Characterization of the Solar Radiation Pressure Perturbation on the Eccentricity Vector and Applications for Eccentricity Control of Low Earth Orbits

Javier Sánchez[1], **Miguel Ángel Martín Serrano**[2], **and Ruaraidh Mackenzie**[3]
[1]*GMV at ESA/ESOC, Robert-Bosch-Str. 5, 64293 Darmstadt Germany,*
telephone: +496151902416, E-mail: javier.sanchez@esa.int
[2] *SCISYS GmbH at ESA/ESOC, Robert-Bosch-Straße 5, 64293 Darmstadt Germany,*
telephone: +496151902273, E-mail: miguel.angel.martin.serrano@esa.int
[3] *ESA/ESOC, Robert-Bosch-Straße 5, 64293 Darmstadt Germany,*
telephone: +496151902595, E-mail: ruaraidh.mackenzie@esa.int

Keywords: *Eccentricity, Solar Radiation Pressure, Orbit Control, Altitude Control.*

1. Extended Abstract

Most payloads operated in Earth-Observation missions benefit from the fact that observations are taken in similar conditions, which allows applying comparative techniques on the data gathered. The mission design must take this into account by selecting adequate “frozen” orbit parameters in order to satisfy the mission requirements. In the particular case of minimizing altitude variations the selection of the orbit eccentricity and its control plays a fundamental role. Hence, near-circular, polar missions usually select the mean eccentricity at its frozen value located at a mean argument of perigee close to 90 degrees. This point is characterized by the fact that long-periodic perturbations due to the Earth potential on the eccentricity vector vanish. Considering enough terms from the Earth potential expansion it can be demonstrated that, when applying an offset to the frozen eccentricity vector, the long-periodic eccentricity variation describes a clockwise rotation about the critical point with nearly constant angular velocity, which evidences the stable nature of this equilibrium point. In practice, the reference orbit for missions with a repeating ground-track is generated by propagating an initial state vector over a repeat cycle using a detailed Earth potential, iterating to achieve minimal eccentricity vector variation over the cycle. By controlling the spacecraft orbit close to this reference the short-periodic (one repeat cycle) eccentricity variation is nearly the same as that of the reference orbit, whereas the long-periodic variation is kept bounded, leading to precise altitude control.

The frozen eccentricity concept described above is founded on the Earth potential perturbation, which for low Earth near-circular orbits is the main one. However, the effect of the Solar Radiation Pressure (SRP) is clearly visible when the eccentricity vector is close enough to its frozen value. When this is the case the drift induced by both the Earth potential and the SRP are of the same order. Neglecting higher order terms it can be demonstrated that the perturbation on the eccentricity vector due to the SRP can be approximated by a seasonal-dependent constant drift in the e_x, e_y plane. This seasonal dependency is given by the orientation of the Sun direction with respect to the orbital plane.

Operationally, the characterization of the SRP effect on the eccentricity vector provides numerous advantages in the orbit control techniques in missions following reference orbits. Common strategies based on steering the eccentricity vector either towards its frozen value or to positions where its drift is minimal may in some cases not be optimal. Better strategies can be devised by taking into account the effect of the SRP, especially in missions with strict altitude control requirements. This paper describes the approach followed to model the combined perturbation of the Earth potential and the SRP on the eccentricity vector. Thereupon, applications to the eccentricity control of ESA spacecraft are given.

The Sentinel-1A satellite launched in April 2014 follows a Sun-synchronous reference orbit with a ground-track repeat cycle of 175 orbits in 12 days, the Mean Solar Local Time of Descending Node is at 6:00 h. Orbit control requirements establish that the deviation with respect to the Earth-Fixed reference orbit shall be kept within a tube-shaped control band of the order of 100 m. This currently makes Sentinel-1 ESA’s most ambitious Earth-Observation mission in terms of orbit control. Such strict requirements lead to an eccentricity control very close to its frozen value, which in combination with its large solar panels results in the predominance of the SRP perturbation. This effect is especially strong around the summer solstice due to the dusk-dawn orientation of the

orbital plane. The characterization of the SRP effect on the eccentricity enables finding seasonal-dependent eccentricity targets, achieving a more efficient eccentricity control.

The Sentinel-2 mission will also profit from this improved eccentricity control technique. Due for launch in June 2015, Sentinel-2 will be controlled about a Sun-synchronous reference orbit, with a ground-track repeat cycle of 143 orbits in 10 days and a Mean Solar Local Time of Descending Node at 10:30 h. The ground-track deviation has to be kept lower than 2 km and altitude variations smaller than 500 m with respect to the reference orbit. Although the orbit control requirements are not as strict as the ones of Sentinel-1 the operations of its optical payload require that orbit maintenance manoeuvres are performed out of the area dedicated to science. This restricts the orbit control manoeuvres location to an argument of latitude range slightly smaller than 180 degrees. Hence, the direction of the eccentricity changes is limited to a certain range. Considering the combined effect of the Earth Potential and the SRP on the eccentricity, it is possible to find different eccentricity targets for every control cycle. These targets aim at reaching a favourable position of the eccentricity vector at the start of the next orbit control cycle.