On Development of High Precision Geodetic Network Based on GLONASS and GPS Measurements in Russia

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Key words:

ABSTRACT

High Precision Geodetic Network has been developed in Russia since 1999. The network is made up of both permanently working and regularly measured points of Fiducial Astronomic Geodetic Network (FAGN) and points of Precision Geodetic Network (PGN).

In total, 50-70 FAGN points and 500-700 PGN points will be established. Precision of relative position of adjacent points will reach $2 \div 3x10^{-8}$ D.

Currently the European part of Russia is almost covered with the mentioned network.

In Russia, State Geodetic Network was developed with ground-based means per the scheme and program suggested by F.N. Krasovsky throughout more than 50 years. The network incorporates approximately 250,000 geodetic points of 1-4 classes. After adjusting Astronomic Geodetic Network (AGN), Satellite Geodetic Network (SGN) created with observations of Soviet GEO-IK satellites, and Doppler Geodetic Network (DGN) created with observations of TRANZIT satellite system (US), State Geodetic Network provides mean square error for relative position of adjacent points equaling ±2-4 cm, and for the points located at a distance of more than 1000 km equaling ±0.5-0.6 m. The coordinates of State Geodetic Network points obtained after joint adjustment realize CS-95 system of geodetic coordinates introduced by the Decree of the Russian Federation Government since July 1, 2002 versus the coordinate system of 1942. Still, the new coordinate system retained the coordinates of Pulkovo that had been specified as the starting point for the coordinate system of 1942. This solution was taken so to minimize a shift of topographic map borders in the European part of this country caused by some changes in geodetic points coordinates and to generally make the shift inconsiderable on map scale.

Precision of geodetic point coordinates in CS-95 is sufficient to cope with most of economics tasks.

However, modern satellite geodetic technologies not only allow increasing accuracy of coordinate determination by an order but lift restrictions from geodetic point lay-out and working procedures imposed by classical geodesy.

These drastic changes provoke developing new geodetic base that will satisfy coordinate determinations with GPS/GLONASS satellite systems in respect of precision and working procedures.

For practical purposes new geodetic constructions should be consistent with the geodetic base already available in this country.

The above mentioned notions formed the basis for the Concept and Program of employing satellite navigation systems for geodetic support of the Russian territory.

These documents provide for developing Fiducial Astronomic Geodetic Network (FAGN) involving 50-70 points, high Precision Geodetic Network (PGN) consisting of 500-700 points, and Satellite Geodetic Network of the 1^{st} class.

In 1999 a test fragment of FAGN and PGN incorporating 4 FAGN points and 15 PGN points was built in the center of the European part of the Russian Federation. In 2000 measurements were carried out on 61 PGN and 10 FAGN points including repeated measurements on 9 PGN and 4 FAGN points of the test fragment. Thus, coordinate determinations on 67 PGN and 10 FAGN points were made in the European part of Russia.

In 2001 the measurements were processed, adjusted and their accuracy estimated in the Central Research Institute of Geodesy, Aerial Surveying and Cartography (CNIIGAiK).

Provision of simultaneous, continuous observations on adjacent FAGN points was a mandatory requirement for the observations on PGN fragments. A session of simultaneous observations on all the PGN points for each receiver siting lasted 72 hours. To provide constituency with the available geodetic network and to check stability of each PGN point center position, geodetic connections with 2 AGN points and 2 marks of I-II class leveling were determined. Measurements were carried out at mask by elevation angle of 5 degrees on FAGN points and of 10 degrees on PGN points. The measurement discreteness was 30 sec.

Permanently working points of the International GPS Service for Geodynamics (IGS) with the ITRF 97 coordinates for the epoch of observations in the network fragments were considered as starting points. The observations were processed with scientific professional software package GAMIT.

Formal estimations of coordinate determination accuracy for FAGN points in relation to adjoining IGN points are 1-2 mm for horizontal coordinates and 1-3 mm for geodetic altitude above the reference ellipsoid surface. For PGN point these estimations are in the range between 1 and 11 mm for each of the three spatial coordinates.

Comparison of point coordinate determination results at different 24-hour periods, with observations lasting several days, does not provide real estimation of accuracy either. This is caused by inconsiderable changes in the geometry of traversing the visible celestial sphere by the observed satellites from day to day which lead to the same errors in coordinate determining, e.g., those caused by local specifics.

Comparison of, e.g., 12-hour period observations leads to residual errors in accounting for the ionosphere impact or Earth crust tides.

Comparison of coordinate determinations on the same points in 1999 and 2000 provides the estimation closer to the real one.

As in ITRF coordinate system not only the coordinates of permanently working IGN points are determined but also speed components of these coordinates changes, the coordinates of the same points in the network fragments of 1999 and 2000 determined in relation to IGS points will differ as well.

Coordinates of the points common to FAGN and PGN fragments of 1999 and 2000 were selected for comparison purposes.

For all this, traditional parameters of coordinate transformation into three linear shifts which interpret general shift of the points under comparison in the 1999 fragment in relation to the same points determined in 2000 were found. Values of the obtained shift parameters DX= -0.011 m, DY= +0.21 m, DZ=+0.018 m along the appropriate axes X, Y, Z in geocentric coordinate system appeared to be close enough to the values of annual coordinate change speeds of permanently working IGS satellite stations Mendeleevo and Zvenigorod in ITRF system. Thus, respective annual speeds for Mendeleevo are V_x = -0.018 m, V_y = +0.015 m, V_z = +0.013 m and for Zvenigorod – V_x = -0.021 m, V_y = +0.013 m, V_z = +0.006 m. Such agreement in the speeds of coordinate changes allows to impartially estimate the accuracy of the results gotten in the network fragments.

Proceeding from the obtained mean square values of residual discrepancies in the coordinates (7-8 mm for horizontal coordinates and 36 mm for altitudes) and assuming reciprocal independence of errors in developing the network in different years, we will find a mean square error in determination of horizontal coordinates on PGN and FAGN points via observations during one season equaling ~ 5 mm and that for altitudes ~ 25 mm. Relatively small number of the network points did not allow us making separate estimation of accuracy of the regularly determined FAGN points that could be reliable enough. However, considering values of residual deviations of the altitudes on FAGN points, their accuracy could be judged not much better than that of PGN point altitudes.

We would like to emphasize that higher accuracy could be achieved than that obtained by the mentioned experiments. To achieve this, more favorable local conditions for observations should be provided (selection of location, elimination of interference), special-purpose working centers should be only used to set antennas, types of the antennas used should be minimized, and the employees should be provided with appropriate pre-starting training.

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