

ANALYSIS OF THE RESULTS OF THE NEW MEASUREMENTS ON THE METROLOGY OBJECTS OF SCIENTIFIC GEODESIC TEST FIELD

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Statement of problem

Modern Surveying instruments are high-tech and their metrological support, including GNSS-receivers and electronic total stations, divide on metrological control of instruments and metrological certification method for determining the geometric and dynamic parameters for measured values. Metrological control most devices, including GNSS-receivers and electronic total stations must also be divided according to test sensors and antennas and operating frequency drift studies of laser rangefinders to be performed separately in special laboratories. Hence, testing the accuracy of the measured values of devices and their conformity to the standard units of measurement performed on the working standard largest mean square error of determination of parameters, such as coordinates of points or components of the vector between points, the distance between points.

Study accuracy of modern methods (technology GNSS) determining the values that measure ground methods quantities, for example GNSS-leveling also can be doing on a working standards.

For metrological certification of the working standards are increasingly use the technology of GNSS. These working standards include the standard linear basis and the fundamental geodetic network.

Analysis of recent research and publications

Maintaining the standard a unit of linear of measurements and the standard linear basis is performed also by means metrological certification. According to regulations [2, 3] metrological certification of the standard basis can run a set of basic instruments BP-1 or a group of 2-3 rangefinders of phase that can provide adequate precision certain for the standard linear basis. The distances measurement of rangefinder or from a total station is significantly affect of the atmosphere. From different firms formula to account for atmospheric corrections - different, but has been noted that the maximum error does not exceed 2 mm. This amendment accuracy can be achieved if an atmosphere of homogeneous will be on all the way of sight beam. In fact, the longer the line, the more errors atmospheric corrections due to changes in the underlying surface along the beam sight, and there is a change in temperature. Therefore, from line of longer than 200 m [11] need to measure the temperature at intervals along the line and use a formula from an integrated model of atmospheric correction. This technique is used for the

secondary standard the VETA 01-03-02-98 NSC "Institute of Metrology" what provides transmission of the standard unit of length with an accuracy of 0.1 mm [1].

In modern geodesy widely used satellite technologies, including the measurement of global navigation satellite systems (GNSS). For the coordinates of points of the standard linear basis what are to determine with highly accurate can reliably get the distance between them [7]. For this is necessary to take into account movement of the phase center the antenna of GNSS receivers. Offset phase center of the antenna for the height is modeled while processing GNSS measurements [4, 5], and in terms can be of essentially eliminated by adjustment of the measurements during long sessions of the observation. Metrological certification of the fundamental geodetic network is carried out by the campaigns GNSS-observations of the during 3-5 days.

Metrological certification of GPS / GNSS-receivers is need for to test them for storing the scale of geodetic network [8], also for the accuracy saving or the transmission of network orientation in the plane coordinates, and especially in the spatial coordinate system. It is also important to know whether achieved reach the accuracy of excess between the points or the height of a point relative to the reference surface by GNSS-measurements, where the element is the value, obtained from GNSS-leveling.

Statement of task

In this paper, based on the experimental data obtained in two expeditions to the standard linear basis to carry out the following:

- apply developed method [9] determining distances of the standard linear basis by the GNSS technology and assess their the errors;
- the evaluate of errors determine a exceedances of the points derived from processing of the GNSS-measurements relation of the reference point and compare them with a exceedances derived from geometric spirit leveling by program II class;
- the evaluate the errors determine orthometric heights of points of the standard linear basis by GNSS-leveling method.

The main material

The task of geodetic metrology that must be addressed in standard linear basis and fundamental geodetic network - the following:

- the certification and testing of GNSS-receivers and rangefinders devices.

