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Flower elliptical constellation of millimeter-wave radiometers for precipitating cloud monitoring at geostationary scale

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Millimeter-wave observation of the atmospheric parameters is becoming an appealing goal within satellite radiometry applications. The major technological advantage of millimeter-wave (MMW) radiometers is the reduced size of the overall system, for given performances, with respect to microwave sensor. On the other hand, millimeter-wave sounding can exploit window frequencies and various gaseous absorption bands at 50/60 GHz, 118 GHz and 183 GHz. These bands can be used to estimate tropospheric temperature profiles, integrated water vapor and cloud liquid content and, using a differentia spectral mode, light rainfall and snowfall.

Millimeter-wave radiometers, for given observation conditions, can also exhibit relatively small field-of-views (FOVs), of the order of some kilometers for low-Earth-orbit (LEO) satellites. However, the temporal resolution of LEO millimeter-wave system observations remains a major drawback with respect to the geostationary-Earth-orbit (GEO) satellites. An overpass every about 12 hours for a single LEO platform (conditioned to a sufficiently large swath of the scanning MMW radiometer) is usually too much when compared with the typical temporal scale variation of atmospheric fields. This feature cannot be improved by resorting to GEO platforms due to their high orbit altitude and consequent degradation of the MMW-sensor FOVs.

A way to tackle this impasse is to draw our attention at the regional scale and to focus non-circular orbits over the area of interest, exploiting the concept of micro-satellite flower constellations. The Flower Constellations (FCs) is a general class of elliptical orbits which can be optimized, through genetic algorithms, in order to maximize the revisiting time and the orbital height, ensuring also a repeating ground-track. The constellation concept nicely matches the choice of mini-satellites as a baseline choice, due to their small size, weight (less than 500 kilograms) and relatively low cost (essential when deploying several identical speceborne platforms). Moreover, the micro-satellite solution clearly addresses the choice of small passive sensors with small size, low weight and power consumption, features which cannot be usually satisfied by active sensors. In this respect, MMW technology is the most compatible with the specifications and constraints of micro-satellites.

In this work, we will discuss the numerical results of a feasibility study aimed at designing a Flower elliptical constellation of 3 micro-satellite millimeter-wave radiometers for pseudo-geostationary atmospheric observations over the Mediterranean region. The Flower constellation will be optimized in such a way to simulate a pseudo-geostationary observation of the Mediterranean area with an observation repetition time less than 2 hours. The mission requirements request the retrieval of thermodinamical and hydrological properties of the troposphere, specifically temperature profiles, integrated water vapor and cloud liquid content, rainfall and snowfall. Several configurations of the MMW radiometer multi-band channels will be discussed, pointing out the trade-off between performances and complexity. Integrated estimation algorithms, based on a Bayesian approache, will be illustrated to retrieve the requested atmospheric parameters, discussing its sensitivity to sensor radiometric precision and accuracy within each frequency-set configuration. After this numerical study, a review of the mission requirements and specifications will be also proposed.