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DESIGN OF A SAR CUBESAT FORMATION FLIGHT CONSTELLATION FOR MARITIME SURVEILLANCE

Abstract

Compact SAR formations operating in SIMO or MIMO mode are gaining interest in literature, with several flying demonstrations appearing in recent years. The interest stems from benefits in signal to noise ratio of a factor or N in SIMO and N in MIMO modes, with a potential swath coverage N times wider than that of a single SAR due to N-1 ambiguity suppression. Both SNR gain and ambiguity suppression enables the design of a new generation of CubeSat-based SAR sensors, otherwise impossible. The all-weather-day-and-night capabilities of SAR imaging, make these formations valuable for several application in the field of hazards, emergency, and security. This paper covers the design of a constellation of CubeSat formation flights for Synthetic Aperture Radar surveillance of maritime traffic, leveraging developments in MIMO distributed SAR systems to achieve system performance and a high revisit rate. Additionally, multiple images can be generated of the same scene in slightly different times, enabling the identification and measures of moving targets (be them vehicles or sea currents), by Along-Track-Interferometric approaches. These advantages are to be considered on top of the flexibility, robustness, and scalability common to distributed sensors formation. The design entails some challenges, such as the precise keeping of the inter-sensor distance of the formation along and across-track, and the design of the orbits for the constellations of formations to meet the observational requirements. The design is conducted using a set performance baseline for individual satellites and a hypothetical set of requirements for minimum system performance, including an operational area of interest set as the Mediterranean Sea. The optimal formation size is investigated at a high level and specified required performance is determined. Following this, the optimal constellation required to achieve the specified minimum performance is conceived using a multi-objective genetic algorithm considering Walker Delta and Walker Star constellation formats. The genetic algorithm focuses on system performance while also considering system cost, both monetarily and from a mission analysis point of view. Two separate operating scenarios are considered in the formulation of the optimal solution, small swath and large swath strip map modes. Each mode consists of a number of satellites in close formation flight in order to achieve the specified minimum performance. Once identified, the performance of solutions output by the genetic algorithm is examined across the target area. Finally, the lifetime of the constellation is investigated under several perturbations to assess constellation maintenance requirements.