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DESIGN AND VALIDATION OF THE ATTITUDE CONTROL SYSTEM FOR THREE-AXIS STABILIZED NANO-SATELLITES

Abstract

The attitude determination and control system (ADCS) plays an indispensable role in nano-satellite on-orbit operation and it could greatly affect the satellite's performance. The design of ADCS should take the volume limitation, power consumption as well as reliability into account. This paper introduces a hardware design of ADCS for three-axis stabilized nano-satellites — "Tian Tuo" (TT). TT, developed by National University of Defense Technology of China, is a nano-satellite series within the 10-50 kg mass range. Up to now, three TT nano-satellites have been successfully launched for technology demonstration, such as optical imaging, space-based AIS and space-based ADS-B validation, etc. Among the TT nano-satellite series, TT-1 and TT-3 nano-satellites share the similar ADCS architecture to achieve three-axis attitude stabilization. In the design of attitude determination subsystem, both of TT-1 and TT-3 nano-satellites employ sun sensors, magnetometers and a three-axis gyro to obtain the attitude measurements. The quaternion estimator (QUEST) and unscented Kalman filter (UKF) algorithm are introduced for the attitude determination. For the attitude control subsystem of TT-1, three-axis magnetic torquers combined with a pitch bias momentum wheel are utilized to accomplish the three-axis stabilization control. The momentum wheel enforces the attitude stabilization in roll and yaw directions by spinning at a fixed rate in the pitch direction of the satellite, and the magnetic torquers generate three-axis control torque by interacting with the geomagnetic field. To improve the attitude control reliability and accuracy of TT-3, four reaction wheels are designed as the main actuators to stabilize the attitude with high precision by producing reaction torque, and the magnetic coils are adopted as the deputy actuators to damp the angular velocity and reaction wheel rates. On-orbit data received by ground station is conducted to analyze the performance of the designed ADCS. The results show that the design of ADCS for three-axis stabilized nano-satellite is suitable, robust and feasible.