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DEVELOPMENT OF GEO NAVIGATION SATELLITE DISIGN

Master's Programme Spacecraft system design

The abstract of the Master's Thesis

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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

The validity of dissertation. According to the federal target program "Maintenance, development and use of the GLONASS system for 2012 - 2020 years the following challenges were determined:

1. Maintain the GLONASS system with guaranteed competitive characteristics of a navigation field;
2. Develop the GLONASS system in the direction of improving its tactical and technical characteristics to ensure parity with foreign systems and ensure the leading position of the Russian Federation in the field of satellite navigation;
3. Ensure the use of the GLONASS system, both on the territory of the Russian Federation and abroad.

High relevance of the issue modernization of GLONASS orbital constellation determined by the need to ensure the competitiveness of the performance level of accuracy, accessibility and sustainability of different consumers navigate the global navigation satellite system GLONASS and significant influence of these characteristics on the composition and structure of the orbital constellation.

Accuracy assurance and availability of navigation in difficult conditions, can be assured by:

1. Bringing the number of spacecraft (SC) standard orbital group to 27 ... 30.
2. Introduction into the nominal orbital constellation of additional spacecraft at high (geostationary, geosynchronous, highly-elliptical) orbit (augmentation).

Assuming the all above within the context of development of the system it is envisaged to elaborate of the issue of developing of a satellite ground based augmentation system GLONASS.

Object of investigation - the navigation spacecraft.

Subject of investigation - design methods -consistent unified spacecraft.

The purpose: project development the spacecraft in geostationary orbit, used in augmentation of GLONASS.

To achieve this goal, the following **of the tasks**:

– requirements analysis to the spacecraft augmentation (SC-FD);
– select basic space platform for SC-FD ;
– determination of improvements of the space platform ;
– determination of project view SC-FD.

The novelty:

1. Similarity method was used in the calculation of the SC-FD based on spacecraft "Glonass-K";
2. Retained interfaces SC-FD with ground control complex (GCC) and GLONASS launch vehicle launch vehicle(LV) "Soyuz-2" with booster "Frigate";
3. Minimized the amount of modifications parts of spacecraft and its basic layout scheme.

Place of dissertation realization. “Applied physics and space technology” department of Federal State Autonomous Educational Institution of Higher Professional Education "Siberian Federal University"

Place of international internships. Institut Aeronautique et Spatial (Toulouse, France).

CONTENTS OF DISSERTATION

In the introduction the urgency of the topic and stated aim of the work, noting its novelty.

In the first chapter requirements to the spacecraft, as part of augmentation of the GLONASS system, using the experience gained during the international internship are justified.

GLONASS satellites emit navigation signals in three frequency bands (L1, L2 and L3).

Thereby the first generation of satellite applies frequency division navigation signals, and in subsequent - code

For SC-FD is proposed to use code division, which allows the consumer to navigation signal of navigation with higher accuracy characteristics.

On the navigation SC-FD is also installed on-board synchronization unit (BSU), borrowed from the spacecraft "Glonass-K" with high specifications and flight qualification.

Ephemeris-time support spacecraft navigation augmentation is proposed to organize the scheme used in the GLONASS system using intersatellite range measurements.

The analysis of the accuracy characteristics of radio navigation system combined field of 24 GLONASS satellites and a functional complement to the various types of orbits , which showed that the increase of the best navigation performance in the Russian Federation and the Arctic, especially in low visibility conditions (in urban and mountainous areas), as well as two-fold coverage of Russia and the Arctic can provide regional complement of four to six satellites in geostationary orbit with an inclination different from zero (circular orbits inclined geosynchronous (GSO) with a period equal to the sidereal day). When this option is considered subsystem of 4 spacecraft moving along a ground track that crosses the equator at

110 ° c. d (4x1 GSO single elimination scheme), which implements the optimal navigation for the territory of Russia.

The conditions of operation of SC-FD, which in comparison with conditions on the GLONASS orbits differ on the total dose of radiation, the magnitude of the magnetic field of the Earth and the duration of the shadow parts of the orbit.

According to the estimations the radiation resistance of GLONASS satellites equipment in orbit during operational life of 10 years is equivalent to the resistance of spacecraft in geosynchronous (stationary) orbit for operational life of 15 years. Therefore, borrowing equipment from the developed GLONASS navigation satellites for the SC-FD is possible without increasing its radiation resistance.

