

Analysis of perturbations and station-keeping requirements in highly-inclined geosynchronous orbits

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In recent years, the growing volume of activities in the northern regions has produced an increasing request for communications services. Several studies have concluded that there are already unsatisfied demands for communications services in the Arctic and that adequate solutions must be developed to meet current and future requirements. Coverage of high-latitude regions (north of, say, 70° degrees) is not possible (or is seriously limited) from the geostationary orbit. On the other hand, low-altitude orbits require large constellations. Well-known alternative solutions are represented by the Molniya and Tundra orbits (at critical inclination with period of 12 and 24 hours, respectively), characterized by a moderate eccentricity and with the argument of perigee at 270° so as to set the apogee at high latitudes. Recently, a geo-synchronous, eccentric polar orbit, called Tundra polar orbit, has been proposed because its 90° inclination eliminates the precession of the ascending node and its 24 h period allows a single, long contact per orbit with the ground station. However, due to the non-critical inclination, the perigee of this orbit is not fixed.

In this work, we have considered a family of eccentric, highly-inclined geosynchronous orbits defined over a wide range of orbital elements. By means of a high-precision model of the terrestrial gravity field supplemented by an adequate representation of other environmental disturbances (lunisolar third-body perturbations, solar radiation pressure and relativistic correction to gravity), we have studied the orbital evolution of these orbits: we have analysed and understood the effect of each perturbation individually and we have identified and arranged specific orbital configurations which allow to reduce or eliminate the motion of the ascending node in the groundtrack. This, in turn, helps minimize the fuel consumption for station-keeping. We have analysed the station-keeping requirements and we have laid out a maneuver strategy that optimizes the fuel consumption. The methods adopted, in particular the way in which the orbital perturbations are treated and the numerical simulations are set up, contain aspects of novelty. The results obtained offer interesting indications for the implementation and station-keeping of satellite constellations in these orbits.