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SPACE SYSTEMS SYMPOSIUM (D1)
Space Systems Architectures (4)

Author: Mr. Giuliano Punzo
University of Strathclyde, United Kingdom, giuliano.punzo@strath.ac.uk

Dr. Derek Bennet
University of Strathclyde, United Kingdom, derek.bennet@strath.ac.uk
Dr. Malcolm Macdonald
Advanced Space Concepts Team, United Kingdom, malcolm.macdonald.102@strath.ac.uk

A FRACTALLY FRACTIONATED SPACECRAFT

Abstract

The advantages of decentralised multi-spacecraft architectures for many space applications are well understood. For example, a popularly envisaged application of such an architecture is the synthetic aperture antenna; composed of, typically, receiving elements carried on-board multiple spacecraft flying in precise formation. In this paper decentralised control means, based on artificial potential functions, together with a fractal-like connection network, are used to produce the autonomous and verifiable deployment and formation control of a swarm of spacecrafts into a fractal-like pattern. The effect of using fractal-like routing of control data within the spacecraft fleet generates complex formation shape patterns, while simultaneously reducing the amount of control information required to form such complex formation shapes. Furthermore, the techniques used ensure against swarm fragmentation, which can otherwise be a consequence of the non-uniform connectivity of the communication graph. In particular, the superposition of potential functions operating at multiple levels (single agents, subgroups of agents, groups of agents) according to a self-similar adjacency matrix produces a fractal-like final deployment with the same stability property on each scale. Results from the investigations carried out so far clearly indicate the feasibility of this approach, outline its robustness characteristics, and versatility in formation deployment and control. Considering future high-precision formation flying and control capabilities, this paper considers, for the first time and as an example of a fractally fractionated spacecraft, a decentralised multi-spacecraft fractal shaped antenna. A fractal antenna pattern provides multiple resonance peaks, directly related to the ratios of its characteristic physical lengths. Such a scenario would significantly improve the level of functionality of any multi-spacecraft synthetic aperture antenna system. Furthermore, multi-spacecraft architecture exploiting fractal-like formations can be considered to investigate multi-scale phenomena in areas such as cosmic radiation and space plasma physics. Both numerical simulations and analytic treatment are carried out demonstrating the feasibility of deploying and controlling a fractionated fractal antenna in space through autonomous decentralised means.