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Decoupled-natural-dynamics Model for the Relative Motion of two Spacecraft without and with J2 Perturbation

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Abstract: This paper presents the analytical steps for decoupling the natural dynamics representing the relative motion of two spacecraft flying in close orbits, both without and with the inclusion of the J2 perturbation. Linear mathematical models with constant coefficients are available in literature for representing such dynamics. In both cases two modes can be highlighted through the eigenvalue analysis of the state matrix: a double integrator, representing the secular part of the spacecraft relative motion, and a harmonic part, related to the typical oscillations present in spacecraft relative dynamics. In this work we introduce a rigorous two-step state vector transformation, based on a Jordan form, in order to decouple the two modes and be able to focus on either of them independently. The obtained results give a deep insight to the control designer, allowing for easy stabilization of the two spacecraft relative dynamics, i.e. canceling out the double integrator mode, which implies a constant drift taking the two spacecraft apart. On the other hand, one could desire an immediate control on the harmonic part of the dynamics, which is here made possible thanks to the decoupled form of the final equations. Furthermore, the obtained decoupled equations of motion present an analytical solution when only along-track control is applied to the spacecraft. This solution is here presented. The phase planes behavior for the controlled cases is reported.

Keywords: *spacecraft relative motion; linear dynamics transformation; Jordan form.*

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