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Modern methods of metrological control of ground-based multi-positional radar base system using GPS complexes

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Abstract. The paper describes the comparative analysis of modern metrological control methods in the tasks of GPS technology applications for high precision multi-positional multipurpose radiotechnical base system. Due to great amount of modern measurement means employing GPS technologies, the question of metrological control of these means becomes of special significance.
Keywords: radar, GPS-technologies, measurement, metrology

Introduction

In the field of radiolocation, radionavigation, and radioastronomy there appears the task of precision measurements of multi-positional base system. Especially, there is the news for phase and TDOA systems with bases of hundreds of meters to kilometres (Fig. 1) [1].

Traditionally, for high precision linear measurements of base distances, classical geodesic methods are used. As shown in [2], for such measurements, specialized geodesic companies with great experience in conducting such works are involved. It is worth mentioning, that costs of such works are essential, because a classical measurement procedure is very labour capacitive and it demands the use of rather

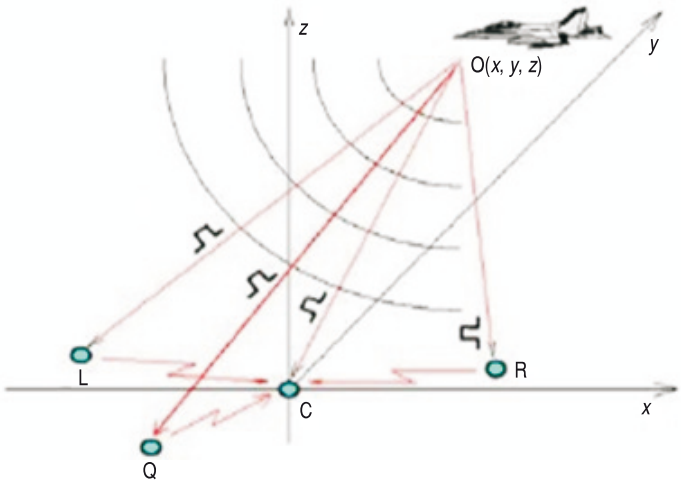

Fig. 1. Small base multi-positional TDOA system configuration (CL,CR, CQ — bases, which are measured using differential GPS-technologies)

expensive and unique geodesic measurement instruments [3]. Rapid development of GPS-technology has extended the spectre of its use for solving the moving and static objects navigation problems. The problem of linear geometrical measurements using GPS-technologies is solved most effectively by differential satellite measurement methods. Advantage of GPS based technology methods is their use in any weather conditions. Considering the fact that modern GPS receivers are widely used in radiotechnical systems for bindings to areas, the complex problem of simultaneous application of GPS technologies for multi-positional system's receiving stations binding to area and base distances between antennas on distant stations measurement and control is very attractive because of decreased exploitation costs [3].

In spite of great variety of publications, dedicated to differential satellite measurement methods, the question of ground receiving complexes of bases using GPS technologies metrology is highlighted too little.

In the work, the comparative analysis of modern metrological control method in the tasks of GPS technology application for high precision of the multi-positional multipurpose radiotechnical base system was proposed.

Metrological control using traditional methods

Metrological control using traditional methods means conduction of additional measurements using traditional means of measurement (light range finder, interference and Ederine devices). For example, metrological control method, that is described in [4], availability of two observation points and metrological-

certified light range finding means of measurement (precision laser range finder). This method allows for making metrological check of ground-based metrical GPS complex which consists of two GPS antennas, two GPS receivers, and a computer with software for differential measurement results processing. The essence of metrological check is this. On every observation point, the antennas of metrological controlled ground-based receiving metrical complex are situated, every of which is connected to its GPS receiver. The measurement results of each GPS receiver are transmitted through the communication lines to computer, in which distances between GPS antennas phase centres are evaluated by differential measurement algorithms automatically. The measurement results are compared with the results of laser range finder results, the error of which, from metrological point of view, has to be three times less than the error predicted to be from metrological controlled ground-based receiving GPS complex.

Metrological control in the key points using exemplary complexes

Another variant of ground-based receiving metrical GPS complex metrology provides existence of geodesic key points with known coordinates and exemplary ground-based receiving metrical GPS complexes [5]. For this purpose, special metrological geodesic polygons with exemplary bases of receiving points are created (Fig. 2) [6].

General look of the phase area of such bases on the geodesic polygon of the National University "Lvivska Politehnika" is shown in Fig. 3 [6].

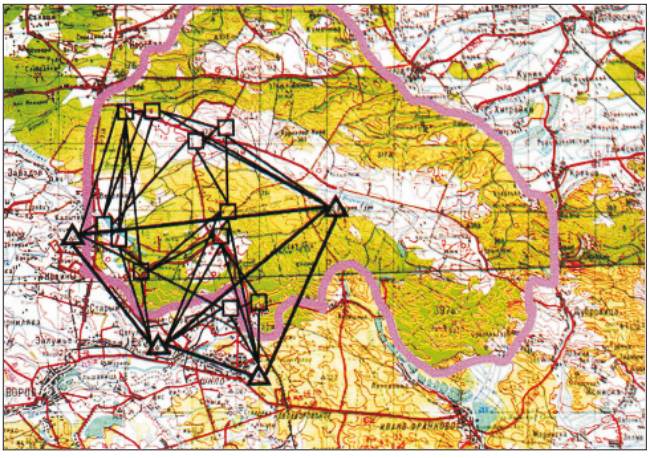

Fig. 2. Scheme of the GPS net of the scientific metrological geodesic polygon

Fig. 3. Phase area of exemplary geodesic bases of the National University "Lvivska Politehnika"

The essence of the metrological control technology in accordance with this method is the following. Calibration and exemplary ground-based receiving metrical GPS complexes are placed on the special piped centres of the geodesic bases in pairs on the minor distances between each other, with known centres of the coordinates. The tops of the centres are equipped with special means for mounting the GPS complexes' antennas.

