Baltic J. Modern Computing, Vol. 12 (2024), No. 4, 454-462
https://doi.org/10.22364/bjmc.2024.12.4.07

Assessment of Accuracy of GNSS Measurement Models using Base Station and Radio Module Solutions

Armands CELMS[1], Linda GRINBERGA[1], Toms LIDUMNIEKS[1,2], Jolanta LUKSA[1], Miks BRINKMANIS - BRIMANIS[1]

[1]Latvia University of Life Sciences and Technologies, Liela street 2, Jelgava, Latvia
[2]Latvian Geospatial Information Agency, Riga, Latvia

armands.celms@lbtu.lv, linda.grinberga@lbtu.lv, toms.lidumnieks@lbtu.lv, jolanta.luksa@lbtu.lv, miksbrinkmanis@inbox.lv

ORCID 0000-0002-9673-1734, ORCID 0000-0003-3291-3755, ORCID 0009-0001-8489-6750, ORCID 0009-0002-6428-2003, ORCID 0009-0004-1387-4687.

Abstract. Global navigation satellite systems (GNSS) historically been known as one of the newest technologies since the 1970s. GNSS originally developed for military purposes in the USA (GPS – Global Position System). There are several satellite systems in the world. Satellites, International Research Base Stations, regional/national and local base stations form a permanent geodetic frame. Research on the size and shape of the Earth-planet, climate, sea, urban planning. In geodesy, a network of global positioning base stations makes it possible to assess the movements of continents, land plates at international level. GNSS is an important technology in navigation, logistics, economics, land surveying and other “geo” sectors.

GNSS equipment/receivers and their manufacturers are applying new designs and electronics. Initially, GNSS instruments were used with single frequency signal reception, later expanding the number of GNSS signal channels to two frequencies. Such technological improvements nowadays improve the certainty, reliability and accuracy – the overall quality of GNSS measurements. The GNSS base station enables the surveyors to determine coordinates with an accuracy of two centimeters in real time (RTK) and with an accuracy of five millimeters using the accumulated post-processing data.

Various types of factors hamper GNSS measurements. The GNSS signal (radio wave) travels in airspace, in urban environments and is a physical parameter. Any obstacle – tree, building walls, and atmospheric effect – makes GNSS measurements less accurate. The GNSS signal must be strong and free from attenuation and suppression effects.

This study develops GNSS models that show the comparison, certainty and reliability of GNSS measurements using different types of GNSS techniques. Evaluation of Latvian Global Positioning Reference Station Network – LatPos system measurements against a corresponding RTK solution method using Latvian Global Positioning Network geodetic point (G2 class).

Keywords: GNSS; GNSS accuracy; Real Time Kinematic (RTK); Radio modules; Global position measurements

Introduction

GNSS - Global Navigation Satellite system is a satellite navigation system that allows users to determine their precise location. GNSS systems are used for many things, like navigation, mapping, surveying, and tracking. Consumers for everything from turn can use GNSS systems - by – turn directions to real time tracking of loved ones. Businesses, agriculture can also use GNSS systems to manage their fleet vehicles, keep track of their assets, and figure out the best way to make deliveries. The benefits of GNSS technology are vast and continue to grow as the technology evolves. GNSS systems are more accurate than ever before, and new applications are being developed all the time. GNSS is changing the way we live and work, and the benefits are just beginning to be realized (Angrisano et al., 2013).

Having more receiver channels allows a GNSS receiver to track and process signals from more satellite systems and frequencies. This can lead to improved accuracy and reliability in determining the receiver's location and timing, as well as improved resistance to signal interference and multipath (WEB, a).

Materials and methods

The development of satellite systems today promotes both the creation of new technologies and strengthens the development of existing inventions. Most of the technologies developed for space exploration are also used in various areas of life today. From the first industries, where various space technologies were applied, until today these technologies are used both in the production of vehicles and in mobile communication devices, as well as in various medical inventions and various high technologies. The application of space technologies in the civil sector also provides opportunities for research and monitoring of rural and forest areas, as well as creating flood control systems (Žagars et al., 2014).

