UDC 528.3

K. BURAK[1], B. LYSKO[2]

[1] Department of Engineering Geodesy, Ivano-Frankivsk National Technical University of Oil and Gas, 15, Karpatska str., Ivano-Frankivsk, Ukraine, 76019, e-mail: burak4111945@gmail.com
[2] Department of Engineering Geodesy, Ivano-Frankivsk National Technical University of Oil and Gas, 15, Karpatska str., Ivano-Frankivsk, Ukraine, 76019, e-mail: 93lisko@gmail.com

THE POSSIBLE USES OF RTN-SOLUTIONS FOR MARKUP WORKS ON CONSTRUCTION

https://doi.org/10.23939/istcgcap2018.01.016

The purpose of the research. Creating the practical recommendations for measuring the main buildings axes (symmetry axes) with the help of RTN method of GNSS measurements and providing the additional control over the marking works with electronic total station. **Methodology**. To ensure the accuracy of the recommended methods, the studies, including experimental ones, with measuring the axes from two basis lines are taken by GNSS receiver in such a way to coincide with the *x* and *y* axes of the object's general plan. To minimize the sporadic errors and increase the accuracy of obtained results, the investigation was made on the inherent basis, which allows the forced centering of tools. The special aspect of this basis is that it is situated very close to the permanent station (10 km). This factor substantially compensates the systematic errors in the results of the relative measurements. **Results:** Results of the study are: it was established that when setting the fixing baseline with the dual-frequency GNSS receiver in the way its points coincide with the main axes of construction netting and the following marking of all the elements of the construction site toward this baseline, the required accuracy is provided, e.g. mutual location of points of main, basic, and detailed axes, and in some cases fitting axes as well. **Scientific novelty and practical significance**. The method, described in the work, involves measuring the main building axes instead of the contiguous construction netting. Then, with the help of the electronic tacheometer, we can extend the measuring nettings of the building. This method allows to avoid building the basic construction netting by changing the mounting geodesic netting with the two basic lines (with at least 4 mounting points), that fix the position of the coordinates axes of the general plan and additionally control the axes marking with the electronic tacheometer from the basic line by using the distances value between the basic lines points, measured with the RTN method.

Key words: GNSS, TPS, RTN measurement, planning works, electronic total station.

Introduction

Global Navigation Satellite Systems (GNSS) are widely used during surveys, construction, and reference measurements together with the traditional methods. [Trevoho et al., 2016]. On our opinion, the most promising methods during the creation of the geodesic marking network are Real Time Networks (RTN) measurements (with reference stations networks), that are not even mentioned in the modern documents [DBN V.1.3-2-2010; DBN A.2.1-1-2014]. However, the advantages of RTN methods are more than obvious (measurements can be taken with one device, the results may be received without post processing just in seconds [Lanjo, Savchuk, 2012; Savchuk et al., 2009, Tereshhuk, Nystorjak, 2013]).

Purpose

Formulating the practical recommendations of defining the main construction axes (symmetry axis), that provide a required accuracy according to the current standards - 3-5 cm [DBN V.1.3-2-2010], and significantly decrease the time spent on geodetic works on the construction. These recommendations will allow to refuse from building the classic construction netting and conduct planning works with GNSS receiver by using RTN methods [Shuljc, Medvedsjkyj, 2009; Mullenix et al., 2011; Parkinson, Spilker, 2006].

Methodology

To build the graticule on the construction site, let's mark two basis AB and CD in-situ with the GNSS receiver, so they are parallel to the *x* and *y* axes of the general plan on which the site is projected. Then, let's mark the axes, using the method from the basic line as described in the work [Burak, 2011]. To solve the problem, one has to know only the coordinates x and y of one basis point and set the position angle of the line to 0° or 90°. Theoretically all planning works may be done from one base line, but we recommend to set at least two in order to provide the visibility on the entire site including the possibility of losing important points during the construction work.

During planning and marking work, GNSS measurements on the nearest observation points are made a short distance from each other (not more than 200 m), so the points will be located in ionospheric conditions and there will be a chance to see the same satellites. It allows to confirm, that influence of errors, entailed by ionospheric delays and satellite clock wrong time will be significantly decreased because of the compensation of their systematic component, that will improve the accuracy of set base lines.

