Local Control Network of the Fiducial GLONASS/GPS Station

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Abstract

The controlling geodetic network for the Moscow station of the Fiducial Astro-Geodetic Network (FAGN) consists of several interrelated geodetic constructions – local networks. The main components for these local networks are standard EDM baselines. Distances and elevations between the centers of these baselines have been determined to a high degree of precision during many years of testing by metrological geodetic instruments. The first epoch of precise GPS determinations for spatial baseline vectors have been established for all control networks connected to the Moscow FAGN station. To solve this task combined (GLONASS/GPS) dual frequency JPS Legacy receivers and Trimble 4000SSE GPS receivers were used. The resulting efficiency from these calculated baseline components and positions for satellite equipment testing ensue greater accuracy and improved antenna calibration. The two astronomical points, plus the main national gravimetric point (which has one of the longest precise time series of absolute gravity observations) have been included in the FAGN control station network. Antenna calibration results and estimations of GPS observation accuracy are discussed in the report.

Introduction

Permanent and periodically active stations of the Fiducial Astro-Geodetic Network (FAGN) have an important role in the creation and support of the Russian Reference Frame. The geodetic centers of this stations must have high stability in a ground and observations must be of a highest precision. Local control networks are creating for fiducial stations to meet these requirements. An example of such network is the control network of the Moscow FAGN station creating on the base of geodetic and metrological means of the Central Research Institute if Geodesy, Aerial Surveying and Cartography.

1. Content and Goals of the Moscow FAGN Station

The controlling geodetic network for the Moscow FAGN station consists of these three interrelated geodetic constructions:

1. a control network at the roof of the building;
2. a local terrestrial control network;
3. plus, an expanded terrestrial control network.

Rooftop control network consists of the four pipe centers established at the institute's roof in the more comfortable conditions of the receiving of GLONASS/GPS radio signals. Three centers of this network (CNG1, CNG2, and CNG3) are fixed near each other at distances approximately 5 to 7 m apart. These are used for comparing satellite equipment characteristics, and especially for determining antenna eccentricities. A fourth center, located from these three at a distance of about 200 meters, forms the baseline used for testing of one frequency GPS equipment.

Local terrestrial control network (Fig.1) consists of the standard EDM baseline centers (B028, B052, B076, and B100), and an astronomical point (ASTR) located in the institute' yard.

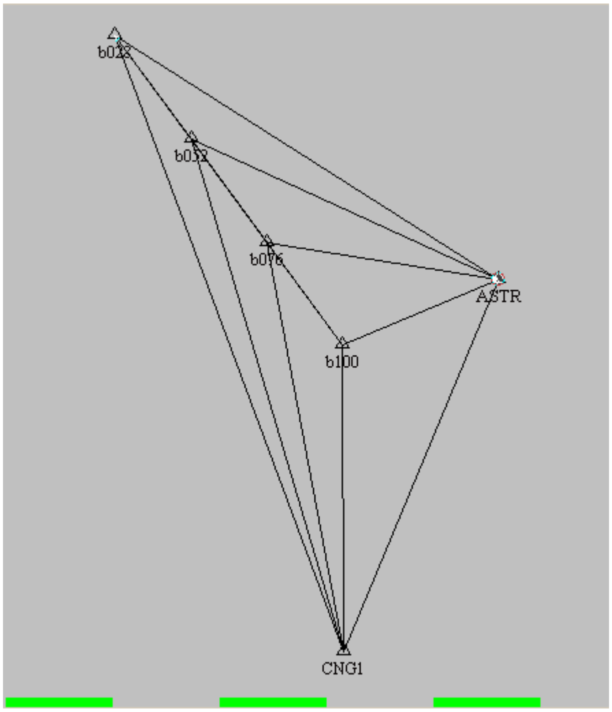

Fig.1. Local terrestrial control network

These centers, except ASTR, are equipped with special centering devises providing the accuracy of centering not more than 0.3 mm. Elementary baseline sections and it's sum components are measured by the precise electronic distance meter SP-2. The root mean square of the measurements is 0.3 mm. Elevations between the centers are determined using precise leveling. Centers of the EDM baseline are used for obtaining of objective characteristics of GLONASS/GPS equipment. The astronomical point in conjunction with the baseline centers serves to assure the stability of the main center (CNG1).

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Expanded control network (Fig.2) consists of the institute geodetic test area, the main gravimetric point, and the main center CNG1. The standard EDM baseline of the geodetic test area is the main metrological mean. It provides serviceability control and objective accuracy estimation for geodetic measurement instruments.