In order to carry out the measurements and collect the data, it is important to carry out preparatory work to identify the points at which the measurements will be possible and to clarify the status of the points. In order to investigate the sites and their availability, it is initially necessary to select a specific area where the measurements will be carried out.

The measurement process will include measurements in the territory of the City of Bauska and Bauska Municipality (Figure 2) taking measurements at points of the National Geodetic Network. The Bauska region only chosen because the LatPos base station 'Bauska 1' is located in the centre of Bauska, which is essential for the LatPos base station to be able to measure at a similar radius as from a GNSS receiver with a radio module solution. The assessment of the National Geodetic Network points in the vicinity of Bauska Municipality concluded that the location of the points is adequate to compare the LatPos base station and individual base station capabilities.

The GNSS receiver STONEX with radio module function is used in the study, whose manufacturer states that measurements can be made within a radius of 5 kilometers from the base station. This factor will be considered in order to successfully select suitable points from the National Geodetic Network database.

In order to test the capability of the GNSS receiver with radio module to measure at different distances, control measurements were performed during the development of the GNSS measurement model parameters.

The control measurements were carried out by installing a GNSS receiver with radio module function in the open field and taking measurements up to a distance of 5 kilometers from the base station, keeping track of the possibility to measure points at different distances from the base. During the measurements, it confirmed that the GNSS equipment manufacturer had specified that measurements within 5 kilometers of the base station could be made without interference, but when trying to measure at a greater distance there were problems with the connection between the GNSS receiver and the GNSS receiver with radio module function, which used as an individual base station (Mitrofanovs, 2016).

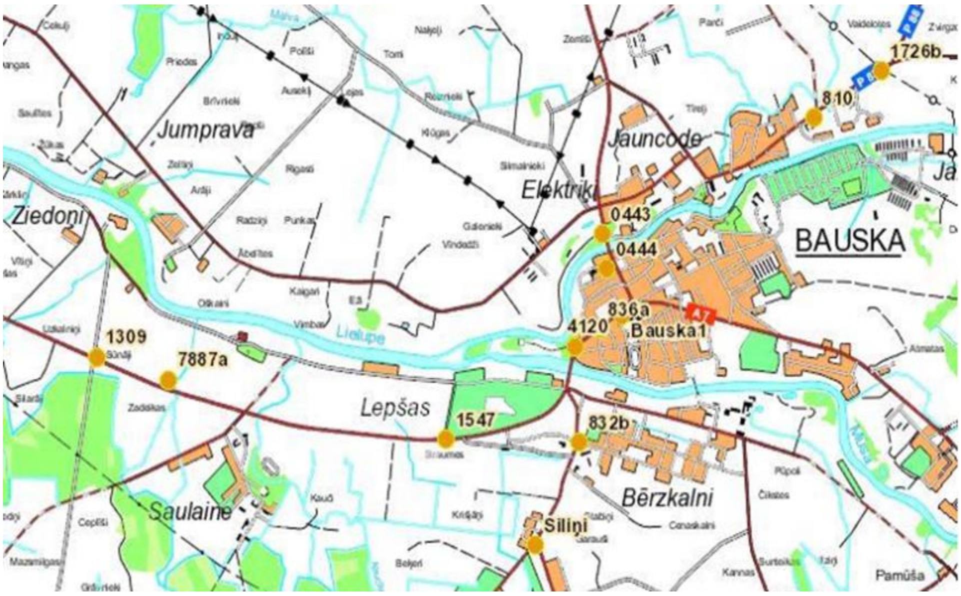

Figure 1. National geodetic network points in Bauska municipality
(Source: Developed by the authors according LGIA informal portal)

Results and discussion

National Geodetic Network's 12 points (Figure 1) within a 5 km radius of each other were selected in the territory of Bauska City and Bauska Municipality. The points used in the study are of class G2 and class N1, the type of fixing being a bottom mark, a bottom benchmark, a wall benchmark and a wall mark. After a detailed examination of the points, it was concluded that three of the selected points are destructible and cannot be accessed without prior agreement, so these points will not be used in the rest of the study.

