Pulse Width-Pulse Frequency Modulation of Thrusters for the Micro-Satellite SSETI/ESMO

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ABSTRACT

In this project we have investigated modulation of controller signals for attitude control thrusters. Our main result is that pulse width-pulse frequency (PWPF) modulation holds a considerable advantage over bang-bang controller systems.

In the satellite industry, demands for lower fuel consumption as well as higher pointing accuracy, has forced researchers to develop better methods of controlling satellite thrusters ever since the first advanced space mission.

This has lead to research on several different methods to "translate" the controller output signal to an on/off signal that can be fed directly to a thruster system. The different methods have their own advantages, and can be used in different situations. But it is of course advantageous to have methods that performs close to optimal for all kinds of systems and configurations.

Pulse-width pulse-frequency (PWPF) modulation of the controller signal is the most commonly implemented thruster control scheme. This method is based on fairly old technology, but still stands strong today. A PWPF modulator consists of a first order lag filter, a Schmitt trigger and a feedback loop. This system modulates both the pulse width and the pulse frequency, and gives a quasi-linear operation of the thrusters.

A bang-bang controller system and a PWPF modulation system were compared. The PWPF modulator and the bang-bang controller were implemented in the model of the European Student Earth Orbiter (ESEO) satellite, for a simulation comparison. The ESEO is chosen because the physical parameters for the European Student Moon Orbiter (ESMO) still not are decided. The physical parameters of ESMO are believed to be similar to those of ESEO.

The simulations were divided in two parts, where one part consisted of simple simulations and the other with noisy simulations. The simple simulations were made with zero initial conditions, static simulation environment and no noise. The noisy simulations were made with fairly aggressive initial conditions, dynamic satellite environment and induced noise. The simulations were done for both linear and nonlinear controllers.

The pointing accuracy was determined by examining the Euler angels, and fuel consumption was determined by looking at the PWPF modulator and bang-bang controller output.

All simulations with PWPF modulation of the thruster control signal were compared with similar bang-bang control systems. The results showed both equal or better pointing accuracy and lower fuel consumption for PWPF modulated systems, regardless of regulator and initial conditions.

Further work on this topic will include studies where we look deeper into how the different parameters of the PWPF modulator affect performance. We will also attempt to find optimal parameters with respect to fuel consumption.

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