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TETHER-AIDED FORMATION KEEPING FOR MULTIPOINT SCIENTIFIC MEASUREMENTS IN LEO

Abstract

This study has been conducted as a part of the trade-off analysis for a tentative ionospheric mission, whose objective is to conduct multipoint ionospheric plasma measurements, distinguishing temporal and spatial variations of the measured parameters. It has been shown that for the experiment in question a formation of four CubeSats is required, which is deployed in a near polar low-Earth orbit and is maintained so as to keep intersatellite distances at 500 to 1000 meters. Furthermore, the four spacecraft should form a tetrahedron, whose shape must be as close to a regular tetrahedron as possible at least near the poles but preferably for as long a part of the orbit as possible. A quality factor ranging from 0 to 1 is usually introduced to quantify the quality of the tetrahedron shape.

Prior research shows that maintaining a regular tetrahedral formation of free spacecraft even for the specially designed relative orbits optimized through the analysis of Hill-Clohessy-Wiltshire equations, requires frequent or continuous orbit corrections, which imposes additional constraints on CubeSats design and shortens the mission's lifetime. It turns out that introduction of only one tether into the system to connect two of the four satellites, on one hand, does not essentially change the system's complexity, while on the other hand, allows significantly improving the characteristic formation quality. A proper choice of initial conditions for the two connected spacecraft ensures gravity-gradient stabilization of the subsystem and prevents secular drift over time. This leads to a substantial decrease in the complexity of searching proper initial conditions for the four-spacecraft configuration by utilizing the linearized HCW equations. It is known that for the optimal configuration of four free satellites the formation quality can be made greater than 0.6, whereas our setup with two of the four satellites tethered allows increasing this benchmark value to 0.9.

Our study then goes on to address the effect of J2 perturbation on the proposed formation. Moreover, a range of different altitudes, inclinations and formation sizes are investigated. Results show that initial conditions optimization leads to a slower degradation rate of the uncontrolled formation. The study ends with proposing an optimal control strategy that aims to maintain the designed reference trajectories of the four spacecraft. The deployment phase accompanied by a control strategy to obtain the desired trajectory after the deployment is discussed.