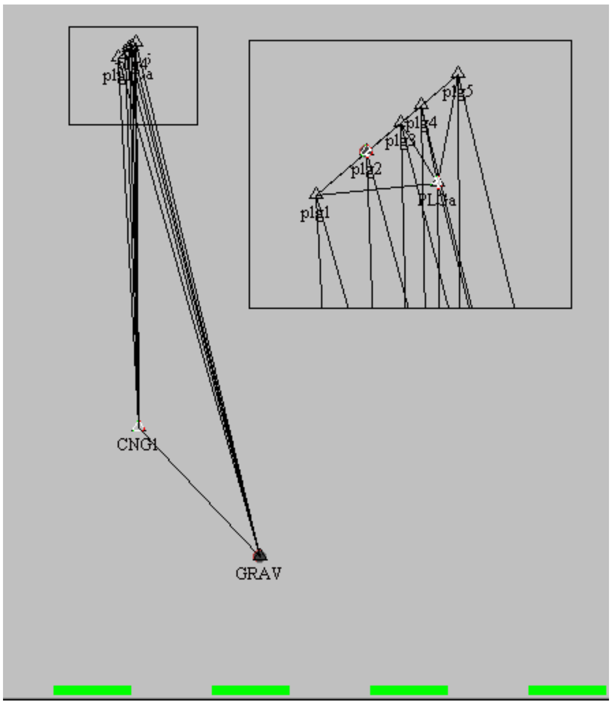

Fig.2. Expanded terrestrial control network
(large scale fragment shows standard baseline and astronomic point)

The EDM baseline of 1.5 km consists of the four elementary sections from 200 to 500 m each. The measurements of the lengths and elevations regularly repeat in order to control and correct them. Astronomical point is also included in the expanded control network. According to technical requirements for satellite geodetic network construction every FAGN point must has a precise gravimetric point. Therefore the Main gravimetric point of Russia is included in the expanded control network. For several decades gravity measurements at this point have repeatedly been taken by gravimeters GBL and GBL-P.

2. Control Observation Results

Initial precise measurement epochs are established for the local control networks during 1999 and 2000. Two 3-hour sessions and two 7-hour sessions of GPS measurements are performed for the local and expanded terrestrial control networks correspondingly. Trimble 4000SSE receivers with the micro centered antennas and JPS Legacy receivers with Regant SD antennas are used for the measurements. JPS equipment was used at the standard baseline centers because of greater accuracy and less studied characteristics.

As a result of the control measurements the accuracy analysis of JPS equipment was made. Accuracy evaluation was performed by RMS computation for the slant lengths and the elevations of EDM basis segments of the control networks. The RMS were computed with the use of absolute deviations by Gauss formula

$$m_\Delta = \sqrt{\frac{\sum \Delta_i^2}{n}},$$

where D is the true error and n is the number of them (i=1,2,...,n), with the use of repeated measurement differences d by

$$m_d = \sqrt{\frac{\sum d_i^2}{2n}},$$

and as a result of processing by GPSurvey software. The results are shown in Tables 1 and 2.

Table 1. Accuracy estimation results for the baseline length

Network names	Accuracy characteristics			
	$m_{D\,(mm)}$	$m_{d\,(mm)}$	$m_{soft\,(mm)}$	m_D/m_{soft}
Local control network (1999)	4.8	2.9	0.8	6.0
Local control network (2000)	3.9	2.9	1.0	3.9
Extended control network (1999)	3.3	2.7	0.3	11.0
Means	4.0	2.8	0.7	7.0

Table 2. Accuracy estimation results for the baseline elevations

Network names	Accuracy characteristics			
	$m_{D\,(mm)}$	$m_{d\,(mm)}$	$m_{soft\,(mm)}$	m_D/m_{soft}
Local control network (1999)	17.2	13.1	1.8	9.6
Local control network (2000)	22.7	13.1	2.1	10.8
Extended control network (1999)	13.6	3.5	0.8	17.0
Means	17.8	9.9	1.6	12.5

As we can see form the tables the more reliable RMS values are about 4-17 times large than those obtained by GPSurvey. This known effect of the formal accuracy estimation is related to a high correlation of measured elements included in this estimation. RMS values obtained by repeated observation session results fall midway between another ones. They closer to real estimations but by 1.5-4 times lower. It should be noted that geoid heights have not been taken into account for lack of this information. This partly explains the RMS values of 1.4 to 2.3 cm, higher than we expected.

Because we have used rather short distances (from 24 to 500 mm) we can suppose that we were determined the constants a of the known RMS formula $m=a+bD$, where D is the length of a measured baseline.

