Estimation of the angular velocity of the small spacecraft of the Earth «AIST-2D» by measuring the vector of measuring the Earth's magnetic field

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Abstract

In this work, an estimate of the angular velocity of rotation of the small spacecraft «AIST-2D» around the center of mass in the mode of orientation and reorientation is obtained. Measurements of the vector of accounting for the Earth's magnetic field with the help of onboard magnetometers were used for the evaluation. Dependences of the components of the angular velocity vector on time are constructed in the orientation and reorientation modes. The results obtained can be used in the analysis of the requirements imposed on the operation of the motion control system of a small spacecraft in order to effectively fulfill its target tasks.

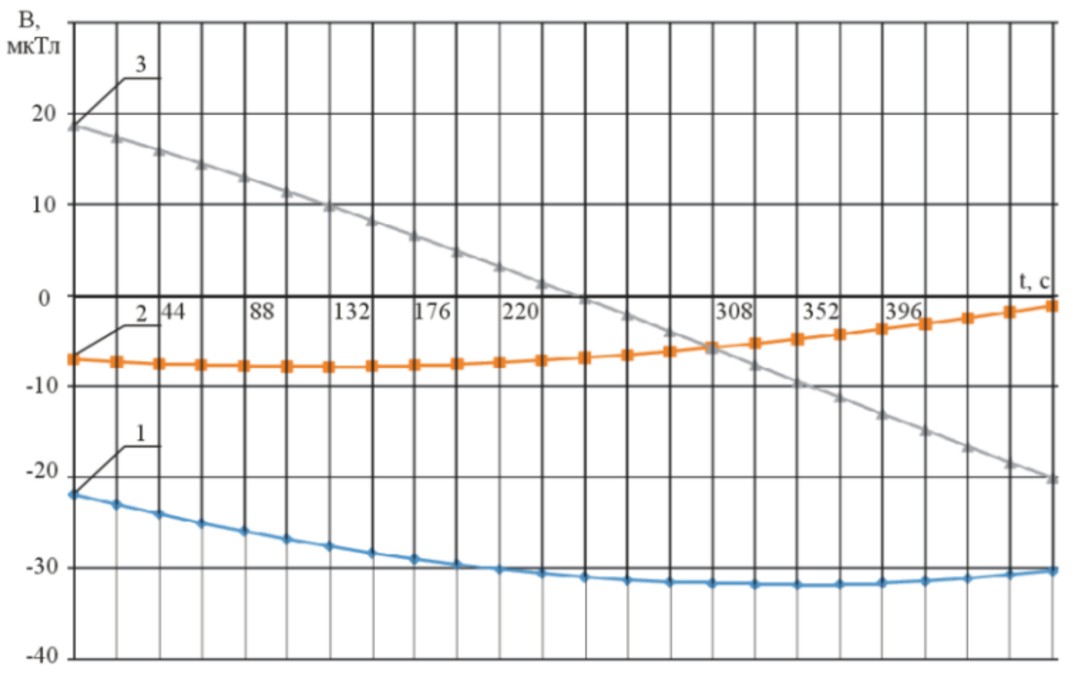


Fig. 1. Measurement data of the components of the Earth's magnetic field induction vector in the orientation mode from 06/30/2016 (the value t=0 corresponds to 22:29:50 Moscow time)

