ASTRODYNAMICS SYMPOSIUM (C1)
Orbital Dynamics - Part 1 (3)

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LONG-TERM EVOLUTION OF GALILEO OPERATIONAL ORBITS BY CANONICAL PERTURBATION THEORY

Abstract

The Galileo constellation is designed in such a way that their satellites evolve in circular MEO orbits at an altitude of about 23200 km. At this altitude, the orbits are affected by tesseral resonances as well as destabilizing lunar-solar effects. This, taken together with the growing population of satellites in the MEO region, raises concern in the orbit evolution of operational satellites as well as debris.

The development of either analytical or semi-analytical theories is of interest for investigating the long-term evolution of both the operational orbits and debris. In the case of Galileo orbits, the period is very close to the 3 to 5 resonance with the Earth's rotation period, and the main perturbation is associated to the harmonic coefficients of degree and order 5.

We use canonical perturbation theory by Lie transforms to approach the long-term evolution of Galileo satellites. The high altitude of Galileo satellites limits the number of significant coefficients in the Earth's gravity field. Then, the model studied limits to a 6x6 tesseral model. After averaging the short-period terms, the Hamiltonian takes the form of an intermediary plus a perturbation factored by the eccentricity. Hence, since the Galileo orbits are designed to have very low eccentricities, the operational orbits accept an analytical solution. In the case of disposal orbits or debris the eccentricity may grow and, therefore, their long-term evolution must be integrated in a semi-analytical way. Nevertheless, since the averaged equations only depend on very slow evolving angles, the semi-analytical integration is very fast and efficient.

The analytical and semi-analytical results are validated with Draper Semi-analytical Satellite Theory (DSST). Because of the very low eccentricities of Galileo orbits, the canonical perturbation theory has been computed in non-singular elements instead of the classical approach in Delaunay elements. We find an encouraging agreement between results of both canonical perturbation theory and those of DSST.

Related Bibliography:

1.- Lara, M., San-Juan, J.F., Folcik, Z.J., Cefola, P., Deep Resonant GPS-Dynamics Due to the Geopotential, Paper AAS 11-239 presented at 21st AAS/AIAA Spaceflight Mechanics Meeting, New Orleans, LA, February 13-17, 2011.

2.- Anselmo, L., Pardini, C., Dynamical evolution of high area-to-mass ratio debris released into GPS orbits, Advances in Space Research, Vol. 43, 2009, pp. 1491-1508.

3.- McClain, W. D., A Recursively Formulated First-Order Semianalytic Artificial Satellite Theory Based on the Generalized Method of Averaging, Volume 1, Computer Sciences Corporation CSC/TR-77/6010, 1977 ("the blue book").