ГЕОДЕЗІЯ

GEODESY

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POLISH ACTIVE GEODETIC NETWORK AS A MULTI-FUNCTIONAL NATIONWIDE NAVIGATION AND POSITIONING SYSTEM

The aim. The aim of the work is the research of the possibilities of using the real time in geodetic satellite measurements, the support system of Ground-Based Augmentation System (GBAS) type [Prasad and Ruggieri 2005, Rife and Phelts 2009, Dawidowicz and Krzan 2014]. The paper analyzes the results and evaluates the actual accuracy of the real field measurements, depending on the selected solution. Applied solutions included using real-time in the measurements, two types of corrections, for the network and of a single reference station, and one or two positioning systems integrated with each other. **The method.** The research measurements were performed using the multifunction precise satellite positioning ASG-EUPOS system operating in Poland since 2008. This system is based on a network of ground reference stations GNSS, which are distributed approximately evenly throughout the country. The testing area consisted of points, which have previously been measured by the static method, and their coordinates have been determined in postprocessing. In the test measurements, four different services that provide differential corrections via the Internet were used. In the final result 3D coordinates of the test area points were obtained, and were subject to detailed analysis, in terms of obtained accuracy and precision of the coordinates determination, on the basis of a single measurement using selected services. **Results.** The results of measurements and performed analyzes of real-time measurements firstly showed advantages of network corrections over corrections from a single reference station. And secondly they helped to demonstrate empirically the advantage of measurements made on the basis of the two positioning systems with respect to the measurement using only one system. The new aspect of this work is the simultaneous use of the real-time measurements corrections for GPS and GLONASS satellites. **Practical significance.** The current state of advancement of the technology of satellite measurements performed in real time, allows the determination of coordinates with different accuracy, from the centimeter level accuracy to the decimeter accuracy. The type of measuring equipment used in this case plays an important role. On the basis of the performed experiment it is recommended to use two system receivers to ensure high measurements accuracy and certainty of the results.

Keywords: RTK/RTN GNSS, GBAS, accuracy, precision of the points coordinates.

Introduction

The main task of the contemporary GNSS (Global Navigation Satellite Systems) used in survey measurements is to determine the coordinates of the points [Lamparski and Świątek 2007]. Currently, GNSS includes four operating systems: American GPS (Global Positioning System), Russian GLONASS (Globalnaia Navigacionnaia Sputnikova Sistema) [www.glonass-iac.ru/en/GLONASS], Chinese BeiDou [www.insidegnss.com/compass] and Japanese QZSS (Quasi Zenit Satellite System) and also the European System Galileo [www.insidegnss.com/ galileo], which is still under construction and now provides only test signals. Two basic technologies of satellite measurements are static and kinematic measurements.

Together with the development of satellite measurement techniques, active geodetic networks have become the standard to create a basic and homogeneous infrastructure providing access to cartographic data and a spatial orientation in a broad size. Many countries in the world have implemented and maintain on their territory uniform, national reference systems, which furthermore are compatible and create wider, so-called continental reference systems. Systems of this type are multifunctional and they are used not only for precision positioning and navigation, but also in spatial planning, cadastre of land and buildings, as well as in crisis management in time of natural catstrophes, disasters and safety hazards.

An important advantage of satellite active geodetic systems is also, that position of objects is described in three dimensions and the fourth dimension is time, because the coordinates are always determined for a given measurement epoch.

The national active systems of geodetic networks in Europe were mostly implemented according to the uniform international standards EUPOS. Although at present the system DGNSS services available in Europe differ in terms of procedures and scope of services offered but the technical conditions for their use are generally compatible with one another. This causes that the surveying companies from different countries can offer and implement their services in such areas.

In Poland, since June 2008 [Bosy and others, 2010], multifunctional precise satellite positioning system has been operating as ASG-EUPOS (Active Geodetic Network – EUPOS) which is a part of a larger project EUPOS (European Position Determination System) [EUPOS 2013]. Since the launch of the system has been observed the implementation of the different measuring methods in surveying applications, which for increasing the precision, accuracy and reliability of their results use permanent stations GNSS.

ASG-EUPOS provides users with its services through two primary corrections systems: real-time and postprocessing [asgeupos 2015].

Real-time Service offers three corrections:

- **NAWGEO** which is an essential service, providing corrections to the real-time measurement both from a single station RTK as well as RTN network corrections. Thanks to the many available corrections formats, NAWGEO service allows users to use a wide range of measurement equipment available on the market. The assumed minimum accuracy of this service is: up to 3 cm – determination of horizontal position and up to 5 cm determination of vertical position.