It is necessary to remark that not quite perfect conditions, such as trees and a billing, are near the centers of the local network affected on the measurements. That was the cause reduces the measurement accuracy in the exchange of the multi phase effect and bracing of satellite signals. The expanded control network centers are placed in open vision conditions in elevations more than 5 degree. This allows considering that the RMS obtained by the measurements of that network more reliable and close to the real accuracy.

3. Antenna Calibration Results

As noted above, some centers of the rooftop network are intended for satellite antenna calibration. This procedure is necessary for improved measurement accuracy. This is especially substantive in cases of the usage of different models of satellite equipment. An example is shown in the MARIANOVICH M, RASIC L., 1999.

The experimental results of dual frequency antenna calibration are shown in the tables 3-6.

Table 3. Calibration results of choke ring antennas for L1 frequency

Parameter	JPS Regant SD										Dorn Margolin	
	No RA0023		No RA0033		No RA0034		No RA0036		No RA0037		No 110518	
	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)
l	1.2	*0.2*	2.9	*0.2*	0.6	*0.3*	2.2	*0.2*	1.5	*0.2*	1.0	*0.2*
v_N	1.2	*0.2*	2.6	*0.2*	0.0	*0.2*	2.0	*0.2*	1.5	*0.1*	-1.0	*0.2*
v_E	0.3	*0.2*	-1.1	*0.2*	0.6	*0.3*	-1.0	*0.2*	-0.1	*0.1*	-0.2	*0.2*
v_U	1.0	*0.1*	0.1	*0.2*	-0.3	*0.1*	-0.6	*0.1*	0.5	*0.1*	3.0	*0.5*

Table 4. Calibration results of choke ring antennas for L2 frequency

Parameter	JPS Regant SD										Dorn Margolin	
	No RA0023		No RA0033		No RA0034		No RA0036		No RA0037		No 110518	
	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)
l	0.6	*0.2*	0.6	*0.4*	0.2	*0.2*	0.6	*0.1*	0.6	*0.2*	0.4	*0.2*
v_N	0.6	*0.2*	0.3	*0.2*	0.2	*0.2*	0.4	*0.1*	0.4	*0.2*	-0.4	*0.2*
v_E	0.2	*0.2*	-0.5	*0.3*	0.0	*0.2*	-0.5	*0.1*	-0.4	*0.2*	-0.1	*0.2*
v_U	1.2	*0.4*	0.4	*0.4*	0.1	*0.4*	0.3	*0.4*	0.0	*0.4*	1.6	*0.5*

Table 5. Calibration results of geodetic antennas for L1 frequency

Parameter	Trimble Compact 4000 SSE L1/L2						Trimble Geodetic 4000 SSE L1/L2				JPS Legasy	
	No 050383		No 050360		No 0061094		No 6632		No 6634		No LA0437	
	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)
l	2.0	*0.2*	1.9	*0.3*	1.7	*1.0*	2.7	*0.4*	2.8	*0.3*	0.3	*0.1*
v_N	-1.0	*0.3*	-1.8	*0.3*	-1.1	*1.0*	0.0	*0.4*	0.0	*0.4*	-0.1	*0.1*
v_E	1.8	*0.3*	0.8	*0.3*	1.3	*1.0*	2.7	*0.4*	2.8	*0.4*	0.3	*0.1*
v_U	-0.1	*0.5*	2.2	*0.5*	1.3	*0.5*	3.3	*0.5*	2.8	*0.5*	-5.4	*0.5*

Table 6. Calibration results of geodetic antennas for L2 frequency

Para-meter	Trimble Compact 4000 SSE L1/L2						Trimble Geodetic 4000 SSE L1/L2				JPS Legasy	
	No 050383		No 050360		No 0061094		No 6632		No 6634		No LA0437	
	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)	Value (mm)	RMS (mm)
l	1.8	*0.4*	1.4	*0.2*	2.0	*0.9*	3.8	*0.5*	3.0	*0.3*	0.4	*0.2*
v_N	1.8	*0.4*	1.0	*0.2*	1.8	*1.0*	3.5	*0.5*	3.0	*0.3*	-0.4	*0.2*
v_E	-0.4	*0.4*	-1.0	*0.2*	-0.9	*1.2*	1.5	*0.5*	0.7	*0.3*	-0.2	*0.1*
v_U	-6.4	*0.5*	4.0	*0.5*	2.5	*0.5*	3.9	*0.5*	3.8	*0.5*	1.9	*0.5*

Typical examples of phase center position changes along with changes in orientation are presented at Fig. 3 and 4.

