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TRANSFORMATION OF COORDINATES OF GEODETIC NETWORK WITH USE OF SATELLITE TECHNOLOGIES ON THE EXAMPLE THE TERRITORY ATTACHED TO THE CITY OF ALMATY

Abstract. This article discusses the method of satellite measurements at the points of the planned and high-rise justification in the attached territories to the city of Almaty. In accordance with the decree of the President of the Republic of Kazakhstan dated April 16, 2014 No. 798, land plots from the Almaty region with a total area of 23,200 hectares with 27 settlements located on them and a population of more than 92 thousand people were annexed to the city of Almaty.

The increase in the territory of the city of Almaty is carried out in order to develop it, ensure security and law and order, improve the functioning of industrial infrastructure, expand access roads, build social facilities, and bus stations. The object of research is the Eastern border of the city of Almaty, the land of Kolsay and Sulusay villages, with an area of 4412.0 hectares. The existing local system of coordinates (further - LCS) the city of Almaty developed in the 60th years of the XX century was calculated on 20 – 30 years' development plan for the city. Now in connection with numerous expansion of borders of the city, LCS doesn't meet requirements imposed to their accuracy when using modern methods of measurements.

Key words: the local coordinate system, state geodetic points, satellite technology, transformation of coordinates.

Introduction. Today, for the successful use of LCS in modern conditions of widespread use of satellite technologies, a number of problems are hindering:

- LCS is a flat rectangular geodetic network, therefore, when expanding the territory to use the local coordinate system, for example, in the annexed territories, in the territories of nearby cities, airports, the difference between the values of the parameters measured on the ground and on a large-scale plan increases.
- When using modern satellite methods to achieve high accuracy, the contractor needs to know either the parameters of the transition to the spatial geocentric coordinate system, or to the state coordinate system of 1942 (SK-42), which are closed. Therefore, these works can only be performed in post-processing mode, subject to the relevant regime requirements. These conditions greatly complicate the processes of geodetic work and make them economically less efficient.
- In some cases, the city network in the process of their development and expansion of the territories of economic development was thickened and supplemented by poor quality support networks that do not meet modern requirements for coordinate accuracy and methods for fixing geodetic points on the ground.
- The accuracy of the local coordinate system created on the basis of the SK – 42 coordinate system does not meet modern requirements and amounts to 1/50 000–1/150 000 or up to several decimeters at a distance of 15–20 km [4,5]. In addition, in the process of development of thickening networks in LCS, the state of things was aggravated by new additional errors. Some points in local coordinate systems have not been preserved, and in many cases it is not clear on the basis of which support points the technical

documentation of the engineering infrastructure was created. In many cases, on the borders of the annexed territories that previously had different local coordinate systems, residuals occur, reaching a meter or more. These shortcomings are inherent in the local coordinate system due to its significant size, because there is a problem of distortion during reduction to the plane.

The choice of satellite geodetic measurement method. To date, the geodetic coordinate system must meet two seemingly difficult compatible basic requirements:

- the coordinate system should ensure the effective use of modern technologies of global navigation satellite systems (GNSS);
- the coordinate system should provide the maximum possible realization of the potential of geodetic and cartographic data created to date by using traditional tools and methods.

An effective tool for topographic and geodetic production has proved itself to be the methodology for determining spatial coordinates by means of satellite geodetic measurements. The homogeneous high accuracy of urban geodetic networks is achieved by applying reasonable optimal methods for satellite observations and appropriate methods for processing them, as well as by using the optimal geometry of the points, their uniform density and the maximum possible combination of old and new geodetic networks [2].

Static survey is a classic survey method, well suited for all sizes of bases (short, medium and long). At least two receiver antennas, centered above the points, simultaneously collect measurement data at the ends of the basis for a period of time.

These two receivers must simultaneously track four (or more) satellites, record data with the same period and have the same elevation angle. The duration of the measurement session can vary from several minutes to several hours. The optimal duration of the observation session is determined empirically and depends on the following factors

- Lengths of the measured baseline.
- The number of satellites in view.
- Geometric factor (Dilution of Precision, DOP).
- The location of the antenna.
- The level of activity of the ionosphere.
- The type of receivers used.
- Requirements for accuracy.
- The need to resolve carrier phase ambiguity.