After the survey process, it can be concluded that the survey process and the results obtained could be improved if a wider range of equipment were available, as surveying with two GNSS receivers connected to both the LatPos base station and the individual base station would speed up the survey time and make the measurements more accurate and comparable. Although the semi-kinematic method provides relatively high accuracy, it is recommended to use the static method and data post-processing to obtain measurements with higher accuracy (Helfriča et al., 2007).

Overall, the measurements carried out in both rounds are positive and the resulting measurement data will allow the development of GNSS measurement models and their analysis. The amount of measurement data obtained, both for the National Geodetic Network and freely selected points is sufficient to allow for measurement comparisons as well as conclusions on the data obtained (Bikše, 2007).

Relatively similar results were obtained in the measurements of the State Geodetic Network for point 1547, which is an N1 class point. The obtained results show that mutual measurements using a GNSS receiver with a radio module function are very similar. The measurements made for point 1547 using the LatPos base station are also similar, but the obtained results are slightly different. If you compare the measurements of the two base systems with each other, the largest difference between the points is 5 centimeters (Figure 2).

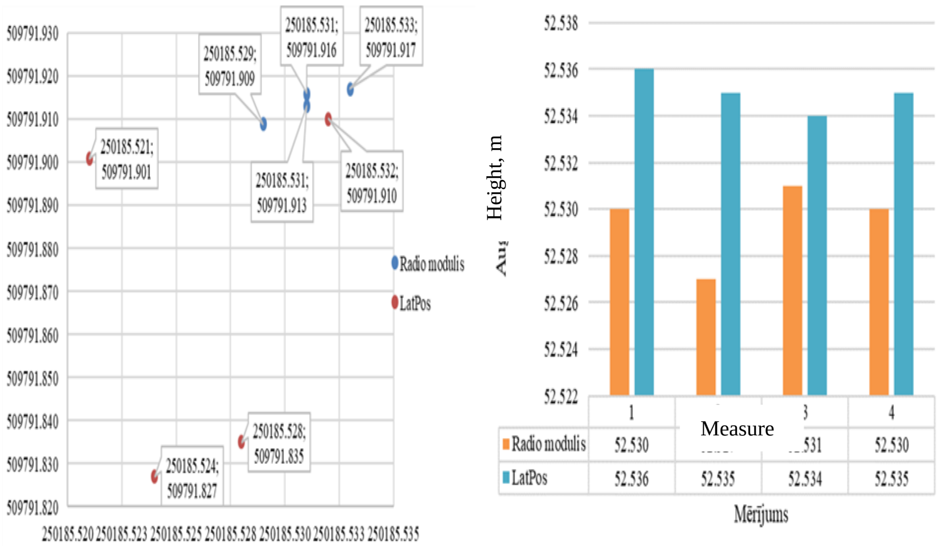

Figure 2. Measurements for point gr1547 N1,

As one of the factors that the measurements for point 1547 are relatively similar is that the point was located in an open area and there were no natural and environmental objects around, which could significantly affect the accuracy of the measurements.

The next point of the State Geodetic Network, for which the obtained height values are analysed, is point 1547. According to the obtained data, it is possible to see that the obtained height values differ, however, this difference is not large (Figure 2).

According to the obtained data, it is possible to predict that the obtained height values of all measurements vary by a few millimeters. The largest difference between the measurements made using a GNSS receiver with a radio module and a LatPos base station is 9 millimeters. The difference in the obtained results is based on the fact that there was a row of trees next to the measured point, which could affect the received signal of the GNSS receiver, so the obtained height values also differ in different measurements. The analysis of the obtained height values was also performed for the point 832b of the State Geodetic Network, which is naturally fixed with a wall rapier in the wall of the building. According to the obtained data, it is possible to observe that the values of the heights of the measurements made for this point differ significantly (Figure 3).

