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SECONDARY RESONANCES DUE TO SOLAR RADIATION PRESSURE IN THE VICINITY OF GLONASS AND GPS REGIONS

Abstract

The secondary resonances due to solar radiation pressure are investigated in the vicinity of orbits of the global navigation systems GLONASS (main resonance is 8:17) and GPS (main resonance is 1:2). Corresponding to secondary resonances the semi-major axes were estimated by analytically from the condition: $\nu_{k\pm} = k(p\dot{\lambda} - q\omega_\oplus) \pm \dot{\lambda}_\odot = 0$. Here $\nu_{k\pm}$ is frequency of the resonant argument $\psi_{k\pm} = k(p\lambda - qS) \pm \lambda_\odot$; k is integer describing secondary resonances $k : (\pm 1)$; p and q are integers describing main resonance $q : p$; λ and $\lambda_\odot$ are mean longitudes of a satellite and the Sun correspondently; $\omega_\oplus$ is the frequency of the Earth rotation and S is the Greenwich sidereal time.

The secondary resonances locations were improved by numerically. Initial data correspond to nearly circular orbits with the eccentricity $e = 0.001$. Initial inclination depends on the navigation system. Initial values of longitude of ascending node Ω are equal to 0, 90, 180, and 270 degrees. The argument of pericenter $g = 0.45804°$. In this case the pericenter is directed toward the Sun when $\Omega = 0°$. Area-to-mass ratio γ is varied from small values corresponding to satellites $\gamma = 0.02$ m^2/kg to high values which correspond to space debris. Dynamical evolution covers a time spans of 24 and 240 years. Initial epoch T_0 is $00^{\mathrm{h}}00^{\mathrm{m}}00^{\mathrm{s}}$ UTC 21.03.1958.

Orbital evolution of objects was modeled with the help of “Numerical Model of Motion of Artificial Satellites” developed at the Tomsk State University. The model of perturbing forces takes into account the major perturbing factors: the gravitational field of the Earth (EGM96 model, harmonics up to the 27^{th} order and degree, inclusive), the gravitation of the Moon and the Sun, the tides of the Earth, the direct radiation pressure (coefficient of reflection of the satellite surface is 1.44) taking into consideration the shadow of the Earth, the Poynting–Robertson effect, and the atmospheric drag. The equations of motion are integrated by the Everhart’s method of the 19^{th} order.

We found the secondary resonance zones for both low ($\gamma = 0.02$, 0.2, and 1 m^2/kg) and high ($\gamma \geq$ 10 m^2/kg) area-to-mass ratios. The secondary resonances have significant effect on dynamical evolution of objects with area-to-mass ratio 10 m^2/kg and more. This result is very important when describing long-term orbital evolution of space debris.

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