Research on anthropogenic influence on satellite positioning accuracy

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Abstract. This paper presents the results of research into the accuracy of satellite-based positioning methods in the vicinity of operating industrial and energy facilities. Modern dual-frequency multi-system satellite receivers allow for high accuracy and productivity in compliance with the basic principles of work related to ensuring the criterion of unity of measurements and the mandatory implementation of the rules of localisation of the object and the receiver(s), as well as the study of geometric and temporal factors of satellite passage, with their subsequent application to perform quality measurements. This technique is widely and effectively used on large area and linear objects by qualified specialists in the field of geodesy. The accuracy of determinations is guaranteed by the openness of the sky and the absence of all kinds of man-made factors that potentially interfere with the reception of radio signals. This paper does not consider the extreme operation of receivers in areas of special signal suppression. It is of great interest to research the accuracy of satellite positioning methods in the vicinity of operating industrial and energy objects.

1 Introduction

The fields of application of satellite radionavigation systems are currently very expanded, not only in the spheres of human activity, but also in the study of the shape and physical processes of the Earth. However, a number of factors affecting the accuracy of satellite positioning remain poorly understood.

2 Goal, tasks, methods of study

To research the degree of anthropogenic influence on the accuracy of satellite positioning, a number of measurements were made using satellite equipment in Taganrog, both in areas with the highest probability of technogenic interference and in areas with minimal presence of technogenic interference. To conduct the experiment, a mobile receiver, the Rover, was used with a universal multi-frequency GNSS receiver, Trimble R8s (Fig. 1). This device is susceptible to anthropogenic factors. Its key technical features are multipath suppression and carrier frequency phase measurement with a low noise level [1].

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Fig. 1. Trimble R8s Universal Multi-Frequency GNSS Receiver.

The Leica GR10 satellite receiver was used as a stationary receiver, "Base Station" (Fig. 2), which was specially designed for use at base stations. The reference stations based on this receiver are multifunctional and reliable, provide high accuracy, and are easy to install and operate. The choice of specific equipment is related to the availability of equipment in the organization where the experiment was conducted.

Fig. 2. Leica GR10 stationary receiver.

For the first experimental survey of the existing points of the plan-altitude network on the territory of Beriev Taganrog Aviation Scientific Technical Complex preference was given to the kinematic method, because on the basis of the received data processing from the receiver will be seen the nature of the impact of radio-electronic equipment of the airport, without significant time costs when using the survey in the "Static" mode. Moreover, the character of impact should be visible in both methods of surveying with non-principled difference for testing the increase of positioning accuracy in the static method.

The results obtained on the airport territory after data processing are given in Table 1. The table shows actual measurement errors, i.e., deviations in plan (mP) and height (mH) for each point and RMS from post-processing.

Table 1. Accuracy of surveying on the territory of the Beriev Taganrog Aviation Scientific Technical Complex.

Surveying	from	to	Solution type	(m_P) (M)	(m_H) (M)	standard deviation (M)	Height (M)
TAGN --- Berievo01	TAGN	Berievo01	Fixed	0.022	0.04	0.009	31.91
TAGN --- Berievo02	TAGN	Berievo02	Fixed	0.019	0.03	0.0085	27.75
TAGN --- Berievo03	TAGN	Berievo03	Fixed	0.021	0.03	0.0045	28.88
TAGN --- Berievo04	TAGN	Berievo04	Fixed	0.023	0.031	0.004	25.25
TAGN --- Berievo05	TAGN	Berievo05	Fixed	0.017	0.028	0.0055	28.43
TAGN --- Berievo06	TAGN	Berievo06	Fixed	0.014	0.028	0.007	16.44
TAGN --- Berievo07	TAGN	Berievo07	Fixed	0.02	0.036	0.008	17.03
TAGN --- Berievo08	TAGN	Berievo08	Fixed	0.019	0.032	0.0065	17.86
TAGN --- Berievo09	TAGN	Berievo09	Fixed	0.008	0.021	0.0065	16.51
TAGN --- Berievo10	TAGN	Berievo10	Fixed	0.009	0.02	0.0035	16.48

The following experimental determinations were carried out on the territory of Taganrog Metallurgical Plant. The peculiarity of most electrothermal plants is high input power, around which very strong magnetic fields are formed. The survey was also made in the "Kinematics" mode. The results obtained after data processing are given in Table 2. The point No.6, which was filmed near the high structure of the workshop, stands out from a rather flat series of indicators. The PDOP value in this case amounted to 3 units, which together with partial overlapping of the celestial sphere gave a predictable result.

The next experimental survey was carried out in the territory of the electrical substation of the 220/110/10 kV substation. The results obtained after data processing are presented in Table 3.

