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COORDINATES DETERMINATION AT THE JOINT ASTRONOMICAL, GEODETIC AND GEOPHYSICAL OBSERVATION STATION NEAR POLTAVA

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Problem in General Terms

There is often a need to carry out joint astronomical, geodetic and geophysical observations (JAGGO) in the same place for solution of many problems of geodesy. Data of these joint observations of point spatial position changes can be used: to study the Earth's figure and its changes, to research various phenomena and processes occurring inside the planet and on its surface, to create coordinate networks for different purposes, to establish zero-point terrestrial coordinate systems, for high-precision navigation.

Analysis of Recent Research and Publications

The experimental station of JAGGO is created for such purpose at Poltava Gravimetrical Observatory (PGO) at the observation base of URAN-2 radio-telescope in Stepanivka village near Poltava [1, 2]. A considerable number of heterogeneous observations were performed during its operation [3]. The peculiarity of this station is that the results of different coordinate determinations at its points in different epoch can be reduced to the same geometrical centre. A corresponding technique of reduction measurements and calculations is used for such reduction [4, 5].

Formulation of the Problem

The purpose of this paper is a description of the results of geodetic measurements (satellite and tacheometric ones) at the JAGGO-station for the coordinates determination and transmission, namely: GPS-observations in 1999 and 2012, the creation of a local coordinate network (LCN) in 2000, reducing the coordinates of the point to one of the station geometrical centres for a simplified technique.

The works on GPS-coordinate determination and network creation were performed at the request of the Observatory (on the initiative of senior researcher Gozhy A.V., who is now a former employee of the PGO, and then was the head of this research direction) by the forces and means of partner organizations and with our participation; other works are done by us.

Coordinate points of the station of joint observations

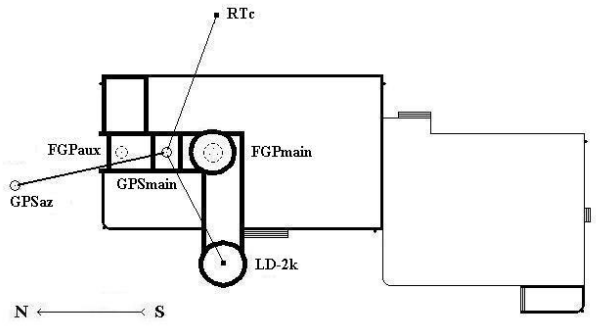
The station of joint observations is 20 km away from Poltava. The scheme of horizontal location of the individual points of the JAGGO-station is shown in the figure. Their short description is given below.

The fundamental geodynamic point (FGP) is equipped in the basement of the building; there are the main (FGPmain) and the auxiliary (FGPaux) bases with the geometrical centres; diameter of the main base is 1,67 meters, it has three marks; diameter of the auxiliary base is 1,14 meters, it has one mark; vertical holes through all floors of the building are above the bases; inclined hole toward the north celestial pole is also above the main base; the holes in the floors of the building are covered with steel lids; all determinations at external observation points may be reduced to the marks of FGP through the holes in all floors of the building by appropriate reduction measurements.

The GPS-determination point is also dual, it consists of the main (GPSmain) and azimuthal (GPSaz) points; the main point is a four-legged steel tripod on a metal grid attached to the iron-concrete plate, which is located above the third floor of the building on its load-bearing walls; the mark is embedded under the tripod in the plate; the azimuthal point is the ground rapper with a mark; it is located 383 m to the north of the main one.

The old point of satellite laser ranging is indicated in the figure as LD-2k by the name of the corresponding device, which was located on the upper third floor in the western tower of the building.

The centre of antenna field of the radio-telescope URAN-2 is RTc.



The Figure. The Scheme of the Local Coordinate Network of the Station of Joint Observations in the horizontal plane (reference designations are given in the text)

The figure shows the points of the local coordinate network connected by straight thin lines; three-story part of the laboratory building of RT URAN-2 (a very thick line), two-story part of the building (a thick line), one-

story part of the building (a thin line); projections of the bases that are in the underground floor of the building (dotted line).

GPS-campaign 1999

The first GPS-campaign to determine the coordinates of points in Stepanivka village was in 11-13.10.1999. Two-day's observations at the main and azimuthal GPS-points were performed by workers of Ukrainian State Aerogeodetic Enterprise (Kyiv) Rudenko S.S., Mel'nyk V.L., Haruta B.E. under the direction of Antoshchuk A.O. and Zagoruyko V.O. with our participation. The GPS-receivers Trimble 4000 SSE were used.

Creation of the local coordinate network in 2000

Local coordinate network in Stepanivka village was created on a basis of the points of the station of joint observations. It includes four points (see the figure). All of them are in the open area, so there were no problems with finding the optimal network configuration.

Geometrical centres of the LCN-points are: the centre of the mark under the tripod of the main GPS-point (or the centre of the upper surface of the tripod over the given mark, the coordinates of both campaigns are given to it); the centre of the metal mark of the ground rapper of the azimuthal GPS-point; the point of intersection of the vertical axis of laser distance meter LD-2k with its upper surface; the centre of antenna field of RT URAN-2.

