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ALFACRUX CUBESAT MAGNETIC DIPOLE DETERMINATION AND ATTITUDE MOTION ESTIMATION USING MAGNETOMETER MEASUREMENTS ONLY

Abstract

Nanosatellites of CubeSat format are frequently used for student education purposes as well as for in-flight space qualification of satellite on-board systems. Short development time of the satellite and comparatively fast launch allow to the student team to obtain skills in almost all topics of aerospace engineering – from mission design, hardware and software development to satellite in-orbit commissioning and telemetry data processing. The AlfaCrux nanosatellite is a 1U CubeSat, developed by the LODESTAR team at the University of Brasília and launched by the Falcon 9 Transporter-4 mission in March 2022. The AlfaCrux is a radio amateur and educational mission to provide a hands-on experience to students and professors in the complete process of developing and operating a space mission. The satellite is equipped with magnetometer and angular velocity sensors built into a printed circuit board with an onboard computer. Its measurements, obtained via radio communication channel, are used for attitude motion reconstruction. The satellite is not equipped with attitude actuators, so its attitude motion is affected by natural torques in orbit, particularly by gravitational torque and magnetic torque due to residual magnetic moment of the satellite. The residual magnetic moment can be produced by onboard devices during operation and it can vary in time.

In this paper the magnetometer measurements are used to estimate the attitude motion and magnetic parameters of the satellite using the minimization technique of the sum of squared difference between the in-flight measurements and measurements estimation according to attitude motion model. The minimization is performed by the differential evolution algorithm, the estimated parameters are the initial quaternion, angular velocity vector, the magnetic dipole vector and the magnetometer measurement bias. It was obtained from the telemetry data processing that the CubeSat dipole is almost aligned with y-axis of the satellite, though its value slightly varies in time. The obtained magnetometer measurements are processed by extended Kalman filter in order to verify its performance and accuracy using the in-flight data. Along with the attitude quaternion and angular velocity vector, the state vector includes the magnetic dipole vector and the magnetometer measurement bias, which is changing due to variable residual magnetic dipole. The extended Kalman filter is implemented on onboard computer, and the results of its testing using hardware-in-the-loop technique with in-flight measurements are presented in the paper.