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STANDARD BASELINES OF YAVORIV SCIENTIFIC GEODETIC OF TEST FIELD FOR VERIFICATION OF MODERN GEODETIC INSTRUMENTS AND TECHNOLOGIES

I. Trevoho, I. Tsyupak, V. Voloshyn, A. Rudyk
Lviv Polytechnic National University

Key words: metrological certification, GNSS-measurements, GNSS-leveling, reference linear basis, fundamental geodetic network.

Formulation of the problem

At present, laser distance measurements (electronic tacheometers) and GNSS receivers are used to measure the lengths of lines in the surveying, especially large ones (more than 1 km). At the same time, electronic tacheometers (ETs) and GNSS-technology allow receiving lines of length in two planes: horizontal and vertical. Lines in the vertical plane are elevations or excesses relative to the model of the Earth (mathematical or physical). The measured lengths of the lines, as well as the excess obtained by direct (ground) and mediocre (satellite) methods, should be compared, that is, it is necessary to ensure the unity of measurements.

Analysis of recent researches and publications on the metrological provision of working standards

Verification of the accuracy of devices that consist of certain blocks, it is advisable to test each of the blocks separately [3]. For example, GPS / GNSS receivers have such an antenna, sensor and controller. Testing the first two radio blocks is worth the special examiners in the factory conditions. But the accuracy of the restoration of the unit of measurement in the measured or determined values must be established in the field conditions on working standards. It is known that benchmark geodetic networks and reference linear bases are working standards [14].

The metrological certification of GPS / GNSS receivers is needed to check the possibility of preserving geodetic network scales [19], the accuracy of retention or transmission of the network orientation in plan coordinates and, especially, in the spatial coordinate system. It is also important to know if the GNSS measurements achieve the accuracy of determining the excess between points or elevation of a point relative to a certain level surface, where the component is the value obtained from GNSS-leveling.

With the increasing accuracy of modern geodetic instruments, it is necessary to ensure that the accuracy of the reference linear bases is at least 3 times better than that of the tested measuring instruments. The metrological attestation of the reference basis can be performed either by the basic set of invarious wires [2] or by a set of two or three selected high precision phase laser distance meters [2] or by a high precision device, which includes the precision laser distance meter PLD-1M [4] or using GPS / GNSS technology using a special method [8]. Interferometers can be used to measure baseline intervals [14]. It should be noted that at the present time, the metrological certification of linear bases is most often performed by high-precision precision electronic tacheometers tested, or by the precision distance meter PLD-1M.

Taking into account the above, it is necessary to make an analysis of the results of the metrological certification of the metrological objects of the Yavoriv NPP.

Presentation of the main research material.

1. Determination of the measured values

When measuring the ET, a polar coordinate system with a center at the point of measurement is used, ie topocentric, and in the GNSS technology, as in satellite methods, is a geocentric rectangular coordinate system. In the first case, direct measurements of the sloping distance and angles (horizontal and vertical or anti-aircraft distance) are used. And in the second one - mediocre: through observation of satellites whose positions are determined preliminarily, taking into account the influence of the gravitational field of the Earth and other natural phenomena [5], which include those that lead to changes in the directions of the axes of geocentric coordinate systems (inertial and earthly) [1]

To take into account the influence of natural phenomena on the body of the satellite, as the points in the center of its mass, in the space and point on the Earth's surface, the corresponding models of these phenomena are used. The influence of phenomena on the position of the satellite and the point in satellite technologies is taken into account dynamically during the prediction of the satellite's motion and the formation of parametric equations for determining the parameters of the satellite's orbit, the coordinates of the points and they are mutually consistent, which allows to obtain high accuracy of determination of parameters from the solution of the system of parametric equations.

2. Metrological certification of the reference fundamental geodetic network

Two metrological objects (Fig. 1) are supported for the metrological calibration of modern geodetic instruments, the development of methods of linear measurements, in particular GNSS-leveling, and the development of new verification methods at the Yavoriv Scientific Geodetic Polygon (NGP): 1) a fundamental geodetic network and 2) reference linear basis.

