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Monitoring of the space system

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A B S T R A C T

We have performed monitoring of the space system that includes the Earth, the Moon, the Sun, and the GPS satellite group. We have discovered semi-diurnal and diurnal periodicities in the number of satellites detected as well as in the altitude, latitude and longitude by a GPS receiver. We have revealed tidal deformations related to changes in the Earth's orientation with respect to the Moon and the Sun.

1. Introduction

Information on the state of a space system can be presented in the form of time series. A time series is a sequence of measured values of a physical quantity locked to real time. In the form of time series, one can present the on-board satellite telemetry as well as any information on a space object. The time series can be equidistant and non-equidistant. In the latter, the measured quantities are separated by arbitrary time intervals, which prevent their spectral analysis.

In most of GPS receivers, the object coordinates and velocities are updated once a second. In the absence of faults, the series are equidistant, i.e., the measured quantities are separated by equal time intervals.

The quality of spacecraft tracking by a ground-based complex depends on the precision of determining the satellite coordinates and velocity. The solution of the positioning problem depends above all on the results of satellite coordinate and velocity measurements. Therefore information on the paths of separate satellites and groups of satellites is determined by the operation quality of the GPS satellite group, which is in turn a constituent part of the Earth–Moon–Sun space system.

Ref. [1] describes the determination of the precise distance between two satellites from GPS data aimed at studying the Earth's gravitational field. Ref. [2] solves the problem of studying the structure formations of the space plasma and their positioning with necessary precision using the GPS. Refs. [3,4] consider the probabilities of threats from collisions of positioning system satellites with the continually growing space waste from exhausted spacecrafts and last stages of carrier rockets. Ref. [5] considers the perspective of flying around the Moon with the aid of positioning data from the GPS group. Ref. [6] suggests an application of GPS positioning for monitoring the mutual positions of two satellites in a high elliptic orbit. Ref. [7] shows how wave phenomena in the upper atmosphere are detected by the network of ground-based GPS receivers. Ref. [8] presents the radio eclipse method of monitoring sporadic formations in the ionosphere by signal phase and amplitude changes on the GPS – LEO

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CHAMP track. In Ref. [9], the radio eclipse method using GPS signal is realized on the basis of a group of six satellites with an orbit inclination of 72° and an altitude of 800 km. The perspective of further development of the elaborated methodology is predicted on the basis of an improved satellite group.

Thus the GPS group can be considered as a part of quite various space systems. As such, it not only solves positioning problems but also provides many other kinds of research in a space system chosen. This is related to the fact that the properties of the space and circumterrestrial medium are reflected in the GPS signal characteristics [8,9]. In addition, the positioning data also carry information on the processes in the space system.

The present paper is devoted to studying periodic processes occurring in the Earth–Moon–Sun–GPS group space system.

In many modern experiments, the results of measurements of various physical quantities are presented in the form of numerical series locked to real time. Since analog records of processes have been almost completely replaced by digital ones, their further computer processing is greatly simplified. Also, there appears the opportunity of using specific mathematical tools. Among them we can mention spectral analysis with the Fourier transformation and the method of ordinate averaging over a test period.

In real experiments, it is hard to obtain series with strict data ordering (equidistant series). However, if measurements are carried out routinely, without long time gaps, the series do not substantially differ from equidistant ones. In this case it is possible to perform an analysis with the standard Fourier transformation using approximations and interpolation. However, if the results are fixed in irregular time intervals and contain large time gaps, the standard Fourier transformation is inapplicable. Therefore, in order to study non-equidistant time series, a special software was worked out, using the method of ordinate averaging over a test period [10].

2. Experimental set and data acquisition

For a period of 20th May 2013–4th October 2013, there have been stored 11,806,000 protocol lines corresponding to measurements of four parameters. The measurements have been of strict equidistant nature. It has been possible to provide such a result after the GPS Receiver GlobalSat MR-350s4, based on the SiRFstarIII chipset, was firmly fixed on the roof of a four-storey building at a height of 21 m above the ground. Its connection to the laptop Acer Aspire AS5720G-102G16Mi was provided via a USB port and a standard cable with an adapter produced by GlobalSat. A reliable laptop power supply from the power network was provided using the Back-UPS APC Smart-UPS 1500 VA. A special software was developed for the detection of the necessary parameters and their presentation as columns.

Thus a large size of information was stored, and there appeared serious difficulties in its processing. We had to reduce the data size by a factor of 1000. So we carried out either simple resampling down or averaging over 1000 adjacent measurements. The second method is more preferable since it improves the signal-to-noise ratio.

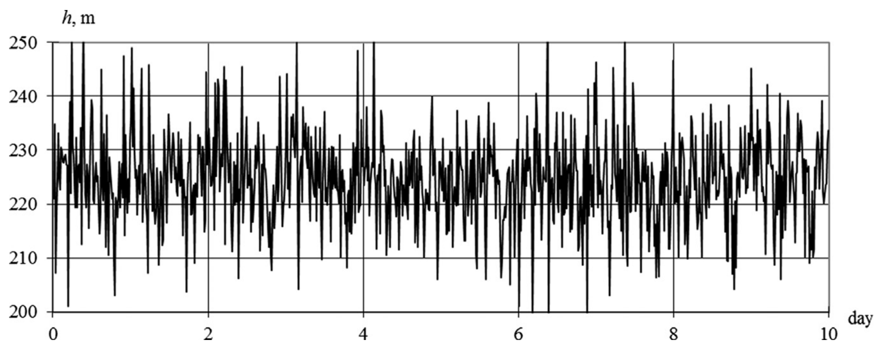

Fig. 1. Results of measuring the altitude h for ten days.

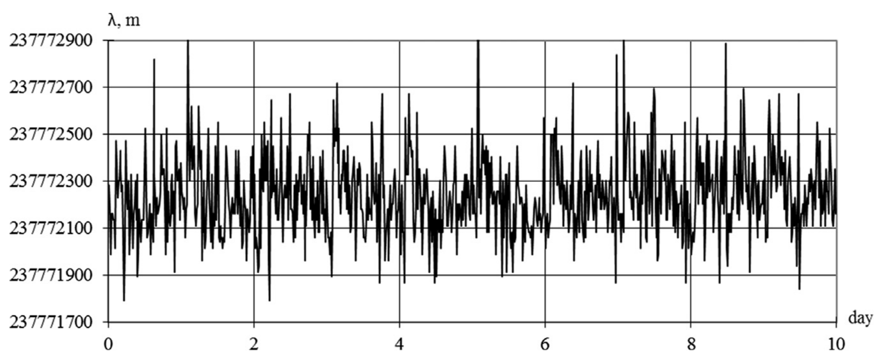

Fig. 2. Results of measuring the longitude λ for ten days.