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ЧЫМЫРОВ А.У., САРГАЗАКОВА Ш.С., ИСМАИЛОВ Н.Ы.
[1]КГУСТА им. Н. Исанова, Бишкек, Кыргызская Республика

CHYMYROV A.U., SARGAZAKOVA SH.S., ISMAILOV N.Y.
[1]KSUCTA n.a. N.Isanov, Bishkek, Kyrgyz Republic
akylbek.chymyrov@aca-giscience.org

ACCURACY ANALYSIS OF THE SATELLITE POSITIONING BY USING GNSS REFERENCE STATIONS

АНАЛИЗ ТОЧНОСТИ СПУТНИКОВОГО ПОЗИЦИОНИРОВАНИЯ С ИСПОЛЬЗОВАНИЕМ БАЗОВЫХ СТАНЦИЙ ГНСС

Бул макалада KyrPOS-CORS тармагын башкаруу борборунун RTK кызматын пайдалануу менен жандоочтук орунду аныктоочу технология изилденген. Тармактык дифференциалдык ондоолорду колдонуп геодезиялык класстагы GNSS кабылдамалар менен жандоочтук өлчөөлөр аткарылган жана алардын тактыгы изилденген.
Өзөк сөздөр: *GPS, GNSS, CORS, жандоочтук орунду аныктоо, RTK, KyrPOS.*

В данной работе исследована технология спутникового позиционирования с применением RTK сервиса от Центра управления сетью CORS – KyrPOS. Выполнены спутниковые измерения приемниками ГНСС геодезического класса с сетевыми дифференциальными поправками и выполнен анализ их точность.
Ключевые слова: *GPS, ГНСС, CORS, спутниковое позиционирование, RTK, KyrPOS.*

The technology of satellite positioning by using RTK service by the KyrPOS -Control Centre of CORS Network is studied in this article. Differentially corrected satellite measurements with geodetic class GNSS receivers were done and their positioning accuracy was analyzed.
Key words: *GPS, GNSS, CORS, satellite positioning, RTK, KyrPOS.*

Introduction

Modern technologies of global satellite positioning systems allow us to solve geodetic problems of various levels: from the development of the State Geodetic Network (SGN) to the inventory of land plots and the creation of Geoinformation systems for various purposes. Due to a fairly rapid change in the situation, the data of geodetic surveys carried out by traditional methods may become outdated even at the stage of processing field measurements. Thanks to the development of modern microelectronics and aerospace technologies, traditional geodetic instruments have been significantly improved. These devices have significantly reduced the measurement time, eliminated manual field logging, and transferred measurement data directly to a computer for processing [1].

The use of global navigation satellite systems (GNSS) in high-precision positioning is rapidly developing and already plays a major role in many types of geodetic measurements. World practice shows that the transition to satellite geodesy methods will significantly reduce the financial costs and labor intensity of geodetic works, engineering and geodetic surveys and geodetic support in the construction, operation and reconstruction of buildings and structures [2,3]. The increase in the number and improvement of the technical parameters of global positioning satellites operated by different countries (GPS in the US, GLONASS in the Russian Federation, GALILEO in the EU, BEIDOU in the PRC), complement their capabilities in joint and open use, as well as increase the reliability and accuracy of geodetic measurements.

Data and methods

The development of network RTK measurement technologies supported by a network of the Continuously Operating Reference Stations (CORS) and modern communication technologies opens up new prospects for performing high-precision measurements with a single GNSS receiver. In this measurement method, the transmission of measured and corrective data in real time from the base receiver to the mobile receiver is carried out mainly via GSM technology, which is, using the services of mobile operators in the country. This to some extent restricts the use of network RTK technology in Kyrgyzstan due to high-altitude conditions and incomplete coverage of the country's territory with mobile communication services.

Permanent satellite base stations are installed in places with the most favorable conditions for receiving satellite signals and within the radius of their operation reliably provide correction data to portable GNSS receivers of users 24 hours a day, 365 days a year. One base station provides the determination of spatial coordinates in real time with centimeter accuracy within a radius of 30 km. Several permanent satellite base stations connected to a network can provide operation over a much larger area.

Fig. 1. Satellite positioning using network RTK

The KyrPOS – CORS Network Management Center operates by the State Enterprise “Cadastre” under the State Agency for Land Resources of the Kyrgyz Republic. Since 2010, it has been providing GNSS differential corrections based on satellite measurement data in the Kyrgyz Republic [4]. KyrPOS monitors the operation of 23 CORS, 6 of which are located in the Chui region, 9 stations operate in the Ferghana Valley, 2 stations in the Talas region, 1 station in the Naryn region and 5 stations are located in the Issyk-Kul region (Fig.2). One station (BISH) is privately owned and jointly operated by KyrPOS [5].