It was confirmed by our research, described in the work [Burak, Lysko, no. 27, 2017]. To take exact relative measurements (of the angles and distances), the experimental studies in the conditions of real construction with reference zone consisting of 4 sites were conducted. The reference zone is located in 10 km from the permanent station. The GNSS receiver was alternatively installed on the reference zone sites with the possibility of forced centering, and, taking into account the phase center, the site coordinates in different averaging measurements were determined. All measurements were taken by dual-frequency GNSS receiver QStar 8 with RTN method throughout 1 hour.

After processing data with famous formulas, with the help of coordinates, the distances and angles were measured, which were compared to the parameters of calibration base, coordinated with the electronic 2 second total station.

According to the multiple experimental measurements, with accordance to designed recommendations (optimal amount of measurement averaging and such factors as distances to the closest permanent stations and geometry of their location, the detailed information is provided in the work [Burak, Lysko, no. 85, 2017]) , it was proved, that the accuracy of vector measurements was 2,52 mm on the distances less than 200 m, and the accuracy of mutual location, including the accuracy of angles definition, was 3,18 mm (taking into account the errors of orientation) when the time difference between measurements on two basis points was less than 1 hour.

It is important to remember that points A, B, C, D are set without such errors as device and viewfinder centering, as well as error of benchmark data. See Fig. 1.

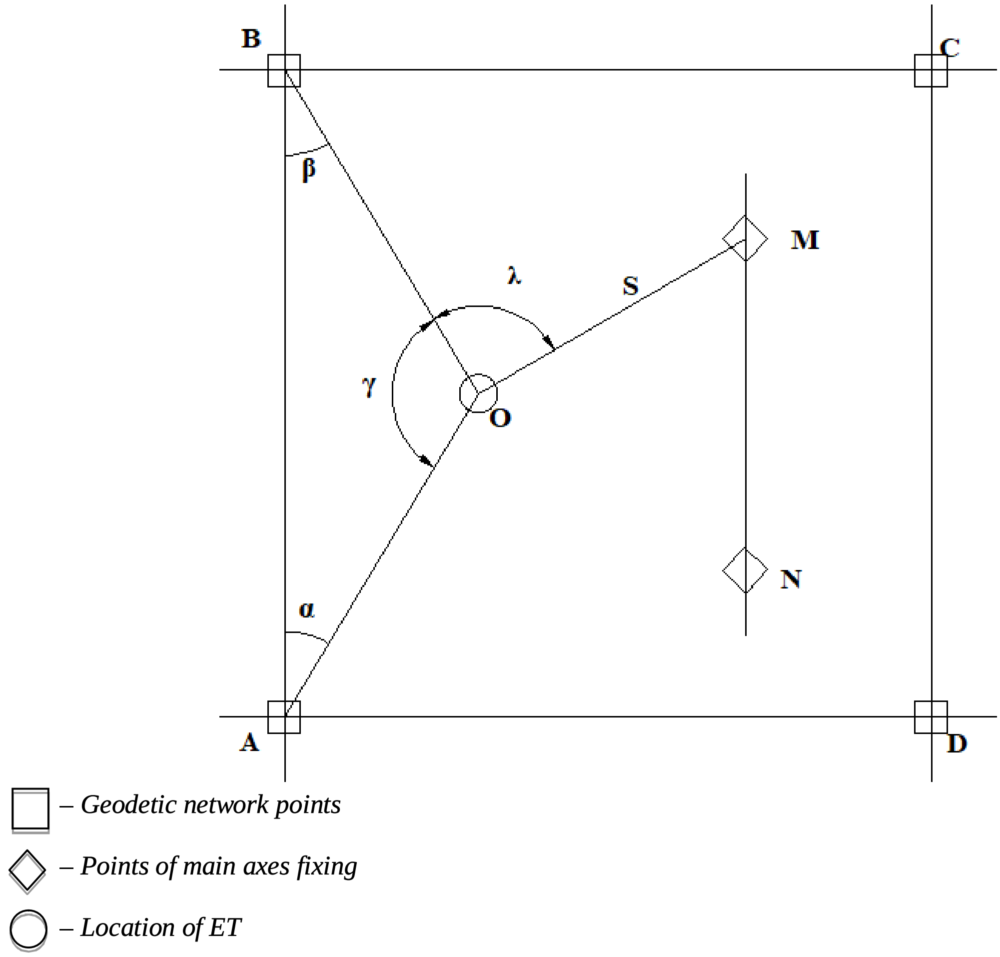

Fig. 1. Typical diagram of planning works with RTN method

Let's review the possibility of using the above described method of taking the main construction axes to provide the marking grid of construction and site, without building the basic construction netting. We will also show how to additionally control the work with the help of basis lengths, obtained from the GNSS measurements.

