Analysis of the functioning of the orientation device to the Earth of a telecommunications space satellite

M N Petrov

1 Siberian State University of Science and Technology named after M.F. Reshetneva, 31, prospect. newspapers Krasnoyarsk Rabochy, Krasnoyarsk, 660037, Russia

E-mail: mnp_kafaes@mail.ru

Abstract. This article presents the results of statistical observations of an operating communications spacecraft. The functioning of the orientation system to the Earth is considered. For ensure the reliability of communication between the satellite and ground stations, it is important to have a constant direction to the coverage area. For this, the spacecraft has an orientation system to the Earth. The orientation aims to create a reliable connection on the territory of the country of the spacecraft owner. The article examines the analysis of the operation of the satellite guidance system to the Earth using the example of a telecommunications communication satellite of the Republic of Kazakhstan. At the same time, the satellite orientation system to the Sun works in parallel to organize a stable and stable connection. The statistics of the operation of the orientation system to the Earth are presented. For this, the satellite has devices responsible for positioning: the orientation devices to the Earth. These devices are two: POZ-1 and POZ-2. The analysis of real statistics is given. The forecast of the system operation for the next nine years has been made.

1. Introduction

For ensure the reliability of communication between the satellite and ground stations, it is important to have a constant direction to the communication coverage area [1-6]. For this, the spacecraft has the orientation system to the Earth.

2. Analysis of the statistics of the operation of the orientation device to the Earth.

In [1], the analysis of the operation of the satellite guidance system in the Sun is considered on the example of a telecommunication communication satellite of the Republic of Kazakhstan. At the same time, the satellite orientation system to the Earth works in parallel to organize stable and stable communication. Consider the statistics of the orientation system to the Earth. For this, the satellite has devices responsible for positioning: the orientation devices to the Earth. These devices are two: POZ-1 and POZ-2.

Figure 1 shows the moments in time at which the Sun falls into the field of sight of the orientation devices to the Earth. This information is calculated in software, orientation and stabilization systems, taking into account the data coming from the initial orientation device unit. This graph shows that the exchange between the initial orientation device unit and the orientation and stabilization system software is carried out normally and without comments.
Figure 2 shows the moments at which the Earth falls in the field of view of the device for orientation to the Earth. This testifies to the normal functioning of the device, even in those moments when the Sun fell into the field of view.

![Graph showing the moments of time at which the Sun falls into the sighting area of the orientation devices to the Earth.](image1)

**Figure 1.** Illumination times of the orientation device to the Earth

![Graph showing the times of detection of the Earth by the orientation device.](image2)

**Figure 2.** Times of detection of the Earth by the orientation device to the Earth

where

0 – orientation device to the Earth POZ1 and orientation device to the Earth POZ2 do not observe the Earth;

1 – the device for orientation to the Earth POZ1 observes the Earth, the device of orientation to the Earth POZ2 does not observe the Earth;

2 – the device for orientation to the Earth POZ2 observes the Earth, the orientation device to the Earth, POZ1 does not observe the Earth;

3 – orientation device to the Earth, POZ1 and orientation device to the Earth POZ2 observe the Earth.

It is crucial to monitor the temperature of the Earth orientation device. Figure 3 shows the statistics data.
The maximum temperature at the summer solstice was:
- 2014 - 37.72 °C;
- 2015 - 40.25 °C;
- 2015 - 42.27 °C (when the device is turned on);
- 2016 - 44.30 °C (when the device is turned on);
- 2017 - 47.34 °C (when the device is turned on).

The degree of increase in the thermal background from year to year is:
- 2014 → 2015 - 2.53 °C;
- 2015 → 2016 - 2.03 °C;
- 2016 → 2017 - 3.04 °C.

In 2015, the upper limit of control of the temperature parameter - TM-parameter T1CO3 + 40 °C was recorded (Fig. 3).

