Paper ID: 51041
oral
student

IAF ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Dynamics (1) (5)

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DESIGN AND HARDWARE-IN-THE-LOOP TEST OF AN ACTIVE MAGNETIC DETUMBLING AND POINTING CONTROL BASED ONLY ON THREE-AXIS MAGNETOMETER DATA

Abstract

The subject of this work is the design of an active and purely magnetic attitude control system which is effective within the constraints set on time of operations, power consumption and peak electric current for a typical CubeSat mission. The control includes both a detumbling and a target area pointing algorithm. The latter is meant to be used as a backup solution, in case of failure of the primary strategy (i.e. Nadir pointing), and can provide stabilization and pointing of the spacecraft without the need of any attitude information, therefore increasing the likelihood to save the mission.

In particular, the algorithm allows achieving a desired attitude with respect to the direction of the Earth's magnetic field vector. It follows that an adequate set of algorithm parameters can be selected to produce nadir pointing, within a desired accuracy, over an area of interest.

Since this control is based only on magnetometer measurements, the calibration of the magnetometer is mandatory to achieve the required accuracy. This was performed by means of the Least Square Method, to estimate and compensate the effects of hard and soft iron distortions. The calibration algorithm was implemented on Field Programmable Gate Array (FPGA) and tested in a Helmholtz cage facility, which allows recreating the magnetic field along the spacecraft orbit. The results showed that even an off-the-shelf magnetometer can achieve adequate performance.

The control algorithms were optimized for the implementation on FPGA. In fact, the target area pointing algorithm was designed to reuse the structure of the primary pointing strategy, so if switching from one to the other they would reuse the same resources, optimizing the area usage on the FPGA. The system was tested using a Hardware-in-the-loop (HiL) setup, developed using System Generator for Digital Signal Processing and Simulink. The HiL platform includes models of the satellite attitude dynamics, the magnetic environment and the magnetic sensors and actuators. Noise on the sensors and disturbances on the attitude dynamics have been included as well, to test the robustness of the algorithm. The results can provide useful information to select the parameters of the control, such as the gains, to estimate the limits of the system, the time of operations and prevent failures.