DETERMINING THE SPACECRAFT BION M-1 ATTITUDE MOTION BY MEANS OF THE WORKSTATION GRAVITON

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Computer workstation GRAVITON was created as a universal tool of the investigation of microgravity environment onboard spacecraft produced by CSDB for scientific and technological experiments. GRAVITON provides both online analysis during an orbital flight by means of processing telemetry information from a spacecraft and postflight processing of all available data, which allow to reconstruct microgravity environment during the flight.

The following telemetry information was processed during the Bion M-1 flight: 1) measurements of spacecraft coordinates and velocities produced by the onboard navigation system, 2) measurements of the spacecraft angular rates received from the spacecraft control system, 3) measurements of the strength of the onboard magnetic field received from the onboard component of the GRAVITON facility. This paper describes the methods and some results of the reconstruction of the Bion M-1 attitude motion.

The reconstruction was made by processing the measurements of two vectors: the spacecraft angular rate and the strength of the Earth magnetic field. The processing technique uses kinematical equations of the attitude motion of a rigid body. In its framework, the measurement data of both types, collected on a time interval, are processed jointly. The angular rate data are interpolated by piecewise-linear functions with interpolation nodes in measurement points, which combined into a uniform grid with the step 12 s. Those functions are substituted in kinematical equations for components of the quaternion that transforms the spacecraft coupled coordinate system to the Greenwich one. The equations obtained present the kinematical model of a spacecraft attitude motion. The solution of the equations, which approximates the real motion, is found by the least squares method from the condition of the best agreement between measurement and calculation data of the magnetic strength. The reconstruction technique was tested with success by processing the data obtained in flights Foton-12, Foton M-2, and Foton M-3 [1 – 3], however in cited papers another way was used for approximation of the angular rate measurements.

Examples of the reconstruction of Bion M-1 attitude motion are presented in Figs. 1, 2. Fig. 1 illustrates the orbital orientation of the spacecraft; fig. 2 illustrates its single-axis solar orientation. The upper right plots in the figures illustrate the interpolation of the angular rate measurements. The angular rate components ω_1, ω_2, and ω_3 are referred to the spacecraft structural coordinate system. The plots are broken lines whose links join in series the points of measurements neighboring in time. The lower plots in both figures illustrate the obtained approximation of magnetic measurements. Each coordinate system on the left plots contains two curves. One of them presents the calculated time dependence of a certain component of the Earth magnetic field in the spacecraft structural coordinate system; the other is a broken line whose links join the points of the component measurements neighboring in time, the measurements being corrected for constant shifts in time and values. The appropriate calculated curves and broken lines are in a good agreement. Therefore, to illustrate the approximation errors the lower right plots contain the differences of measurements and their calculated analogs.

The upper left plots in the figures illustrate the spacecraft attitude motion. In Fig. 1, α_1, α_2, and α_3 are the angles of rotations of the structural coordinate system around its own axes 1, 2, and 3 respectively (roll, yaw, and pitch) relative to its nominal attitude in the spacecraft orbital orientation. The reconstruction of the orbital orientation was made to verify the technique. In fig. 2, α and β are the angles of deviation of axis 2 of the structural system (it is a normal to the spacecraft solar arrays) from the direction to Sun. Those angles lie in the perpendicular planes, which intersect along the line Earth – Sun. The reference plane of angle β contains axis 3 of Greenwich coordinate system; this angle is counted towards North. Angle α is counted towards East. Function $\chi(t)$ characterizes the Earth shadow. The spacecraft is illuminate by Sun when $\chi > 0$; it is in the Earth shadow when $\chi < 0$. The horizontal line near the plot of $\chi(t)$ marks the level $\chi = 0$. One can conclude from the plots of angles α and β that errors of the solar orientation don't exceed 5°.

The figure captions contain the following quantities: the time shift τ of magnetic measurements with respect to the onboard time, constant shifts $\Delta_1, \Delta_2, \Delta_3$ in those measurements, and estimates of standard deviation σ of random errors in measurements of a single component of the magnetic strength. The quantities $\Delta_1, \Delta_2, \Delta_3$ are referred to the structural coordinate system. Standard deviations of estimates of initial conditions of reconstructed motions can be expressed in terms of angles of infinitesimal rotations of the structural coordinate system around its own axes. The standard deviations of those angles are about 0.5°. One can find more detail reconstruction results on Bion M-1 attitude motion in [4].

