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Space Structures II - Development and Verification (Deployable and Dimensionally Stable Structures) (2)

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AN ATTITUDE/SPIN CONTROL ARCHITECTURE FOR A SPACECRAFT EQUIPPED WITH A FLEXIBLE ROTATING PAYLOAD BASED ON MODEL PREDICTIVE CONTROL

Abstract

Many Earth observation missions, implementing space-based microwave sensing techniques for collecting Earth surface information, employ spinning sensors to cover large swaths of terrestrial areas, thus improving the rate at which global maps of those measured data are generated. These spacecraft (as Soil Moisture Active Passive (SMAP) developed by NASA or Copernicus Imaging Microwave Radiometer (CIMR) currently under development by Thales Alenia Space) consist of a main non-spun platform and a rotating part composed of an antenna boom, a deployable reflector and a rotation mechanism. As the reflector is designated to rotate about the nadir axis producing conically scanned antenna beams with precise surface incidence angle, the payload pointing accuracy needs to be addressed at both spin subsystem and platform level.

In this work, a representative model of the dynamic behaviour of SMAP satellite is developed as a study case to design the proposed control strategies; in particular, the SMAP-like payload structural model is built using FEM commercial codes. The spacecraft is equipped with a Reaction Wheels Assembly (RWA) to accomplish both momentum compensation for the spun element and three-axis attitude control, a motor for the spin mechanism and magnetic torque rods for RWA desaturation.

The objective of the study is to develop the spacecraft control architecture in the frame of Model Predictive Control (MPC) theory. MPC refers to a class of algorithms in which the control action is obtained by computing an open-loop optimal sequence of control moves over a predefined time horizon; moreover, the ability to set constraints on process inputs and outputs directly in the problem formulation allows to account for actuators' limits (as wheels maximum torque and momentum). In the study two operative phases of the satellite are addressed: the spin-up, in which the 6-meter diameter antenna is spun-up to the operative condition of 14.6 RPM, and the Science Phase, in which precise nadir pointing and stability of the flexible system must be kept for acquiring high-resolution measurements. To this purpose, control-structure interaction between attitude/spin control system and flexible dynamics, system's imbalances, motor torque errors and external disturbances are carefully addressed by the control system.

A nonlinear simulator reproducing the in-orbit dynamics of the flexible spacecraft is then developed to validate the performance of the MPC controller in terms of pointing accuracy and robustness to uncertainties. Furthermore, to properly estimate its effectiveness, a comparison with a baseline controller shaped to achieve the prescribed mission requirements is presented.