It is known that the measurement toward the baseline is based on measuring the distances l_1, l_2 and angle γ. It defines the coordinates of location after the ET and gives the opportunity to make amendments to the prototype without errors. Such a method has several advantages. For example, it is relatively simple in usage, the mutual accuracy of setting elements isn`t influenced by the errors of device centering, errors of point O fixing, and errors of benchmark data. However, it has the drawbacks as well, one of which is the absence of control. That's why it's recommended to repeat the measurements from both points O [Burak, 2011].

In case the points setting is made by a GNSS receiver and the base length is known, there is an opportunity to add one more additional control of defining the coordinates of point O. Let's review it in more detail. First, we have to set the length of the baseline, for example AB according to the cosine theorem.

$$\mathrm{AB} = \sqrt{l_1^2 + l_2^2 - 2l_1 l_2 \cos\gamma}. \quad (1)$$

Then compare this value to the baseline length, defined from the coordinates of the equation.

$$\mathrm{AB} = \sqrt[2]{(X_b - X_a)^2 + (Y_b - Y_a)^2} \quad (2)$$

where X_a, X_b, Y_a, Y_b – coordinates of fixing points obtained from the results of satellite observations.

Let's define the possible difference between these two values, estimated by the formulas (1) and (2). In order to simplify the process, let's review the case when the sides l_1 and l_2 are the same and are measured with ET with the same accuracy. Mean squared error (MSE) are equal m_{l_1}=m_{l_2}.

$$AB = \sqrt{2l^2 - 2l^2\cos\gamma} = \sqrt{2l^2(1-\cos\gamma)} \quad (3)$$

Let`s differentiate this function (3) on $\boldsymbol{l}$ and $\boldsymbol{\gamma}$ and receive:

$$\frac{\partial AB}{\partial l} = \frac{2l(1-\cos\gamma)}{\sqrt{2l^2(1-\cos\gamma)}} = \sqrt{2(1-\cos\gamma)} =$$

$$= \sqrt{\frac{4(1-\cos\gamma)}{2}} = \sqrt{4sin^2\frac{\gamma}{2}} = 2\sin\frac{\gamma}{2} \quad (4)$$

$$\frac{\partial AB}{\partial \gamma} = \frac{l\sin\gamma}{\sqrt{2(1-\cos\gamma)}} = \frac{l\sin\gamma}{\sqrt{4\sin^2\frac{\gamma}{2}}} = \frac{l\sin\gamma}{2\sin\frac{\gamma}{2}} =$$

$$= \frac{2l\sin\frac{\gamma}{2}\cos\frac{\gamma}{2}}{2\sin\frac{\gamma}{2}} = l\cos\frac{\gamma}{2} \quad (5)$$

From here:

$$m_{AB}^2 = \left(\frac{dAB}{dl}\right)^2 m_S^2 + \left(\frac{dAB}{d\gamma}\right)^2 \frac{m_\beta^2}{\rho^2} = =$$

$$= \left(2\sin\frac{\gamma}{2}\right)^2 m_S^2 + \left(l\cos\frac{\gamma}{2}\right)^2 \frac{m_\beta^2}{\rho^2}$$

$$m_{AB}^2 = 4m_s^2\sin^2\frac{g}{2} + \frac{m_b^2}{r^2} l^2\cos^2\frac{g}{2} \quad (6)$$

The maximum value will be:

$$m_{AB}^2 = 4m_S^2 + l^2\frac{m_\beta^2}{\rho^2} \quad (7)$$

Values by the formula (6) are illustrated in Fig. 2. The distance $\boldsymbol{l}$ is marked on the axis of abscissas and angle $\boldsymbol{\gamma}$ – on the axis of ordinate.

Analysis shows that depending on the location of point A toward the baseline AB, the maximum and minimum m_{AB} values are $m_{AB\min}$ = 1.2 mm when l = 120 m, and m_{ABmax} = 3.0 mm, l = 140 m. The accuracy of defining the m distances m_S = 0.0015 m and angle m_β = 2″ were taken into account.