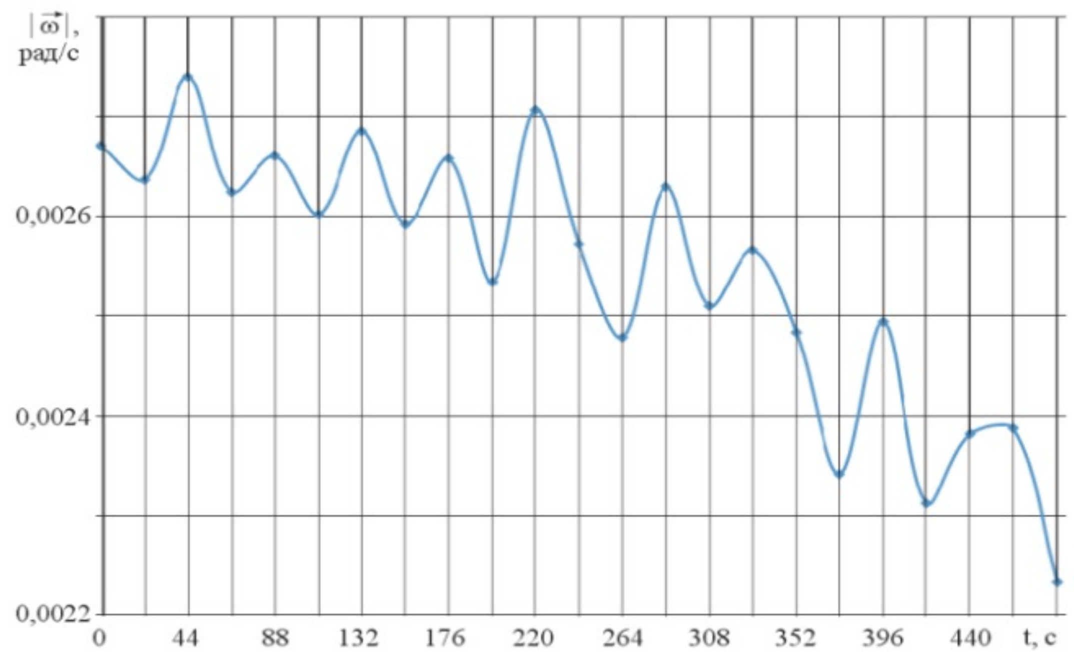


Fig. 2. Dynamics of the angular velocity modulus of the small spacecraft for remote sensing of the Earth "AIST-2D", corresponding to the measurements of the components of the induction vector of the Earth's magnetic field (Figure 5) dated June 30, 2016 (value t=0 corresponds to 22:29:50 Moscow time)

Introduction

The small spacecraft for remote sensing of the Earth "AIST-2D", in fact, is a space laboratory designed to test in outer space a number of technologies, systems, equipment, as well as to study the impact of outer space conditions on equipment. In addition to scientific research, one of its functions is remote sensing of the Earth, which implies the detection of emergencies, the search for natural resources, etc., an experienced radar is also installed on board to detect underground structures, pipelines and communications, which makes this device an important reconnaissance object.

Estimation of the parameters of the rotational motion of a small spacecraft for remote sensing of the Earth is an important task that affects the efficiency of a small spacecraft in fulfilling its target tasks [1-3]. For the small spacecraft «AIST-2D», the angular velocity accuracy in the orientation mode is 0.5 deg/s.

This value guarantees the required resolution of the resulting image when shooting terrestrial objects. The operational requirements for a small spacecraft for remote sensing of the Earth do not provide for strict restrictions on the parameters of rotational motion, as for spacecraft for technological purposes. The process of surveying the Earth's surface is much faster than technological processes, however, the presence of solar panels makes it necessary to orient them relative to the Sun, unlike small spacecraft without solar panels.

The MAC-1 (micro acceleration compensator) measuring equipment installed on the spacecraft was comparable to the measuring equipment installed on «AIST-1». During the operation of the equipment, a number of shortcomings were eliminated, however, due to the dense layout, the target and productive equipment still significantly affects the measurement data, as it happens in operation. This became possible when measuring two different magnetometers. An example of processing measurements of the components of the Earth's magnetic field vector is shown in Fig. 1

Methods and Materials

The small spacecraft «AIST-2D» includes angular velocity meters and analog magnetometers. Based on the data from this equipment, calculations were made. To estimate the angular velocity by measuring the components of the Earth's magnetic field induction vector, the Boer formula was used:

$$\vec{\omega} = \frac{\vec{B} \times \left(\dot{\vec{B}} - \dfrac{\tilde{d}\vec{B}}{dt} \right)}{\vec{B}^2}$$

where: $\vec{\omega}$ - is the angular velocity vector of a small spacecraft;
$\vec{B}$ - vector of induction of the Earth's magnetic field;
$\dfrac{\tilde{d}\vec{B}}{dt}$ - local time derivative of the Earth's magnetic field induction vector.