In accordance with the chosen satellite observation sessions, the differential measurements of the distances between the centres with known metrological geodesic base's coordinates are conducted with the following comparison of the results.

Metrological control using micrometrical device

The method that allows us to conduct metrological control of the ground based receiving metrical GPS complexes in the conditions of the radio technical systems operation is shown in [7]. The essence of this method is the following. Metrological controlled ground-based receiving metrical GPS complex, the receiving stations of which are situated in centres with known coordinates (on the antennas of the multi-positional radio technical systems) conduct a measurements session of the bases between receiving and transmitting stations or the radars of the multi-positional systems. After that, using calibrated device with linear shift in one micrometer in the limits of several decades of centimetres of the linear scale, the fixed shift of the antenna block of the GPS complex is conducted on one position of the multi-positional system. After that, differential measurements are repeated. On the results of the GPS complex antenna shift data comparison, obtained on the scale of the calibrated micrometrical device and difference in bases, measured using GPS complex before and after its antenna shifting, the conclusion about the metrological correspondence of the ground-based receiving metrical GPS complex

are made. As shown in [7], the error of the distances measurement using ground based receiving metrical GPS complex is defined as:

$$\pm\delta = \frac{\Delta}{d}\left(1 \pm \delta_0\right)\delta_0, \tag{1}$$

where: δ — is the relative error of the distance measurement by the ground-based receiving metrical GPS;
Δ — is the absolute error between a base of the measured by ground-based receiving metrical GPS complex and shift value of the GPS antenna difference (value of the linear shift along the scale of the micrometrical device);
d — is the value of the GPS antenna shift (value of the linear shift along the scale of the micrometrical device);
δ_0 — is the rationed relative error of the micrometrical device.

The scheme of the GPS antennas placement is shown in Fig. 4.

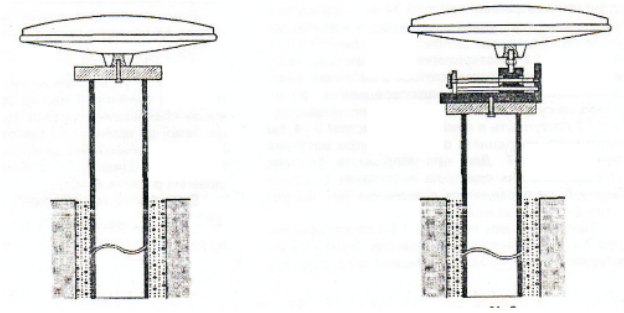

Fig. 4. GPS complex antennas placement on the centres of the geodesic bases without and with the micrometrical device

In Figs. 5 and 6, the photos of the micrometrical device with GPS antenna, which are mounted on the pipe pillar of the geodesic bases and the scale of the micrometrical device linear shift, are shown.

Comparative analysis of the metrological control methods using ground-based receiving metrical GPS complexes for differential radio technical multi-positional base system' measurements

Metrological control of the ground-based receiving metrical GPS complexes using traditional methods in comparison with other methods differ with the complex measurement scheme, demands great time expenses on the measurement session and the use of additional expensive and unique measurement devices. Because of

Fig. 5. Photo of the micrometrical device with mounted GPS antenna on it in the process of metrological control of the GPS complex

Fig. 6. Photo of the linear shift scale

the use of metrical devices, there are some restrictions of this method application. Especially, it concerns the ranges of distances and all weather capability. The method of the metrological control in the key points, using exemplary complexes, unlike the previous method is all weather and does not have restrictions on the distances' measurements. But the difficulties, labour and expensiveness are the same. The method of metrological control, using micrometrical device against other methods is simpler and all weather one. The errors of the micrometrical device are one micrometer, what allows for conducting metrological control of the ground-based receiving metrical GPS complexes, which have distance measurement error in the limits of several cents of millimetres to millimetres.

Conclusions

1. GPS technologies are widely spread in the fields of positioning and base's measurements of the radio technical systems and complexes. Due to great amount of the modern measurement means, that use GPS technologies, the question of metrological control of these means becomes of a special significance.

2. Metrological control of the ground-based receiving metrical GPS complexes is used for radiolocation and radionavigation. It means the use of complicated technologically and labour-consuming process that requests availability of metrological geodesic polygons as well as precise and expensive instruments.
3. From the point of view of the labour reduction for metrological inspection, the advantage over other methods has the method based on the use of the micrometrical device. The feature of the method is that in some cases it can be used in the places of the radio technical systems operation. In this case, only micrometrical device has to pass the metrological inspection.

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Nowoczesne metody pomiaru pozycji naziemnych systemów radarowych z wykorzystaniem technologii GPS

Streszczenie. W artykule przedstawiono analizę metod precyzyjnego pomiaru pozycji sytemu bazowego z zastosowaniem technologii GPS. Metody te w szczególności są stosowane do pomiaru pozycji systemów radioelektronicznych.

Słowa kluczowe: radiolokacja, radionawigacja, zastosowanie technologii GPS