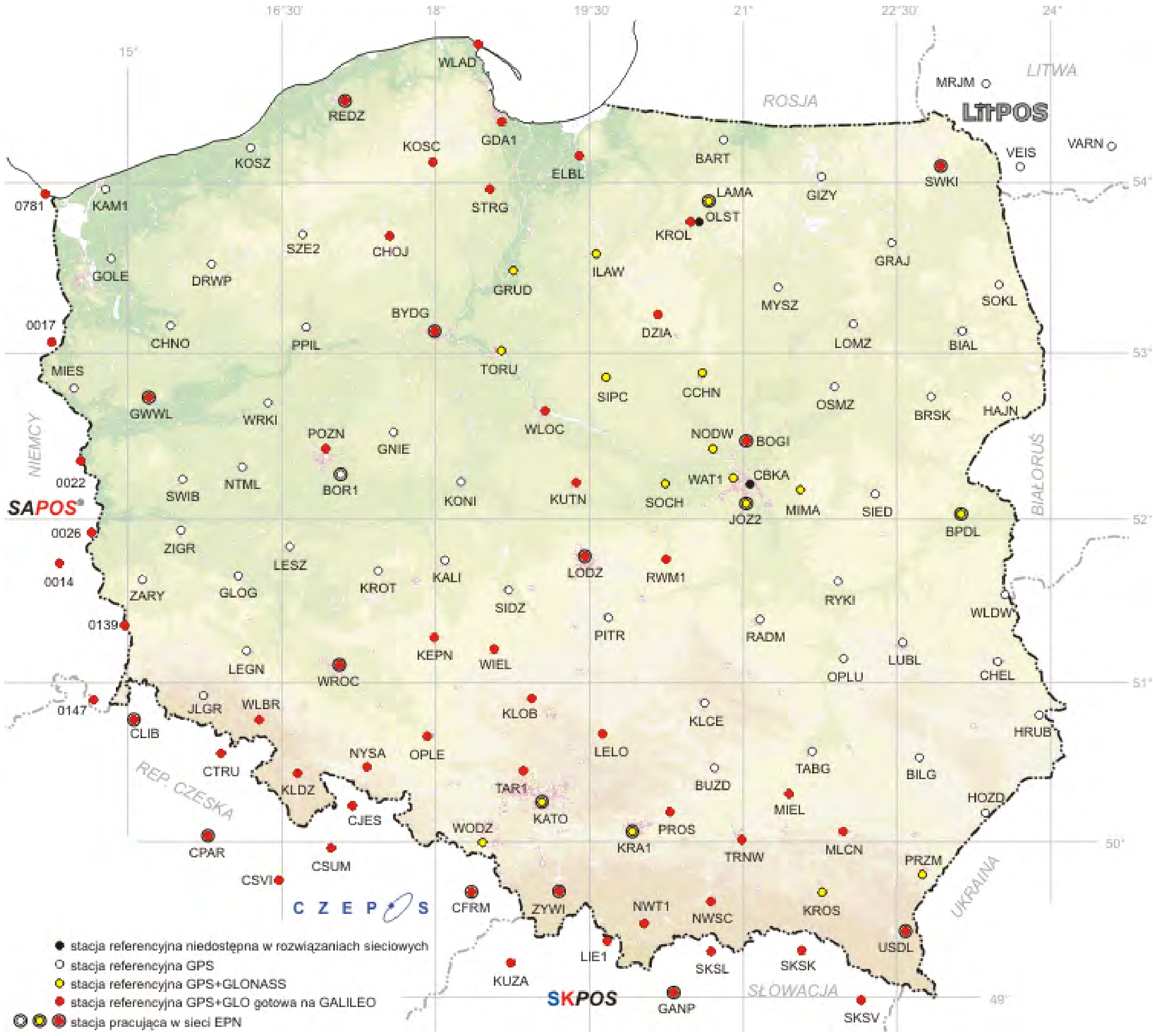

Fig. 1. Arrangement of reference stations in the ASG-EUPOS system

- **KODGIS** is a service dedicated for the kinematic measurement of DGPS, in which the assumed minimum accuracy of position determination is 0.25 m.
- **NAWGIS** is dedicated to the less accurate coordinate determination using cheaper code receivers GNSS. Standard format RTCM used in this service is recognized by all receivers equipped with an DGPS function. It provides positioning to an accuracy of a few meters (Approx.3 m).

Postprocessing provides two services:

- **POZGEO** allows performing automatic calculations in postprocessing mode of GPS observation performed by user with a static method. For the calculations are used phase observations performed with single and dual frequency receivers, converted to the specified observational data format and sent to the system.
- **POZGEO D** provides observations of the physical reference stations ASG-EUPOS system and created virtual reference stations, on the basis of the parameters preset by the user. This allows users to develop their own observational data based on two approaches. The first approach is a classic example for postprocessing, in which reference stations ASG-EUPOS constitute a reference system for the network of determined vectors.

Possible to obtain precision of the coordinates in both of these services depends on the class of measuring equipment, measuring environment and observation session length and on the average ranges from 0,01 to 0,10 m [Ryczywolski at all, 2010].

The ASG-EUPOS system includes currently (April 2015 r.) network of permanent reference stations consisting of 125 points, including 102 polish stations while 23 are foreign stations (Fig. 1).