When calculating an energy balance and thermal mode SC-FD it is necessary to consider the shadow areas time increment.

Navigation satellites in the system is used as radionavigation "point" with known positioning, emitting highly stable navigation signal covering the entire globe and near-Earth space. This introduces specific requirements for the construction of the satellite as a whole and its components:

- navigation antenna must be installed so that its phase center is located at a minimum distance from the longitudinal axis of the satellite, which is aligned with the center of mass of the satellite, and coincides with the radius vector of the orbit;
- for BSU should be created comfortable operating environments (heat with an accuracy better than 1°C) and provides shielding from magnetic fields;
- minimization of unpredictable non-gravitational forces (radiation pressure, reactive power, etc.).

Therefore, SC-FD should be similar to SC GLONASS system and meet all requirements for spacecraft navigation. Most appropriate on the tasks and size (weight, size, power consumption) for SC-FD is a navigation satellite " Glonass-K" with a operation life of 10 years, which is proposed to use as a base pattern. Based on the above the content of the equipment of the typical SC-FD has been defined: on-board information and navigation system (BINK), on-board synchronization unit, retroreflective optical antenna system , on-board control subsystem, pointing and attitude control subsystem, propulsion subsystem, thermal control subsystem, electric power subsystem.

In the second chapter it is examined a possibility of using the spacecraft "Glonass-K” - borrowed onboard, and evaluated the workscope of their modifications using the similarity.

On-board information and navigation system should be built on the basis of BINK-K2, which do not use the instruments forming a navigation signal with frequency division multiplexing (with replacement power supplies 100V to 27V with conservation of mass and size characteristics).

On-board synchronization unit and optical retroreflective antenna system is borrowed from the spacecraft "Glonass-K" without modification.

GSO orbit are positioned above the the GLONASS system orbits, therefore it is essential to take into account the extending range and decrease time - angular measure of the Earth that causes a corresponding decrease in the width of the navigation antenna pattern. According to the results there is a radio link budget calculation to determine the required gain navigation antenna with a narrow beam width, which compensates for the increase in the range and the required antenna intersatellite range. Based on these requirements, geometric and electrical characteristics of these antennas are defined.

According to the results of the ballistic analysis, the requirements to the total characteristic velocity required to navigate SC-FD to the operating position and keep it on the orbit for the entire period of its operation. The volume filling the tank of the propulsion system is selected and the mass of the working fluid for orbit correction and unloading organization reaction wheels orientation system is determined. As a prototype the propulsion spacecraft "Glonass-K" which uses the tank volume of 30 liters is chosen

Task on control , monitoring and ensuring ballistic SC-FD are solved in a similar manner as in the GLONASS system (which does not require further elaboration means GCC), which allowed borrowing of onboard control complex with SC "Glolnass-K".

"Glonass-K" scheme orientation may be applied to the SC-FD however the peculiarities of its implementation must be considered. The application of an electromagnetic device for unloading reaction wheels (UDM) for GSO is not effective due to the weak magnetic field of the Earth in these orbits. The calculations performed enabled to determine the frequency of discharge UDM (as once in 9 months), required estimated cost mass carrier (1kg) and the value of the angular momentum UDM (50Nms).

Based on the calculation of the energy balance and thermal analysis the possibility of spacecraft power system applications spacecraft "Glonass-K" is confirmed, preserving the characteristics of solar cells and batteries. It is also confirmed the adequacy of space radiation and surface temperature control system of electric heaters power.

The third chapter defines the SC-FD design, the calculations and estimation of the budget masses, dimensions, moment-centering characteristics based on the need to minimize the amount modifications component parts and its basic spacecraft design-layout scheme.

Estimated cost of mass block SC-FD is presented in Table 1 below

Table 1- Estimated cost of mass block SC-FD

Device name	Weight, kg
Block SC:	1010
1 SC-FD	950
1.1 On-board special subsystem	216,68
1.2 On-board control subsystem	70,08
1.3 Antennas	42,99
1.4 Propulsion subsystem	60,8
1.5 Attitude and orbit control subsystem	81,7
1.6 Electric power subsystem	128,9
1.7 Thermal control subsystem	13,49
1.8 Mechanisms	72,98
1.9 Structure	158,02
1.10 Cables	80,0
1.11 Weight for compensation	40,0
1.12 Balance weights	15,0
1.13 Additional payload	8,0
2 Separation device	33,0
3 Docked connectors	1,0
4 Set of mounting	1,0
5 Balance weights	25,0
6 LV launch mass	1100
7 Reserve	90

Weight of SC-FD allows the use of "Soyuz-2" with booster "Frigate" for a single launch operation.