According to flight data on a spacecraft with similar thermal circuits of the Earth orientation device and with temperature sensors installed at the POS seats, the difference in temperature between the device design and the seat is from 6 to 6.8 °C. According to the analysis, the difference between the switched on and off device is 7.1 °C - 8 °C for the devices of orientation to the Earth POZ2 and POZ1, respectively, it is necessary to compare it with the TM-parameters TPOZ1 / 2. The data indirectly indicate that the temperature of the POZ2 instrument seat on the spacecraft reached ~ 40 °C during the specified period.

The reason for the parameter T2POZ2 exceeding control tolerances (over 40 °C) is as follows. The optical window of the Earth orientation devices absorbs additional thermal radiation from the surface of the EVTI shell and lock. At the same time, the heat flux emitted by the optical windows of the device for orientation to the Earth into space is reduced. The reason is the negative influence of the overhanging design of the shell and the lock on the visibility factor of outer space by the devices of the Earth orientation device. Due to the closer location of the orientation device to the Earth POZ2 to the shell structure, the temperature of the orientation devices to the Earth POZ2 is higher than the temperature of the orientation device to the Earth POZ1. That is, when designing and calculating the heat balance, the developers did not take into account that the transition system has a conical shape, and not cylindrical; as a result, the real heat flux falling on the device for orientation to the Earth POZ2 is greater than the calculated one. This circumstance caused the temperature of the radiator of the device of the Earth orientation device POZ2 to go beyond the upper limit of the TM parameter control.
Table 1. Predicted temperatures of the Earth orientation device during the summer solstice during hardware stabilization system and the maximum per day duration of the stay of the Earth orientation device seats at temperatures above 40 °C.

|      | Predicted temperatures, °C | Duration of stay at temperatures above 40 °C, hh: mm |
|------|----------------------------|-----------------------------------------------------|
|      | TPOZ1 | Seat POZ1 | TPOZ2 | Seat POZ2 | Seat POZ1 Average integrated per day | Seat POZ2 Average integrated per day | TPOZ1 | Seat POZ2 |
| June | 2014  | 41.4      | 35.4  | 45.4      | 39.4          | 15.6                  | 14.0  | 0.00       | 0.00       |
| June | 2015  | 44.0      | 38.0  | 48.0      | 42.0          | 16.1                  | 14.5  | 0.00       | 2:11       |
| June | 2016  | 46.0      | 40.0  | 50.0      | 44.0          | 16.6                  | 15.0  | 0.00       | 3:11       |
| June | 2017  | 47.0      | 41.0  | 51.0      | 45.0          | 16.8                  | 15.0  | 1:48       | 3:11       |
| June | 2018  | 47.6      | 41.6  | 51.6      | 45.6          | 16.9                  | 15.3  | 1:48       | 3:25       |
| June | 2019  | 48.0      | 42.0  | 52.0      | 46.0          | 17.0                  | 15.4  | 1:48       | 3:41       |
| June | 2020  | 48.4      | 42.4  | 52.4      | 46.4          | 17.1                  | 15.4  | 2:11       | 3:41       |
| June | 2021  | 48.7      | 42.7  | 52.7      | 46.7          | 17.2                  | 15.5  | 2:44       | 3:41       |
| June | 2022  | 49.0      | 43.0  | 53.0      | 47.0          | 17.2                  | 15.6  | 2:44       | 3:41       |
| June | 2023  | 49.3      | 43.3  | 53.3      | 47.3          | 17.3                  | 15.6  | 2:44       | 3:41       |
| June | 2024  | 49.6      | 43.6  | 53.6      | 47.6          | 17.4                  | 15.7  | 2:44       | 3:54       |
| June | 2025  | 49.9      | 43.9  | 53.9      | 47.9          | 17.4                  | 15.8  | 2:44       | 3:54       |
| June | 2026  | 50.1      | 44.1  | 54.1      | 48.1          | 17.5                  | 15.8  | 3:01       | 3:54       |
| June | 2027  | 50.4      | 44.4  | 54.4      | 48.4          | 17.5                  | 15.9  | 3:01       | 3:54       |
| June | 2028  | 50.6      | 44.6  | 54.6      | 48.6          | 17.6                  | 15.9  | 3:24       | 3:54       |
| June | 2029  | 50.8      | 44.8  | 54.8      | 48.8          | 17.6                  | 16.0  | 3:24       | 4:11       |