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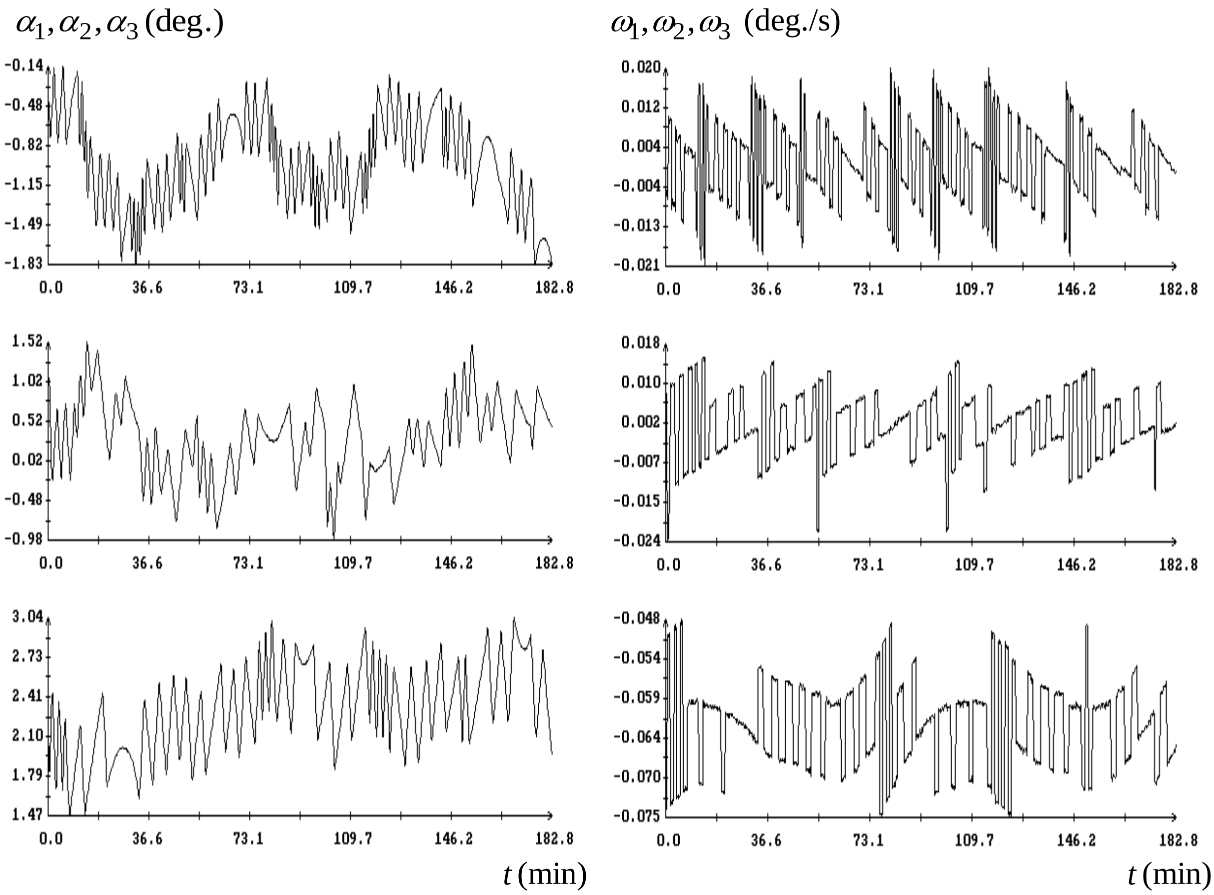


