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MODELING AND CONTROL OF AN EARTH OBSERVATION SATELLITE EQUIPPED WITH A SPINNING FLEXIBLE ANTENNA

Abstract

Next-generation satellites feature innovative technologies developed to meet increasingly demanding tasks in space missions. In this scenario, large rotating antennas hold critical importance in driving progress within the Earth Observation landscape. The key advantage of implementing moving payloads is to expand the scanned area with respect to previous technologies, thereby reducing the time required to complete a set of measurements and significantly enhancing data acquisition capabilities. However, this advanced setup leads to a higher degree of complexity in several aspects of the mission design, and in particular in analyzing the overall system dynamic behavior and in designing a suitable attitude control architecture. This study specifically focuses on a spacecraft equipped with a rotating antenna, composed of an articulated flexible boom and a large deployable reflector, and two solar panels. The rotation of the flexible antenna induces inertial loads due to (a) centrifugal force, (b) antenna unbalancing and (c) coupling with the overall attitude motion of the spacecraft. As a result, both periodic and steady-state deformations of the antenna affect the observation performance. This research aims to evaluate the deformations occurring in a realistic mission scenario and subsequently mitigate the interaction between flexible and rigid dynamics by controlling the satellite attitude motion. The dynamic equations of the orbiting multibody flexible spacecraft are derived using Kane's formulation, also including the gravitational effects. The reduction of elastic deformation is addressed with a nonlinear feedback attitude control law. This incorporates a flexibility compensation term directly derived from the relationships between the platform controller and the modal amplitude accelerations, reconstructed by using a distributed sensing network. This mitigation accounts for the overall spacecraft elastic dynamics, which is affected by both the antenna

and the solar panels. The control law is aimed at acquiring and maintaining a nadir-pointing orientation, utilizing an array of appropriately steered momentum exchange devices. Precisely, the mean boresight axis of the spinning antenna is directed toward the nadir direction and simultaneously the orientation of the solar panels is optimized for maximum irradiance. To test the effectiveness of the proposed attitude control logic in achieving the desired orientation while compensating for antenna deflection, numerical tests are performed. These simulations demonstrate the capability of the control system to mitigate the influence of the flexible appendages on the attitude motion. The study is completed with a comprehensive analysis of the uncertainties that may impact the performance of the controller.