For base lines, dual-frequency receivers are used. Dual frequency receivers have two big advantages. First, measurements at two frequencies provide greater accuracy than single-frequency receivers when determining long bases even during increased activity of the ionosphere (ionospheric storms). Secondly, dual-frequency receivers require significantly shorter measurement sessions to obtain determinations of a given accuracy [6].

The coordinates and heights of state geodetic points (hereinafter SGP) located in the north-eastern border of the city of Almaty: the lands of the village of Almerek should have been used as starting geodetic points:

- SGP "Pokrovka" class 2 with a height mark from the leveling of class 4,
- SGP "Pervomayskaya" 3 classes with a height mark from leveling 3 classes,
- SGP "Alatau" class 2,
- SGP "Kyzylgayrat" 1st category with a height mark from leveling 4 classes,
- SGP "Pumping" 1 category with a height mark from leveling 4 classes.

As a result of processing the obtained materials of preliminary observations and the calibration of the initial SGP, the SGP Alatau, the center of which was destroyed at the time of the measurements, was excluded from the source [7].

Also, when processing the results of GPS measurements in various areas (on the plain and in the mountains) and the analysis of calibration and network equalization of altitude values, it was concluded that it is impossible to obtain the heights of the determined polygonometry points with a given accuracy specification. Therefore, all conducted static GPS measurements were used to obtain only the planned position of the polygonometry points of the developed air defense. The altitude values of points of the developed network are obtained by the combined method. For some points, leveling courses of grade 4 were laid, and the heights of the remaining points were determined by RTK observations with control for benchmarks and polygonometry points whose heights were obtained from leveling of grade 4 and above.

Using the GNSS Credo software package, processing of satellite geodetic measurements was performed, according to the measured:

- the distance from the satellite to the receiver by code (pseudorange);
- the distance from the satellite to the receiver in the phase of the carrier frequency (Phase);
- the era (date and time) in which the measurement was made.

It should also be noted that the importance for calculations are ephemeris (satellite orbit parameters).

The initial data were satellite geodetic measurements and ephemeris in the format of Trimble satellite geodetic receivers. The calculation of satellite geodetic measurements in differential mode is performed. In this mode, the simultaneous operation of two or more receivers is assumed, with each pair of receivers working simultaneously forms a baseline — a vector in space that can be calculated from observational data. The main simulated value in the calculation of the baseline is the double difference of the phase observations. Simplified positioning equation for phase measurements can be expressed as follows:

$$\Phi rs = f/c * (\rho rs + with * (\delta tr + \delta ts) + \delta tr - \delta ion) + Nrs + \varepsilon \quad (1)$$

where, Φrs – the measured value of the phase for receiver r to satellite s; ρrs – geometrical distance between the receiver and the satellite; δtr, δts – corrections of hours of the receiver and the satellite; Nrs – phase ambiguity (unknown number of the whole cycles of the phase bearing); δtr, δion - tropospheric and ionospheric delays; ε – other factors of influence; f – frequency of electromagnetic wave of the signal; c – light speed.

Double differences (2) are formed by forming the difference of the equations, first between two satellites from one receiver (thus compensating for the correction of the receiver's clock and partly the influence of the atmosphere), then between two satellites along two receivers (the satellite clocks and, to a greater extent, the influence of the atmosphere) are compensated . In this case, when forming the differences, the integer nature of the ambiguity is preserved (3).

$$\Phi dd = f/c * (\rho dd + \delta trdd - \delta iondd) + Ndd + \varepsilon dd \quad (2)$$

