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PROSPECTS OF METROLOGICAL PROVISION LINEAR GEODETIC OF MEASUREMENTS ON THE GEODETIC TEST FIELD

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Abstract

This paper gives brief information on existing metrological support for the Yavoriv of scientific of the geodetic of test field (SGTF) for testing of modern of surveying equipment (rangefinders, electronic total stations and GNSS receivers). Analyzed ways to improve the fundamental geodetic network and the standard linear of basis, as working standards for testing, in accordance, GNSS receivers and a rangefinders, as well as for study an accuracy technology of GNSS leveling.

Keywords: the geodesic metrology, working of standards, test line of the geodetic basis, the fundamental geodetic network, GNSS observations, GNSS leveling.

1. Introduction

Requirements for metrological certification and monitoring precision geodetic measurements and related instrumentation are growing. Currently, the most common measurements are - linear and measurement phase of the carrier wave, such as global navigation satellite systems (GNSS). Metrological support is the installation and use of metrological rules and regulations, as well as the development, creation and use of technical means (working standards) which are needed to achieve the desired unity and precision of measurements. We know that of the working standards are the fundamental geodetic network and test line of the geodetic basis on which the test of geodetic instruments is performed.

In our view, the development of metrological provision is to: 1) improve the accuracy working standards for the certification of geodetic instruments due to increased measurement accuracy, 2) creating the conditions for research and testing the accuracy of satellite technology, including GNSS leveling and satellite methods for the determination of the geodynamic movements of the earth's surface.

2. The existing metrological support scientific of geodesic network in YAVORIV

Working standards (Fig. 1) on Yavoriv SGN (Trevoho & Tsyupak, 2011b) are: 1) test line of the geodetic basis (points T1, ..., T20) to check linear measurement devices and 2) fundamental of geodetic reference network (GOSH, VASL, ANDR, TZSU and POLY) for testing receivers GNSS. On Fig. 1 indicated the distance between points in kilometers.

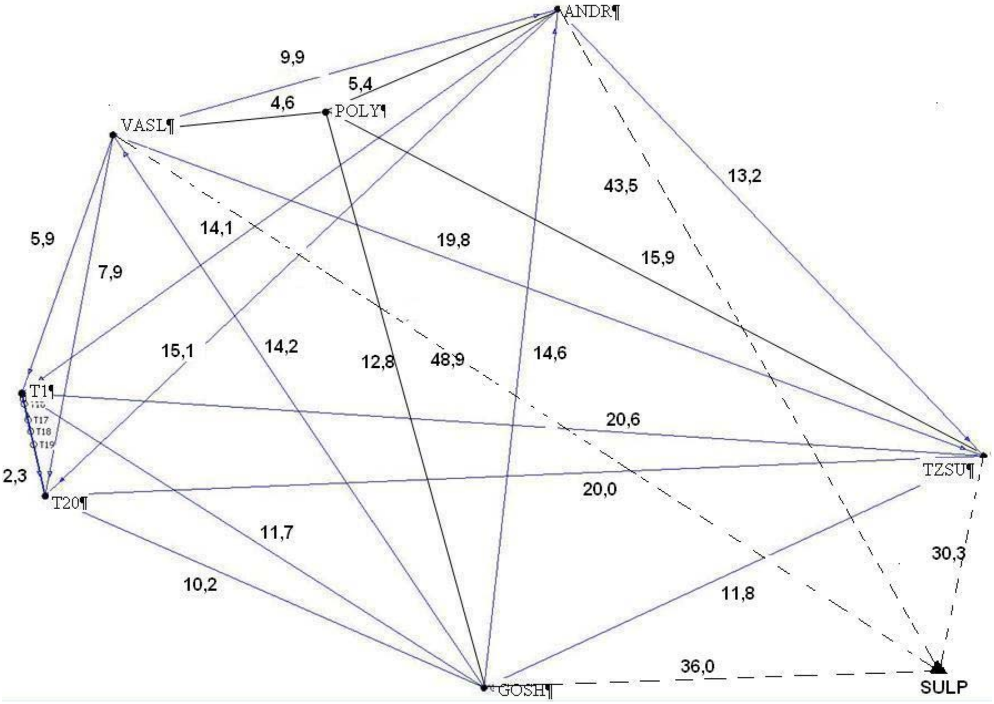

Fig. 1. Scheme of the fundamental geodetic network and the test line of the geodetic basis