Geodetic tie of the LCN-centres to the GPS-points (which coordinates were determined during GPS-campaign 1999) was conducted on 18.10.2000 by the specialists of the Ukrainian State Research and Production Center of Standardization, Metrology and Certification (Kyiv) from the group of Samoilenko O.M. (V.E. Sobolev, V.V. Zayets', O.V. Markitan) and with our participation by the method that was used in other observatories [6].

The survey was performed using tacheometer SOKKIΛ SET500 No.13872. The weather conditions were the following: mostly sunny, sometimes cloudy, the temperature was about +5°C, the pressure was 746 mmHg. The images of the targets were clear. The guidance of the tacheometer was carried out on the centres of reflectors and marks or directly to the centres of the points at angles and distances measurements. Measuring of horizontal and vertical angles at each point were performed in two complete sets. The mean square error of measurement in one complete set was ±5″. The line lengths were measured in two sets of 5 guidances in each, and the heights of the tacheometer and reflectors were determined with an accuracy of ±1mm. The mean square error of measuring length of inclined lines between the points was (3+3*S[km])mm. It is clear that all three measurements were performed together.

GPS-campaign 2012

This GPS-campaign was held in 30-31.10.2012 to determine the coordinates of points in Stepanivka village. Daily observations were performed at the point GPSmain, four-hour and five-hour observations were performed at the point GPSaz. The set of GPS-receivers Trimble 5700 with antennas Zephyr Geodetic and Zephyr was used. The work was carried out in collaboration with the State Scientific and Production Enterprise "Poltava geodetic center" (Poltava), the primary observer was its specialist Stakhiv D.V.

Reducing the coordinates of the external point to the geometric centre of the station using a simplified technique

Previously, we planned reducing the coordinates of any external observation point (for example, GPSmain) to the geometric centres of the station (i.e., to the marks of the FGP) would occur through two vertical through-holes over FGPmain and FGPaux by the appropriate technique of reduction measurements and calculations, that provided the mutual control of the final result, as well as accurate carrying the azimuth [4, 5].

We could not open the vertical through hole over the FGPmain. Therefore, we decided to carry out the transmission of spatial, spherical or plan coordinates by a simplified technique, namely, only through one vertical through hole over the auxiliary base to its one mark. In this case, the number of reduction measurements and calculations is decreased in comparison with the method described in the papers [4, 5], i.e., measurements over FGPmain are not performed. The control of the final result is provided by carrying out at least two series of reduction measurements according to the simplified technique, but the precise azimuth of the direction can not be transmitted.

Such transmission of coordinates from the point GPSmain to FGPaux were executed in 2017, in this case the horizontal angles, distances and elevations were measured by a theodolite, tape and level respectively.

As for the altitude component of the coordinates of the points, it has long been transferred to the geometric centres of the station through one vertical through hole over FGPaux [3, 7].

Results

Processing of GPS-observation in 1999 was performed by the research worker of MAO of NASU Stophay Yu.A. Precise ephemeris of IGS and observations of IGS-stations "Goloseevo" and "Mendeleevo" were taken for this purpose. A "floating" type of ambiguity solution was used to compute the long vector-bases, so such decisions were "iono free float". Coordinates of the points GPSmain and GPSaz (Table 1) were calculated in the system ITRF97.

Table 1

Coordinates of the GPS-points in the system ITRF97

Name of point	X (m)	Y (m)	Z (m)
GPSmain	3398093,3861	2363731,1153	4836354,0121
GPSaz	3397879,3746	2363514,3860	4836587,6646

Coordinates of other centres of the LCN (Table 2) were calculated by Samoilenko's team on the ellipsoid WGS-84 (with the following parameters: a=6378137,0; α=1/298,2572236; e^2=0,0066943801) on the basis of the

GPS-points coordinates of the campaign 1999 and of the tacheometric measurements in the network in 2000.

Table 2

Coordinates of other points of the LCN

Name of point	X (m)	Y (m)	Z (m)
RTc	3398029,5131	2363858,7016	4836365,0730
LD-2k	3398120,0864	2363737,5262	4836373,0235

Observational data of the GPS-campaign 2012 were transferred to the Research Institute of Geodesy and Cartography (Kyiv) for processing. The data for 1999 was also re-processed together with them. Based on the results of the two campaigns, position of the GPS-points and rates of change of coordinates were calculated in the common coordinate system IGS08 and height system GRS80.

We refined values of reductions in the satellite determinations at the point GPSmain in 2012 and the appropriate correction of the coordinates and rates of their changes (tables 3 and 4, respectively) made.

