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FOREWORD

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Authors of the papers are teachers, researchers and practising professionals from Latvia, Lithuania, Belarus, Kazakhstan, Romania, Russia and Ukraine.
In research are studied problems of land administration, land management, real property cadastre, rural development, geodesy and cartography, geoinformatics, other related fields and education in land management and geodesy.
Each author is responsible for correct information of his/her article.

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Editorial board

ПРЕДИСЛОВИЕ

Сборник научных статей научно – методической конференции "BALTIC SURVEYING'14" является периодическим изданием научных статей, которые публикуются в электронном (ISSN 2243-6944) и печатном (ISSN 2243-5999) виде. Периодичность издания сборника один год.
Конференция состоялась 7-9 мая 2014 года в г. Елгава, ул. Академияс 19, в Латвийском сельскохозяйственном университете и была организована Кафедрой землеустройства и геодезии.
Авторами статей являются преподаватели, ученые и специалисты производства Латвии, Литвы, Белоруссии, Казахстана, Румынии, России и Украины.
В статьях обобщены научные и практические вопросы земельной политики, землеустройства, кадастра недвижимого имущества, сельского развития, геодезии и картографии, геоинформации и др. направлений, а также научные проблемы образования в сфере землеустройства и геодезии.
Каждый автор отвечает за правдивость информации, содержащейся в статье.

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Редколлегия

CONTENT

RESEARCH RESULTS OF THE RTK MEASUREMENT ACCURACY USING GNSS RECEIVERS

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Abstract

With the development of networks of active reference stations and the implementation of network solutions for various services providing, including VRS- network and centralized NTRIP servers, satellite measurements in real time (RTK) reached a new qualitative level. Examples of such services of geodetic use providing in Ukraine include networks of satellite stations ZAKPOS / UA-EUPOS, TNT-TPI GNSS Network, System.NET etc.

The paper presents the results of the conducted experimental studies of RTK- measurements accuracy using GNSS receivers. It is proved at the considerable experimental material that there is no increase of accuracy from the use of dual-system receivers in real time. An important factor is only the significant improvement of the receiving time of fixed solution.

Key words: RTK measurements, accuracy, virtual reference station - VRS

Introduction

Using signal of multiple navigation systems simultaneously may provide users with practical advantages of satellite equipment. Most satellite signals receivers, which are produced in the world generally (except products for special purpose), - dual-system, which can operate with two full navigation systems: GPS and GLONASS. This should be a big plus according to the developed over the years trend of satellite positioning (Dodson, 1999). It is believed that in order to determine the coordinates according to the signals of satellite navigation systems it is necessary to receive them at least from four satellites, in case receiver sees more satellites – it is very good: it will be able to choose the optimal configuration among all satellites and define coordinates with more precision. At first glance, it is obvious. In order to understand this evidence it is sufficient to consider two navigation systems from the technical side. The most noteworthy may be three stereotypes. The first stereotype - is a statement that an increase in the number of satellites increases the accuracy of position finding. The second stereotype - that in difficult conditions (urban planning, natural canyons) - the probability increases of detecting a sufficient number of satellites with the help of the second system. Third one – concerning interference immunity GLONASS, as this navigation system is a FDMA system, namely a system with frequency channels division (Habrich, 1999).

When the number of satellites increases, respectively, and the geometry of their location increases respectively. Calculations, using the program Planning (from the company Trimble) show that in the equatorial zone by adding GLONASS to GPS – the improvement is about 15 % -20 %. At the poles and closer to them, due to different orbits, this improvement can be up to 25%, maybe 35%.

So, the first conclusion we can make is the following : the use of 2- system receiver can give us a "theoretical " accuracy increasing by 20 % -30 % (Kozlow, 1998).

As to the second stereotype, we may take into consideration the data of the specific experiments (Leick, 1998). They were held in various major cities around the world and have shown on the broad streets the use of two systems gives acceptable results no more than 10 %, and on the narrow ones - upshot will never happen.

For the third stereotype there is no single answer, as interference immunity of GLONASS signals will depend on many factors (the specific implementation of the radio frequency, its design, etc.).

Detection of spatial coordinates with the help of satellite measurements using GPS navigation system in real time (RTK) has recommended itself as effective means of operational coordination in various areas. In the last decade, the active development of mobile communication (the territories coverage by which are constantly expanding) promotes widespread use of RTK technology.

Claimed by the manufacturer and confirmed by long experience of work benefits of RTK technology - are beyond doubt (Meng, 2007). However, a number of issues concerning both technological nature and accuracy of the spatial coordinates defining, generates much discussion and false prerequisites when choosing a method for satellite observations of different purposes and accuracy class. These may include issues on the effectiveness of the use of multiple satellite receivers GPS and GLONASS. Our experimental studies are dedicated to this problem.