Table 1

Determined the corrections to the measured lines

Line	Correction, mm	Line	Correction, mm
S ₁₋₂	-0,20	S ₃₋₂₀	-0,38
S ₁₋₃	0,02	S ₉₋₁₄	-0,01
S ₁₋₉	0,05	S ₉₋₁₅	0,01
S ₁₋₁₄	0,05	S ₉₋₁₆	0,04
S ₁₋₁₅	0,07	S ₉₋₁₇	0,21
S ₁₋₁₆	0,09	S ₉₋₂₁	0,03
S ₁₋₁₇	0,28	S ₉₋₂₀	-0,38
S ₁₋₂₁	0,06	S ₁₄₋₁₅	0,02
S ₁₋₂₀	-0,41	S ₁₄₋₁₆	0,04
S ₂₋₃	-0,08	S ₁₄₋₁₇	0,22
S ₂₋₉	-0,11	S ₁₄₋₂₁	0,04
S ₂₋₁₄	-0,07	S ₁₄₋₂₀	-0,36
S ₂₋₁₅	0,05	S ₁₅₋₁₆	-0,03
S ₂₋₁₆	0,04	S ₁₅₋₁₇	0,20
S ₂₋₁₇	0,28	S ₁₅₋₂₁	0,10
S ₂₋₂₁	0,06	S ₁₅₋₂₀	-0,08
S ₂₋₂₀	-0,37	S ₁₆₋₁₇	0,02
S ₃₋₉	-0,04	S ₁₆₋₂₁	0,08
S ₃₋₁₄	-0,02	S ₁₆₋₂₀	0,12
S ₃₋₁₅	0,04	S ₁₇₋₂₁	0,27
S ₃₋₁₆	0,05	S ₁₇₋₂₀	0,82
S ₃₋₁₇	0,25	S ₂₁₋₂₀	0,67
S ₃₋₂₁	0,05	-	-

Estimated the error lines and intervals as measurements - less than 1 mm (max. 0.82 mm).

Results GNSS-leveling. The spatial location of the points determined by technology GPS / GNSS easily converted into the geodetic coordinates - latitude B, longitude L and geodetic height H reference to the geocentric ellipsoid WGS-84. Whereas, on the basis of the reference made a geometric spirit leveling of program of the second class, we can estimate the accuracy of elevation points or exceedances between points of the standard linear basis.

Ensuring unity of standard units of measurement in the exceeding hights that were derived of the geometric spirit leveling and in the exceeding hights determined by technology GNSS leveling is also important.

To control the calculation accuracy GNSS technology exceedances comparison exceedances between points of geodetic basis and the same excess derived from geometric leveling program for the second class. It was found that the error calculation exceedances for GNSS-observations (observation session - 6 hrs) the following: minimum -10 mm, maximum 8 mm, RMS of residuals is 5 mm. The one daily a observation session gives somewhat better results: minimum deviation -8 mm, maximum 7 mm, RMS of residuals is 5 mm. Were calculated a heights of quasi geoid reference the WGS-84 ellipsoid. It is also important to consider that geodetic

height H measured normal to the ellipsoid but orthometric per a line force of gravity. Differences between ortometrychnymy and normal heights at heights of about 300 m does not exceed 0.1 mm [7].

To investigate the accuracy of the surface reconstruction quasigeoid height quasigeoid \square relatively ellipsoid WGS-84 were approximated second degree two functions: 1) as a function of the square polynomial $f(s)$ of one variable - the distance s from referentsnoho point against which the coordinates of points determined by GPS observations / GNSS (linear basis points are in alignment); 2) second degree polynomial as a function $f(B, L)$ of two variables - latitude and longitude B L. The results of approximation are shown in Table 2.