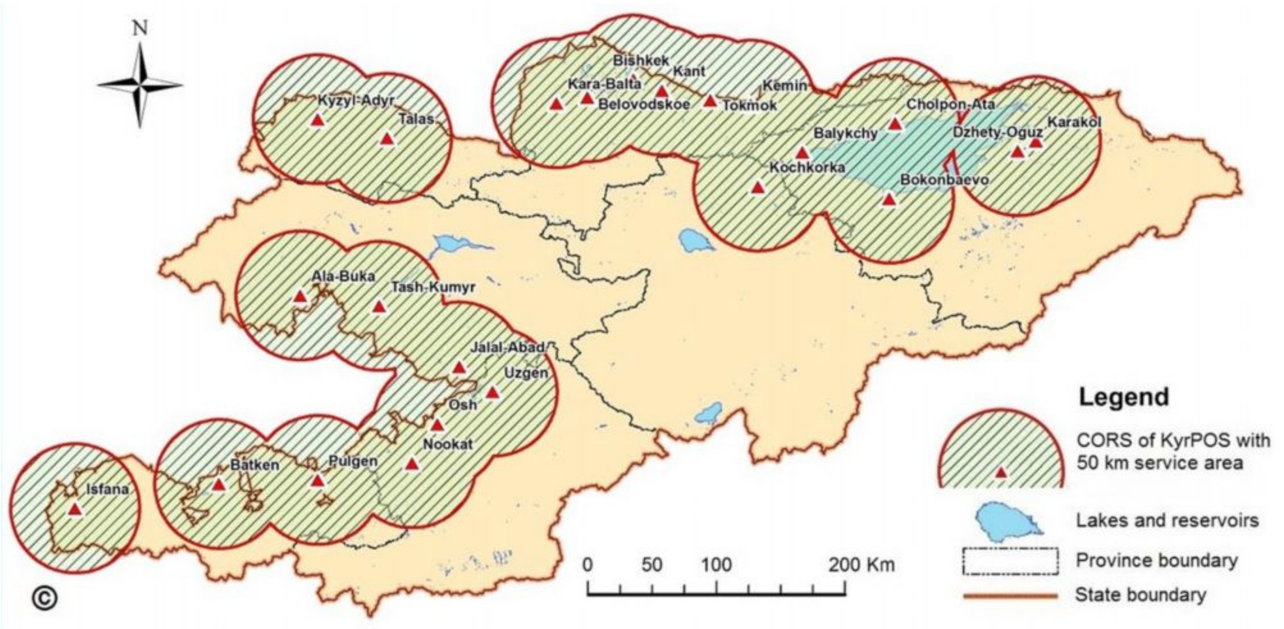

Fig. 2. Network of Continuously Operating Reference Stations of KyrPOS (2021)

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It should be noted that KyrPOS provides satellite differential correction services in the most densely populated and economically active regions of the country for the purposes of land and urban cadastre, which limits the use of network RTK methods in other remote areas. Even with the increase in the coverage area of CORS stations to the maximum possible 50 km, more than 40% of the country remains without access to the services of differential corrections to satellite measurements from KyrPOS.

International experience shows that the network RTK measurement method is becoming one of the most popular and effective methods of satellite geodetic measurements in engineering and road construction works [6,7]. Further development of the network of permanent GNSS reference stations of KyrPOS should be one of the priority directions of scientific and technical development of the country.

Another effective and reliable method of geodetic measurements is Precise Point Positioning (PPP), which is used to refine the results of calculations and ensure the accuracy of the location of points determined using RTK measurement mode. For this purpose, satellite measurement data with a single GNSS receiver using the "Static" method for at least 4-6 hours and the services of various available global RRR services are used. The studies performed using the observation data from four permanent GNSS stations located in different regions of Kyrgyzstan and statistical analysis of the obtained RRR results showed that GNSS observations lasting 24 hours and 4 hours give the greatest deviation of positioning on the horizontal plane, respectively, 2.5 cm and 4.5 cm, and deviations of geodetic heights of about 10 cm [8]. This positioning accuracy allows the use of this method also when creating reference networks for engineering and geodetic surveys and topographic surveys in remote and hard-to-reach areas with a single satellite receiver of the geodetic class.