Materials and methods

Prerequisites for resolution of such problem may include very close ideology of building these systems, as well as the proximity of time intervals of their creation. As a result of numerous joint research, it is found that by improving the geometric factor that depends on the number of satellites which can be used simultaneously, and their distribution within the visible sky, the accuracy of the coordinates in both plan and height can be improved about for 1.5 times (Swan, 1999). In this case, an additional increase of accuracy in the common use of GPS and GLONASS signals is achieved by increasing the amount of processed information and the corresponding reduction of systematic errors which are typical for each of these systems separately, it means that a well known in geodesy rule operates - the greater number of these measurements is better to assess the accuracy of the received results.

Along with these factors, the autonomous integrity control of signals in the receiver is also improved. When using the systems for navigation it is established that their integration can improve the interference immunity in the conditions of natural and artificial obstacles, as well as the continuity and reliability of navigational definitions results.

However, to solve geodetic problems, the problem of GPS and GLONASS systems integration at typical for geodesy high level of accuracy is more difficult (Wang, 1999). Testing methods for such systems integration is based on the use of the developed in recent years, high-precision and dual-system frequency receivers adapted to receive radio signals from the two aforementioned systems.

If during the long-term static observations, the tangible effect from using GLONASS signals practically is not detected (tabl.1), then according to the generally accepted statement, nowadays reliable and fast kinematics in real time (RTK) simply is not possible without a combination of satellite signals of GPS and GLONASS (Zinoviev, 2005).

Regarding the first statement, then Table. 1 shows the results of daily GNSS - observations (throughout the whole 2013 year) from stations of network ZAKPOS/UA-EUPOS in Lviv Polytechnic National University, which clearly confirm this.

Results of static GNSS- observations using dual-system receivers

Table 1

Solution	**Coordinate**		
	N, **mm**	E, **mm**	U, **mm**
GPS_GLO	3.3	2.9	6.4
GPS	3.0	2.8	4.1

Concerning the second statement, we have carried out a special experimental study of RTK-measurements accuracy using a GNSS receivers. The essence of these studies was as follows:

12. to organise experimental GNSS observations on the use of receivers on the station FRAN (Ivano -Frankivsk) with known coordinates (the station FRAN, part of the network ZAKPOS/UA-EUPOS, conducted experimental GNSS observations on the use of multiple-receiver for a long time).
13. to obtain unambiguous results and their further comparison, it was decided to make observations by four receivers simultaneously from the navigation system GPS and GPS + GLONASS using one antenna and splitter.
14. perform surveillance in real time, from the network (virtual reference station - VRS) and from individual GNSS stations located at different distances from the station FRAN.

Observations were done using GNSS receivers Topcon GRS- 1 with antenna PGA- 1. The same type firmware (TopSURV) were installed at all receivers. Wiring equipment scheme is shown in Figure 1, and a diagram of the experimental network - in Figure 2.

Statistics of conducted observations is given in Table 2.

Most observations were carried out in a continuous mode during office hours from a single reference station and VRS at the same time and this constituted "Experiment 1". Another day, observations were performed similarly, only reference station varied and, therefore, it constituted "Experiment 2". All in all there were three days of observation, and their total number was 356 874. Distances to the reference stations were 41, 80 and 103 km, respectively. Since the coordinates of the station FRAN, where observations were conducted, were sufficiently determination from long-term (nearly two years) static observations, the estimation accuracy of received observations results from RTK was calculated as a simple difference and was set in topocentric coordinate N, E, U.

Fig. 1. Equipment for the experiment organization.