External dimensions and layout SC-FD were formed considering normal functioning of the orbit and placing into the booster with the necessary clearances, as well as in into the ground transport container.

General view of the spacecraft developed in the operating position is shown in Figure 1.

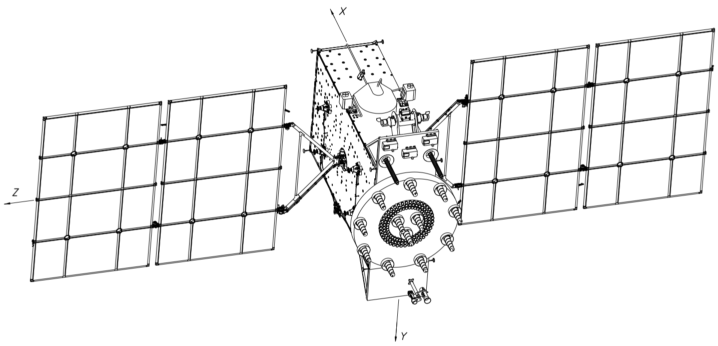

Figure 1 - General view of the SC-FD in the operating position

Placement of SC-FD into the booster is shown in Figure 2

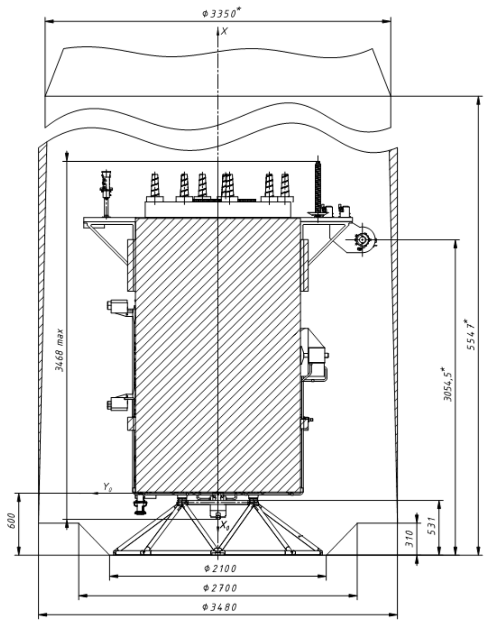

Figure 2 - Placing the SC-FD into the booster

On the results of the research the project navigation SC-FD is designed with the characteristics as presented in Table 2

Table 2 - SC-FD general characteristics

Parameters	Value
Purpose:	- formation and continuous emission of radio navigation signals with code division (L1, L2 and L3); - data exchange and measurements on inter-satellite link; - creation, storage and transmission of digitized high-side timeline tied to ground scale; - passive optical relay interrogation ranging signal quantum optical ground stations to provide calibration of radio.
Lifetime	10 year
Orbit	Attitude 35786км, inclination *i*=0-64°, eccentricity 0
SC-FD mass	950 kg
Power consumption SC-FD	1434 watt
Battery capacity	2685 watt-hour
Size of solar panels	17 $м^2$
Power of solar panels	2268 watt
Launch vehicle	LV "Soyuz-2" with booster "Frigate"
The duration of input SC-FD in the correct functioning	21 days

In conclusion part the main conclusions and results are presented.

MAIN PROVISIONS OF DISSERTATION WERE PUBLISHED IN THE FOLLOWING PAPERS

1. V.D. Zvonar , R.F. Fatkulin, M.A. Ilin , S.V. Timofeev. Navigation spacecraft in geostationary orbit / / Intelligence and science : proceedings of XIII International youth scientific conference "Intelligence in Science" - Zheleznogorsk , 2013 . - P. 19-20 .

2. S.V. Timofeev, M.A. Ilin , V.E. Chebotarev, V.D. Zvonar, R.F. Fatkulin. Feature selection of electric heaters spacecraft with constraints/ VE Chebotarev [etc.] / / Studies have Naukograd : Scientist . magazine. - Zheleznogorsk , 2012. - P. 20-22.

CONCLUSIONS AND RECOMMENDATIONS

The designed SC-FD can function without any restrictions on circular orbits 35,786 km radius with different inclinations.

The solutions applied in the development of the project SC can be used to create SC augmentation for a system GLONASS.