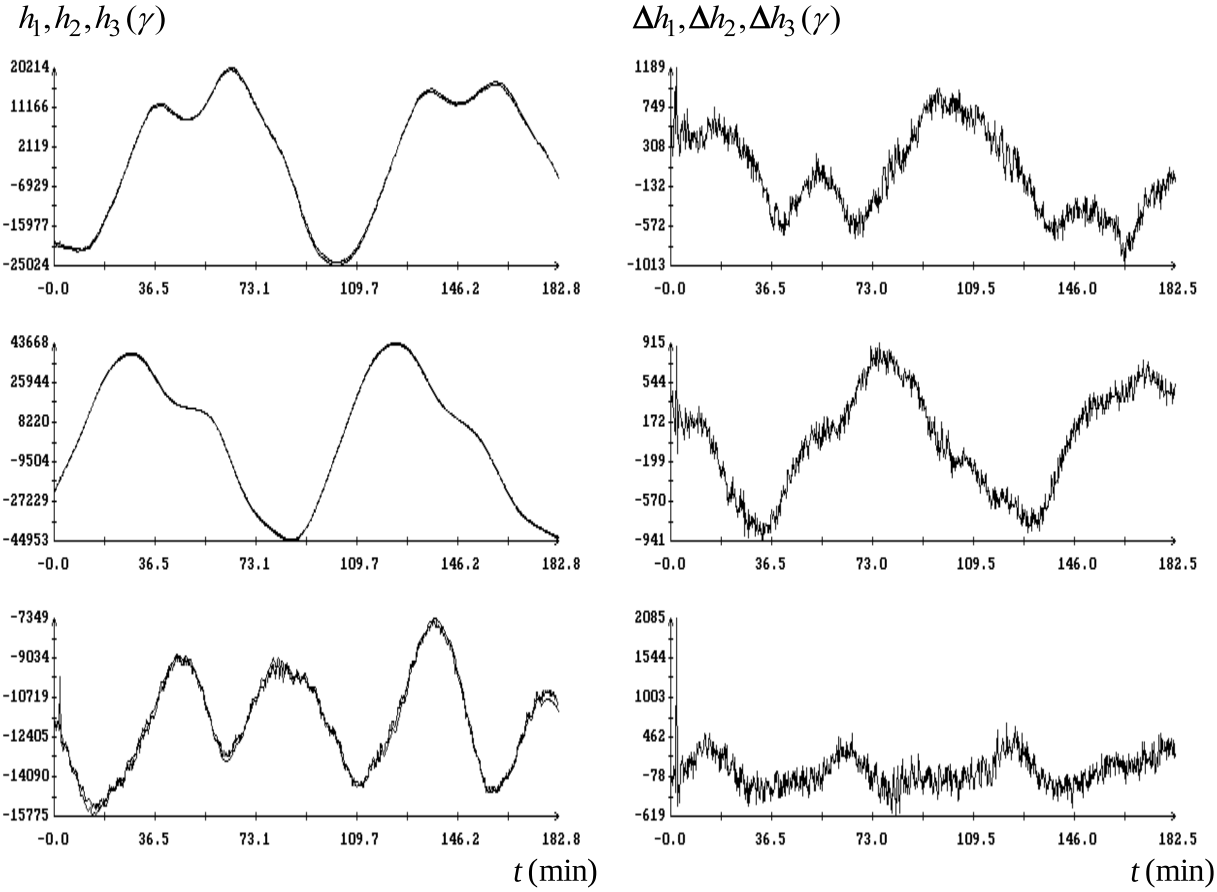
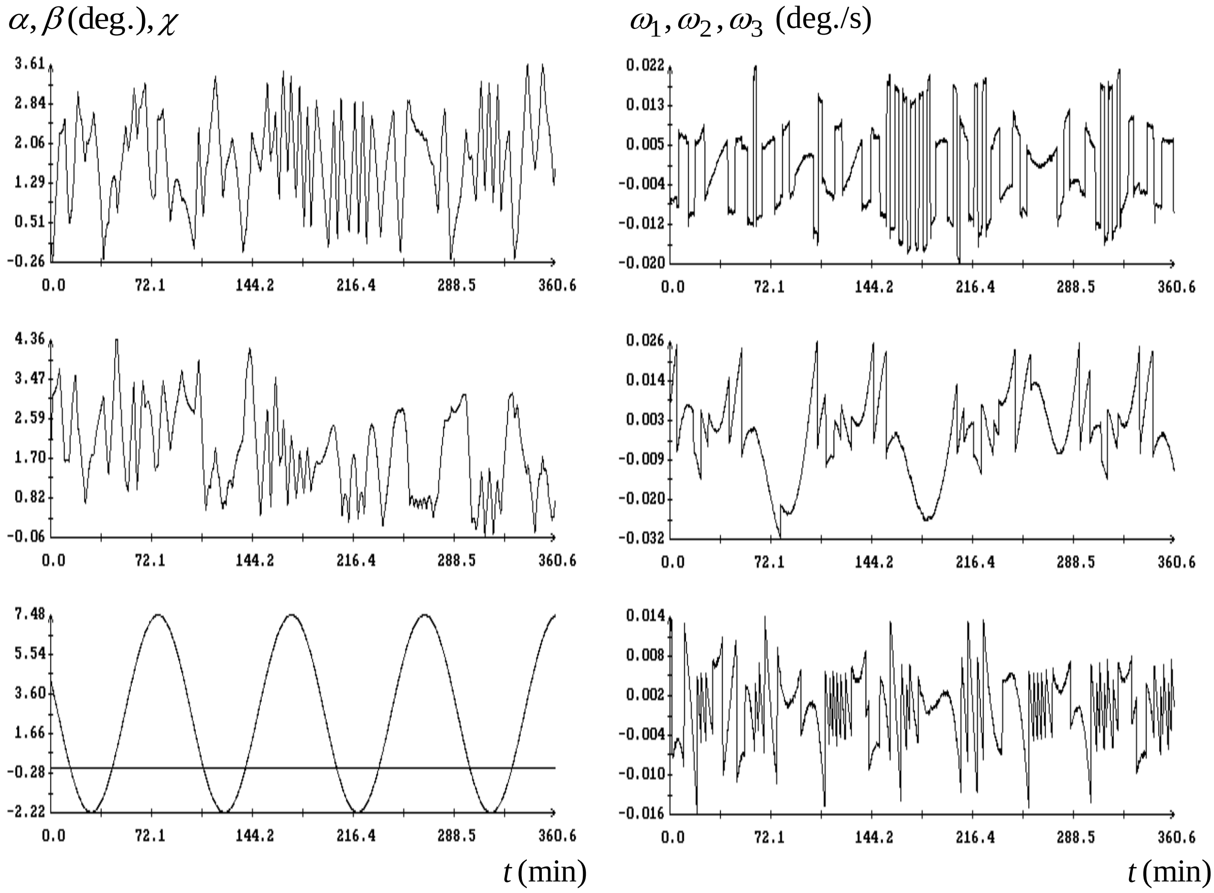


