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ONBOARD ATTITUDE PERTURBATION ESTIMATION FOR GYROLESS SPACECRAFT

Abstract

Impacts of the various environmental attitude perturbations on the absolute measurement accuracy (AMA) and absolute pointing error (APE) performance of Earth-orbiting spacecraft are well known. Indeed, because of the stringent relative pointing error (RPE) requirement, most attitude estimation filters are designed as low-pass noise filters with the consequence that they are slow to react to environmental perturbations not modeled in the attitude filter. As the true attitude of the spacecraft is oscillating under the periodic effects of the encountered environmental perturbations, the slow-reacting estimate of the attitude quaternion does not follow these oscillations, decreasing the AMA performance.

A common solution to this problem consists in increasing the bandwidth of the attitude estimation filter in order to follow the effects of the environmental perturbations. However, by doing so, the estimation filter would also react to sensors noise, hence impacting the RPE requirement unless the attitude controller gains are decreased to filter out the noisy attitude state estimates. An integrator would most likely need to be added to avoid a large steady-state error, otherwise the absolute pointing error (APE) specification would not be met. However, experience shows that a controller integrator will reduce the stability margins.

The novel approach proposed in this research is to estimate those environmental attitude perturbations with a nonlinear disturbance observer (NDO) in order to account for the effect of the perturbations in the main estimation filter, thereby improving the AMA, APE and RPE performances of an Earth-orbital spacecraft. To extend the applicability of the proposed solution to gyroless spacecraft, the nonlinear observer is combined with an angular rate determination algorithm and a simple α-filter.

The performance of the proposed perturbation attitude estimation strategy is validated in numerical simulations for different mission scenarios and a parametric analysis of the nonlinear observer is conducted. Simulation results show that an accurate estimation of environmental perturbation torques is achieved and that the estimation error along each axis is bounded. Finally, details on the implementation of the proposed estimation strategy onboard ESA's gyroless PROBA-2 spacecraft and early flight results are discussed.