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A NOVEL CONCEPT FOR EARTH REMOTE SENSING USING A BI-STATIC FEMTO-SATELLITE SWARM IN SUN SYNCHRONOUS ORBIT

Abstract

Recent developments in spacecraft design exploiting micro-electro-mechanical systems (MEMS) with sensing, computing, full-duplex communications and micro-power generation have introduced the prospect of a new class of low-cost, low-mass femto-scale spacecraft suitable for use in swarm and distributed missions. Current concepts for functional devices have been designed by exploiting existing technologies to develop femtosatellite prototypes. Distributed femtosatellites are seen as means of reducing the cost of conventional Earth remote sensing and monitoring missions. In this paper we investigate a swarm of femtosatellites released from a carrier spacecraft to perform a range bi-static radar applications using a novel sparse antenna and digital signal processing concept.

A preliminary design of a femtosatellite using commercial off-the-shelf (COTS) technology is firstly presented which can provide an acceptable level of mission capability and environmental survivability. The prototype is a flat femtosatellite built on Kapton film instead of conventional printed circuit board (PCB) to reduce mass and increase surface area-to-mass ratio. These features enable the femtosatellites to take advantage of solar radiation pressure for orbit control without on-board propellant, extending their orbital lifetime and mission capability. A patch antenna or a Vivaldi antenna can then be used as payload to perform Earth remote sensing or target detection missions.

Due to the limitations introduced by the size and weight, the mission concept is based on dawn-dusk sun synchronous orbits, whose orbit plane remains perpendicular to incoming solar radiation. The femtosatellites would therefore be under direct illumination during the entire orbit without eclipse, maximise electrical power generation for the payload and enabling orbit control using solar radiation pressure.

The concept of a swarm of discrete elements co-operating to enable the implementation of sparse, but extremely large aperture radio frequency antennae is then considered. The antenna directional gain can in principle be adapted by changing the position and attitude of the individual units in the swarm formation.

Using the unique environment enable by a dawn-dusk orbit, with solar radiation pressure used for orbit control, the sparse and randomly located femtosatellites exploit unsynchronised phase rotations and can be described by a non-coherent model to analyse the performance of the swarm for multiple bistatic radar applications. Example scenarios, such as ship and aircraft tracking and in-orbit debris tracking are

considered to characterise the feasibility of different applications. Furthermore, the sizing of the main carrier spacecraft is also considered.