Metrological certification of the test line of the geodetic basis is performed since 2003. Total length of the reference base – 2260 m, which is sufficient for most topographic electronic total stations. Standard basis consists of 20 points, which are fixed tubular diameter 200 mm centers. Precision centering devices ≤0.2 mm. Intervals of basis have special design: 1) the phase plot to control the frequency of rangefinder, 2) interval of basis, are not included in the phase plot – multiples of 10m. The latter property allows eliminate the phase error component the rangefinder during testing. According to the results of metrological certification of standard linear basis ((Trevoho, Tsyupak & Hager, 2011a) its accuracy meets working standard of first class $(0.6+1\cdot10^{-6}L)$ mm. Note that the first metrological certification on the test of the geodetic basis was performed by the laser rangefinder PLD-1M (higher precise), and the following – by means precise electronic total stations and technology GPS (Table 1).

Table 1. The metrological certification of standard linear basis

Year of measurements	Instrument
2003	PLD-1M, laser ranger
2006	Trimble 5700, receivers GPS
2006	ET Trimble 5601 DR-Standart, ranger
2007	ET Trimble 5601 DR-Standart, ranger
2009	Leica TCR1201+R400, ranger
2009	Trimble 5700, receivers GPS
2010	Trimble 5700, Leica GX1230GG, receivers GNSS
2011	ET Leica TM 30R, ranger and ET Trimble S8, ranger
2011	Trimble 5700, Leica GX1230GG, Nov L1L2VA, receivers GNSS
2012	ET Leica TM 30R, ranger and ET Trimble S8, ranger
2012	Trimble5700, Leica GX1230GG, receivers GNSS

Comparative analysis (Table 2) the results of metrological certification the test line of the geodetic basis do found (Trevoho, Tsyupak & Hager, 2011a) that measurement error lines by rangefinder or by electronic total station and by means GPS technology is almost equal in absolute value. Moreover, short lines (to 200 m) easier to measure by rangefinder, longer lines - more precisely determined by GPS technology. Note that the line measured precision laser rangefinder PLD-1M adopted by reference for comparative analysis (Table 2). Thus, GPS technology can be used for metrological certification of the test line of the geodetic basis.

Table 2. The differences of the length of the intervals linear basis (in mm)

Inter-vals	GPS Trimble 5700								
	2006 p.	2009 p.	2006 p.			2009 p.			
	PLD-1M (2003)	PLD-1M (2003)	Trimble 5601DR (2006)	Trimble 5601DR (2007)	Leica TCR (2009)	Trimble 5601DR (2006)	Trimble 5601DR (2007)	Leica TCR (2009)	GPS (2006)
1-2	0,1	0,4	0,5	0,1	-0,3	0,8	0,4	0,0	0,3
2-3	-0,2	-0,6	-0,7	-0,3	0,6	-1,1	-0,7	0,2	-0,4
3-4	-0,2	-0,6	-0,2	0,0	0,0	-0,6	-0,4	-0,4	-0,4
4-5	0,0	0,5	0,6	0,3	-0,2	1,1	0,8	0,3	0,5
5-6	0,0	-0,4	0,2	0,3	0,1	-0,2	-0,1	-0,3	-0,4
6-7	0,0	1,3	-0,4	-0,2	-0,4	0,9	1,1	0,9	1,3
7-8	0,0	-0,5	0,6	0,3	0,2	0,1	-0,2	-0,3	-0,5
8-9	0,0	1,0	-0,8	-0,1	-0,7	0,2	0,9	0,3	1,0
9-10	0,0	-1,5	0,1	0,2	1,1	-1,4	-1,3	-0,4	-1,5
10-11	0,0	0,6	0,7	-0,1	-0,2	1,3	0,5	0,4	0,6
11-12	0,0	0,2	-1,0	-0,2	-0,9	-0,8	0,0	-0,7	0,2
12-13	0,0	-0,8	0,7	0,4	0,5	-0,1	-0,4	-0,3	-0,8
13-14	0,0	-0,7	0,2	0,3	1,4	-0,5	-0,4	0,7	-0,7
14-15	-0,3	-0,7	0,6	0,3	0,6	0,2	-0,1	0,2	-0,4
15-16	0,2	1,3	-0,1	0,0	-2,0	1,0	1,1	-0,9	1,1
16-17	0,3	-0,8	-	-	1,7	-	-	0,6	-1,1