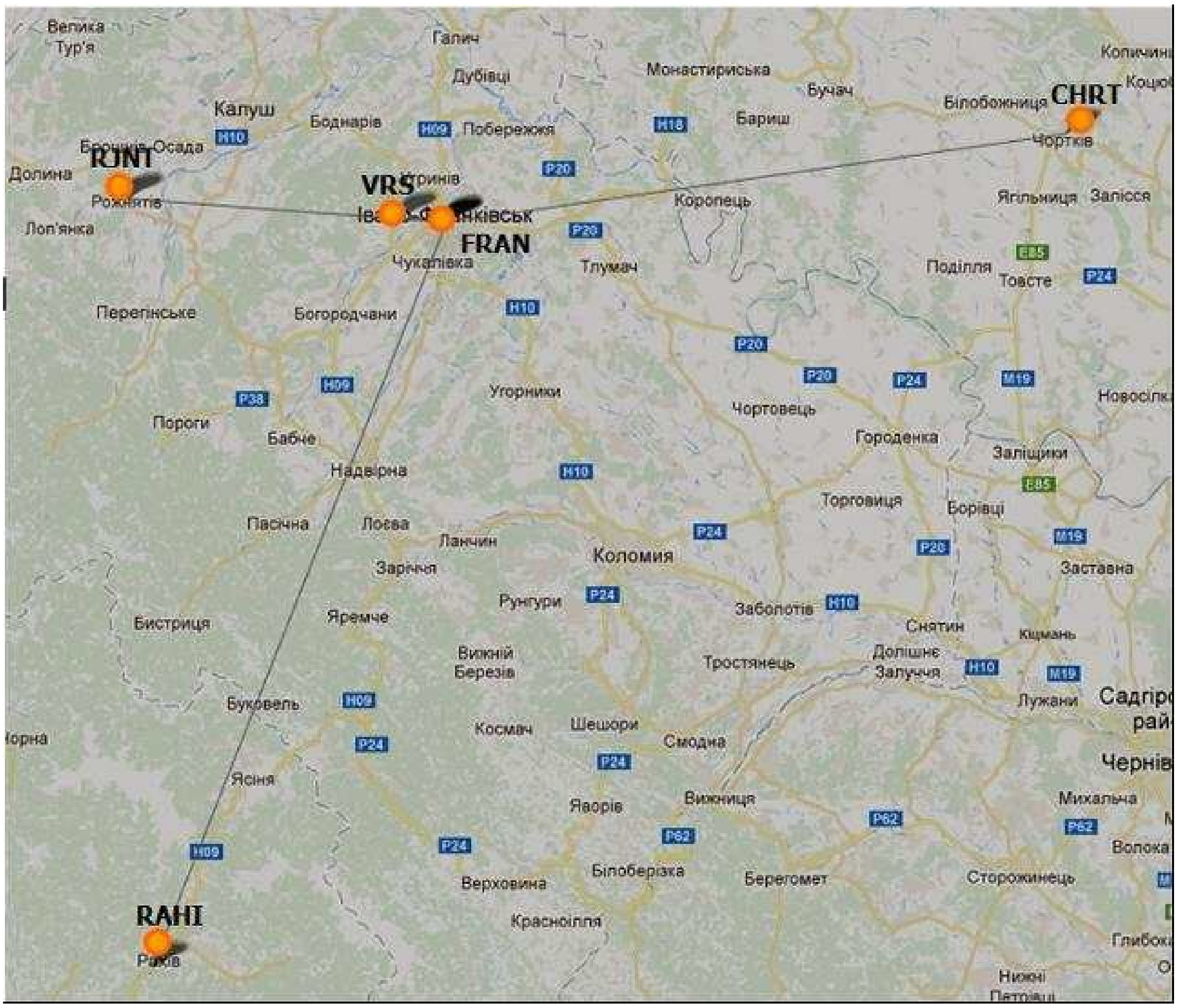

Fig. 2. The experimental network scheme.

Statistics of observations

Table 2

<table>
<tr><th rowspan="3">Exp.</th><th rowspan="3">Station</th><th rowspan="3">Satellite systems</th><th rowspan="3">Distance, km</th><th colspan="4">Number of satellites</th><th rowspan="3">Number of observations</th></tr>
<tr><th colspan="2">GPS</th><th colspan="2">GLONASS</th></tr>
<tr><th>min</th><th>max</th><th>min</th><th>max</th></tr>
<tr><td rowspan="4">1</td><td rowspan="2">RJNT</td><td>GPS</td><td rowspan="2">41</td><td>6</td><td>6</td><td>-</td><td>-</td><td>30626</td></tr>
<tr><td>GPS+GLO</td><td>6</td><td>9</td><td>4</td><td>9</td><td>30663</td></tr>
<tr><td rowspan="2">VRS</td><td>GPS</td><td rowspan="2">6</td><td>6</td><td>9</td><td>-</td><td>-</td><td>27760</td></tr>
<tr><td>GPS+GLO</td><td>6</td><td>9</td><td>5</td><td>9</td><td>29512</td></tr>
<tr><td rowspan="4">2</td><td rowspan="2">CHRT</td><td>GPS</td><td rowspan="2">80</td><td>5</td><td>9</td><td>-</td><td>-</td><td>25969</td></tr>
<tr><td>GPS+GLO</td><td>6</td><td>9</td><td>5</td><td>9</td><td>25973</td></tr>
<tr><td rowspan="2">VRS</td><td>GPS</td><td rowspan="2">6</td><td>6</td><td>9</td><td>-</td><td>-</td><td>36636</td></tr>
<tr><td>GPS+GLO</td><td>5</td><td>9</td><td>4</td><td>9</td><td>39615</td></tr>
<tr><td rowspan="4">3</td><td rowspan="2">RAHI</td><td>GPS</td><td rowspan="2">103</td><td>5</td><td>9</td><td>-</td><td>-</td><td>20321</td></tr>
<tr><td>GPS+GLO</td><td>5</td><td>9</td><td>2</td><td>9</td><td>29814</td></tr>
<tr><td rowspan="2">VRS</td><td>GPS</td><td rowspan="2">6</td><td>6</td><td>9</td><td>-</td><td>-</td><td>31267</td></tr>
<tr><td>GPS+GLO</td><td>5</td><td>9</td><td>4</td><td>9</td><td>28950</td></tr>
</table>

