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Author: Dr. Duan Xun
University of Barcelona, Spain

Prof. Gerard Gomez
University of Barcelona, Spain
Prof. Josep J. Masdemont
Universitat Politecnica de Catalunya (UPC), Spain
Prof. Xiaokui Yue
Northwestern Polytechnical University, China

AVOID THE SUN-EARTH SYSTEM EXCLUSION ZONES AND STATION–KEEPING CONTROL MANEUVERS FOR A SOLAR SAIL MOVING ALONG A LISSAJOUS ORBIT

Abstract

For orbits around L_1 in the Sun-Earth system, there is a region around the solar disk, as seen from the Earth, which has to be avoided in order that the signals comming from the spacecraft are not hidden by the electromagnetic radiation of the Sun. This exclusion zone is, approximately, of three degrees about the solar disc as seen from the Earth. Something similar happens for orbits around the L_2 point of the same system, that must avoid eclipsed regions due to the Earth or, eventually, some bright regions of the sky.

And this paper also investigates a station-keeping control maneuvers for a solar sail moving along a Lissajous orbit around a collinear libration point. The dynamical model used for the study is the Sun–Earth circular restricted three-body problem perturbed by the solar radiation pressure acceleration.

For the avoid the exclusion zones, at each epoch, there is a one-to-one correspondence between a pair of effective phases and the state on the Lissajous. Using this representation, the 2D tori defifined by Lissajous orbits become straight lines with slope ω_1/ω_2 in the effective phases plane. If the duration of a Lissajous spacecraft mission is long enough, and the satellite will irremediable cross the exclusion zone, so some maneuvers must be foreseen to avoid it. When the solar sail parameters vary the equilibrium points also do, so they will not be aligned with the Sun-Earth direction. As a consequence, after a solar sail maneuver the exclusion zone of the Lissajous orbit changes and, eventualy, can dissapear.

Due to the Lissajous orbits inherent instability, a spacecraft injected in one of these orbits will soon escape from it, and a station– keeping strategy is required to keep the spacecraft close to it. We have designed a control strategy that uses the knowledge of the position, the sail orientation (defined by the cone angle, and the clock angle), and the sail reflectivity parameter. The station–keeping maneuvers are performed changing these sail parameters.

For the definition of the control strategy, we calculate the time-derivative of the unstable amplitude as function of the variations of the cone angle, the clock angle and the reflectivity parameter. If at a given epoch the unstable amplitude of the reference orbit is not zero, one of the solar sail parameters is changed to stabilize it. Several simulations have been done to illustrate the procedure.