IAA Transactions, No. 8, "Celestial Mechanics", 2002

Dynamics of artificial satellite orbits with the effects of luni-solar perturbations

Y. A. Abdel-Aziz[1,2], E. Wnuk[2]

[1]National Research Institute of Astronomy and Geophysics (Helwan Observatory), Helwan, Cairo, Egypt
[2]Astronomical Observatory of Adam Mickiewicz University, Sloneczna 36, 60-286 Poznan, Poland

In this paper we propose an analytical solution of some problems of Earth's artificial satellite moving on high orbits (at altitude above 20 000 km). Perturbations due to geopotential (zonal and tesseral harmonics) and luni-solar attractions are considered up to the second order. The solution will avoid the singularities from small eccentricities and small inclinations. We derive the theory of perturbation using the Hori-Lie algorithm and the Hamiltonian canonical transformaion. We discuss different classes of orbits, in particular geostationary, close to geostationary and geosynchronous as well as 1:1 and 1:2 resonance cases. We present also comparision of our analytical solution with numerical integration of motion for chosen artificial satellites.

High Earth's artificial satellites were set on geostationary or 12-hr orbits (for example GPS, GLONASS). The region of geostationary ring (GEO, GTO) is now very crowdy so, there is a very real danger of collision among objects moving on these orbits. This is the reason for searching for other types of satellite orbits. One of them might be geosynchronous orbit, but in contrast to geostationary ones its inclination to the equator is considerably different from zero. Other possibilites are orbits with perigee close to Earth and apogee being at the distance of 40 000 km or even farther away.

To determine and calculate the position of satellites on these types of orbits methods of numerical intergation of equations of motion were used until now. Existing analytical methods can solve this problem only with low accuracy. Difficulties are caused mainly by the lack of satisfactory analytical solution of the resonance problem for geosynchronous orbits as well as by the lack of efficient analytical theory combining luni-solar perturbations with geopotential attraction. Numerical integration is time consuming in some cases, and then for qualitative analysis of satellite's motion it is necessary to apply analytical solution. This is the main reason for developing analytical theory of the motion of high artificial satellites.

To achieve this purpose, we construct an analytical theory of motion of high Earth's artificial satellites and cosider the following items by

(1) including the combined effects of geopotential (zonal and tesseral harmonics) and luni-solar attractions;

(2) describing the motion of high geosynchronous satellites;

(3) applying the theory for some satellite missions.

The theory of satellite's motion is derived by applying the Hori-Lie algorithm and the Hamiltonian canonical transformation method. The initial Hamiltonian of the problem includes the influence of the gravitation fields of the Earth, the Sun and the Moon. Single canonical transformation eliminating the periodic terms (long and short period terms) is applied for the generating functions. With the use of these functions the final formula describing different types of perturbations is obtained. Solving the resonance problem needs special treatment.