17-19	-0,1	-0,1	-	-	-1,0	-	-	-1,0	0,0
19-20	0,2	-0,1	-	-	0,9	-	-	0,6	-0,3
mean	0,00	-0,08	0,07	0,09	0,08	0,06	0,08	-0,01	-0,08
m	0,14	0,78	0,56	0,24	0,90	0,81	0,68	0,54	0,75

The fundamental geodetic network currently consists of five items that are fixed with concrete monolith with diameter of 0.70 m at a depth of 4 - 4.5 m. The precision of centering is ≤0.2 mm. Analysis of multi-processing GNSS observations (Trevoho & Tsyupak, 2011b) of the fundamental geodetic network suggests that the accuracy of the spatial coordinates are less than 1cm. From the analysis of the coordinates of these points, that are determined annually from 2005 to 2008 years, was estimated the rate of coordinates change (Trevoho & et. al, 2009) with an average r.m.s. less than 1 mm/year.

3. Research of accuracy of coordinates determination and distances between points on the duration of the session of GNSS observations

For metrological certification of standard linear basis and fundamental geodetic network is used the method of GPS. The use of GPS technology to determine the distances of the standard linear basis showed good results, as the comparative analysis in the data table 2 shows. Therefore, for the correct application of the method of GPS for metrological certification, was made a research that carried out changes of coordinate points from reference point depending on the duration of observation sessions of GPS. For this purpose, two sessions of daily observations were performed at points, which were distance from reference points at ~10, ~14 and ~20 km (Tsyupak, 2012). These observations determined the coordinates of points and the distances between them for observing sessions with duration from 1 to 24 hours, with step increase of the session duration by 1 hour. For example, we present the results of research in the form of graphs for the smallest (Fig. 2) and the largest (Fig. 3) distances.

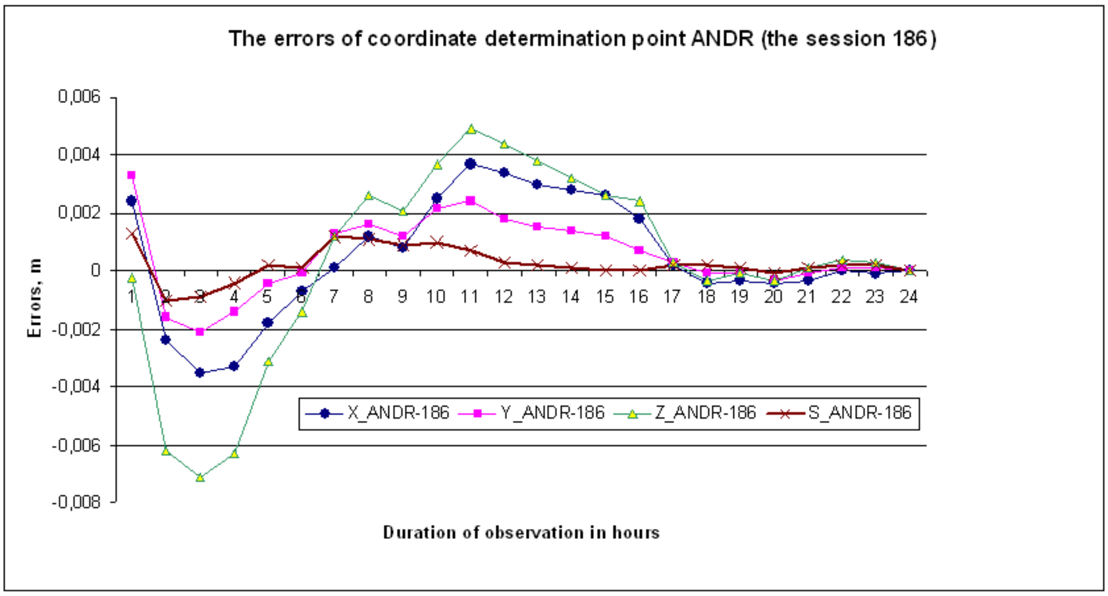

Fig. 2. Graph of coordinate determination point ANDR (~10 km) errors based on GPS-observation sessions of varying length during the daily session 186.