Results and discussion

In this paper, the accuracy of satellite measurements of geodetic points by using the network RTK method was investigated and analyzed. The Leica GS15 GNSS receiver was used, which consists of the following components: receiver, antenna, milestone, level, mount, and controller. This receiver model supports 4 satellite systems (GPS L2, GPS L5, GLONASS, Galileo), works in RTK and static mode. The GNSS receiver has a built-in GSM communication system for sending and receiving measurement data and differential corrections from the CORS Network Control Center using the service of a local mobile operator. The Trimble Business Center software package, version 3.70, was used for processing and analyzing measurement data.

Three base stations of the permanent GNSS reference stations of the network (Fig. 3 and 4) were used for satellite measurements with obtaining differential corrections from KyrPOS. At least 3 measurements with a vector from each base station were performed at each point to analyze the accuracy of their calculation results (Fig. 5).

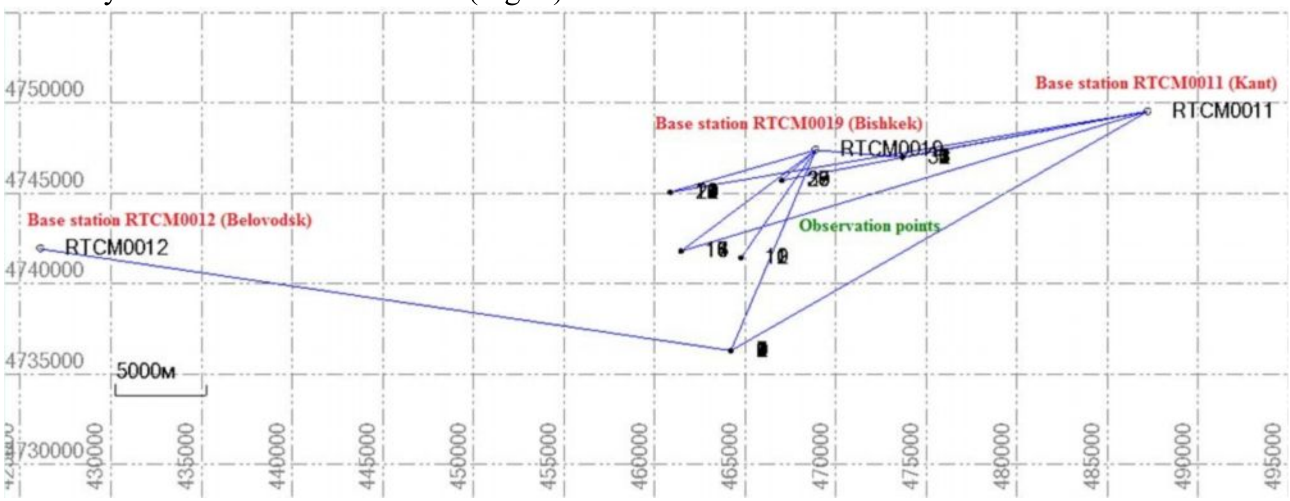

Fig. 3. Baselines of satellite measurements with base stations of the KyrPOS network

