ATTITUDE GROUND SYSTEM FOR THE MAGNETOSPHERIC MULTI-SCALE MISSION

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Abstract: *The Magnetospheric Multiscale (MMS) mission is a Solar-Terrestrial Probe mission consisting of four identically instrumented spin-stabilized spacecraft flying in an adjustable tetrahedron formation around the Earth. The MMS spacecraft formation allows for three-dimensional study of the magnetic reconnection, which is the primary objective of the mission. The MMS spacecraft were launched on March 13, 2015 GMT. Due to the challenging and very stringent attitude and orbit requirements for maintaining the science orientation, as well as the formation of the spacecraft, multiple ground functionalities were designed to support the mission. These functionalities were incorporated into a ground system known as the Attitude Ground System (AGS).*

AGS has been used widely to support a variety of three-axis and spinning stabilized spacecraft missions within NASA GSFC. The original operational concept of the MMS mission required the AGS to perform highly accurate predictions of the effects of environmental disturbances on the orientation of the spacecraft, and plan attitude maneuver targets necessary to keep the spin axis within a tolerance box requested for science support. The orbit adjustment or formation control requirements drove the need to also perform calibrations that have never been done before. The mission required to provide fast and accurate calibrated values of the inertia tensor, center of mass, and accelerometer bias for each MMS spacecraft. Some of the ground calibration requirements have been loosen due to the implementation of on-board calibration schemes outlined in a companion paper for this conference (citation pending). The scope of this paper is to describe the original design and actual implementation to verify and validate the performance of the onboard system.

During early design of the AGS functionalities, a Kalman filter for estimating the attitude, body rates, center of mass, and accelerometer bias using only star sensor and accelerometer measurements was heavily analyzed. A set of six distinct filters was evaluated and considered for estimating the spacecraft attitude and body rates using star sensor data only. Four out of the six filters being analyzed were used to support the Time History of Events and Macroscale Interactions during Substorms (THEMIS) and Space Technology-5 (ST-5) missions. The analyses exposed high dependency and sensitivity on the knowledge of the spacecraft inertia tensor for both body rates and accelerometer bias estimation. The conclusion of the analysis led to the design of an inertia tensor calibration technique using only star sensor data. Another important result of the analysis was a design of two Kalman filters; one to estimate the spacecraft attitude and body rates, and one to estimate just the accelerometer bias, instead of a fully augmented one. The calibration results of the mass properties (inertia tensor and center of mass), as well as *the performance of the accelerometer bias, spacecraft attitude and body rates filters using flight data are presented and compared against the mission requirements.*

Keywords: *Kalman filters, SpinKF, accelerometer bias, calibration of mass properties, inertia tensor calibration, center of mass calibration.*