The final experimental survey was carried out on the territory of the microdistrict "Andreevsky", the territory of which is located in the north-eastern part of the city, where there are no potential sources of anthropogenic impact [2-4]. The results obtained after processing the data from the equipment are presented in Table 4.

Table 2. Measurement accuracy at TAGMET site.

Surveying	from	to	Solution type	(mP) (M)	(mH) (M)	standard deviation (M)	Height (M)
TAGN --- Tagmet01	TAGN	Tagmet01	Fixed	0.015	0.03	0.0075	16.40
TAGN --- Tagmet02	TAGN	Tagmet02	Fixed	0.017	0.028	0.0055	16.86
TAGN --- Tagmet03	TAGN	Tagmet03	Fixed	0.011	0.017	0.004	13.76
TAGN --- Tagmet04	TAGN	Tagmet04	Fixed	0.020	0.031	0.0055	13.53
TAGN --- Tagmet05	TAGN	Tagmet05	Fixed	0.018	0.03	0.006	9.73
TAGN --- Tagmet06	TAGN	Tagmet06	Fixed	0.028	0.045	0.004	13.70
TAGN --- Tagmet07	TAGN	Tagmet07	Fixed	0.016	0.028	0.006	12.58
TAGN --- Tagmet08	TAGN	Tagmet08	Fixed	0.014	0.022	0.004	12.54
TAGN --- Tagmet09	TAGN	Tagmet09	Fixed	0.008	0.017	0.0045	17.28
TAGN --- Tagmet10	TAGN	Tagmet10	Fixed	0.009	0.02	0.0055	14.02

Table 3. Accuracy of measurements on the territory of the electrical substation.

Surveying	from	to	Solution type	(m_P) (M)	(m_H) (M)	standard deviation (M)	Height (M)
TAGN --- PS01	TAGN	PS01	Fixed	0.027	0.038	0.0075	3.29
TAGN --- PS02	TAGN	PS02	Fixed	0.028	0.042	0.0075	2.61
TAGN --- PS03	TAGN	PS03	Fixed	0.02	0.042	0.0095	2.16
TAGN --- PS04	TAGN	PS04	Fixed	0.021	0.041	0.0085	5.60
TAGN --- PS05	TAGN	PS05	Fixed	0.019	0.032	0.0065	3.10
TAGN --- PS06	TAGN	PS06	Fixed	0.022	0.04	0.009	5.18
TAGN --- PS07	TAGN	PS07	Fixed	0.023	0.039	0.005	3.20
TAGN --- PS08	TAGN	PS08	Fixed	0.014	0.03	0.008	3.49
TAGN --- PS09	TAGN	PS09	Fixed	0.017	0.032	0.006	2.69
TAGN --- PS10	TAGN	PS10	Fixed	0.019	0.03	0.002	0.96

Analyzing the results presented in the tables, we can say that in all cases the actual error of coordination is 2-3 times higher than the calculated value of RMS of determinations.

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Table 4. Accuracy of measurements on the territory of the "Andreevsky" microdistrict.

Surveying	**from**	**to**	Solution type	(m_P) **(M)**	(m_H) **(M)**	standard deviation (M)	Height (M)
TAGN --- ANDR01	TAGN	ANDR 01	Fixed	0.013	0.021	0.004	41.02
TAGN --- ANDR02	TAGN	ANDR 02	Fixed	0.015	0.029	0.007	41.91
TAGN --- ANDR03	TAGN	ANDR 03	Fixed	0.017	0.023	0.003	41.86
TAGN --- ANDR04	TAGN	ANDR 04	Fixed	0.016	0.032	0.0055	35.57
TAGN --- ANDR05	TAGN	ANDR 05	Fixed	0.015	0.025	0.005	36.09
TAGN --- ANDR06	TAGN	ANDR 06	Fixed	0.017	0.027	0.005	37.73
TAGN --- ANDR07	TAGN	ANDR 07	Fixed	0.019	0.021	0.001	30.33
TAGN --- ANDR08	TAGN	ANDR 08	Fixed	0.019	0.035	0.0075	29.07
TAGN --- ANDR09	TAGN	ANDR 09	Fixed	0.011	0.019	0.0065	32.41
TAGN --- ANDR10	TAGN	ANDR 10	Fixed	0.018	0.035	0.0065	33.57

Based on the resulting calculations, the following summarizes the actual deviation plots for all site dimentions in plan (mP) and elevation (mH) (Fig. 3 and Fig. 4).

