Features Of Geostationary Satellite Navigation By Time Difference Of Arrival Method

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Abstract – **Features of the geostationary satellite navigation (definition of coordinates and velocities) by multiposition radio passive systems with the use of the time difference of arrival method have been considered. It is shown that in this case the most expedient way of solving the system of nonlinear equations for definition of coordinates of the satellite is linearization of the system with the successive iterative approximation to a preset criterion of accuracy. The full satellite state vector is formed by the extended Kalman filter.**

Keywords **– geostationary satellite, time difference of arrival method, state vector.**

I. INTRODUCTION

Effective navigation of "foe" GEOS (Geostationary Earth Orbit Satellite) by passive multiposition systems, which provide reception and concurrent processing of onboard transmitter radio signals, is possible by using, in particular, the TDOA (Time Difference Of Arrival) method [1], [2], [3]. Search of an optimum analytical technique for definition of GEOS coordinates, by using the TDOA method depending on the features of the monitoring object trajectory is an actual problem.

II. MAIN PART

As a result of the action of perturbing forces, the GEOS carries out the so-called drift precession in all directions around its nominal position [4]. Therefore all the components of the state vector become functions of time. To prevent the satellite from going beyond the allocated zone, its coordinates should be estimated and predicted with the required accuracy. Considering the fact that with the present technology of using the geostationary orbit the radius of the imaginary sphere, within which the GEOS can drift, should be not more than 5 km, it may be assumed that the vector of the initial GEOS state for a nominal trajectory is a sufficiently accurate a priori value in solving of the system of nonlinear equations both in using the linearization method and iteration approximation and in Kalman filtering.

The radio system for definition of the GEOS coordinates can be constructed by the VLBI (Very Long Base Interferometer) principle based on the use of multiposition interferometers with long bases (distance between receiving stations) and with the number of measuring stations not less than four.

Mathematical modelling is executed for a variant of the construction of the passive radio system by the VLBI principle. In such systems, for definition of delay differences, there should be created a scale for fixing the measurements to common time. Such a scale can be realized with the use of the GPS time synchronization receivers with a root-mean-square error of fixing the time of radio signal reception not more than $3 \cdot 10^{-9}$ s.

III. CONCLUSION

From the results of the mathematical modelling of the described algorithm for definition of the GEOS coordinates in the Matlab environment, the following conclusions may be made:

1. In placing (with a tolerance of ± 600 km) the system receiving stations at the vertices of a square with a length of the side 2000 km, the root-mean-square error of the GEOS coordinates located on the geostationary orbit part visible from all receiving stations, in the navigation polar system of coordinates with a synchronous change of the receiving station latitude from equator (latitude = 0 deg) up to the north pole (latitude = 90 deg) is:

- slant range (R)	from 4000 m	(at the equator)
	up to 1500 m	(at the pole);
- azimuth angle (β)	from $2 \cdot 10^{-4}$ deg	(at the equator)
	up to $0{,}5 \cdot 10^{-4}$ deg	(at the pole);
- elevation angle (ε)	from $5 \cdot 10^{-4}$ deg	(at the equator)
	up to $1{,}5 \cdot 10^{-4}$ deg	(at the pole).

2. The root-mean-square error in measurement of the coordinates of the positions of the phase centers of the receiving station antennae should be not more than 1 m. Otherwise, this error begins to bring the dominating contribution to the errors in measurement of the GEOS coordinates in comparison with the error in measurement of time differences of radio signal arrival which, as it has been mentioned above, is defined, as a rule, by the error of fixing to the common timing system.

3. Root-mean-square errors of the estimation of the GEOS state vector by the Kalman filter are:

$$\delta R \le 100 \text{ m}; \quad \delta\varepsilon \le 1 \cdot 10^{-4} \text{ deg}; \quad \delta\beta \le 1 \cdot 10^{-4} \text{ deg};$$

$$\delta\dot{R} \le 0{,}5 \text{ m/s}; \; \delta\dot{\varepsilon} \le 1 \cdot 10^{-5} \text{ deg/s}; \; \delta\dot{\beta} \le 1 \cdot 10^{-5} \text{ deg/s}.$$

The filter transient time not more than 5 minutes.

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