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IN-ORBIT ALLAN VARIANCE FOR GYROSCOPE NOISE CHARACTERIZATION IN EARTH OBSERVATION SATELLITES

Abstract

The paradigm of Earth observation missions is embracing the use of distributed space systems, particularly satellite constellations. This shift aims to optimize service delivery for emerging imagery markets. Notably, these strategies emphasize the deployment of smaller sensor field-of-views with heightened capacity and revisit rates. However, the challenges associated with this approach include more stringent requirements on pointing accuracy and attitude determination. In order to improve estimations from a given sensor set, the applied filtering algorithm needs precise knowledge of the noise characteristics inherent in each contributing sensor for an optimal tuning. Gyroscopes, frequently employed for both coarse and fine attitude control, demand a comprehensive technique for describing and modeling their error sources. The Allan variance is a standard methodology for characterizing the random behavior of the intrinsic noise of the gyroscopes as a function of integration time. While a fixed low vibration table is often necessary to obtain the data for this analysis, the data acquisition is fairly straightforward in laboratory settings. Ensuring stability during testing is imperative to prevent misinterpretation of external movements or vibrations as internal noise. Unfortunately, these stability requirements present considerable challenges when attempting to conduct such tests in orbit. This work introduces a novel methodology for obtaining the Allan variance curve measured in a controlled laboratory environment using data collected from gyroscopes and star trackers aboard orbiting satellites. By conducting two different tests, each involving a specific satellite maneuver, effectively dividing the integration time range into two regions, the desired level of accuracy is achieved. This discrimination is crucial for validating expected noise parameters post-launch and throughout the satellite's operational lifetime, which becomes critical with the use of COTS gyroscopes not designed or validated for the use in space applications. The feasibility of this approach was initially verified through simulation and subsequently with real orbit data, yielding successful results. This innovative development allows us to re-characterize gyroscopes beyond the assembly and testing facilities to quantify performance degradation over their operational lifespan, attributed to launch conditions, accumulated radiation exposure, or other hazards. The presented methodology represents a significant advancement in ensuring the long-term reliability and performance of low cost Earth observation satellites in distributed systems.