where,

$$Ndd = Nr1s1\ Nr1s2 - (Nr2s1\ Nr2s2) \quad (3)$$

The preservation of the integer nature of the ambiguity in modeling is one of the factors ensuring high accuracy in calculating the baseline. In the calculation, equations of double differences are formed, the unknown of which are the corrections to the coordinates of the determined receiver and the values of the ambiguities. Solving the system of equations using the least squares method, we obtain the values of the ambiguities at which the sum of the squared corrections (VTPV) is minimal. However, these values are not integer, which does not correspond to the initial definition of ambiguity. Each rounding of the parameter obtained by solving the system of equations leads to a departure from the minimum VTPV. The problem is to find a set of ambiguities that leads the solution in the least way away from the minimum VTPV obtained by the least squares method and to prove that this set is indeed optimal. The criterion for the acceptability of an integer solution is the ratio. Each of the integer sets of ambiguities - candidates takes the solution away from the minimum VTPV by dVTPV. The ratio is obtained as the quotient of dVTPV (best candidate) / dVTPV (second best candidate). Thus, the larger the ratio, the more reliable the obtained integer solution can be considered true. If the ratio is greater than the threshold, the final calculation of the baseline is performed provided that the ambiguities are fixed (fixed solution), if less than the threshold, the solution obtained by modeling the ambiguities remains - a floating solution [8].

After importing the statistical satellite measurement data, the baselines between the SGP points are calculated: *Nasosnyi-Kyzylgairat, Nasosnyi-Pokrovka, Pokrovka-Kyzylgairat, Nasosnyi-Pervomaika, Pervomaika-kyzylqairat, Pervomaika-Pokrovka* which is shown in figure 1.

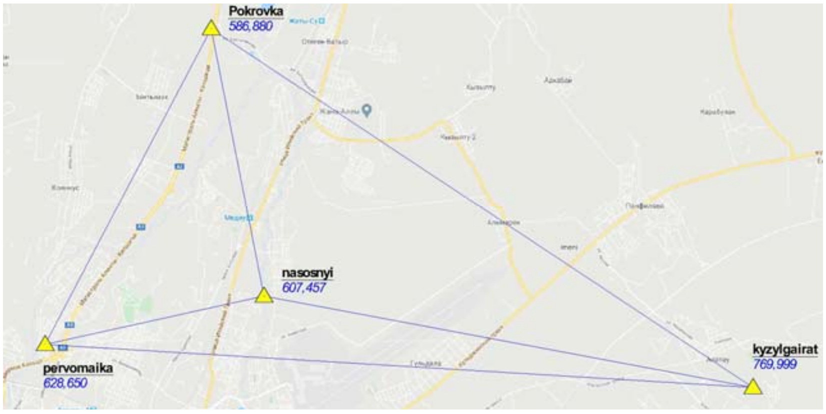

Figure 1 - Scheme of the SGP network of the studied area

Based on the processing of baselines, the following statements are compiled:

- processing of baselines, which contains the results reflecting the quality of the performed GNSS measurements (UPC and covariance of the elements of the baseline)
- coordinates of points along baselines, containing coordinates in the WGS system of 84 stations

the position of the receivers for points along each baseline, as well as the length of the baseline in space and the ellipsoidal distance between two stations, obtained by solving the inverse geodesic problem on an ellipsoid.

The main simulated measurements in calculating the baseline are the double differences of the phase observations.

With the development of geodetic networks by satellite methods, closed figures can be formed from vectors, the so-called polygons. Checking the closure of polygons before adjusting the network is a way to check the quality of the calculation of baselines and reject bad decisions.

Closing polygons consists in summing vectors within a closed shape. In the absence of measurement errors, the sum of the vectors forming a closed polygon will be zero. In reality, even under good observation conditions, obtaining zero values. In addition to the quality of the decision of the baselines, the closure of the polygons also reveals errors in measuring the heights of the receivers.

After processing the base lines, in the presence of redundant measurements or several starting points, it is necessary to carry out the adjustment of the satellite geodetic network. In the GNSS system, adjustment is performed in the spatial geocentric coordinate system WGS84, the adjustment results are reduced to the projection plane of the user coordinate system.

The initial data for adjustment are processed baselines (vectors) reduced to the centers of points and their covariance matrices, as well as the coordinates of the starting points. The adjustment module simulates the coordinates on an ellipsoid, which allows you to assign points as initial points in plan and height separately.

According to the adjustment results, a statement of corrections of equalized vectors and a catalog of coordinates of the equalized points are shown which are shown in table 1 and 2.