All stations are connected by a special dedicated fiber-optic network with two working synchronously Administration and Control Centers (CZK), where the raw observations recorded at individual stations are sent. This ensures the practical implementation of the reference system ETRF89 in Poland, while additional system products in the form of GNSS corrections and raw but checked observations of reference stations provide precise real time positioning, support the navigation throughout the country and allow postprocessing of static measurements in a homogeneous reference system.

Description of the research experiment

In the test measurements a new-generation satellite receiver Trimble R10 integrated with the GNSS antenna, equipped with a TSC3 controller was used. It is a 440-channel satellite signal receiver, which is capable of performing integrated measurements for: GPS, GLONASS, BeiDou, SBAS systems as well as Galileo in the future. The new type of measurement solution (HD-GNSS) significantly reduces the convergence time of the receiver and at the same time improves the accuracy and reliability of the position determination in comparison to the earlier solution of Fixed / Float type, especially in difficult satellite conditions [www.trimble.com]. In addition, the Trimble R10 is equipped with a Trimble Xfill ™ technology, which uses special Trimble CenterPoint® RTX™ service, which provides GNSS corrections via satellite or the Internet with a precision for the Precise Point Positioning (PPP) solutions. This enables continuity of RTK measurements in the case of short interruptions in connection with a RTK base station or VRS network what significantly increases the efficiency of surveying works. Built-in tilt sensor allows performing correct measurements with a slight deflection from the vertical. While the electronic level built in the front panel protects the user from accidentally leaving the vertical during the measurement, through signaling level position on the controller. Additionally, the tilt parameters of the level can be stored at each measurement, then they can be included into the final processing of the results.

For a detailed assessment and verification of the usefulness of selected real-time services (NAWGEO) in the national, multi-purpose ASG-EUPOS positioning system the experimental measurements were performed at a test facility located in Krakow on the campus of the Faculty of Environmental Engineering and Geodesy at the University of Agriculture in Krakow in the area of streets: Balicka, Majora Łupaszki and Godlewskiego (φ=50,083°, λ=19,825°. h= 216 m above sea level). The test facility was the proving ground area consisting of 8 points, which precise coordinates have previously been determined by a static GNSS method. Points were arranged at distances from 120 m to 194 m between them, in the suburban area of low buildings, meeting the minimum requirements for the performance of satellite observations, only on two points (2053 i 2054) there were disadvantages arising from the location of the point in the immediate vicinity of buildings and other obstacles (Fig. 2).

Test measurements were made using the basic service (NAWGEO) used by surveyors in kinematic measuring by satellite GNSS RTK/RTN positioning techniques [Odijk at all, 2014].

Two types of solutions of corrective amendments were used (network solution – RTN and single station solution – RTK) in two versions: with use of GPS system and GPS+GLONASS system (Table 1).

Altogether four independent tests were performed, and four different correction data streams were transmited by a NTRIP protocol using the wireless communication GSM.

Fig. 2. Location of the test facility

Table 1

Basic information on the tests used in the research measurement

Marking of the test	Solution type	Satellite systems	Data format	Information
I	Network (RTN)	GPS+GLONASS	RTCM 10403.1 (VRS)	1004(1), 1005(5), 1007(5), 1012(1), 1030(5), 1031(5), 1032(10), 1033(5), 4094(10)
II	Network (RTN)	GPS	RTCM 10403.1 (VRS)	1004(1), 1005(5), 1007(5), 1030(5), 1032(10), 1033(5), 4094(10)
III	Single station (RTK)	GPS+GLONASS	RTCM 10403.1 (VRS)	1004(1), 1005(5), 1007(5), 1012(1), 1033(5)
IV	Single station (RTK)	GPS	RTCM 10403.1 (VRS)	1004(1), 1005(5), 1007(7), 1033(5)

Table 2

Examples of measurements recorded during the test measurements

Point number	Date / hour	Antenna height	PDOP	The number of satellites	Number of Entries	x	y	H	RMS 2D	RMS 1D
		[m]				[m]	[m]	[m]	[m]	[m]
139301	2015-02-25 07:06:09	1.696	1.6	13	5	_324.675	_566.440	214.246	0.005	0.008
139302	2015-02-25 07:06:17	1.696	1.6	13	5	_324.675	_566.441	214.245	0.006	0.009
139303	2015-02-25 07:06:27	1.696	1.8	13	5	_324.675	_566.440	214.243	0.006	0.009
…….	…….	…….	….	…	…	…….	…….	…….	…	…
139330	2015-02-25 07:11:28	1.696	1.6	13	5	_324.677	_566.435	214.248	0.004	0.007

30 independent measurements at each point of the research network within each series of tests were performed, each of which was preceded by a new initialization of the receiver. The measurements were made using assumed following parameters:

- elevation mask 10 degrees above the horizon,
- DOP factor < 6,
- minimum number of observed satellites 6,
- time of the point measurement 5 seconds.

