Formation Flying in Space-Borne Artificial Magnetic Dipole Field

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In this paper we consider a new dynamical scenario in which a constantly charged spacecraft (follower) moves near a leader spacecraft that follows a circular Keplerian orbit around the Earth, and generates a rotating artificial magnetic dipole. The mass of the follower is assumed to be negligible compared with the one of the leader, which is supposed to be in a high-Earth orbit (such as GEO), so the Lorentz force on the follower due to the geomagnetic field is ignored. With these assumptions, the leader's motion is not perturbed by the follower, which moves only under the influence of the Earth's gravitational force and the Lorentz force. This model was introduced by Peng in [1].

The magnetic dipole is supposed to be produced by three concentric and orthogonal superconducting wires, in such a way that it can point in any direction. In this study we consider three different orientations of the dipole of the leader, radial, tangential and normal, according to its relative position in the orbital plane.

We will focus on the dynamics of the system and its possible use for formation flying. For this purpose we study the zero velocity surfaces and the zero velocity curve projections to classify the allowable domains of the motion. The critical points of the system and their stability are explored, according to the parameters of the model, among which we will pay special attention to the physical parameter, beta, which is defined as the ratio of the leader's mean motion around the Earth to the dipole's rotating rate.

Furthermore, the phase space around the equilibrium points in terms of its Poincaré map representation is fully studied, and the Fourier representation of the Poincaré map results is computed. As a result, the different families of periodic orbits, as well as invariant tori around them are computed. Several formation flying configurations are explored, such as, four satellites are placed at four symmetric equilibrium points, at four suitable periodic orbits around four symmetric equilibrium points, and at one carefully chosen invariant torus around one equilibrium point of type centre × centre × saddle. Finally, linear feedback control is applied for the formation keeping.

[1] C. Peng, “Relative Orbital Motion of a Charged Object near a Spaceborne Radially-Directed Rotating Magnetic Dipole”, IAC-15.C1.4.10, pp. 1–20, Sep. 2015.