Table 1 - Statement of corrections of equalized vectors

Vector	Correction X	Correction Y	Correction Z	Norms. correction X	Norms. correction Y	Norms. correction Z
nasosnyi-kyzylqairat	- 0.011	0.003	- 0.005	- 3.168	0.520	- 0.739
nasosnyi-Pokrovka	0.007	0.008	0.006	0.007	0.008	0.006
Pokrovka-kyzylqairat	0.002	- 0.005	- 0.008	0.657	- 0.861	- 1.179
nasosnyi-pervomai	0.000	0.007	0.009	- 0.026	1.054	1.284
pervomai-kyzylgairat	0.000	0.010	0.031	0.044	1.199	3.554
pervomai-Pokrovka	0.001	0.003	- 0.004	0.320	0.421	- 0.596

Table 2 - Catalog of coordinates of equalized points

Name	Coordinates, m			H (ell)
	N	E	H	
Pokrovka	4810726.660	660950.703	586.880	586.880
kyzylgairat	4801558.739	674802.845	769.999	769.999
nasosnyi	4803889.719	662299.424	607.457	607.457
Pervomaiskaya	4802656.158	656706.149	628.650	628.650
kyzylqairat	4801558.736	674802.842	769.991	769.991

The list of corrections of equalized vectors contains corrections to the components of the baselines (VΔX, VΔY, VΔZ) obtained from the least-squares solution of the system of parametric correction equations. Also, the normalized correction calculated by the formula is displayed in the statement:

$$Vnormi = Vi/\sigma i \quad (4)$$

where σi – vector component of base line (ΔX, ΔY or ΔZ), by results of three-dimensional equalizing.

After receiving the catalog of coordinates of the equalized points, the point of the State Enterprise "Kyzylgayrat" was excluded in which the error in the conversion exceeded 5 cm. Coordinate transformation parameters were determined in the CREDO TRANSKOR software package, where 3 points participated. A graphical representation will help to display project points and show comparisons of the relative positions of the combined points. Figure 2 shows a visual representation of the calculated coordinate offsets in the UTM43N coordinate system relative to the local coordinate system.

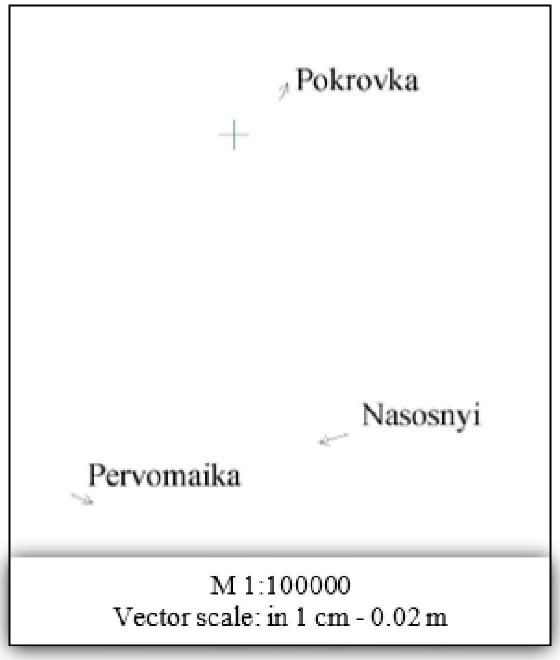

Figure 2 - The difference between the coordinates of the points of the coordinate systems UTM 43N and LCS

According to the results of the search for parameters by the coordinate systems UTM - LCS, we obtain the accuracy that meets the requirements of regulatory documents:

- the largest planned error is 28 mm;
- the smallest planned error is 7 mm;
- the transition parameter from UTM to the local coordinate system is determined by applying the Helmert transform method, which is shown in figure 3.

Параметр	Значение
имя	32643: WGS 84 / ...
тип преобразо...	Гельмерт
x1, м	4805757,512
y1, м	159985,425
x2, м	13935,549
y2, м	1670,425
m	1,000127394429
α, ° ' "	-0°09'32"

Figure 3 - Transition parameters from WGS 84 to LCS

Where the fields “x1”, “y1” are designated as the coordinates of the starting point in the UTM 43N coordinate system, “x2”, “y2” are the coordinates of the starting point in the local coordinate system, the calculated scale factor is displayed in the “m” field, in the “ α "is the value of the angle of rotation [9].

