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# EXPLOITATION OF THERMAL RADIATION RESONANCE FOR DEORBITATION OF SPACECRAFT THROUGH ATTITUDE CONTROL

**Abstract**

Significant advances were made in the early '60s on the characterization of resonances originating from the coupling of the solar radiation pressure (SRP) and Earth's oblateness, in particular, the $J_2$ harmonic. It was observed that the oscillations in a spacecraft's orbit perigee resulted from the resonant action of the two perturbations on the eccentricity; this in turn enhanced the effect of drag, ultimately accelerating orbital decay. This phenomenon was clearly at play in the motion of NASA's Echo 1, a 9.7 $m^2/kg$ balloon-type communication satellite that had its lifetime significantly reduced due to a near SRP-$J_2$ resonance.

The more recent research on the subject, under the umbrella of the Horizon 2020 project, explored the possibility of exploiting these natural resonances as a low-cost passive deorbitation strategy to alleviate the amount of debris in LEO. In their work, as in earlier works, resonance conditions are derived under the standard cannonball assumption, thereby limiting the identification of resonance to very few orbits. In our previous work, we expanded the range of applications for deorbitation by means of SRP-$J_2$ resonance by showing that it is possible, through controlled rotational motion of a plate-like spacecraft, to induce a $\phi$-resonance of considerable strength in an arbitrary orbit. An analogous perturbation to the SRP is the thermal radiation pressure (TRP). Even though TRP is a well-known phenomenon and has been studied for massive asteroids since the beginning of the last century (Yarkovsky-YORP effects), it is only recently that the impact of nonuniform thermal emission was also found to be non-negligible for thin objects, such as solar sails or solar panels.

In this work, we build on our prior investigation, which was restricted to the SRP and $J_2$ perturbations, and extend the methodology to TRP-$J_2$ $\phi$-resonances in semi-major axis. The feasibility of the deorbitation strategy based on this resonance is verified in a realistic environment, modelled by the state-of-the-art coupled orbit-attitude propagator D-SPOSE, where the full dynamics is propagated including the main perturbing accelerations and torques. We also provide a comparison of the proposed deorbitation scheme to two alternate solutions: one is the SRP-$J_2$ resonance in semi-major axis and the other one involves a bang-bang approach to attitude tracking to lower the orbit's semi-major axis. Several test cases are studied to highlight the capabilities and limitations of the TRP-$J_2$ $\phi$-resonances for deorbitation of spacecraft in LEO in comparison to previously published solutions.