In such a way, RMS of setting the basis AB by the satellite method and the maximum error of defining this distance toward the baseline will be equally accurate. It gives the opportunity to compare the data of distance value and additional control when measuring.

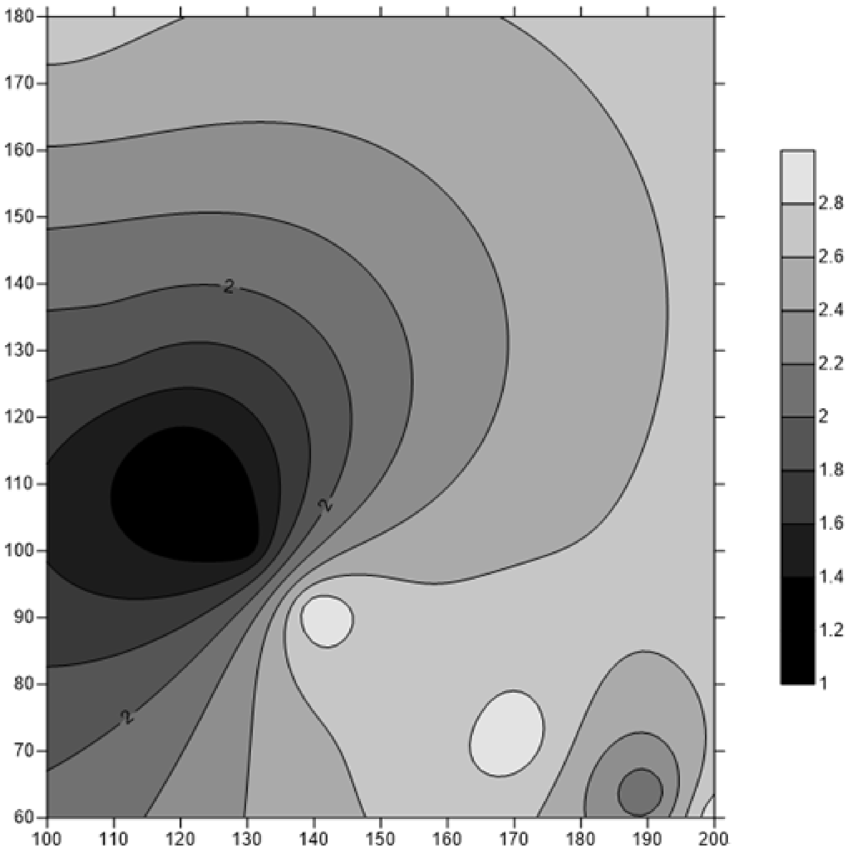

Fig. 2. Value of distance definition error depending on the location of point O on the construction site

Summary

Guaranteed by the manufacturing companies of reference station networks, accuracy of defining coordinates in RTN mode by using the antenna for GNSS equipment installation equals 2-5 cm, which is enough for marking the main axes of buildings and red building lines according to the sites of geodesic base and makes it possible to refuse from building the classic construction netting.

When using the stillages for GNSS antenna centering, the basis length, obtained from these measurements, allows to reliably control the accuracy of station coordinates, on which, during the detailed planning works, the electronic total station is installed during the land planning.

REFERENCES

Burak K. O. *Tekhnologhija rozplanuvaljnykh robit i vykonavchykh znimanj z vykorystannjam TPS*. Geodesy, Cartography and Aerial Photography. 2011, no. 75, pp. 53–57.

Burak K. O., Lysko B. O. Exploring the accuracy of lengths constructions when solving the engineering geodesy issues with RTN method. Geodesy, Cartography and Aerial Photography. 2017, no. 85, pp. 5–12.

Burak K. O, Lysko B. O. *Rezuljtaty doslidzhennja tochnosti RTN metodu GNSS vymiriv jedynym (vykhidnym) bazovym rishennjam ta mozhlyvosti jogho vykorystannja dlja rozmichuvaljnykh robit pry budivnyctvi. Naukovyj visnyk NLTU Ukrajiny*. 2017, no. 27, pp. 145–150.