Using the transition key shown in Figure 3, we perform the coordinate transformation, the results of which are shown in Table 3.

Table 3 - Transformed coordinates of SGP points

Payment order N	Initial coordinate system of UTM			Final coordinate system LCS			Standart error		
	Point name	N	E	Point name	N	E	Vn	Ve	Vs
1	2	3	4	5	6	7	8	9	10
Points participating in determination of parameters									
1	Pokrovka	4810726.660	660950.703	Pokrovka	18907.970	2622.040	0.017	0.007	0.018
2	Nasosnyi	4803889.719	662299.424	Nasosnyi	12073.948	3989.915	- 0.008	- 0.028	0.029
3	Pervomaiskaya	4802656.158	656706.149	Pervomaiskaya	10824.730	- 1600.680	- 0.008	0.021	0.022

The proposed algorithm for calculating the parameters of the transition to the local coordinate system is applicable only for this study area.

The results of the work revealed a number of problems in the state of the existing SGN in Almaty. Based on the work done, a conclusion is made about the unsatisfactory condition of the existing geodetic base of Almaty. This is also confirmed by the study of information from various works, the actual state of network points, used coordinate and high-altitude systems, static GPS observations at points of the state geodetic network (hereinafter - SGN) of classes 1 and 2, it was decided to make a large number of GPS observations on points of the SGN in order to identify their suitability for use in the development of air defense.

According to the measurement results, it was found that determining the relative position of the GHS and the observed air defense points in terms of and especially in height within the tolerance is possible only in small local areas.

The initial coordinates of the points used have marginal errors in terms of and in height of the relative position and orientation. The use of reference stations of different companies located in the city of Almaty was not used due to the fact that single reference stations in Almaty were determined by various methods and their spatial position is heterogeneous, which does not contribute to high-quality high-precision measurements. They are not suitable not only for the development of air defense, but also for the production of topographic surveys at a distance of more than 10 km from the reference station, and centering works for capital construction more than 3-5 km.

Conclusion. Based on the foregoing, there is currently an urgent need to modernize the existing GHS and create on its basis a new unified frame geodetic network in Almaty using satellite measurements.

Thus, the local coordinate system, to one degree or another, is characterized by the main disadvantages:

- low and heterogeneous accuracy of the reference geodetic networks;
- the impossibility (due to operational restrictions) to effectively apply modern satellite technology in the existing local coordinate system.

As a consequence of these factors, a complex of problems arises, without the solution of which the operation of the local coordinate system is difficult, and sometimes impossible. The problems are related to the need to determine with high accuracy the parameters of the transition from the local coordinate system to the state system of geodetic coordinates SK-42. Coordinate errors of the reference geodetic networks in the LCS, and often the unknown coordinates of the points of these networks in the SK-42 coordinate system, make this requirement quite difficult.

The solution to this problem is very complicated, because the errors of the old local geodetic networks and the local coordinate system affect. Consequently, there is a need to modernize geodetic structures (urban geodetic networks) and, on their basis, modernize the LCS of the city, provided that the discrepancies in the catalogs of local coordinate systems and, accordingly, in the large-scale maps and plans available, in engineering and legal documentation are minimized.

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АЛМАТЫ ҚАЛАСЫНА ҚОСЫЛҒАН АУМАҚ МЫСАЛЫНДА СПУТНИКТІК ТЕХНОЛОГИЯЛАРДЫ ПАЙДАЛАНА ОТЫРЫП, ГЕОДЕЗИЯЛЫҚ ЖҮЙЕНІҢ КООРДИНАТАСЫН ТРАНСФОРМАЦИЯЛАУ

Аннотация. Бұл мақалада Алматы қаласына қосылған аумақтардағы жобалық-биіктік негіз пункттеріндегі спутниктік өлшеу әдісі қарастырылады. Қазақстан Республикасы Президентінің 2014 жылғы 16 сәуірдегі № 798 Жарлығына сәйкес Алматы қаласына жалпы ауданы 23 200 га, онда орналасқан 27 елді мекен және халық саны 92 мың адамнан асатын жер учаскелері қосылды.