Results and discussion

Table 3 shows the characteristics of the coordinates determination accuracy in all three experiments, and in Table 4 shows average indicators of accuracy after filtration of measurements. The process of filtering determination these results that were obtained as a result of measurements after short disruptions in the Internet connection or after abrupt changes of fixed upshot for the floating or vice versa.

Statistics of accuracy of the coordinates determination of RTK- measurements

Table 3

Experiment	N min, cm	N max, cm	E min, cm	E max, cm	U min, cm	U max, cm
1 GPS_GLO_RJNT	-8.6	6.3	-4.6	8.4	-10.2	18.1
1 GPS_GLO_VRS	-4.6	6.7	-6.9	4	-13.5	4.6
1 GPS_RJNT	-14.8	10.8	-8.2	12.9	-20	16.8
1 GPS_VRS	-9.5	7.4	-4.2	5.4	-13.8	8.8
2 GPS_CHRT	-20.3	25	-18.1	3	-25	25
2 GPS_GLO_CHRT	-13.8	8.6	-18.5	2.3	-21.5	23.1
2 GPS_GLO_VRS	-11.8	12.1	-5.2	9.2	-18.3	17.8
2 GPS_VRS	-17.3	12.7	-7.1	11.3	-25	20
3 GPS_GLO_RAHI	-6.4	12	-8.1	7.7	-25	0.9
3 GPS_GLO_VRS	-5	8.2	-3	8.5	-11	16.6
3 GPS_RAHI	-0.7	25	-9	15.8	-25	13.2
3 GPS_VRS	-7.7	9.7	-8.8	8.1	-16.4	20

Table 4

Statistics of accuracy of the coordinates determination after filtration of RTK- measurements

Experiment	Number of observations	Filtration in plane	Filtration in height, cm	Accuracy in plane, cm	Accuracy in height, cm
1 GPS_GLO_RJNT	30648	26647	17615	2.8	2.4
1 GPS_GLO_VRS	29488	29100	23651	1.7	2.1
1 GPS_RJNT	30620	18008	19141	3.1	2.3
1 GPS_VRS	27748	27043	21139	1.9	2.2
2 GPS_CHRT	25963	11765	12853	6.7	4.5
2 GPS_GLO_CHRT	25961	13335	15295	7.2	4.7
2 GPS_GLO_VRS	39556	31768	23541	2.8	2.3
2 GPS_VRS	36600	23454	18617	2.9	2.3
3 GPS_GLO_RAHI	29796	29772	28178	3.9	11
3 GPS_GLO_VRS	28944	27071	19348	2.4	2.2
3 GPS_RAHI	20298	12374	9514	10.6	9.8
3 GPS_VRS	31252	26761	17258	2.8	2.3
Total	356874	277098	226150		

Analysis of the data in tables 3 and 4 shows that there is no increase of accuracy from the using of dual-system receivers in real time. An important factor is only the significant improvement of time for initialization and, therefore, increase of the number of fixed upshot over certain period of time.

Conclusions

22. Experimental GNSS observations by RTK method were conducted on a separate station with known coordinates FRAN using four receivers Topcon GRS- 1.

23. The observations were performed in real time, from the network ZAKPOS / UA-EUPOS (from virtual reference station - VRS) as well as from individual GNSS stations, located at different distances (~ 40, 80, 100 km) from the station FRAN. Totally more than 350 000 of observational data are received.

24. Averaged accuracy for variant GPS_GLO_VRS amounted: 0.9 cm, 1.1 cm, -0.6 cm for the coordinates respectively, and for GPS_VRS - 0,8 cm, 0.7 cm, -1.6 cm.

25. Averaged accuracy for variants GPS_GLO_ and GPS_ from individual stations did not differ significantly among themselves. The differences in accuracy were shown only depending on the distance from them. Thus, during the observation from station RJNT (40 km) - coordinate accuracy was -1.2 cm, -1.9 cm , 4.0 cm respectively , from the station CHRT (80 km): -2.6 cm, -8.2 cm, 6.4 cm, and from the station RAHI: 2.8 cm , 3.4 cm, -12.1 cm

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