According to the collected data, it is possible to see that the height values obtained by connecting to the individual base station are relatively similar and fluctuate within 5 millimeters, while the height values obtained by connecting to the LatPos base station differ from each other within 11 millimeters. Comparing all the obtained height readings for the measured point, the most redundant difference between the measurements is 16 millimeters, which is a relatively large difference. The difference in the obtained height values is justified by the fact that the measured point was located close to the wall of the building, which can affect the received signal GNSS in the receiver, thus also affecting the obtained result.

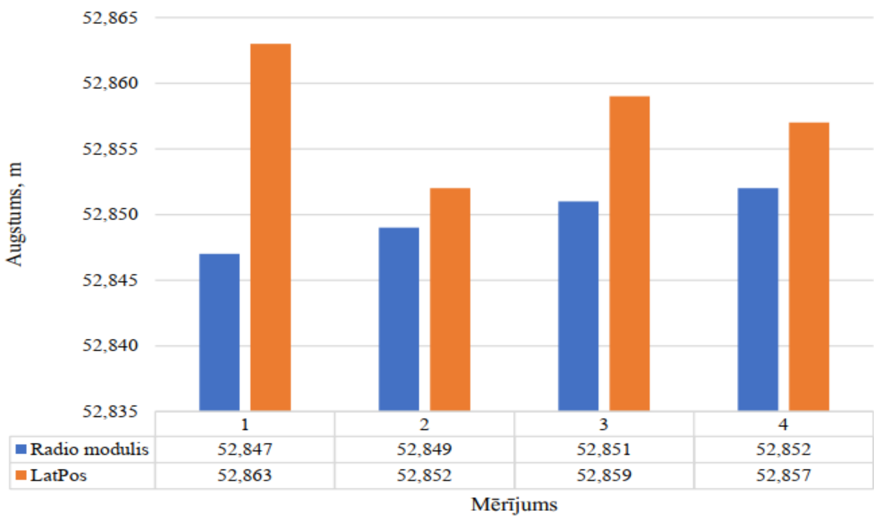

Fig. 3. Measurements (Heights) for point Sr_832b N1.

The obtained results are slightly different in the measurement model for point 1309, which is Class N1 National Geodetic Network Point. In the measurement model of this point, it can be observed, that there is a relatively bigger difference. If measured points, when using the GNSS receiver with functions of the radio module and this difference is up to 2 cm between the measured points using the LatPos base station "Bauska 1", for which the difference between measurements are up to 10 cm. When comparing all the measurements, the accuracy of the measurements exceeds 10 cm, which are significant differences and by accurately measuring the points with different methods. It would not be desirable to allow the obtained results for point 1309 to be based on this; there was a relatively tall tree row next to the point of the State Geodetic Network, which could have affected the accuracy of the measurements (Figure 4).

