Assessment of Power Consumption Improvement in Position and Attitude Control of Spacecraft using Electromagnetic Force Assist

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Abstract. Electromagnetic Force Assist is proposed as method to reduce power consumption in formation flight maneuvers between spacecraft that use auxiliary coils to generate electromagnetic forces in proximity operations. This paper estimates the potential improvement in power consumption (as indirect metric of potential propellant savings) in spacecraft maneuvers using RINGS (Resonant Inductive Near-field Generation Systems), a prototype system developed to investigate electromagnetic formation flight and wireless power transfer between spacecraft. An assessment of power consumption reduction is based on comparing the control effort required in selected 3-DOF maneuvers. The control effort performance of a linear quadratic Gaussian (LQG) controller for thruster-only maneuvers is used as baseline, and is compared to the control effort when two other controllers (based on sliding mode control and feed-forward control) provide electromagnetic force assist in addition to the baseline thrusters.

Introduction and Motivation

Formation flight requires that the spacecraft involved are able to provide station keeping [1-4]; perturbations such as solar pressure forces consumption of onboard propellant for this purpose [5]. To increase the life expectancy of a formation mission, electromagnetic actuation has been proposed as means to assist the onboard thrusters when compensating disturbances during station keeping. Solar panels provide access to unlimited electric energy that can be used to power actuation coils to generate multi-axial electromagnetic forces. This paper evaluates for the first time the potential propellant savings while using electromagnetic force assist in motion control of formation maneuvers, using the RINGS platform. The paper uses the control effort of a LQG controller (using thrusters only) as baseline, to compare with the control effort of two other controllers that use a combination of thrusters and electromagnetic force assist on a set of proposed maneuvers.

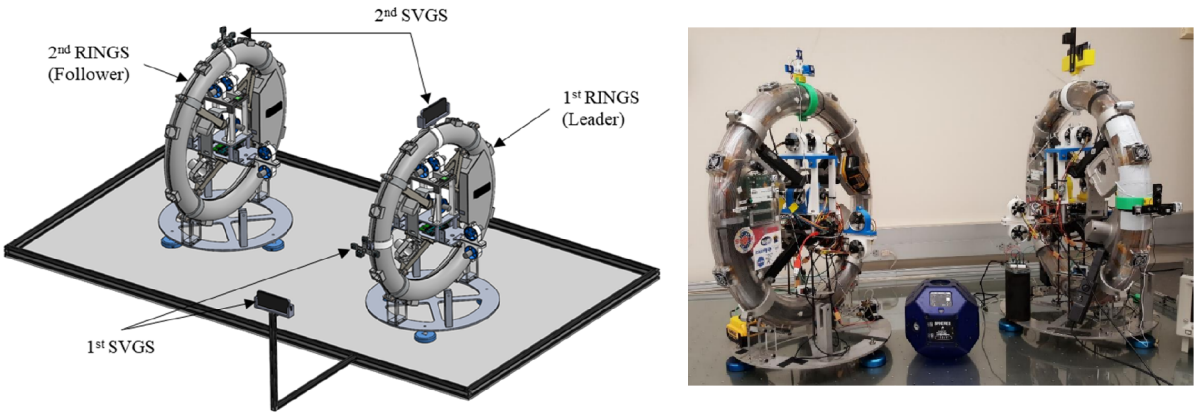

Figure 1. Demonstration of electromagnetic force assist for 3-DOF formation maneuvers using RINGS

Results and Discussion

This paper presents an assessment of power savings in spacecraft formation flight by use of electromagnetic force assist. The assessment was done in simulation using 3-DOF planar motion control platform of the RINGS prototype spacecraft. The results indicate that significant savings in control effort are possible by using electromagnetic force assist, in particular when combining a feedforward controller with sliding mode feedback. The effectiveness of electromagnetic force assist depends on the specific path followed during a maneuver. Optimized path planning is therefore required to maximize the benefits of the proposed method.

References

[1] Martin, M., Klupar, P., Kilberg, S., Winter, J. (2001) Techsat 21and revolutionizing space missions using microsatellites. *AIAA*, **SSC01**.

[2] Sabol, C., Burns, R., McLaughlin, C. (2001) Satellite Formation Flying Design and Evolution. *AIAA J. Spacecraft and Rockets*, **38:** 270-278.

[3] Hariri, N., Gutierrez, H., Rakoczy, J., Howard, R., Bertaska, I. (2020) Proximity Operations and Three Degree-of-Freedom Maneuvers Using the Smartphone Video Guidance Sensor, *Robotics*, **9(3) 70:** 1-18.

[4] Miller, D., Sedwick, R. (2002) NIAC Phase I Final Report, 'Electromagnetic Formation Flight', Massachusetts Institute of Technology.

[5] Kwon, D., Sedwick, R., Lee, S., Ramires-Riberos, J. (2011) Electromagnetic Formation Flight Testbed Using Superconducting Coils, *AIAA J. Spacecraft and Rockets*, **48**: 124-134.