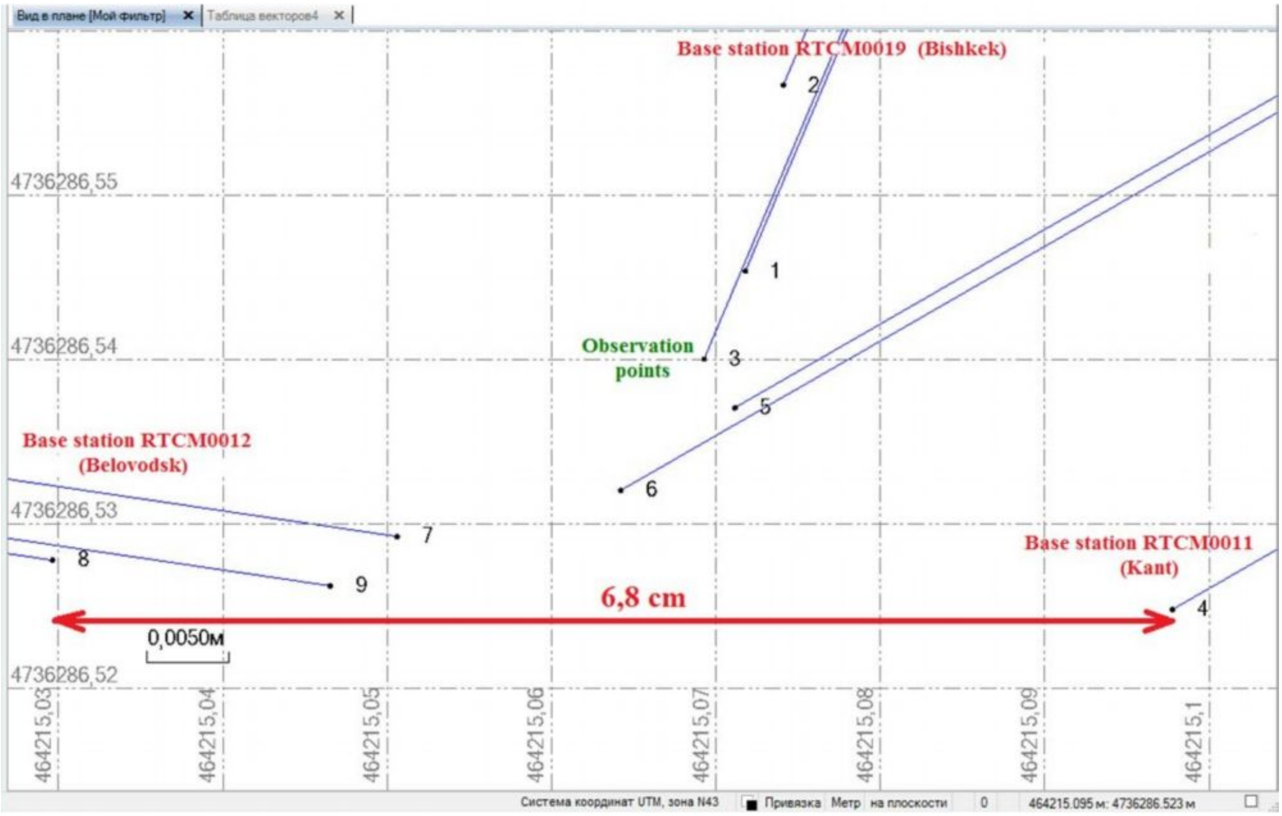

Fig. 4. Scheme of vectors of satellite measurements

Вид в плане [Мой фильтр] | Таблица векторов4

Вектора							
От точки	До точк	СКО	Точность в плане (95%)	Точность по высоте (95%	Спутник	Число эпох	Длина вектора
RTCM0019	1	0,005	0,028	0,032	11	7	12032,337
RTCM0019	2	0,005	0,028	0,033	11	6	12032,325
RTCM0019	3	0,005	0,029	0,033	11	7	12032,342
RTCM0011	4	?	0,032	0,035	12	5	26515,104
RTCM0011	5	0,006	0,033	0,036	12	4	26515,121
RTCM0011	6	0,006	0,032	0,035	12	6	26515,129
RTCM0012	7	?	0,031	0,035	13	82	38533,785
RTCM0012	8	0,006	0,033	0,037	14	6	38533,765
RTCM0012	9	0,006	0,035	0,039	14	6	38533,782

Fig. 5. Table of vectors of satellite measurements at a geodetic point

Conclusion

Analysis of the results of determining the location of points by the network RTK method showed that this method has a high accuracy of satellite measurements that meet high accuracy requirements. The root-mean-square measurement error (RMS) of the vectors from each base station was no more than 1.5 centimeters for the measurements of each station, but the height accuracy in some cases was less than 12 cm.

But at the same time, the analysis of all measurement data and vector processing from all base stations showed that the maximum error between the planned coordinates of the point determined from different base stations reaches 6.8 cm (Fig. 4). This proves that satellite measurements using the network RTK method can solve many problems of applied geodesy, cartography and geoinformation systems, but can not be used in the creation of geodetic reference networks for various purposes. The creation of state geodetic networks and condensation networks requires the use of absolute satellite measurement methods and independent data calculation using special software systems and final satellite ephemeris, as well as Precise Point Positioning (PPP) methods.

The emergence of fundamentally new technical means-satellite geodetic receivers required a significant revision of traditional approaches to the creation of geodetic networks and the implementation of engineering and geodetic works. It requires the creation of a concept, regulatory documentation and standards governing the use of satellite geodesy in solving engineering problems, the reconstruction of geodetic networks, improving the accuracy and reliability of determining the conversion parameters between the geocentric earth-wide coordinate system, state and local geodetic coordinate systems, and the formation of catalogs of coordinates of points in all used coordinate systems.

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