Neglecting the total derivative compared to the local one, we obtain equations for the components of the angular velocity in the coordinate system associated with the magnetometer [3]:

$$\omega_{x_1} = \left(\frac{B_{y_i} - B_{y_{i-1}}}{\Delta t_i} B_{z_i} - \frac{B_{z_i} - B_{z_{i-1}}}{\Delta t_i} B_{y_i} \right) \cdot \frac{1}{B_{x_1}^2 + B_{y_1}^2 + B_{z_1}^2};$$

$$\omega_{y_1} = \left(\frac{B_{z_i} - B_{z_{i-1}}}{\Delta t_i} B_{x_i} - \frac{B_{x_i} - B_{x_{i-1}}}{\Delta t_i} B_{z_i} \right) \cdot \frac{1}{B_{x_1}^2 + B_{y_1}^2 + B_{z_1}^2};$$

$$\omega_{z_1} = \left(\frac{B_{x_i} - B_{x_{i-1}}}{\Delta t_i} B_{y_i} - \frac{B_{y_i} - B_{y_{i-1}}}{\Delta t_i} B_{x_i} \right) \cdot \frac{1}{B_{x_1}^2 + B_{y_1}^2 + B_{z_1}^2}.$$

Table 1. Main parameters of the «AIST-2D» small space vehicle.

Parameter		Dimension	AIST-2D
Weight		kg	530
Number of large elastic elements		-	2
Orbit height		km	490
Stabilization error in angle and angular velocity		degree degree/s	0,004 0,0002
Ensuring uniaxial solar orientation with an error not exceeding (P = 0,96):	by angular position	degree	3
	by angular velocity	degree/s	0,5
Maximum angular speed		degree/s	1
Maximum angular acceleration		degree/s²	0,15

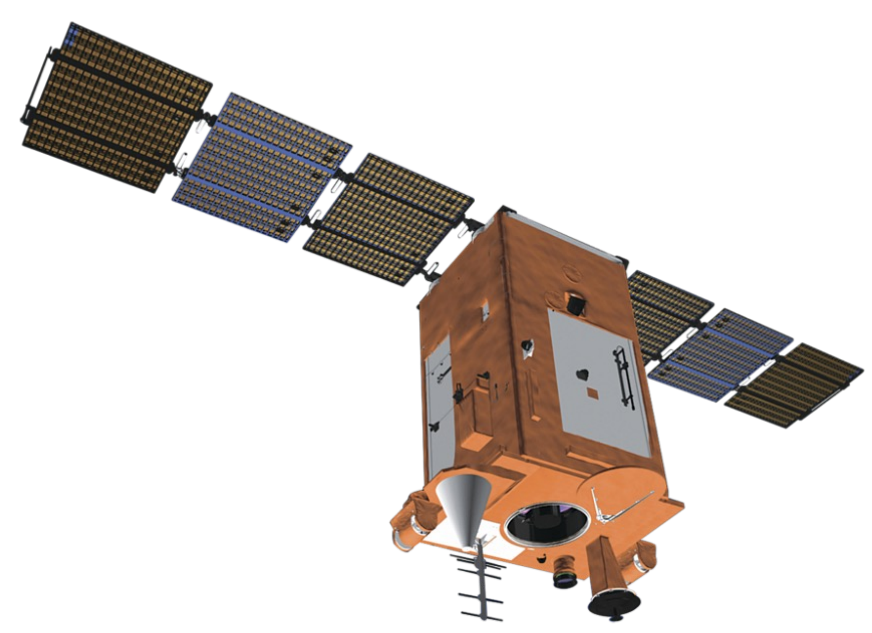
Results

For numerical simulation, a small spacecraft for remote sensing of the Earth «AIST-2D» was chosen, the main characteristics of which are given in Table 1. Estimation of the angular velocity modulus for the measurement section presented in Figure 1 using Boer's formulas is shown in Figure 2.

The result obtained coincides with the measurements of the angular velocity using angular velocity sensors, as well as the results of other authors [4,5]. This result fully confirms the main characteristics of the small spacecraft for remote sensing of the Earth «AIST-2D» declared in Table 1.

Conclusions

The paper considers the issues of estimating the angular velocity of the rotational motion of the small spacecraft for remote sensing of the Earth "AIST-2D" using measurements of the components of the induction vector of the Earth's magnetic field. The obtained estimate confirms the declared characteristics of the small spacecraft and corresponds to the results obtained by other authors. This approach can be used to estimate the angular velocity of rotation of a small spacecraft in the absence of more accurate measuring instruments.



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