During measurements antenna GNSS integrated with a satellite receiver was set fixed using tribrach, which was precisely centered and levelled over the measured point, on a heavy wooden tripod using the optical plummet equipped with cross levels. This solution was used to eliminate the ambiguity antenna alignment at the measured point during measurement. During the measurements standard results were recorded in the following form: designation of the measured point, exact date and time of the measurement, coefficient PDOP values, number of satellites being tracked, under which the position has been determined (L. sat), the number of RTK / RTN positions measured at the point (e), coordinates (x, y) in the PL-2000/21 reference system, heights in Kronsztadt'86 (H'K86) system, approximated by the receiver errors of the horizontal position determination (RMS 2D) and heights (RMS 1D). Examples of results of the measurements are shown in Table 2.

Analysis of the results of measurements

Coordinates of the points determined by static measurements were taken as reference for the needs to perform data analyses of obtained measurements results using each type of test. Relative to them deviations of measurements were calculated for each series of observation using the generally accepted formulas:

$$dx = x_w - x_p$$

$$dy = y_w - y_p$$

$$dH = H_w - H_p$$

The calculations were made separately for each of the applied solution. It was observed that the results were significantly different depending on the type of correction used when measuring and also on the location of measured control points. In addition, each series of measurements was characterized by the occurrence of some outlier measurements.

To analyze these relationships measurement results were analyzed for obtained differences: *dx, dy, dH* between the coordinate values assumed as model and the measured once. The distributions of these differences, for each individual coordinate and for each type of solution are shown graphically in Fig. 3 – 8.

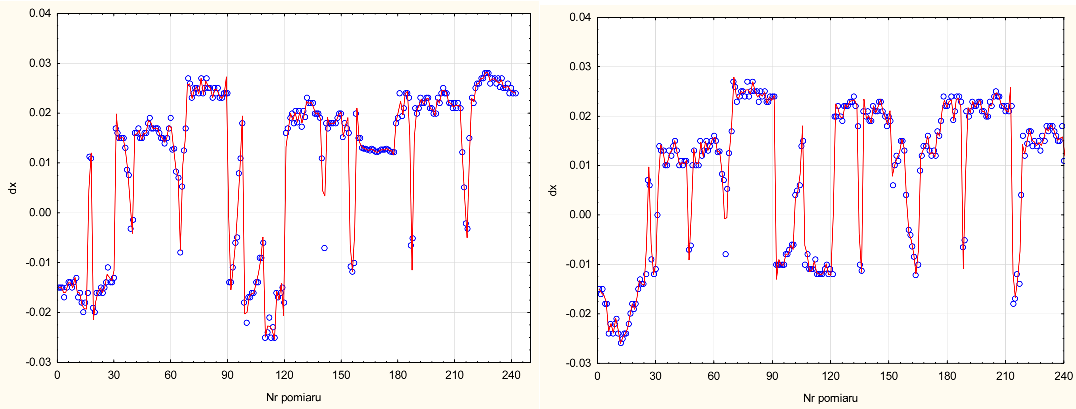

Fig. 3. Distributions of value dx obtained in network solutions RTN:GPS+GLONASS and GPS

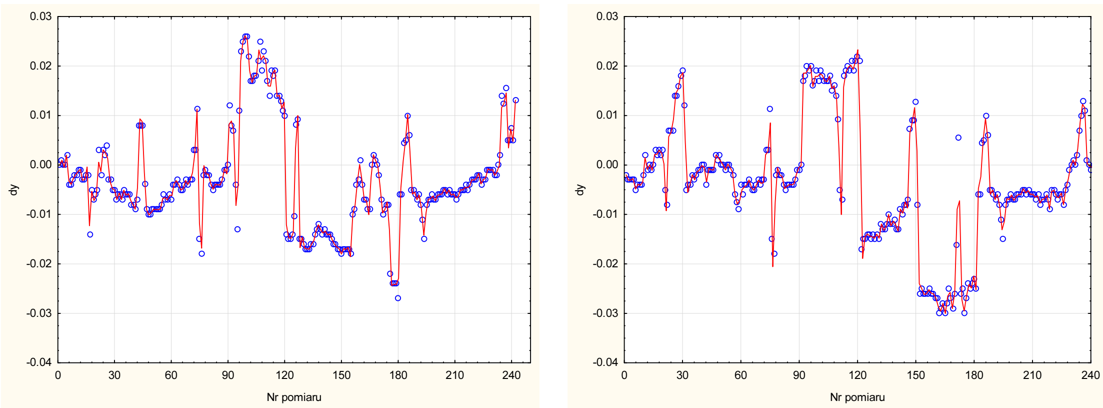

Fig. 4. Distributions of value dy obtained in network solutions RTN: GPS+GLONASS and GPS