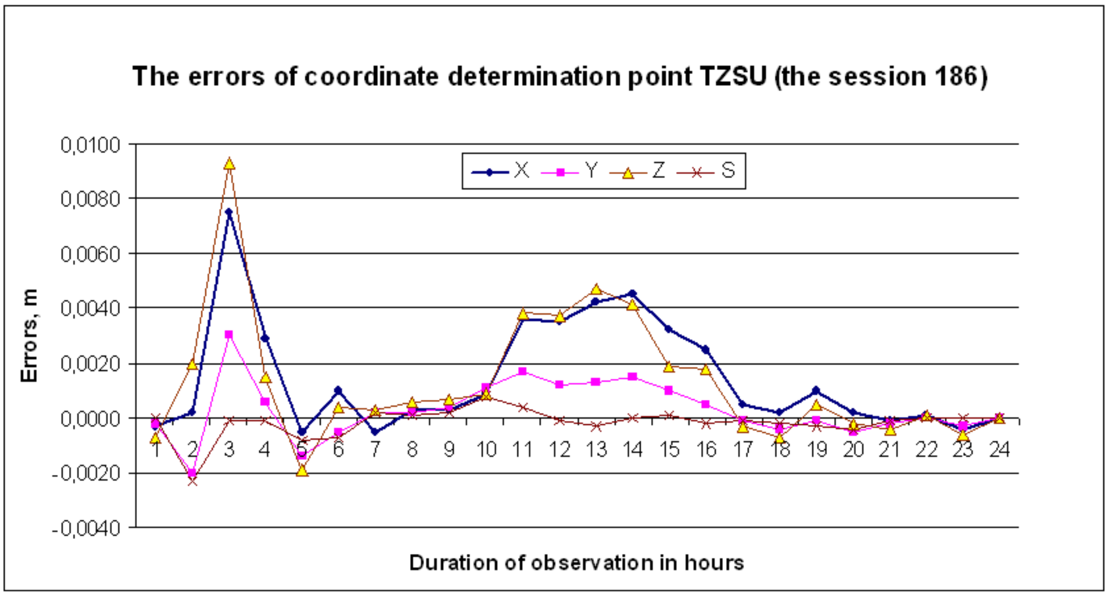

Fig. 3. Graph of coordinate determination point TZSU (~20 km) errors based on GPS-observation sessions of varying length during the daily session 186.

Graphs on Fig. 2 and Fig. 3 show that the largest error in determining of the coordinates Z and X, in the coordinate Y – the error smaller, but the slightest one in the distance. The accuracy of determining the coordinates of points increases to a value less than 0.5 mm and the length of observation session of 17-18 hours, but distances of the same accuracy can be obtained if you observe for distances between points 10-20 km for 12-13 hours. Thus, the distance calculated from the coordinates of points, which were defined by the results of GPS observations – have accuracy higher than the coordinates.

Given the results of these of studies the observations GNSS session in 2011 was lasted 17-18 hours for lines, that longer than 200 m, for shorter - 4 hours.

In 2012, the length of GNSS observations sessions for the points of test linear of the geodetic basis for distances over 100 m was 16-17 hours, while for shorter ones - 12 hours. Table 3 shows the results of comparing the measured lines in 2012 by the total station Trimble S8 and the GNSS technology with the measurements by precise laser rangefinder PLD-1M in 2003.

Table 3. Analysis of the metrological certification of the test line of the geodetic basis lines with total station and GNSS method in 2012

Point	Differences distances in mm		
	TrimbleS8 2012	GNSS 2012	TrimbleS8 2012
	PLD-1M (2003)		GNSS 2012
1 - 3	-	0,1	-
1 - 9	-	0,7	-
1 - 12	-	-0,8	-
1 - 14	-0,8	-0,7	-0,1
1 - 15	-1,6	-1,7	0,1
1 - 16	-1,2	-0,5	-0,7
1 - 17	0,2	0,3	-0,1
1 - 20	-1,3	0,6	-1,9

Note that the lines, which were measured by total station tend to increase the measurement error with increasing the line length, what is possible due to algorithm of atmospheric correction and significant influence of the underlying surface on the laser beam. At the same time this error may be due to fact that the coefficient in the regression equation ($L=a+b\cdot s$, a and b – the coefficients, s - the measurement, L - the result of measurement line) was previously determined with an error.