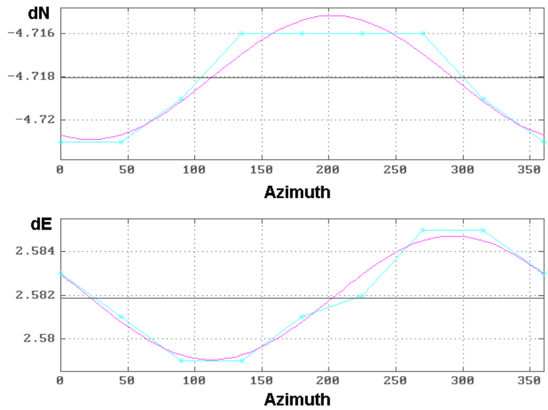

Figure 3. Phase center position changes of antenna RA0033 for L1 frequency in m (broken line is observation result, smoothed line is harmonical approximation)

Conclusive evidence from antenna calibrations proves that Geodetic 4000SSE L1/L2 antennas have the largest eccentricities. For antennas of this type Trimble Company guaranties a coincidence between phase and geometric centers within 5 mm (Micro Centered..., 2000). As the research shows for these antennas, a radial error of 2.9 to 3.7mm from a phase center position can be expected. Linear eccentricity for choke ring antennas change from 0.3 to 2.9 mm. An interesting fact, antenna eccentricities for the L2 frequency are considerably lower than for the L1 frequency. For test antennas they are not higher than 0.6 mm. So called zero centered antennas JPS Regant SD (Javad Positioning Systems, 2000) have linear eccentricity components varying from 0.6 to 2.9 mm for the L1. In comparison the similar antenna Dorn Margolin (L1/L2 Choke Ring Antenna, 2000) has a corresponding value of 1.0 mm. Notably, antennas Legant N0LA0437 and Regant SD NoRA0034 from JPS Company have the smallest eccentricities for both frequencies.

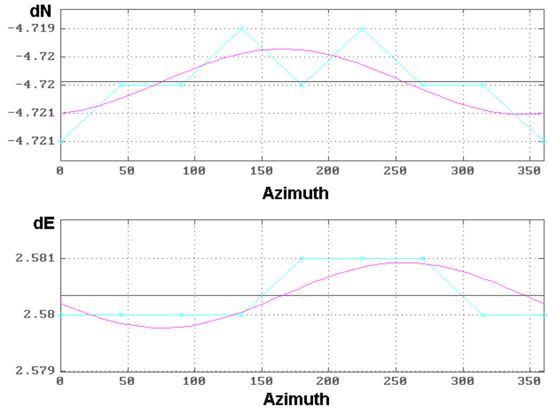

Fig.4. Phase center position changes of antenna RA0023 for L2 frequency in m (broken line is observation result, smoothed line is harmonical approximation)

Summarised values of RMS of phase center positions are presented in Table 7.

Table 7. Summarised values of RMS of phase center positions

Antenna classes	RMS of phase center positions in mm					
	radial			vertical		
	L1	L2	L1/L2	L1	L2	L1/L2
Zero centered (Choke Ring)	1.7	0.5	1.3	1.3	0.6	1.1
Micro centered (Geod., Compact)	2.3	2.6	2.4	2.2	4.3	3.4

A comparison among the different antennas and their maximum errors and antenna eccentricities in phase center positions are shown in Table 8.

Table 8. Maximal differences of phase center positions

Antenna classes	Maximal differences of phase center positions in mm					
	horizontal				vertical	
	dN		dE		dU	
	L1	L2	L1	L2	L1	L2
JPS Regant SD	2.6	0.4	1.7	0.8	1.6	1.2
Common	4.4	3.9	3.9	2.5	8.7	10.4

As the research indicates, coordinate errors caused by eccentricities of the tested antennas can extend to 4.4 mm for horizontal and 10.4 mm for height components. The use of one-type antennas, the JPS Company antennas in our case, allows diminishing the influence of eccentricity from 2 to 10 times.

Results and conclusions

After the trial period of GPS observation in the control network for the Moscow FAGN station, we conclude:

- The first epoch of a local control of positions for the Moscow FAGN station centers has been established;
- Using satellite equipment from the JPS Company, the accuracy of horizontal and vertical positions about 4.0 mm and 17.8 mm has been attained correspondingly;
- Analysis by comparison indicates that formal RMS obtained by standard software can be 7 to 12 times optimistic than actual ones;
- This testing of antennas emphasizes the necessity to take in account antenna eccentricities to ensure precise control and the stability of FAGN centers;
- Chock Ring antennas are about twice accurate than dual frequency antennas of other types;
- It is shown that the usage of one-model antennas in an observation session allows improving the accuracy of positioning;
- Ignoring errors due to the eccentricities of antennas can result in positioning errors of 10 mm.

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