24th IAA SYMPOSIUM ON SMALL SATELLITE MISSIONS (B4)
Generic Technologies for Small/Micro Platforms (6A)

Author: Mr. Shinya Fujita
Tohoku University, Japan

Mr. Yuji Sato
Tohoku University, Japan
Dr. Toshinori Kuwahara
Tohoku University, Japan
Dr. Yuji Sakamoto
Tohoku University, Japan
Prof.Dr. Kazuya Yoshida
Tohoku University, Japan

ON-GROUND VERIFICATION OF ATTITUDE CONTROL SYSTEM FOR 50-KG-CLASS MICROSATELLITES USING A HARDWARE-IN-THE-LOOP-SIMULATOR

Abstract

Space Robotics Laboratory of Tohoku University is currently developing a series of 50-kg-class microsatellites for Earth observation. In this paper, we propose design of an attitude control system (ACS) focusing on its computers which enables ground target tracking with an accuracy of 0.1° and present evaluation results tested by a hardware-in-the-loop-simulator. Two different types of on-board computers were used cooperatively to archive high-precision and robust attitude control. This ACS will be equipped on our 4th microsatellite "RISESAT" and launched by the Epsilon rocket in 2018.

The primal mission of RISESAT is multi-spectral observation of the Earth surface using a 5 m GSD high-precision-telescope with liquid-crystal-tunable-filters. During an observation, the high-precision-telescope takes a dozen images of a ground target by changing wavelength. General Earth observation satellites using push-broom cameras require high attitude stability to obtain continuous images. However, RISESAT has to track a ground target with an accuracy of 0.1° and 0.008°/s attitude stability because imaging and wavelength switching take few seconds in total. Maximum angular velocity while tracking amounts to 0.8°/s when flying over the target. Therefore, not only noise of sensors but also delay non-uniformity or errors of communication between sensors and computers have great effects on control accuracy.

To solve this problem, new ACS consists of Attitude Control Unit (ACU) and Sub-Attitude Control Unit (ACUS) was developed. Primal attitude computer ACU is a FPGA-based computer and can simultaneously communicate with multiple sensors and actuators such as star trackers and reaction wheels. Communication timing of each components are measured with an accuracy of 0.1 ms based on pulse-per-second signal from a GPS receiver. Reliability of the hardware is proven by our 3rd microsatellite "DIWATA-1".

Fine attitude determination and control using extended Kalman filters (EKFs) are executed by an auxiliary attitude computer ACUS. ACUS is a microprocessor-based high-speed computer and is connected to downstream of ACU. Using a GPS receiver, an EKF and the IAU76/FK5 model including 106th order nutation model, ACUS can determine its orbit with an accuracy of 20 m in geocentric-celestial-reference-frame within 1 ms. Power consumption (0.6 W) and board dimension (90 × 87 mm) of ACUS are also suitable for CubeSats. ACUS receives information of sensors every 100 ms from ACU and sends back processed results through a serial communication interface.

A hardware-in-the-loop-simulator contributed to verify the ACS including effects of computation and communication time. The ACS design and evaluation results are described in this paper.