DBN V.1.3-2-2010. *Systema zabezpechennja tochnosti gheometrychnykh parametriv u budivnyctvi. Gheodezychni roboty u budivnyctvi.*

DBN A.2.1-1-2014. *Inzhenerni vyshukuvannja dlja budivnyctva*

Lanjo O., Savchuk S. *Doslidzhennja tochnosti RTN-vymirjuvanj u merezhi* UA-EUPOST / ZAKPOS. *Visnyk gheodeziji i kartoghrafiji*. 2012, no. 4.

Mullenix D., Fulton J, Brooke A. RTK Networks: Single Baseline and Network Solution Options. TIMELY INFORMATION Agriculture, Natural Resources & Forestry. 2011, pp. 1–2.

Parkinson B. W., Spilker J. J. Global Positioning System: Theory and Applications. Washington, 2006, 798 p. (American Institute of Aeronautics and Astronautics).

Savchuk S., Zademlenjuk A., Piskorovsjkyj A. *Eksperymentaljni doslidzhennja tochnosti* *vyznachennja koordynat metodom RTN z vykorystannjam GPRS Internet z'jednannja. Suchasni dosjaghnennja gheodezychnoji nauky ta vyrobnyctva* [Modern achievements in geodetic science and industry]. 2009, issue 1 (17).

Shuljc R. V., Medvedsjkyj Ju. V. *Rozrobka i doslidzhennja metodyky stvorennja gheodezychnoji osnovy na montazhnomu ghoryzonti pry vysotnomu budivnyctvi. Mistobuduvannja ta terytorialjne planuvannja: nauk.-tekhn. Zbirnyk.* Kyiv: *KNUBA*, 2009, no. 34, pp. 539–542.

Tereshhuk O., I. Nystorjak O. *Analiz GNSS-sposterezhenj u Pivnichnomu reghioni Ukrajiny. Mistobuduvannja i terytorialjne planuvannja.* 2013, no. 48.

Trevoho I., Kupko V., Neezhmakov P., Olejnyk A., ta inshi *Gheodezyja y metrologhyja boljshykh dlyn y korotkykh vektorov. эksperymentы y эtalonы.* Suchasni dosjaghnennja gheodezychnoji nauky ta vyrobnyctva: nauk.-tekhn. zbirnyk *NU "Ljvivsjka politekhnika"* [Modern achievements in geodetic science and industry]. 2016, issue II (32), pp. 55–562.

К. БУРАК[1], Б. ЛИСКО[2]

[1] Кафедра геодезії, Івано-Франківський національний технічний університет нафти і газу, вул. Карпатська, 15, Івано-Франківськ, Україна, 76019, ел. пошта: burak4111945@gmail.com

[2] Кафедра геодезії, Івано-Франківський національний технічний університет нафти і газу, вул. Карпатська, 15, Івано-Франківськ, Україна, 76019, ел. пошта: 93lisko@gmail.com

МОЖЛИВОСТІ ВИКОРИСТАННЯ RTN-РІШЕНЬ ДЛЯ РОЗМІЧУВАЛЬНИХ РОБІТ НА БУДІВНИЦТВІ

Мета даного дослідження. Розроблення практичних рекомендацій для винесення головних осей будівель (осей симетрії) з використання RTN методики GNSS-вимірів та забезпечення додаткового контролю розмічувальних робіт з використанням електронного тахеометра. **Методика.** Для дослідження точності пропонованих рішень виконані дослідження, в тому числі і експериментальні в умовах будівельного майданчика, з розмічування осей від двох базових ліній, попередньо винесених GNSS-приймачем так, щоб вони збігалися з осями ***x*** і ***y*** генерального плану об'єкта. **Наукова новизна та практична значущість.** В роботі пропонується замість суцільної будівельної сітки виносити відразу головні осі будівель, а від них безпосередньо, за допомогою електронного тахеометра, розвивати розмічувальні мережі споруди. Метод дає можливість відмовитись від побудови класичної будівельної сітки, замінивши опорну геодезичну мережу двома базовими лініями (мінімум 4 опорні точки), які закріпляють положення осей координат генерального плану та додатково контролювати розмічування осей електронним тахеометром способом від базової лінії, використовуючи для контролю значення віддалей між точками базових ліній, виміряне методом RTN.

Ключові слова: GNSS; TPS; RTN-вимір; розпланувальні роботи; електронний тахеометр.

Received 07.03.2018