Алматы қаласының аумағын ұлғайту оны дамыту, қауіпсіздік пен құқықтық тәртіпті қамтамасыз ету, өнеркәсіптік инфрақұрылымның жұмыс істеуін жақсарту, кіру магистральдарын кеңейту, әлеуметтік объектілерді, автовокзалдарды салу мақсатында жүргізіледі. Зерттеу объектісі Алматы қаласының шығыс шекарасындағы аумағы 4412,0 га болатын Көлсай және Сұлусай ауылдары. XX - ғасырдың 60 жылдары әзірленген Алматы қаласының жергілікті координата жүйесі (бұдан әрі - ЖКЖ) қаланы дамытудың 20-30 жылдық жоспарына ғана есептелген. Қазіргі уақытта қала шекарасының бірнеше рет кеңейтілуіне байланысты, ЖКЖ қазіргі заманауи әдістерді пайдалану кезіндегі олардың дәлдігіне қойылатын талаптарға жауап бермейді [1].

Кредо ГНСС бағдарламалық пакетін қолдану арқылы спутниктік геодезиялық өлшеулер өңделді, мұнда спутниктік геодезиялық өлшеулер мен эфемерлер бастапқы деректер болды. Статистикалық спутниктік өлшеулер деректерін импорттағаннан кейін келесі пунктер арасындағы негізгі сызықтар есептелді: Насосный-Кызылгайрат, Насосный - Покровка, Покровка - Кызылгайрат, Насосный - Первомайская, Первомайская - Кызылгайрат, Первомайская - Покровка. Базалық өңдеудің негізінде жасалды: орындалған GNSS өлшеулерінің сапасын көрсететін нәтижелерді қамтитын бастапқы сызбаны өңдеу парағы (ОКҚ және базалық элементтердің ковариациясы); эллипсоид бойынша кері геодезиялық есепті шешу жолымен алынған ғарыштағы базалық сызықтың ұзындығы және екі станция арасындағы эллипсоидтық қашықтық, сонымен қатар әр базалық сызық бойындағы нүктелер үшін қабылдау станцияларының WGS84 жүйесіндегі координаталардан тұратын негізгі координаттар парағы.

Базалық есептеу сапасын тексеру және дұрыс емес шешімдерді қабылдамау үшін полигондар желіні теңестіру алдында тұйықталды. Базалық сызықтарды өңдегеннен кейін жерсеріктік геодезиялық желі теңестірілді. GNSS жүйесінде түзету WGS84 кеңістіктік геоцентрлік координат жүйесінде жүргізілді, түзету нәтижелері таңдалған координаталар жүйесінің проекцияланған жазықтыққа өтеді. Түзету нәтижелері бойынша теңестірілген векторларды түзету туралы есеп және теңестірілген нүктелер координаттарының каталогы жасалады. Түзетілген нүктелердің координаттарының каталогы жасалды, қателік 5 см-ден асқан Қызылғайрат геодезиялық пунктін алып тастау туралы шешім қабылданды.

UTM 43N және ЖКЖ арасындағы координаталарды трасформациялау параметрлерін анықтауда 3 пункт қатысқан Кредо ТРАНСКОР бағдарламалық пакетінде жүргізілді. Іздеу нәтижелері бойынша өтпелі параметрлер анықталды: ең үлкен қате - 28 мм; ең аз қате - 7 мм; Сонымен қатар, UTM-ден жергілікті координат жүйесіне ауысу параметрі Хельмерт түрлендіру әдісі арқылы анықталады. Алайда, жергілікті координаттар жүйесіне көшу параметрлерін есептеу алгоритмі тек осы зерттеу аймағында қолданылады.

Өлшеу нәтижелері бойынша жоспардағы геодезиялық пунктер мен бақыланатын нүктелердің салыстырмалы позициясын және биіктігін анықтау тек шағын аудандарда мүмкін екендігі анықталды. Жоғарыда айтылғандарға сүйене отырып, қазіргі кезде қолданыстағы геодезиялық желіні жаңарту және оның негізінде спутниктік өлшеулерді қолдана отырып, Алматы қаласының жаңа бірыңғай геодезиялық желісін құру қажеттілігі туындайды.