Taking into account the actual operating temperatures of the POZ for 2014 – 2017 and the degree of degradation of the optical coating of the spacecraft radiator and the POZ radiator, the maximum predicted temperature at the end of the hardware stabilization system during the summer solstice will be (the analysis data are given in curly brackets):
- body of the device for orientation to the Earth POZ1 – 50.8 °C (48.8 °C);
- the seat of the device for orientation to the Earth POZ1 – 44.8 °C (51.2 °C);
- body of the device for orientation to the Earth POZ2 – 54.8 °C (52.3 °C);
- the seat of the device of orientation to the Earth POZ2 – 48.8 °C (54.3 °C).

3. Conclusion
During normal operation, attitude control is carried out according to the information of the star device. The orientation device to the Earth is not obligatory in the basic version of the triaxial stabilization mode, and its absence does not affect the characteristics of the spacecraft during normal operation. When analyzing the reliability of the orientation and stabilization system in the triaxial stabilization mode of the Earth orientation device is not included in the structural reliability diagram. Therefore, the absence of the Earth orientation device does not affect the probability of failure-free operation of the orientation and stabilization system during normal operation. Since the devices for orientation to the Earth are back-up during the implementation of the normal mode of the triaxial stabilization mode, then for periods when the temperature of their seats is predicted to go beyond the upper limit, they can be turned off. These periods during the hardware stabilization...
system are the periods from May to July of each year of an operation lasting up to 3.2 hours per day in 2016 and up to 4.2 hours per day at the end of the hardware stabilization system.

The operating time of the device of orientation to the Earth POZ1 is as of 01.01.2018 – 8335 hours, which is about 6% of the total working resource of the device. The operating time of the device of orientation to the Earth POZ2 is 2149 hours as of 01.01.2018, which is about 1.5% of the total working resource of the device.

The spacecraft developer made a change to the attitude control system to change the temperature control boundaries of the radiators of the orientation devices to the Earth POZ1 and the orientation devices to the Earth POZ2 from +40 °C to +55 °C.

According to the analysis of the spacecraft at the end of the hardware stabilization system, the maximum temperature of the instruments will be 48.8 °C and 52.3 °C in terms of TPOZ1 / 2 parameters with a tolerance of 50 °C. It is necessary to take measures to prevent an increase in temperatures above permissible or to increase the border of this temperature above 52.5 °C.

References
[1] Petrov M N and Anarov M Zh 2018 Analysis of the functioning of the attitude control and stabilization system of a geostationary communication satellite (Krasnoyarsk, Polycom. St. Vavilov)
[2] Ignatov A I and Sazonov V V 2018 Stabilization of the solar orientation mode of an artificial Earth satellite by an electromagnetic control system Cosmic research Vol 56 5 pp 375–383
[3] Ovchinikov M Yu, Penkov V I, Roldugin D S, Varatarao R and Ryabikov V S 2017 Motion of a satellite equipped with a pitch flywheel and magnetic coils in a gravitational field // Cosmic research Vol 55 3 pp 218–225
[4] Zavoli A, Giulietti F, Avanzini G and de Matteis G. 2016 Spacecraft dynamics under the action of Y-dot magnetic control law Acta Astronautica Vol 122 pp 146–158
[5] Lyubimov V V and Podkletnova S V 2016 Optimal control laws for decreasing the angular momentum and damping the angular velocity of nanosatellites and microsatellites with magnetic coils on board Bulletin of Samara State Aerospace University. Acad. S. P. Korolev Vol 15 2 pp 57–67
[6] Ovchinikov M Yu and Roldugin D S 2019 A survey on active magnetic attitude control algorithms for small satellites Progress in AerospacPSiences DOI: 10.1016 / j.paerosci.2019.05.006