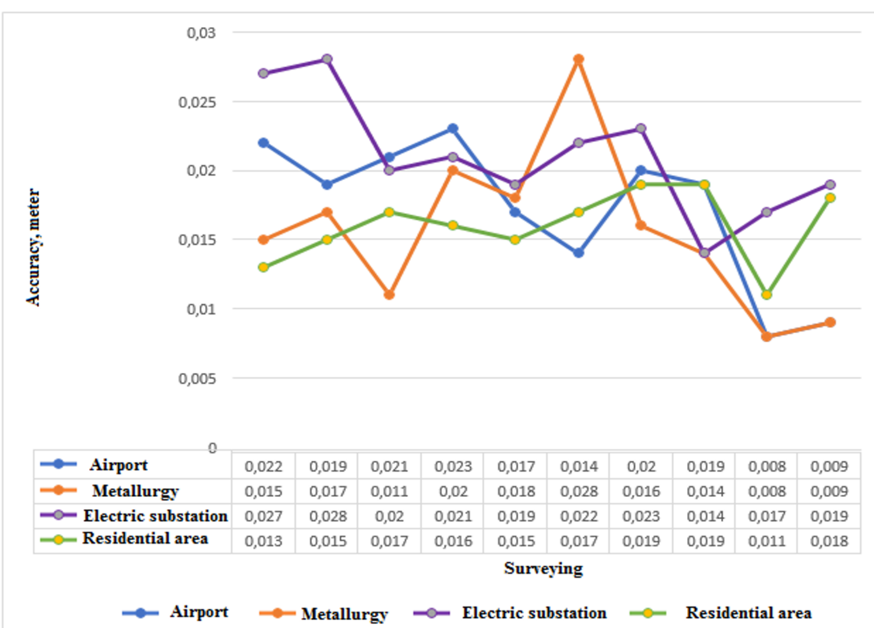

Fig. 3. Actual deviations of points in plan.

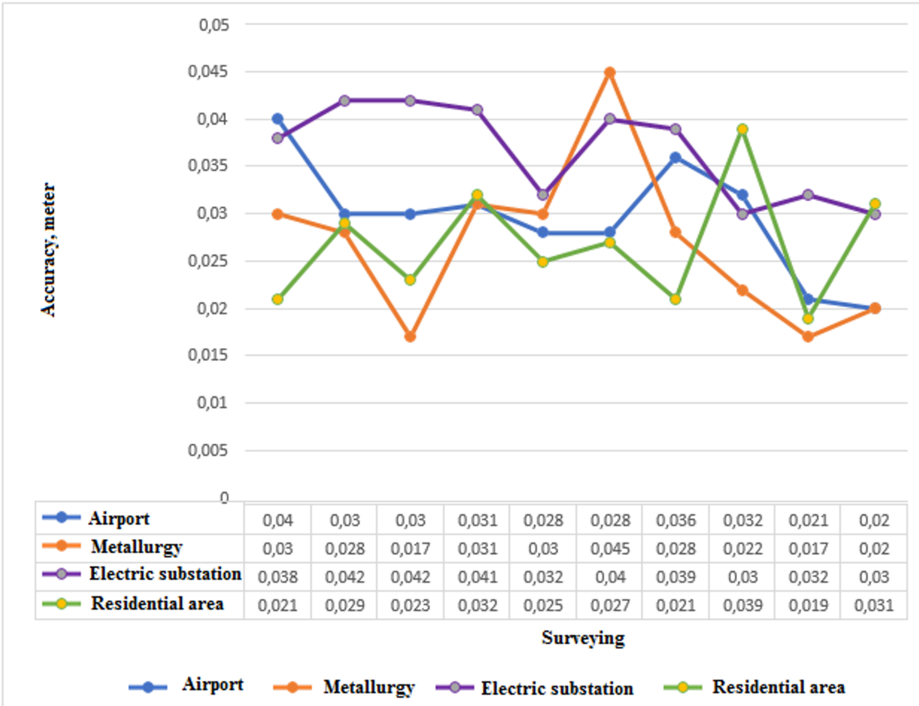

Fig. 4. Actual height deviations of points.

3 Conclusions

The graphs show that the accuracy of measurements at all sites is in an acceptable ratio, as well as it can be seen that some values obtained when surveying the territory of the electrical substation and the airport area not significantly, but exceed the values obtained when surveying other sites, including the control residential area, where the impact of anthropogenic factors was presumably the least. Modern GNSS receivers are equipped with a sufficient degree of protection from electromagnetic and radio interference, and additional consideration in the post-processing of refined ephemeris minimizes the impact of anthropogenic factors on the accuracy of coordinate measurement by satellite method. When working at industrial facilities, more attention should be paid to the openness of the horizon, as based on the data obtained, a large error is introduced by the deterioration of the parameter PDOP. In especially difficult conditions, when working in the immediate vicinity of large workshops, cooling towers, etc., it is desirable to use optical-electronic devices, and satellite determinations should be used only for creation of high-precision plan justification.

Consequently, modern dual-frequency multi-system GNSS devices and their corresponding software can be recommended, while ensuring, in addition to the above, the uniformity of measurements [5], for widespread use in geodetic works of appropriate accuracy at industrial and energy facilities.

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