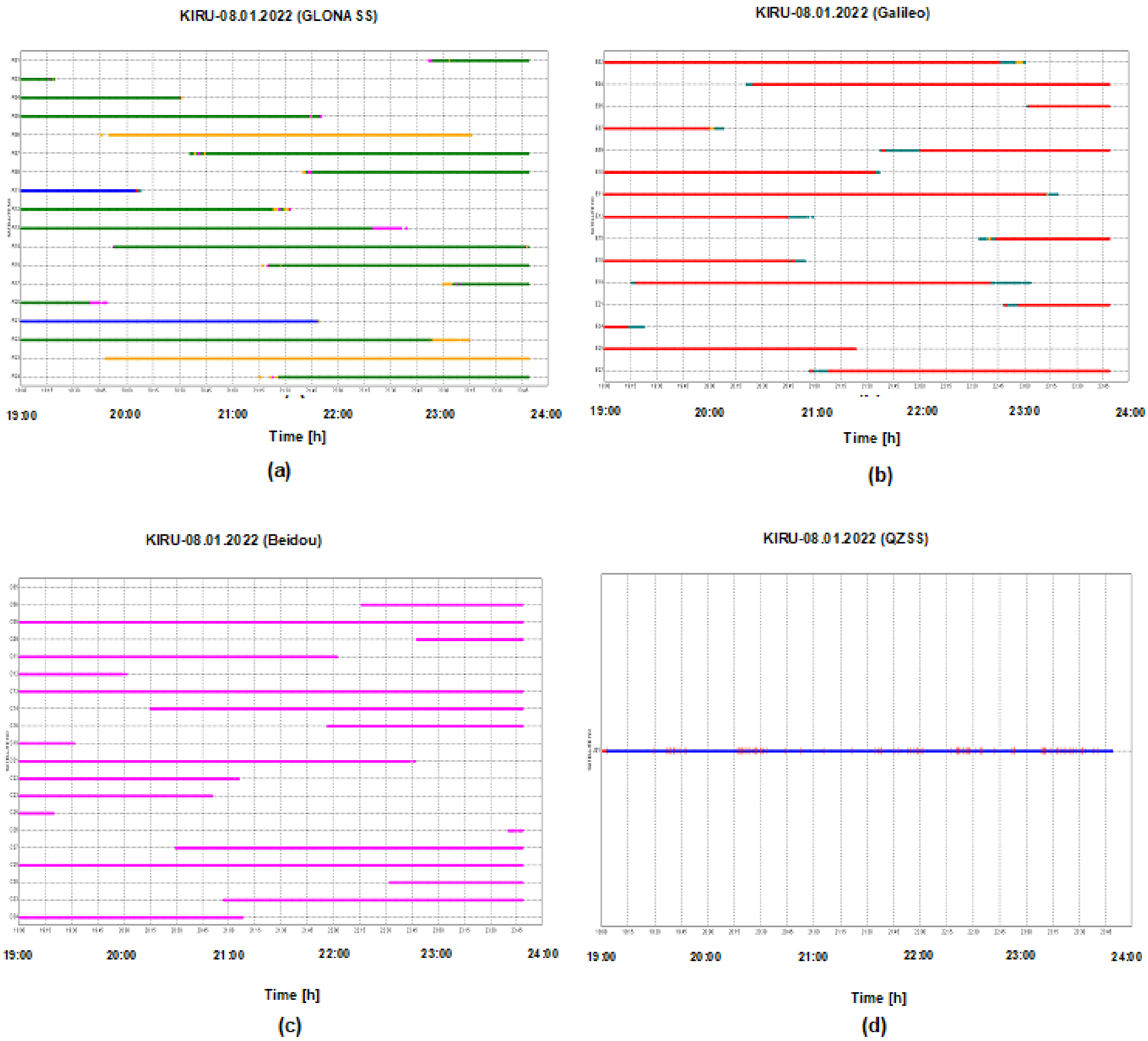


Figure 12

Satellite visibility (GLONASS (a), Galileo (b), Beidou (c), QZSS (d)) of Point KIRU on 8 January 2022 between 19:00 and 24:00 hours