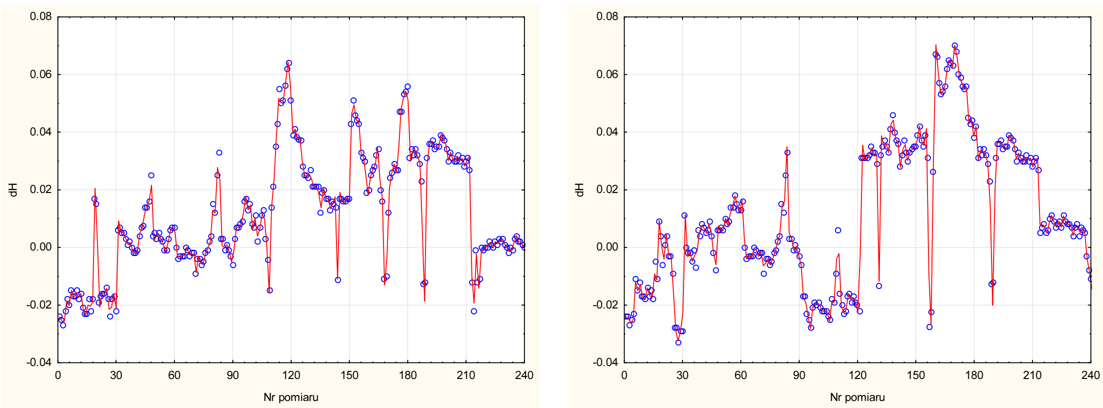

Fig. 5. Distributions of value dH obtained in network solutions RTN RTN:GPS+GLONASS and GPS

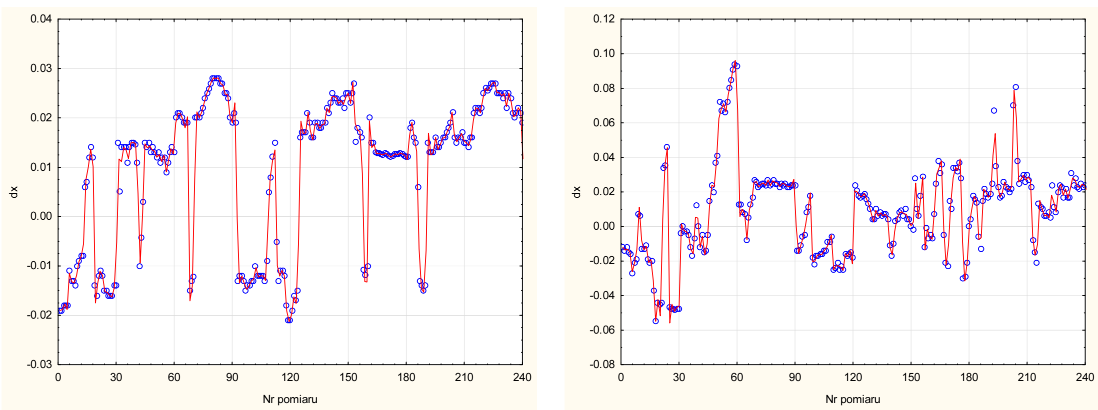

Fig. 6. Distributions of value dx obtained in network solutions RTN:GPS+GLONASS and GPS

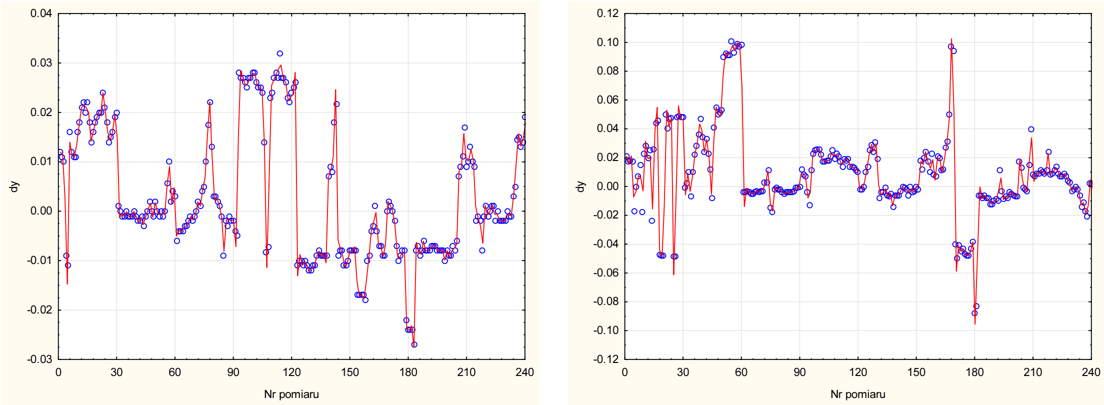

Fig. 7. Distributions of value dy obtained in network solutions RTN:GPS+GLONASS and GPS

