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Stochastic Estimation of Ephemerides of Navigation Satellites in Perturbed Orbits[1]

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Abstract—The errors of navigation satellite ephemerides are one of the key factors to determine the accuracy of satellite navigation. To improve the accuracy of ephemerides calculation, modern satellites are equipped with inter-satellite measurement equipment. However, random interference is inevitably present in the data transmission path and it is necessary to minimize its effect. To perform this task, it is proposed to use the stochastic estimation of ephemerides of navigation satellites that are moving along disturbed orbits in the form of a procedure of parametric optimization based on the minimization of the additive set of two functionals. The optimization of the first functional provides the minimum of uncertainty in the estimation of ephemerides. The optimization of the second functional provides the minimum of the norm of the vector of orbital parameters variations in the current time interval. To illustrate the effectiveness of the proposed approach, a numerical simulation of the satellite constellation's ephemerides estimation was carried out for the corresponding trajectory perturbations. The simulation results illustrate the possibility to determine the ephemerides of navigation satellites with the accuracy within units of meters based on the approach considered that uses the noisy inter-satellite measurements.

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INTRODUCTION

The errors of determining current ephemerides of navigation satellites play one of the main roles when determining the accuracy of satellite navigation. The influence can be significant even at small time intervals [1–3]. For example, due to the influence of the gravity of the Moon and the Sun, as well as the second zonal harmonic, the total error can grow up to 300–400 m within an hour.

To reduce these errors in GLONASS and GPS navigation systems, hardware-software upgrades are being implemented based on the installation of measurement equipment on board of the satellite [4]. For example, GLONASS-M satellites are equipped with on-board inter-satellite measurement equipment [5, 6], GLONASS-K satellites are equipped with devices for receiving and forming of inter-satellite radio links [6–8], etc. In general, the use of inter-satellite measurements that allow determining the distances between satellites with centimeter accuracy is one of the most promising directions for the development of satellite navigation to improve the accuracy of determining the orbital parameters of the satellite constellation [9–13].

STATING THE PROBLEM

Despite the high accuracy of inter-satellite measurements, they do not allow to determine the position of the satellite with the required accuracy without additional processing due to unavoidable stochastic interference in the reception/transmission path of the navigation measurements. Earlier in [14] it was shown that

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