A study on the effect of solar and microwave radiation force on solar power satellite orbit

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Solar Power Satellite/Station (SPS) is a powerful solution for environmental problems such as exhaustion of fossil fuels. Because SPS has large solar panels, solar radiation pressure is one of key perturbations to SPS orbit. In addition to this, microwave power transmission exerts a reaction force on SPS. Our objective is qualitative and quantitative analysis of the effect of solar and microwave radiation force on SPS orbit.

At first, we give the physical interpretation of these two perturbations, a rough estimation of effects on SPS orbit, and the comparison with other perturbations such as J_2 perturbation. The averaged equation of eccentricity tells that solar radiation force gives rise to the secular change of the eccentricity. The 1-dimensional potential analysis tells that microwave radiation force brings a small broadening of the semi-major axis.

Then, we investigate the possibility of strict geosynchronization of SPS by steering the pitch angle of the solar panel. Two control methods are proposed. One of them is conducted by optimal control theory.
These methods demand extremely high reflectivity of the solar panel, about 94¥%. Therefore, these methods are considered not practical.

Finally, we derive averaged equations of motion about the eccentricity and the argument of the perigee to find appropriate orbits for the SPS, by considering that SPS can send a microwave to a rectenna cite even if the eccentricity shifts from zero to some extent. The derived equations have Hamiltonian, which enables us to compute the long-term behavior of SPS on the eccentricity-argument of perigee phase space. We can classify the SPS perturbed orbits into libration, rotation and unstable orbits, depending on the behavior of SPS on the phase space. There exists an equilibrium point in the libration region of phase space where the secular change of the eccentricity becomes zero and the apse-line is strictly synchronized to the earth-sun line.

We derive the same averaged equations by canonical perturbation theory, which enables us to calculate the simultaneous effects of solar and microwave radiation force in an elegant manner. We found that microwave radiation force shifts the equilibrium point.

In addition to the two-dimensional analysis, we investigate the out-of-plane effects of the solar radiation with respect to equatorial plane numerically. The orbit inclination and the eccentricity oscillate due to the solar radiation force normal to the orbit plane. A secular change in the right ascension of the ascending node also occurs, resulting in the precession of orbit plane. It was shown that three-dimensional equilibrium point exists in the ecliptic plane as same as that in the equatorial plane for the two-dimensional case.

From a long-term viewpoint, we propose a new and effective orbit for SPS at the nonzero equilibrium eccentricity, which can minimizes the deviation of microwave incidence angle at the rectenna cite. For the SPS operation, the out-of-plane radiation pressure effect is cancelled by tilting the attitude of the SPS.