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Analysis of Dependence of Spacecraft Movement Parameters Determination Precision on Sighting Angles in a Multipositional Monitoring System

S. V. Kovbasyuk and L. B. Kanevskyy

Zhytomyr Military Institute of National Aviation University, Zhytomyr, Ukraine

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Abstract—Dependence of precision of estimating spacecraft's movement parameters on angles of sighting in a multipositional monitoring system is analyzed. Calculation results obtained by simulation modeling confirm the possibility of using knowledge on target's sighting angles range to achieve the best possible precision of spacecraft's movement parameters determination when surveying the located object.

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Intensive development of the space industry which has been observed during the last decades lead to a significant increase in the number of artificial space objects (SO) in the near-Earth space, which include active and defunct spacecrafts as well as a significant number of launch and accident fragments, the so-called space debris. Under these conditions solving the problems of providing targeted application of spacecrafts, secure launch of new and operation of existing spacecrafts considering security and defense interests it is reasonable to maintain a catalog of SO.

The difficulty of maintaining such a catalog is due to resolving a contradiction of obtaining high-precision prompt and reliable ballistics-navigation data. For example, in order to reliably forecast for future collisions of existing spacecrafts with other SO it is necessary to provide estimation and forecasting of distances between the space objects with precision comparable to their dimensions [1].

It is difficult to satisfy such precision requirements in real-time (based on one or two consecutive revolutions) using autonomous Earth measuring stations (MS). One approach that allows improving precision of the estimated space object movement parameters consists in using multiposition systems (MPS), by which we mean a set of n autonomous MS with joint data processing [2–4].

Improvement of precision of estimating movement parameters in this case depends in the number of MS, their tactical and technical characteristics, methods of processing and combining data from several MS of MPS, time of SO's presence in the monitored space, as well as relative placement of MS and observation target, i.e. the geometric factor [4, 5]. The dependence of influence of MS number, characteristics and the value of base on the resulting precision of estimating SO's movement parameters are well-studied [6–9] and prove efficiency of MPS. However the influence of the geometric factor meaning observation target's sighting angles in azimuth and elevation planes requires additional analysis.

This paper aims to study the influence of relative placement of SO and autonomous MS as part of MPS on precision of estimating SO movement parameters.

PROBLEM DEFINITION

Autonomous observation of a space point where a space object may appear at a particular time instant by each MS of MPS, for example, in local radar coordinate system of first MS, will depend on three angles: α, β_1, β_2 (Fig. 1a), where α denotes angle between projections of target observation direction of two MS, and $\beta_{1,2}$ stand for target elevation angles. Another geometry of the same problem, namely a different geographical placement of MS in MPS and relative MS and SO placement is depicted in Fig. 1b. Ellipses in the figures denote error regions when estimating observation target's coordinates by each MS. Obviously, problem's geometry has strong influence on the estimated SO movement parameters during joint processing. By sighting angles that determine observation target direction in MPS we mean elevation angles of each MS and angle α, which denotes the difference of azimuth directions to SO.