Table 3

Coordinates of the GPS-points in the system IGS08

Date	X (m)	Y (m)	Z (m)
	GPSmain		
1999,779	3398093,4554	2363731,1556	4836354,1296
2012,832	3398093,1692	2363731,3310	4836354,2300
	GPSaz		
1999,779	3397879,4405	2363514,4237	4836587,7765
2012,832	3397879,1669	2363514,6056	4836587,8808
Date	B (° ' ")	L (° ' ")	H (m)
	GPSmain		
	(49°37')	(34°49')	
1999,779	49,232828"	21,618328"	124,6183
2012,832	49,238256"	21,633649"	124,6075
	GPSaz		
	(49°38')	(34°49')	
1999,779	1,515634"	18,842111"	108,6811
2012,832	1,520798"	18,857338"	108,6823

Table 4

Rates of change of the GPS-points coordinates

Name of point	VX (m/year)	VY (m/year)	VZ (m/year)
GPSmain	-0,0219	0,0134	0,0077
GPSaz	-0,0210	0,0139	0,0080
Name of point	VB ("/year)	VL ("/year)	VH (m/year)
GPSmain	0,000416	0,001174	-0,0008
GPSaz	0,000396	0,001166	0,0001

The problem of refinement of the reduction was due to the fact that the value of height of the point GPSmain +124,5863m was received from the observations in 2012, what differed about 3 centimeters from the one observed in 1999. Probably, there was a random error in measuring the antenna height. Regular determinations of the elevation between the marks of azimuthal and main GPS-points by the geometric levelling method gave a value of +14,5032m to the epoch of campaign 2012 (Table 4 in [7]). And taking into account the height of +1,422m of the upper surface of four-legged steel tripod over its mark, the final elevation was +15,9252m. Since the height of the azimuthal point is +108,6823m, the height of the main GPS-point is +124,6075m, as shown in Table 3.

From the corrected rectangular coordinates of the points GPSmain and GPSaz, we determined the length of the chord between them for two observational epochs, and its rate of change (383,8828m, 383,8745m, – 0,0006m/year, respectively).

Conclusions and perspectives

1. Coordinates determination by GPS-method at the points GPSmain and GPSaz are performed to support the state coordinate system, as well as to provide geodynamic studies at the station of joint observations.

2. The performed determinations allowed to include the point GPS-main in the state geodetic network of Ukraine as "URAN-Stepanivka". It is referred to a special group of points of GPS-determination, located mostly in observatories and observational stations.

3. The local coordinate network was created at the station of joint observations which allows us to transmit coordinates from the GPS-points to other points of the network.

4. Reducing the coordinates from the point GPSmain to the geometric centre of auxiliary fundamental geodynamic point FGPaux was carried out by the simplified technique of reduction measurements and calculations.

Coordinates determination of the points by GPS-method at the JAGGO-station will be continued to support the state network and other geodynamic studies.

References

1. Gozhy A., Tyshchuk M. Stvorennia stantsii sumisnyh astronomichnyh, geofizychnyh i geodezychnyh sposterezhen' dlia potreb doslidzhen' z geodynamiky //Kinematika i fizika nebesnyh tel. Prilozhenie. -Kiev, 1999, №1. –S.113-114.

2. Tyshchuk M., Gozhy A. Stvorennia eksperymental'noi stancii sumisnyh astronomichnyh, geodezychnyh i geofizychnyh sposterezhen' //Suchasni dosiagnennia geodezychnoi nauky ta vyrobnyctva: Zb. nauk. pr. -L'viv, 2003. -S.103-109.

3. Tyshchuk M., Gozhy A. Funktsionuvannia stantsii sumisnyh astronomichnyh, geodezychnyh i geofizychnyh sposterezhen' poblyzu Poltavy //Suchasni dosiagnennia geodezychnoi nauky ta vyrobnytstva: Zb. nauk. pr. Vypusk I (29). -L'viv, 2015. - S.44-47.

4. Tyshchuk M., Gozhy A. On reduction of results of joint astronomical, geodetic and geophysical observations to one geometrical centre // Kinematika i fizika nebesnyh tel. Prilozhenie. -Kiev, 2005, №5. –S.369-371.

5. Tyshchuk M. Pro pryvedennja rezul'tativ vyznachen' koordynat na dopomizhnyh punktah sposterezhen' do osnovnogo geometrychnogo centra

//Suchasni dosjagnennja geodezychnoi' nauky ta vyrobnyctva: Zb. nauk. pr. Vypusk II (14). -L'viv, 2007. – S.68-72.

6. Samoylenko A.N. Lokalnaya geodezicheskaya set' na Simeizskom geodinamicheskom poligone. - Kiev, 1996. - 36s. – (Preprint / NAN Ukrainy, Glav. astron. observatoriya; GAO-96-1R).

7. Tyshchuk M., Gozhy A. Nivelirni roboty na stantsii sumisnyh astronomichnyh, heodezychnyh i heofizychnyh sposterezhen' poblyzu Poltavy //Suchasni dosiagnennia geodezychnoi nauky ta vyrobnytstva: Zb. nauk. pr. Vypusk II (30). -L'viv, 2015. - S.32-35.

Coordinates determination at the Joint Astronomical, Geodetic and Geophysical Observation Station near Poltava

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The station of joint observations in the Stepanivka village and its local coordinate network are briefly described. The results of GPS-campaigns in 1999 and 2012 years to determine the coordinates of the main points of the network are given. The rates of changes of the coordinates of these points and the length of the chord between them are presented. The coordinates of other points of the local network are calculated. The coordinates of the external point are reduced to the geometrical centre of the station using a simplified technique.