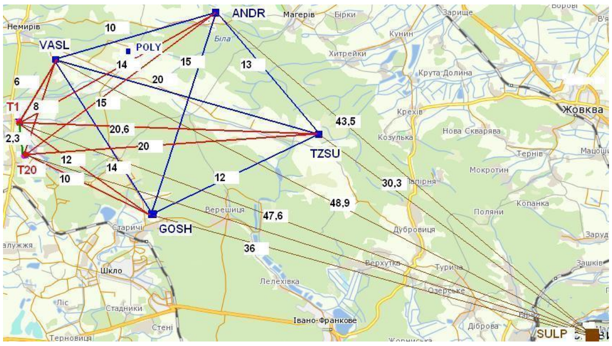

Fig. 1. Scheme of the fundamental geodetic network and the reference linear basis

Metrological certification of the fundamental geodetic network has been carried out since 2002 with the processing of GPS / GNSS-observations. The recording of observations is carried out, basically, at intervals of 10 seconds, which allows better solving uncertainties and correcting jumps of the phase. Observations are usually performed by day-to-day sessions, with a total duration of 3-5 days. In 2005-2008, attestation was carried out annually. This allowed us to estimate the speed of change of coordinates of the network points and to show the average points of the coordinates of the points in the initial period of this period 2005.4767. The evaluation showed a reliable determination of these values [11]. Two more GNSS surveillance campaigns were completed in 2010 and 2013. [15].

According to the results of six GNSS monitoring campaigns (2005-2008, 2010, and 2013), the internal accuracy of the network does not exceed 3□10-7 [15].

3. Development of geometric leveling network

It is known that the processing of GNSS observations can also determine the height of points, or better, the excess between the points relative to the mathematical and physical models of the Earth, respectively, geodetic and normal heights. The error in determining the geodetic height following the observations of GNSS can reach up to 5-6 mm. When determining the normal heights of points based on the results of GPS-leveling, there are additional errors caused by the simulation of the surface of the quasigoid [9]. Due to the error in determining the surface of a quasigoid, the precision of GPS-leveling or the calculation of normal heights can range from a few centimeters [20] to several tens of centimeters [21].

To control the error of the results of GPS-leveling, which can be obtained by different techniques, it is necessary to turn the reference linear basis and the fundamental geodetic network into reference points. For this, the height of each item must be obtained from the geometric leveling of the II class [17]. In 2014-2016, a network of geometric II-class was developed (Fig. 2). The total length of the double steps of leveling with the tie to the rappers of the I-class is 120 km. Leveling is carried out using the Leica DNA-03 code leveler. Misalignment in landfills from 2.1 to 3.3 mm.

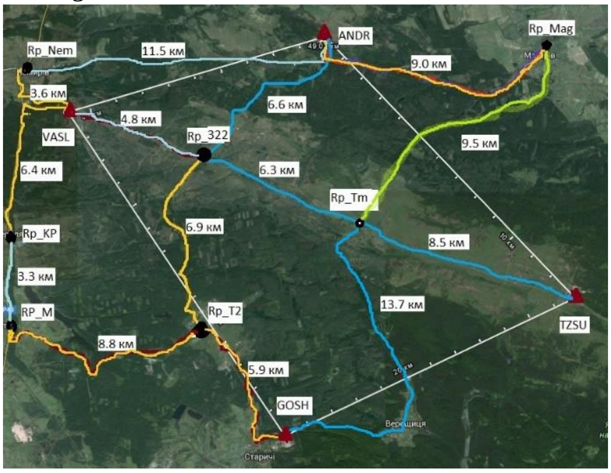

Fig. 2. Scheme of geometric leveling net of II class

In processing the results of geometric alignment, corrections were introduced [9] for the non-parallelism of the loop lines and for the deviation of the straight lines. To calculate the last necessary measurements of gravity at the points of standing of the rails, and practically at the locations of the rappers, which are the end points of the leveling sections. At these points measured geodesic coordinates (B - latitude and L - longitude). The latitude of each ramp is required to calculate the normal value of the gravity □ at these points. Previously, in the works of scientists of the Lviv Polytechnic University [6, 10] a gravimetric network was created and gravimetric stripping of the territory of the scientific geodetic polygon was performed. Accuracy of gravimetric definitions near 1 mGal.