Table 2

Residual deviation after the approximation

Point	$f(s)$	$f(B,L)$
T1	0,000	0,000
T2	0,003	0,002
T3	-0,010	-0,011
T9	0,004	0,003
T14	0,001	0,000
T15	0,003	0,003
T16	0,003	0,003
T17	-0,006	-0,004
T21	0,003	0,005
T20	0,000	-0,002
m_{aprox}	0,0053	0,0057

The approximation done also having the lowest number of reference points of the standard linear basis for case that known of heights of extreme points and another 2-3 points derived of a geometric spirit leveling that need to approximate surface in the area of test field by a least squares method. The maximum difference between the residual deviations obtained after approximation of a heights quasigeoid for all markers and certain minimum number of the points is 1-2 mm. Hence, having the height of several points identified with geometric spirit leveling, and the rest only with processing GNSS-measurements can be calculated normal or orthometric heights with error about 1 cm.

It is known [4] that the quasi geoid of surface can be determined using the model of the gravitational field of the Earth. Currently, the best models is the EGM96 and, in particular, EGM2008. These models are often used to calculate heights quasi geoid \square and get the orthometric or normal heights, that are described in the works of many authors, in particular in [8, 14].

In our studies using gravity models EGM2008 and EGM96 were calculated the orthometric h_{EGM08} and h_{EGM96} (or normal) height of points by GNSS-leveling and compared with heights obtained from the geometric spirit leveling h_L . Differences between the heights of the error

gives GNSS-leveling, error or quasi geoid surface representation corresponding gravitational model in the region. In order to metrological studies it is important to calculate the error exceeded by geodetic elevation points ($dH_i = H_i - H_0$) obtained by processing GNSS-measurements and orthometric ($dh_i^{ort} = h_i^{ort} - h_0^{ort}$). Calculate the relative errors exceeding specified with geometric leveling. Research results GNSS-leveling errors present in the table 3 and table 4.

Table 3

**GNSS-leveling errors in meters
(geoid: model EGM2008, Krasovski ellipsoid)**

	$h_{EGM08} - h_i^{HiE}$	$dH_i - dh_i^{HiE}$	$dh_i^{ort} - dh_i^{HiE}$
T1	-0,130	-0,007	-0,019
T2	-0,131	-0,008	-0,020
T3	-0,118	0,004	-0,007
T9	-0,132	-0,010	-0,021
T14	-0,128	-0,006	-0,018
T15	-0,131	-0,009	-0,021
T16	-0,130	-0,009	-0,019
T17	-0,118	0,001	-0,008
T21	-0,126	-0,009	-0,015
T20	-0,110		

Table 4

**GNSS-leveling errors in meters
(geoid: model EGM96, Krasovski ellipsoid)**

	$h_{EGM96} - h_i^{HiE}$	$dH_i - dh_i^{HiE}$	$dh_i^{ort} - dh_i^{HiE}$
T1	-0,512	-0,007	-0,019
T2	-0,513	-0,008	-0,020
T3	-0,501	0,004	-0,007
T9	-0,514	-0,010	-0,021
T14	-0,511	-0,006	-0,018
T15	-0,514	-0,009	-0,020
T16	-0,512	-0,009	-0,019
T17	-0,501	0,001	-0,008
T21	-0,509	-0,009	-0,015
T20	-0,494		

Conclusions

Based on the results we doing the following conclusions.

1. Designed by a method for operational control of the lengths of lines of the standard linear basis by the technology GNSS, which provides accuracy of about 1 mm.

2. By processing GNSS-measurements, can obtain more reliable results (especially for lines > 500 m) than of the measurements certified ET (for the standard linear basis with measuring the meteo-data only in point of observation).

3. The heights of quasi geoid have determined relative to WGS-84 ellipsoid at 9.5 times larger than the relatively Krasovskii ellipsoid.

4. Model EGM2008 geoid represents the territory of Yavoriv test field with errors 11-13 cm.

5. The EGM2008 model is more accurate than the model EGM96 at 4 times.

6. The exceeding between the heights of points of the standard linear basis were defined by the GNSS technology with standard deviation of 5 mm.

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Analysis of the results of the new measurements on objects of scientific metrology geodesic polygon

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In this article reviewed the metrological aspects of the Earth's coordinate system, maintaining its accuracy in determining new points and geodetic networks in this system.