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DEVELOPMENT OF A COMPLEX ACTIVITIES FOR INCREASING PERSPECTIVE NAVIGATION SPACECRAFT AUTONOMY

Mater's Programme Spacecraft system design

The abstract of the Master's Thesis

Krasnoyarsk 2014

The thesis work is done at the "Applied physics and space technology" department of Federal State Autonomous Educational Institution of Higher Professional Education «Siberian Federal University».

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INTRODUCTION

Aim: Development of a complex activities for increasing perspective navigation spacecraft autonomy with retention of accuracy characteristics level.

Object: Factors which effect navigation spacecraft autonomy.

Subject: Methods for increasing navigation spacecraft autonomy with retention of accuracy characteristics level.

Hypothesis: Analysis and taking into account accuracy factor values transmitted in navigation message in navigation task solutions make it possible retention of accuracy characteristics levelwithout connection with ground complex during longer period.

Actuality and novelty information: Accuracy characteristics increasing of global navigation satellite system GLONASS is one of tasks of federal target program "Maintenance, development and operation of GLONASS system during the period 2012 – 2020". Now in current version of Interface Control Document for GLONASS system the information about algorithms of usage accuracy factor values is not available.

Venue of dissertation implementation: JSC "M.F. Reshetnev "Information Satellite Systems".

International internship place: ThalesAleniaSpace, Toulouse, France.

CONTENT OF WORK

Nowadays, global navigation satellite systems are crucial for navigation service domain for different user types (ground, air, marine), both on the territory of our country and worldwide. One of the main part of a global navigation system is navigation spacecraft (NSC). The efficiency of whole navigation satellite system and readiness and service quality for users considerably depend on of NSC.

Reliable operation of NSC depends on reliability of each on-board systems, operation of ground control complex, especially on timely load of ephemeris data to NSC and competent on orbit spacecraft control.

A need of frequent updated ephemeris data load to NSC makes global navigation satellite system dependent on operation of ground control complex. To decrease such dependence and increase autonomy of NSC and the whole system it is necessary to decrease the number of communication sessions. However, one of the main characteristic for global navigation satellite system is the accuracy level of user positioning.

To achieve better results navigation messages transmitted by NSC contain the parameters which allow estimate accuracy level of user positioning featuring the NSC. Thereby, user navigation receiver has feature that enables to analyze and estimate the role of each NSC in total navigation task solution. However, the current version of interface control document information has no about algorithms of usage accuracy factor values for user receivers.

For modelling of GLONASS system accuracy characteristics a mathematical model of spacecraft subsystem is used with the following initial conditions for the model: GLONASS constellation is composed of 24 satellites in three orbital planes whose ascending nodes are spaced 120° apart. 8 satellites are equally spaced in each plane with argument of latitude displacement of 45°. Aside from that the orbital planes have 15 -argument of latitude displacement relative to each other. The satellites operate in circular 19100-km orbits at an inclination 64.8, with orbital period for each satellite equaling approximately 11 hours 15 minutes. Such spacing of the satellites allows continuous and global coverage of the terrestrial surface and the near-earth space.

For simulation of users positioning following initial conditions were used: quantity of users is 98570, all users are equally spaced on terrestrial surface of Earth.

For simulation of user receivers the following initial conditions are used:

-receiver operates in compliance with ICD for GLONASS system requirements;

-receiver use an elevation angle no less or greater than 5°;

-receiver calculates spacecraft position and geometrical distance in compliance with PZ-90.02, coordinate with Earth and UTC (SU) timescale;

-calculates solution for determining the location and time based on the data broadcast from all visible satellites, compensates for dynamic measurements of the Doppler shift in the code and carrier phase nominal signal CSA;

-eliminates inefficient GLONASS satellites from solving the problem on positioning information from the navigation message transmitted by each NSC;

-uses updated and internally compatible ephemeris and time characteristics for all satellites, which are used to determine the location;

-loses support in cases when the satellite stops transmitting CSA radio navigation signal;

-determines the accuracy of the transmission timescale in relation to a stationary point with known coordinates.

The simulation was performed based on the following conditions: a navigation task for all visible satellite at the entire range of simulation is calculated and solved individually for each user at each step of the simulation. Modeling interval was identified as 1 second and modeling duration - 24 hours (86400 seconds).

Modeling was carried out in several stages.

Stage 1: Based on reference to the existing position and velocity errors of NSC given in Table 1 values of determining the pseudorange errors were calculated.

Table 1. Accuracy of transmitted coordinates and velocity

	Predicted coordinates (m)	Velocity (cm\s)
Along track component	7	0,03
Cross track component	7	0,03
Radial component	1,5	0,2

Stage 2: On the available statistics of accuracy factor values for each NSC according to Table 2 corresponding values of the pseudorange errors were calculated.

Table 2. Accuracy factor values according to accuracy of measurements.

Value of accuracy factor	Accuracy of measurements, m
0	1
1	2
2	2,5
3	4
4	5
5	7
6	10
7	12
8	14
9	16
10	32
11	64
12	128
13	256
14	512
15	Not applicable

Further using the pseudorange errors calculated in the first stage of the simulation, for which the corresponding values of errors in determining the location and speed of the NSC are known with the use of interpolation methods were calculated errors in determining positioning and velocity for NSC for the error in determining pseudoranges obtained from Table 2 were calculated. To calculate the error of location of NSC associated with the error in determining the pseudorangeempirical formula was used.

Stage 3: Based on the calculated values of NSC position errors obtained at Stage 2 the accuracy characteristics of the GLONASS system were simulated.

The algorithm of using the accuracy factor:

Exclude NSC with value of pseudorange error greater than a threshold of 6 meters from navigation task solution if the exception does not entail the following events:

-Reduce the number of NSC involved in navigation task solution to three;

- The value of GDOP will n\zzexceed 6;

If there are several NSC with a value greater than the error threshold in the visibility zone of navigation consumer equipment, an exception must be carried out by one NSC with checking the above conditions after each out, the order of exclusion should be selected so that the first should be excluded NSC with a maximum error . If there are 2 or more NSCs with the same value of error in the first place should be excluded the NSC after exclusion of which the value of GDOP is minimal.

THE INTERNATIONAL INTERNSHIP

The international internship at Thales Alenia Space, Toulouse, France from 21 May till 13 July 2013 contributed to gaining knowledge about methods, standards and technologies used by European Space Agency for space craft's elements design.

In the course of the internship methods of accounting factors affecting the battery life of the spacecraft, best practice of using design information for the design of spacecraft were studied including standardization system used in the EU space industry. Methods for estimating the reliability and availability of functioning spacecraft used by the European Space Agency were investigated. The data obtained enabled to conduct a comparative analysis of foreign global navigation satellite systems, and to find alternative solutions to the problem.

CONCLUSIONS AND RECOMMENDATIONS

As a result of the investigations it was found that studies using the described rules processing factor values precision in navigation solution has been achieved to improve the level of accuracy characteristics of the GLONASS system.

Considering the results obtained it is feasible to use the algorithm in navigation user equipment.

As further research in this area, after implementing the separate (differential) accuracy factor it is planned to assess the impact of separately ephemeris accuracy and especially precision time-frequency information to the navigation solution.