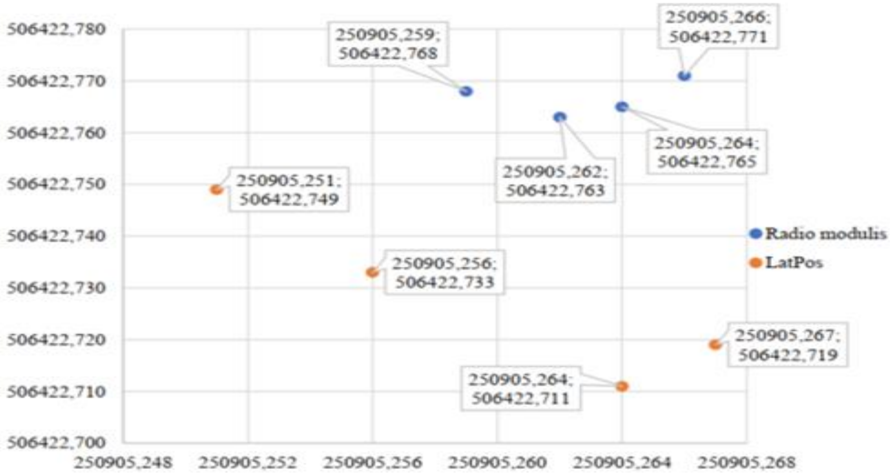

Fig. 4. Measurements (Coordinates) for point gr 1309 N1.

The obtained measurement model for point 1309 shows that it is essential to pay attention to the surrounding environment during the measurement process and, if necessary, evaluate how it is possible to improve the accuracy of the measurements. Also, the obtained data show that during the surveying process, using a GNSS receiver with a radio module function, it is possible to obtain more accurate data for measurements in an area where there are factors that can affect the accuracy of measurements.

According to the obtained GNSS measurement model, it is possible to conclude that when connecting to the LatPos base station during measurements at this point, the received signal has been disturbed, therefore the obtained coordinates differ by 2 centimeters both between mutual measurements and between measurements made when connecting to the individual base station.

Table 1. Result table of GNSS measurements for points of the National Geodetic Network

Point Name	Radio module			LatPos base station		
	X	Y	h (m)	X	Y	h (m)
1309 N1	250905,266	506422,771	48,881	250905,264	506422,711	48,884
	250905,262	506422,763	48,878	250905,256	506422,733	48,883
1547 N1	250185,531	509791,916	52,530	250185,524	509791,827	52,536
	250185,531	509791,913	52,527	250185,528	509791,835	52,535
832b N1	250164,285	511075,733	52,847	250164,273	511075,734	52,863
	250164,289	511075,735	52,849	250164,275	511075,741	52,852
4120 N1	250998,342	511032,782	51,799	250998,343	511032,689	51,795
	250998,346	511032,773	51,797	250998,348	511032,698	51,812
836 N1	251153,420	511266,053	54,280	251153,419	511266,049	54,273
	251153,418	511266,049	54,281	251153,424	511266,045	54,285
0443 N1	251983,400	511291,282	41,683	251983,406	511291,276	41,686
	251983,409	511291,279	41,686	251983,404	511291,281	41,685
0444 N1	251681,831	511341,201	44,652	251681,846	511341,220	44,665
	251681,844	511341,128	44,656	251681,652	511341,204	44,645

In general, when evaluating the obtained GNSS measurement models, the obtained results are different for different points (Table 2). The coordinates obtained for some of the points are relatively similar both when measuring using a GNSS receiver with a radio module function and when using the LatPos base station "Bauska 1". For most of the points for which the coordinates of the points differed significantly in the obtained measurement models, there was an environmental or natural obstacle near the point's measurement location, which affected the received signal with the GNSS receiver, as well as the obtained measurement result (WEB, a).

Analyzing the developed GNSS measurement models, the location of the point and the surrounding environment are determined as the main factor that affected the accuracy of the measurements, which can cause disturbances in the surveying process for the fixed measurements, because the signal received by the GNSS receiver is affected. The effects of the ionosphere also affected the accuracy of the measurements and troposphere, however, the GNSS technologies used in the study is able to reduce the influence of these factors, so we believe that the most important factor affecting the accuracy of the measurements was precisely the influence of the surrounding environment of the points.

