INCREASING THE ACCURACY OF ORBIT FORECASTING ON THE BASIS OF IMPROVEMENT OF STATISTICAL METHODS FOR PROCESSING MEASUREMENTS

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ABSTRACT.

An adaptive technique of orbital elements determination taking into account statistical characteristics of disregarded disturbances was developed to overcome the limitations of the traditional approach. This technique, called "Optimum Filtration of Measurements (OFM)", has some common features with the Least Square Technique and the Kalman filter. Special corrections are added to the results of integration of the equations of motion. The experience of application of this technique demonstrated the possibility of increasing the accuracy of estimation and prediction of satellite orbits. This paper presents the review of investigation results obtained recently on the basis of applying the OFM technique, namely:

- Development of the algorithm and software for filtering the measurements with using the considered technique;
- The technique efficiency evaluation from the results of processing the modeled and real information.

1. INTRODUCTION

The development of the techniques of orbital parameters determination from measurements began some hundreds years back. It is associated with names of Kepler (beginning of 17-th century), Gauss and Legendre (beginning of 19-th century), Fisher (beginning of 20-th century) and some other scientists. They developed the least-square technique (LST) and the maximum likelihood technique (MLT), which remain as a basis of modern algorithms of estimation and prediction of orbits [1, 2].

The intensive space exploration began after launching of the first Soviet satellite in 1957. A lot of new applied problems appeared. On this basis, as well as in connection with unique achievements in computer technology, the new era began in the development of orbit estimation and prediction techniques. The most essential methodological achievements consist in *accounting for random disturbances in the satellite motion model on the basis of applying the Kalman filter (KF) [3], as well as in developing the technique of successive processing of measurements [4]*. A lot of publications were devoted to these issues, such as work [5], monographs by V. Mudrov [6] and P. Elyasberg [7]. The most complete review of modern orbit estimation and prediction techniques was given in D. Vallado's monograph [8].

We shall consider the problem of orbit estimation and prediction from measurements in the simplified (linear) formulation. In the majority of cases the solution of nonlinear problems is reduced just to this formulation.

The time variation of satellite's state vector (x) occurs according to the differential equation

$$\frac{dx}{dt} = A(t)\cdot x + B(t)\cdot q(t). \qquad (1)$$

Here A and B are known matrixes, q is the Gaussian random process with known statistical characteristics:

$$E[q(t)]_0 = 0, \quad E\left[q(t)\cdot q^T(\tau)\right]_0 = K_q(t,\tau)_0. \quad (2)$$

The measurements, carried out at various time instants (t_i), are the known linear function of the state vector

$$z_i = h_i \cdot x(t_i) + v_i,\ i=1, \ldots, k, \qquad (3)$$

and contain random errors v_i distributed according to the normal law with specified statistical characteristics

$$E[v_i]_0 = 0, \quad E\left[v_i \cdot v_j^T\right]_0 = R_{ij}, \quad E\left[v_i \cdot q(t)^T\right]_0 = 0. \quad (4)$$

It is required to determine the state vector estimate $\hat{x}(t)$ with the minimum variance at any time instant $t \geq t_k$.

Table 1. Techniques of solution of the considered problem under various conditions

Problem solution techniques	Modifications of statistical characteristics			
	Noise q is absent		Noise q is present	
	$R_i \cdot \delta_{ij}$	R_{ij}	$K_q \cdot \delta(t-\tau)$	$K_q(t,\tau)_0$
Joint	LST	MLT	**Optimum filtration of measurements**	
Successive	Recurrent LST	-	KF	KF modifications

Various techniques are applied for solving the considered problem. They differ in these or those simplifications (modifications) of statistical characteristics Eq. 2 and Eq. 4, as well as in application of grouped (joint) or successive processing of measurements. Tab. 1 presents the solution techniques corresponding to various modifications of problem formulation.