Fig. 1 Spacecraft motion in the orbital orientation. Instant $t = 0$ on the plots corresponds to 12:05:31.7 UTC 2013.04.21, $\tau = -63.4$ s, $\Delta_1 = 4765\gamma, \Delta_2 = 1093\gamma, \Delta_3 = -544\gamma, \sigma = 409\gamma$.



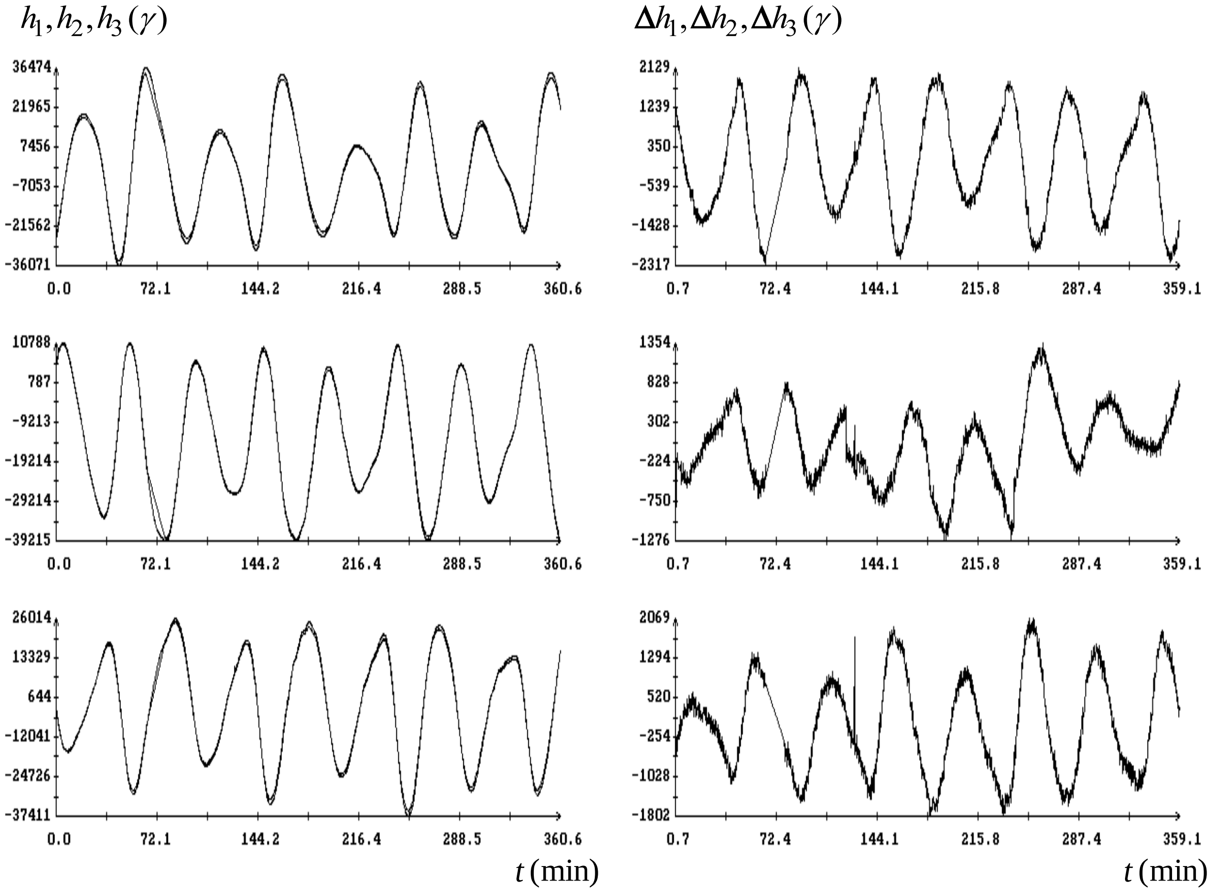


Fig. 2. Spacecraft motion in the solar orientation. Instant $t = 0$ on the plots corresponds to 22:07:07.7 UTC 2013.05.14, $\tau = -55.5$ c, $\Delta_1 = 5571\gamma, \Delta_2 = 1190\gamma, \Delta_3 = -791\gamma, \sigma = 926\gamma$.

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