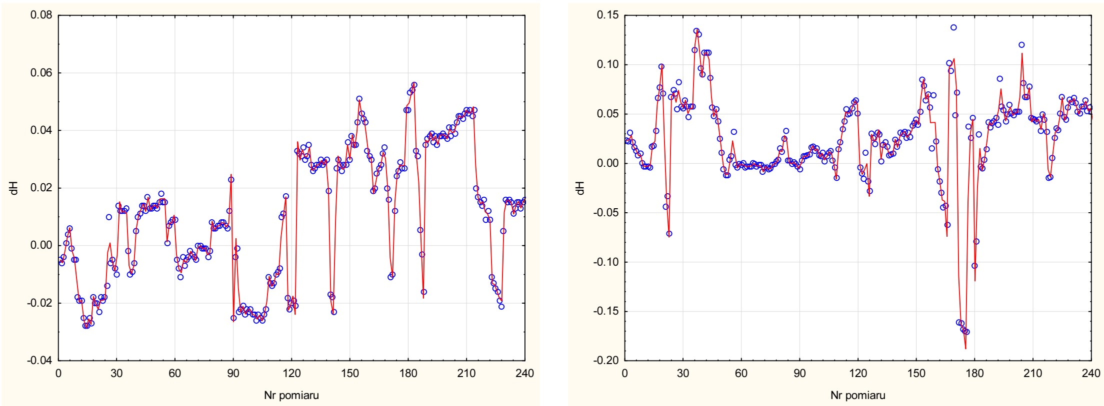

Fig. 8. Distributions of value dH obtained in network solutions RTN:GPS+GLONASS and GPS

It follows from the drawings 3 – 8 that the differences in the individual coordinates for adopted network solutions fall within the following ranges:

- using network corrections (measurement RTN):

– differences *dx* – from -0.025 m to +0.028 m for the GPS+GLONASS solution and from -0.026 m to +0.027 m for the GPS solution;

– differences *dy* – from -0.027 m to +0.026 m for the GPS+GLONASS solution and from -0.030 m to +0.022 m for the GPS solution;

– differences *dH* – from -0.027 m to +0.064 m for the GPS+GLONASS solution and from -0.033 m to +0.070 m for the GPS solution,

- using corrections from a single station (measurement RTK):

– differences *dx* – from -0.021 m to +0.028 m for the GPS+GLONASS solution and from -0.055 m do +0.094 m for the GPS solution;

– differences *dy* – from -0.027 m to +0.032 m for the GPS+GLONASS solution and from -0.088 m do +0.101m for the GPS solution,

– differences *dH* – from -0.028 m to +0.056 m for the GPS+GLONASS solution and from -0.171 m to +0.138 m for the GPS solution.

On this basis, it can be concluded that the differences dx, dy and dH between coordinates adopted as model and the measured coordinates generally fall within the accuracies provided by the NAWGEO service. Only in the case of individual measurements for the differences dy (for measurements RTK – GPS+GLONASS) and for differences *dH* (for measurements RTN – GPS+GLONASS and RTN – GPS and also RTK – GPS+GLONASS) they are slightly larger than the given accuracy. Exceptions are differences *dx*, *dy* and *dH*, obtained by RTK measurements solely based on GPS system satellites signals, where the ranges of these differences far exceed established accuracy of the NAWGEO service.

To characterize the resulting differences *dx*, *dy* and *dH*, depending on the type of the applied corrections, generally known statistical models were used and following values for them were calculated: minimum (Min), maximum (Max), average (Average), median, standard deviation (**σ**) and dispersion (R). The calculated values for these statistical measures on the basis of generally known relations [Stanisz 2006] are presented in tables 3–6.

Table 3

Test I – network solution RTN – GPS+GLONASS

Variable	Average	Median	Min	Max	R	σ
	[m]	[m]	[m]	[m]	[m]	[m]
dx	0.010	0.016	-0.025	0.028	0.053	0.016
dy	-0.003	-0.004	-0.027	0.026	0.053	0.010
dH	0.012	0.007	-0.027	0.064	0.091	0.020

Table 4

Test II – network solution RTN – GPS

Variable	Average	Median	Min	Max	R	σ
	[m]	[m]	[m]	[m]	[m]	[m]
dx	0.009	0.014	-0.026	0.027	0.053	0.015
dy	-0.003	-0.004	-0.030	0.022	0.052	0.012
dH	0.011	0.007	-0.033	0.070	0.103	0.025

Table 5

Test III – solution RTK – single station GPS+GLONASS

Variable	Average	Median	Min	Max	R	σ
	[m]	[m]	[m]	[m]	[m]	[m]
dx	0.009	0.014	-0.021	0.028	0.049	0.015
dy	0.003	-0.001	-0.027	0.032	0.059	0.013
dH	0.010	0.012	-0.028	0.056	0.084	0.022

Table 6

Test IV – solution RTK – single station GPS

Variable	Average	Median	Min	Max	R	σ
	[m]	[m]	[m]	[m]	[m]	[m]
dx	0.009	0.010	-0.055	0.094	0.149	0.026
dy	0.009	0.007	-0.088	0.101	0.189	0.030
dH	0.026	0.026	-0.171	0.138	0.309	0.046

It follows from the presented tables that the mean values of the differences *dx* and *dy* obtained from the measurement in all tests are at milimeter level and fall in the range from -3 mm to 10 mm. While the average values of observed differences in height *dH* are contained in the range from 10 mm to 26 mm.

