DETERMINATION AND LONG-TERM PREDICTION OF ORBITAL PARAMETERS OF THE RADIOASTRON MISSION

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ABSTRACT

The Radioastron space mission is the main part of international collaborative VLBI project with the same name. The spacecraft launched in July 2011 on highly elliptical Earth orbit is carrying a 10 m space radio telescope (SRT). Apogee distance of the orbit changes between 280,000 and 350,000 km and provides baselines much greater than the Earth diameter, when using SRT in conjunction with ground-based VLBI networks. In order to correlate data from the Radioastron and ground-based stations the motion of the spacecraft should be accurately determined.

Because of relatively high effective area to mass ratio of the spacecraft solar radiation pressure considerably affects the orbit. Perturbing force depends on spacecraft's attitude, i.e. on currently observed radio source. Solar radiation pressure as well is the major source of acting on the spacecraft perturbing moment. SRT observations are to be carried out in precise and stable orientation of the satellite in inertial frame of reference. Its attitude control system uses reaction wheels for compensation of perturbing external moment during astronomical observations. While in constant orientation angular speed of reaction wheels increases monotonically, and at some point the system requires an unloading, which is conducted by means of jet thrusts. Because of specific location of jet engines each unloading results in spacecraft's velocity change of value 3–7 mm/s. Unloadings can occur up to three times a day and make spacecraft's orbit determination difficult.

The paper is devoted to problems of Radioastron orbit determination and long-term prediction taking into account spacecraft's dynamics peculiarities and using operation data of attitude control system.

This paper describes Radioastron motion model, particularly solar radiation pressure model (main source of the error), which is based on spacecraft's surface shape and depends on its parameters of reflectivity and specularity. Solar radiation pressure model is being used for calculation both perturbing force and moment from solar radiation pressure.

The paper provides Radioastron orbit determination technique, which among other solves for parameters of unloadings and solar radiation pressure. In addition to conventional tracking data the technique is using spacecraft telemetry information. This information contains data on jet engines operation, which helps to estimate parameters of unloadings. The telemetry also gives rotation speed of reaction wheels, which is related to perturbing moment acting on the spacecraft

and hence provides additional source of information about solar radiation pressure coefficients.

Given technique is being applied for Radioastron orbit determination with use of spacecraft's actual tracking and telemetry data. Tracking data includes standard two-way radio range and Doppler measurements, one-way Doppler data obtained by means of on-board hydrogen frequency standard, laser tracking data and optical angular measurements. The technique allowed to determine orbit of the Radioastron with sufficiently high accuracy to perform data correlation between SRT and ground-based radio telescopes in carried out so far experiments.

Effective scheduling of ground-based facilities requires knowledge of the spacecraft's position for a long time ahead. Perturbations due to reaction wheels unloadings and changing solar radiation pressure take place during prediction of the Radioastron motion. While solar radiation is somewhat defined, because spacecraft's orientation is known on reasonable prediction interval, unloadings occur in more arbitrary manner. This paper shows a method developed to decrease the error in predictions due to uncertainty in upcoming unloadings by prediction angular momentum stored by reaction wheels and transformation of this momentum into perturbation of the spacecraft's motion. The method proved to be effective for long-term scheduling of Radioastron VLBI observations. Use of this method helped to decrease error of ground-based facilities scheduling from 30 minutes to 2–3 minutes when predicting Radioastron motion for half a year ahead.