Түйін сөздер: жергілікті координата жүйесі, мемлекеттік геодезиялық пункттер, спутниктік технологиялар, координата трансформациясы

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ПРЕОБРАЗОВАНИЕ КООРДИНАТ ГЕОДЕЗИЧЕСКОЙ СЕТИ С ИСПОЛЬЗОВАНИЕМ СПУТНИКОВЫХ ТЕХНОЛОГИЙ НА ПРИМЕРЕ ТЕРРИТОРИЙ, ПРИСОЕДИНЕННЫХ К Г. АЛМАТЫ

Аннотация. В данной статье рассматривается метод спутниковых измерений на пунктах планово-высотной основы в присоединенных к городу Алматы территориях. В соответствии с Указом Президента Республики Казахстан от 16 апреля 2014 года № 798 к городу Алматы присоединены земельные участки с Алматинской области общей площадью 23 200 га с расположенными на них 27 поселениями и численностью населения более 92 тысяч человек [1].

Увеличение территории города Алматы проводится в целях его развития, обеспечения безопасности и правопорядка, улучшения функционирования промышленной инфраструктуры, расширения въездных магистралей, строительства социальных объектов, автовокзалов. Объектом исследования является восточная граница города Алматы, земли с. Кольсай и с. Сулусай, площадью 4412,0га. Существующая местная система координат (далее – МСК) города Алматы, разработанная в 60 годы XX-века, была рассчитана на 20–30 летний план развития города. В настоящее время в связи с неоднократным расширением границ города, МСК не отвечает требованиям, предъявляемым к их точности при использовании современных методов измерений.

С применением программного комплекса Кредо ГНСС была выполнена обработка спутниковых геодезических измерений, где исходными данными послужили спутниковые геодезические измерения и эфемериды в формате спутниковых геодезических приемников Trimble.

После импорта данных статистических спутниковых измерений рассчитаны базовые линии между пунктами ГГП: Насосный - Кызылгайрат, Насосный - Покровка, Покровка - Кызылгайрат, Насосный - Первомайская, Первомайская - Кызылгайрат, Первомайская - Покровка. На основе обработки базовых линий составлены: ведомость обработки базовых линий, которая содержит результаты отражающее качество выполненных GNSS-измерений (СКП и ковариации элементов базовой линии); ведомость координат точек по базовым линиям, содержащая координаты в системе WGS 84 станций стояния приёмников для точек по каждой базовой линии, а также длину базовой линии в пространстве и эллипсоидальное расстояние между двумя станциями, полученное путём решения обратной геодезической задачи на эллипсоиде.

Выполнено замыкание полигонов перед уравниванием сети для проверки качества расчета базовых линий и отбраковки плохих решений.

После обработки базовых линий выполнено уравнивание спутниковой геодезической сети. В системе ГНСС уравнивание производилось в пространственной геоцентрической системе координат WGS84, результаты уравнивания редуцируются на плоскость проекции выбранной системы координат. По результатам уравнивания составлен ведомость поправок уравненных векторов и каталог координат уравненных пунктов. Составлен каталог координат уравненных пунктов, было решено исключить пункт ГГП "Кызылгайрат" в которой погрешность превышал 5см.

Определение параметров преобразования координат между UTM 43N и МСК осуществлялась в программном комплексе Кредо ТРАНСКОР, где участвовало 3 пункта. По результатам поиска параметров перехода выявлены: наибольшая плановая ошибка составляет 28 мм; наименьшая плановая ошибка составляет – 7 мм; помимо этого, определен параметр перехода из UTM в местную систему координат, применив метод преобразования Гельмерта. Однако, предложенный алгоритм расчета параметров перехода в местную систему координат, применим только для данного исследуемого участка.

По результатам измерений выявлено, что определение взаимного положения ГГС и наблюдаемых пунктов ПВО в плане и особенно по высоте в пределах допуска возможно только на небольших локальных площадях. Исходя из вышесказанного в настоящее время стоит острая необходимость модернизации существующей ГГС и создания на ее базе новой единой каркасной геодезической сети г. Алматы с использованием спутниковых измерений.

Ключевые слова: местная система координат, государственные геодезические пункты, спутниковые технологии, преобразование координат.

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