These results indicate high accuracy of the measurements based on the average of the series of 30 observations.

While the measure of variability – the dispersion R compiled in Tables 3–6, characterizing the variability of individual differences points out, that for network solutions RTN – GPS+GLONASS and RTN – GPS as well as the solution RTK – GPS+GLONASS from single station measurement precision was obtained in the form of deviations respectively:

- *dx* in the range from 4,9 cm to 5,3 cm,
- *dy* in the range from 5,2 cm to 5,9 cm,
- *dH* in the range from 8,4 cm to 10,3 cm.

These deviations show that the actual measurement precision is significantly lower, and for a single measurement it could be up to five times deterioration.

Muh worse results were obtained on the basis of a solution using only measurements for GPS satellites. In this case, corrections from a single

reference station gave precise measurement at a decimeter level, respectively:

- *dx* = 14.9 cm,
- *dy* = 18.9 cm,
- *dH* = 30.9 cm.

Moreover these results are confirmed in tables 3–6, by the value of the standard deviation (σ), which is on average more than twice biger in test IV with respect to other solutions although the reference station on the basis of which the measurements RTK – GPS were made, is at a distance of less than 5 km from the measured object.

Conclussions

1. In Poland since June 2008 has been operating a multi-purpose satellite system for precise positioning called ASG-EUPOS, which is part of a larger project EUPOS. This system, based on permanent stations GNSS allows to improve the precision, the accuracy and reliability of the results of the satellite measurements. ASG-EUPOS provides users with its two primary services: real-time and postprocessing.

2. Measurement experiments were carried out using ASG-EUPOS network aimed at finding, in which ranges of values fall the differences of coordinates *dx*, *dy* i *dH*, between their values determined by the static method (adopted as the reference), and determined by RTN and RTK methods using satellites systems GPS+GLONASS or only GPS satellites. They showed that these differences of coordinates generally are included into the accuracies provided by the NAWGEO service. The exceptions are differences dx, dy and dH, obtained from measurements RTK – GPS, where the ranges of these differences far exceed established accuracy of the NAWGEO service.

3. The mean values of the differences dx and dy obtained from measurements in all tests are at the level of milimeters and are included in the limits from -3 mm to +10 mm. While the observed average values of differences in height dH are contained in the range from +10 mm to +26 mm. This indicates a high accuracy of the measurements basing on the average of the series of 30 observations. The precision of a single measurement is up to five times lower for network RTN – GPS+GLONASS and RTN – GPS solutions and RTK – GPS+GLONASS solutions from a single station, in the case of network RTK – GPS solution – it is much more than ten times lower.

4. Basing on the results of the experimental test can be established, that highest accuracy and reliability of results provide RTN – GPS+GLONASS measurements.

5. It seems necessary to carry out similar experimental measurings in other seasons of the year, which will be considered more independent, and thereby enable more accurate knowledge of the actual precision of the real time satellite measurements based on the corrections derived from the NAWGEO service of the ASG-EUPOS system network.

REFERENCES

Bosy J., Oruba A., Graszka W. (2010). ASG-EUPOS i podstawowa osnowa geodezyjna w Polsce. Biuletyn WAT, Vol. LIX, Nr 2, pp. 7–15.

Dawidowicz K., Krzan G. (2014). Accuracy of single receiver static GNSS measurements under conditions of limited satellite availability. Survey Review, 2014. – Vol. 46. – No 337.

Lamparski J., Światek K. (2007). GPS w praktyce geodezyjnej. Wydawnictwo Gall, Katowice.

Odijk D., Teunissen P. J. G. and Khodabandeh A. (2014). Galileo IOV RTK positioning: standalone and combined with GPS. Survey Review, 2014. – Vol. 46. – No 337.

Prasad R., Ruggieri M. (2005). Applied Satellite Navigation Using GPS, GALILEO, and Augmentation Systems. Boston: Artech House, ©2005.

Rife J., Phelts R.E. (2009). Formulation of a Time-Varying Maximum Allowable Error for Ground-Based Augmentation Systems. Aerospace and Electronic Systems Stanford University.

Ryczywolski M., Oruba A., Wajda S. (2010). Coordinate stability monitoring module working within ASG-EUPOS reference station network. EUREF 2010 International Symposium, 2–5.06.2010, GUGiK, Gavle (Sweden) 2010.

Stanisz A. (2006). Przystępny kurs statystyki. T1. StatSoft Polska, Kraków.

Trimble HG-GNSS processing. White Paper, Trimble Survey Division, Westminster, Colorado, USA, September 2012.

http://www.asgeupos.pl/.

https://www.glonass-iac.ru/en/GLONASS/.

http://www.insidegnss.com/compass/.

EUPOS – Technical Standards [Online] (2013) http://www.eupos.org/images/eupos_files/eupos%20technical%20standards%20isc-r13_2.pdf.

http://www.insidegnss.com/galileo/.

