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OPTIMIZATION OF LOW EARTH ORBIT SATELLITE CONSTELLATIONS FOR REGIONAL POSITIONING

Abstract

Satellite navigation constellations orbit the Earth in medium and geosynchronous orbits. Their high altitude provides wide coverage, which may be redundant if only regional coverage is needed, at a high launching cost. We propose a design scheme for regional navigation satellite constellations in low-Earth orbits. We aim at producing long and continuous coverage durations, characterized by a minimized Geometrical Dilution of Precision (GDOP), with respect to a predefined mid-latitude ground location. The design process is composed of three stages. First, we determine the semimajor axis, eccentricity, and inclination by constraining the satellites to pass from south to north and from north to south in a subsequent orbit over the ground location. Second, we uniformly distribute the satellites over three arcs of three equidistant orbital planes, where the satellite arc of the central plane is centered over the ground location. Third, we select the differential longitude of the ascending node between the planes, the differential argument of latitude between the satellites, and the angular shifts of the arcs in the two external planes, with respect to the arc in the central plane, by minimizing the GDOP integral.

The proposed method produces constellations that provide GDOP-optimized and continuous coverage windows, recurring twice each day. The results include numerical solutions for constellations in altitudes of 500 to 850 km, with ground locations positioned at latitudes of 30 to 60 deg, and number of satellites ranging from 15 to 50. Each coverage duration spans from 30 to 100 minutes, depending on the number of satellites and altitude, with a mean GDOP of approximately 3. We infer the optimal satellite arrangements among the three orbital planes for any given number of satellites, by examining a study case. Moreover, we show that for each constellation altitude, ground location latitude, and a satellite arrangement, there are up to 2 optimal solutions, which differ in their angular shift values. For performance verification, we use a GMAT simulation, which implements a gravitational field of degree 25 by order 25, solar radiation pressure, and lunisolar gravitational perturbations. This paper main contribution is the optimal geometry analysis of low Earth orbit satellite constellations, which are designed for regional positioning and for long and continuous coverage durations.