4. Metrological certification of the reference linear basis

The reference linear basis (ELB) has been operational since 2003. The ELB metrological certification is carried out by high precision electronic tacheometers (ETs), as well as by GNSS technology (Table 1). The first certification of the ELB was carried out by the metrologists of the NSC "Institute of Metrology" with the installation of higher precision [4], which includes the precision laser distance-meter PLD-1M. ELB lines measured with SKP 0.2 ... 0.5 mm.

Table 1

Metrological certification of ELB from 2003 to 2014

Year attestation	Devices
2003	PLD-1M, precision laser distance monitor
2006	Trimble 5700, GPS receivers
2006	Trimble 5601 DR-Standard, electronic station
2007	Trimble 5601 DR-Standard, electronic station
2009	Leica TCR1201 + R400, electronic station
2009	Trimble 5700, GPS receivers
2010	Trimble 5700, Leica GX1230GG, GPS / GNSS receivers
2011	ET Leica TM 30R, Electronic Tachymeter
2011	ET Trimble S8, electronic station
2011	Trimble5700, Leica GX1230GG,
2012	NovAtel Nov L1L2VA, GPS / GNSS receivers
2012	ET Leica TM 30R, Electronic Tachymeter
2012	ET Trimble S8, electronic station
2013	Trimble5700, Leica GX1230GG, GPS / GNSS receivers
2013	Leica TCR1201 (02.07.2013), electronic station
2013	Trimble S8 (07/17/2013), electronic station
2014	Trimble S8 (12.12.2013), electronic station

If, according to the standard values of the lengths of the intervals of Yavorivsky ELB to take measurements in 2003, the SLP measurements of ELB intervals with electronic stations and GNSS technology, respectively, are equal to 0.91 and 0.78 mm. The mean square deviation of the measurement of the basis of the ET basis and the GNSS technology is 0.54 mm. Thus, the order of the errors of measuring the intervals of ELB ET (accuracy □ (1 + 1□10-6□D) mm) and GNSS technology in general are the same. At the same time, the errors of measuring the lines of ET greater than 200 m (with the correction of atmospheric impact corrected by meteorological measurements only at the initial point) increase and for the line about 2230 m can reach 4-5 mm. In the case of GNSS technology, the error of determining the distance depends mainly on the duration of the observation session and slightly (up to 0.2-0.3 mm for the lines 10-20 km) of the length of the line.

The determination of the lengths of the ELB lines by the method [8] in all combinations with simultaneous 24-hour GNSS observations at 10 points showed that out of 45 lines - 28 have errors up to 0.1 mm, and errors of 42 lines - less than 0.5 mm. The maximum error is 0.82 mm.

Conclusions

1. The internal error of the determination of the coordinates of the points of the fundamental geodetic network is less than 3□10-7, which corresponds to the accuracy of the standard 1 level.
2. Lengths of lines with GNSS technology can be determined with errors less than 1 mm.
3. According to the results of metrological certification, the ELB points and the fundamental geodetic network are stable for more than 10 years.

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Standard baselines of Yavoriv scientific geodetic of test field for verification of modern geodetic instruments and technologies

I. Trevoho, I. Tsyupak, V. Voloshyn, A. Rudyk

The article analyzes the results of metrological certification of special fundamental geodetic network and the standard baselines as working standards. It confirms the high accuracy and reliability of the use of GNSS technology for metrological certification of standard objects.