4. On development of metrological support on Yavoriv SGTF

At present stage, addition to the usual tasks of geodetic of the metrology (calibration and testing geodetic instruments) we should ensure monitoring and evaluation of the accuracy of current satellite technology to determine different parameters are, for example, the GNSS leveling and the monitoring of geodynamic of changes of the Earth's surface. These include questions of debugging algorithm of detect systematic or functional of the errors of measurement and assessment of the random errors of the measurements.

In order to provide the study of the accuracy of GNSS levelling performance and precision of geodynamic movements monitoring of the Earth's surface, a leveling network of first grade is drafted and a network of gravimetric points on the Yavoriv SGTF.

The fundamental geodetic network improvement project includes the following steps:

- make the levelling the network under the program first grade (scheme on Fig. 4) between the points (GOSH, VASL, ANDR, TZSU, POLY) of the fundamental geodetic network and two points of test line of the geodetic of basis (T1 and T20). This the network of the leveling will be connecting with the line of first grade of state the levelling of network in three points;
- maximum error of the first grade leveling $3\sqrt{L}$ mm, where L - length of the levelling;
- total length of lines projected leveling ~ 150 km;
- it is planned to determine the acceleration due to gravity at 2 points fundamental geodetic network with accuracy about 10 µGal;
- using these the points of gravimetric as the reference, will be scheduled to perform gravimetric survey of the surface in a radius of 100 km around the Yavoriv SGTF for the uniform of grid ~(30×30) km, which corresponds to (16′×25′) – according to latitude and longitude;
- expected that the heights of geoid will be calculated with RMS that is a few centimeters.

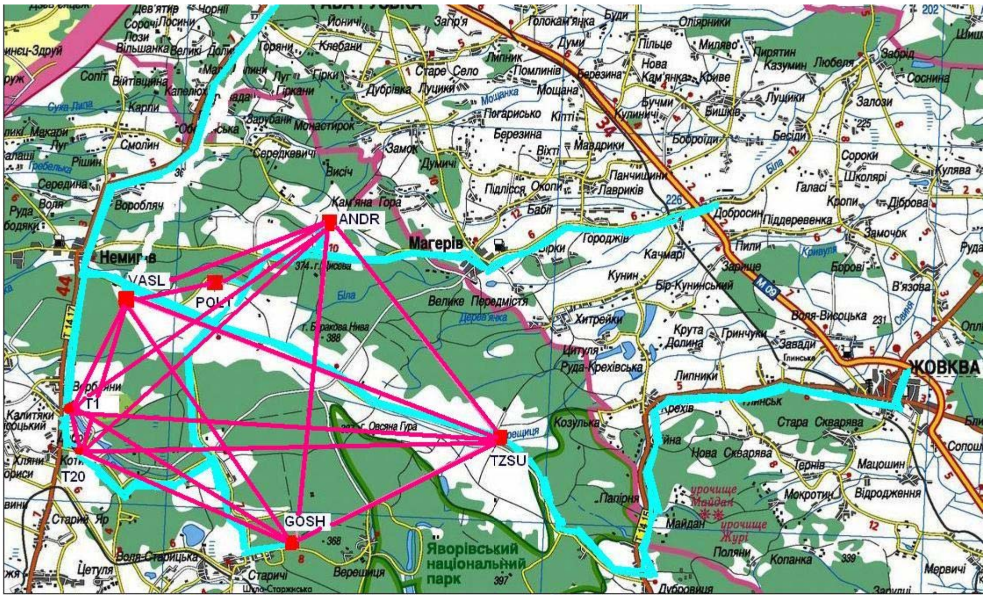

Fig. 4. Scheme of first grade leveling.

5. Conclusions

1. The fundamental geodetic network of the Yavoriv SGTF meets the operating standards of the 1st level and can be used for metrological certification of GNSS receivers of all classes.
2. Project to improve and enhance the capabilities of basic geodetic network will allow: a) to develop methodologies and study precision of the GNSS leveling, b) to investigate the accuracy of geodynamic monitoring of the Earth's surface.
3. Perspective development of the Yavoriv SGTF will provide of the requirement of modern geodetic of the metrology.

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