According to the developed measurement models, it can be concluded that when measuring points with complications, the results are significantly more accurate when using a GNSS receiver with a radio module function, because both the obtained point coordinates and the point height values were relatively more similar to this surveying method. Although the GNSS receiver with the radio module function has a relatively smaller radius in which it is possible to perform measurements, it is able to show higher accuracy measurements in fieldwork, which is a significant advantage if the object to be measured is not relatively large. A GNSS receiver with a radio module function can be a significant benefit if it is necessary to perform surveying in areas where LatPos base station coverage is weak. However, if the measured object has a good coverage of LatPos base stations, then the obtained data is in accordance with the requirements and it is not necessary to perform measurements by connecting to the individual base station. There is also a significant benefit in terms of consumed resources and time, because when surveying using LatPos base stations, it is not necessary to install individually the base station in the object, as well as this base station should not be looked after, so that uninformed persons do not affect the progress of the surveying process. The measurements made in the study are summarized in two tables.

Table 2. Result table of GNSS measurements for freely selected points

Point Characterization	**Radio module**		
	X	Y	h (m)
Under the tree	251000,240	510976,417	50,428
Open field	251010,830	511004,164	50,718
Under the tree	250170,120	511051,845	51,841
Middle of the tree	250172,628	511052,908	52,012
Open field	250161,819	511062,351	52,014
Open field	250240,800	508964,908	52,103
Under the tree	250241,526	508959,256	52,109
Open field	250330,134	508234,716	50,972
Open field	250332,294	508225,622	51,019
Between buildings	250164,385	511075,833	52,857
Point Characterization	**LatPos base station**		
	X	Y	h (m)
Under the tree	250999,533	510976,533	50,409
Open field	251010,832	511004,169	50,723
Under the tree	250170,209	511051,804	51,829
Middle of the tree	250172,616	511052,851	51,995
Open field	250161,824	511062,348	52,011
Open field	250240,809	508964,832	52,099
Under the tree	250241,542	508959,342	52,123
Open field	250330,128	508234,723	50,965
Open field	250332,304	508225,612	51,025
Between buildings	250164,373	511075,834	52,863

Conclusions

It is important to observe the differences in coordinates and heights over a longer period. GNSS measurement patterns show that global positioning cannot provide a stable measurement, it will always vary. It is important that when determining the result, it should be with high certainty and reliability. For all geodetic measurements, there is a justification of the principle of mutual repeatability. The homogeneity and stability of the geodetic network can be observed by high-quality repeated measurements following the best-principle methodology.

The obtained GNSS measurement models show that both the base station systems and individual base stations provide high accuracy measurements; however, there are various environmental factors that influence measurement accuracy.

Surveyors must pay close attention during the surveying process applied base stations for the received signal, as well as the measured situational elements to the surroundings, as various environmental factors can influence the received signal in the GNSS receiver from the base station, thus also affecting the accuracy of the measurements.

References

Angrisano, A., Gaglione, S., Gioia, C., Massaro, M., Troisi, S. (2013) Benefit of the NeQuick Galileo Version in GNSS Single-Point Positioning. International Journal of Navigation and Observation: Article ID 302947, 11 pp.

Bikše, J. (2007) "Higher Geodesy", Teaching Aid, RTU Publishing; http://geomatika.rtu.lv/sites/geomatika.rtu.lv/files/geomatika/Macibu_materiali/Augstaka%20geodezija.pdf

Helfriča, B., Bīmane, I., Kronbergs, M., Zuments, U. (2007). *Geodesy* (in Latvian). Riga, *Latvian Geospatial Information Agency*. 263 p.

Mitrofanovs, I. Performance Studies of Satellite Navigation Systems with Phase Measurements; Doctoral Thesis – Riga: Rigas Technical University, 2016. – 149 p.

WEB (a). Base Definitions for Land Surveyors. https://learncst.com/base-definitions/

WEB (b). Understanding Different Satellite Systems, 2022. https://www.bodet-time.com/time-servers/articles-and-resources/1771-understanding-different-satellite-systems.html

Žagars, J., Zvirgzds, J., Kaminskis, J. (2014), "Global navigation satellite systems" (GNSS), in Latvian text. Ventspils, *Ventspils International Radio Astronomy Center,* 231 p.

Received September 15, 2024, accepted November 5, 2024