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ПОЛЬСЬКА АКТИВНА ГЕОДЕЗИЧНА МЕРЕЖА ЯК БАГАТОФУНКЦІОНАЛЬНА ЗАГАЛЬНОНАЦІОНАЛЬНА СИСТЕМА НАВІГАЦІЇ І ПОЗИЦІОНУВАННЯ

Мета. Метою роботи є дослідження можливостей використання в режимі реального часу геодезичних супутникових вимірів, системи підтримки наземних систем функціонального доповнення (GBAS) типу. У статті аналізуються результати і оцінено фактичну точність вимірювань реальних польових вимірів, залежно від обраного рішення. Прикладні рішення містили використання вимірів у реальному часі, два типи корекції, для мережі з однією базовою станцією, і одну або дві системи позиціонування, інтегровані одна з одною. **Методика.** Науково-дослідні виміри проводилися за допомогою багатофункціонального супутникового позиціонування ASG-EUPOS системи, що працює в Польщі з 2008 року. Ця система заснована на мережі наземних опорних станцій ГНСС, які поширюються приблизно рівномірно по всій країні. Поверхня випробування складається з точок, які були раніше виміряні статичним методом і їхні координати були визначені в подальшій обробці. У тестових вимірах використовувалися чотири різні послуги, які забезпечують диференціальні поправки через Інтернет. У результаті були отримані 3D-координати точок випробувань, які і є предметом детального аналізу, з погляду отриманої точності і точності визначення координат, на основі одного виміру, використовуючи вибрані послуги. **Результати.** Результати виконаних вимірювань та аналіз вимірювань у режимі реального часу, по-перше, показали переваги мережевих поправок над поправками від однієї базової станції. А по-друге, вони допомогли продемонструвати емпірично перевагу вимірювань, зроблених на основі двох систем позиціонування стосовно вимірювання за допомогою всього лише однієї системи. Новий аспект цієї роботи полягає в одночасному використанні в режимі реального часу вимірювань поправок GPS і ГЛОНАСС супутників. **Практична значущість**. Поточний стан просування технології супутникових вимірів, виконаних у режимі реального часу, дає змогу визначити координати з різною точністю, з точністю на рівні сантиметрів в дециметровій точності. Тип вимірювання устаткування, використовуваного в цьому випадку, відіграє важливу роль. На основі проведеного експерименту рекомендуємо використовувати два системні приймачі, щоб гарантувати високу точність вимірювань і впевненість у результатах.

Ключові слова: RTK / RTN GNSS; GBAS; точність; точність координат точок.

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ПОЛЬСКАЯ АКТИВНАЯ ГЕОДЕЗИЧЕСКАЯ СЕТЬ КАК МНОГОФУНКЦИОНАЛЬНАЯ ОБЩЕНАЦИОНАЛЬНАЯ СИСТЕМА GPS

Цель. Целью работы является исследование возможностей использования в режиме реального времени геодезических спутниковых измерений, системы поддержки наземных систем функционального дополнения (GBAS) типа. В статье анализируются результаты и оценена фактическая точность измерений реальных полевых измерений, в зависимости от выбранного решения. Прикладные решения содержали измерения в реальном времени, два типа коррекции, для сети с одной базовой станцией, и одну или две системы позиционирования, интегрированные друг с другом. **Методика**. Научно-исследовательские измерения проводились с помощью многофункционального спутникового позиционирования ASG-EUPOS системы, работающей в Польше с 2008 года. Эта система основана на сети наземных опорных станций ГНСС, которые распространяются примерно равномерно по всей стране. Поверхность испытания состоит из точек, которые были ранее измеренные статическим методом и их координаты были определены в дальнейшей обработке. В тестовых измерениях использовались четыре различные услуги, которые обеспечивают дифференциальные поправки через Интернет. В результате полученные 3D-координаты точек испытаний, которые и являются предметом детального анализа с точки зрения полученной точности и точности определения координат, на основе одного измерения, используя выбранные услуги. **Результаты**. Результаты выполненных измерений и анализ измерений в режиме реального времени, во-первых, показали преимущества сетевых поправок над поправками от одной базовой станции. А во-вторых, они помогли продемонстрировать эмпирически преимущество измерений, сделанных на основе двух систем позиционирования по отношению к измерению с помощью всего лишь одной системы. Новый аспект этой работы заключается в одновременном использовании в режиме реального времени измерений поправок GPS и ГЛОНАСС спутников. **Практическая значимость**. Текущее состояние продвижения технологии спутниковых измерений, выполненных в режиме реального времени, позволяет определить координаты с разной точностью, с точностью на уровне сантиметров в дециметровой точности. Тип измерения оборудования, используемого в этом случае, играет важную роль. На основе проведенного эксперимента рекомендуется использовать два системных приемники, чтобы гарантировать высокую точность измерений и уверенность в результатах.

Ключевые слова: RTK / RTN GNSS; GBAS; точность; точность координат точек.

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