NUMERICAL AND ANALYTICAL SPACECRAFT ATTITUDE PREDICTION

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ABSTRACT

The goal of this paper is to do the comparison between the numerical and analytical results of a spacecraft attitude prediction. Some external torques are introduced in the equations of the motion and the comparisons are done considering each torque both separately and acting together. The considered torques are: gravity gradient torque, aerodynamic torque, solar radiation torque and magnetic torque.

In the numerical approach it is used the quaternion to represent the attitude and a 4th order Runge Kutta method to integrate the equation of motion. The dynamic equations of the satellite's rotational motion are described by the Euler equations and the four kinematic equations for the attitude quaternion. The Euler equations give the variation rate of the components of the satellite's spin velocity that depend on the components of the external torques in the satellite fixed system The simulations are develop in FORTRAN language.

Applications are developed considering the Brazilian spin stabilized satellites SCD1 and SCD2, which are quite appropriated for verification and comparison of the theory with the real data adquired and processed by the INPE's Satellite Control Center (INPE's SCC). Spin stabilized satellites has the spin axis along the biggest principal moment of inertia's axis A spherical coordinate system fixed in the satellite is used to locate the satellite spin axis in relation to the terrestrial equatorial system. The spin axis direction is specified by its right ascension and the declination angles. The time evolution of the spin axis right ascension and declination angles is gotten from the numerical results of the quaternion attitude propagation.

The analytical approach is applied directly for a spin stabilized satellite and the equations of motion are described in terms of the spin velocity and the spin axis right ascension and declination angles. In this paper, the averages the components of each torque over on orbital period are used in order to get an analytical solution of the equations of motion. The solution for the spin velocity has linear and exponential terms. The temporal variations on the right ascension and declination of the spin axis produce the precession and drift of the spin axis. The numerical implementation in this case is done with software MATLAB.

The comparing the results it is important to observe the deviation between the actual attitude data supplied by INPE and the computed attitude for each satellite. Here this deviation is called pointing deviation and is given by the angle between the actual spin axis and the computed spin axis. To evaluate the pointing deviation the dot product between the actual and computed spin axis is calculated.

The comparisons are important to validate some simplifications that were required in the analytical approach. The results show that the average components of the external torque are sufficient to observe the main influence of each torque in the spacecraft attitude.