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STABLE 3-D TETHER STRUCTURES IN ORBIT

Abstract

In-orbit measurements of physical fields (gravity, geomagnetic, electromagnetic, etc.) are greatly improved when a full tensor of their spatial derivatives is available. Four field strength vector sensors (accelerometer cubes, three-channel magnetometers, etc.) located in the vertices of a non-degenerate tetrahedron make a minimal configuration sufficient for obtaining a full tensor. The preferable sizes vary depending on a mission goal; in many cases it ranges from 1 to 100 km. Tetrahedron flight formations offer a possible solution but they necessitate the determination and maintenance of its configuration. Moreover, the manifold of possible kinematic patterns of such formations is very poor An alternative solution is a set of four satellites or modules of the same satellite tied to one another with tethers, a tetrahedron. All tethers in it need to be permanently stretched to assure the stability of its configuration. Spinning up the tetrahedron creates the centrifugal force, which helps to stress the tethers. Yet, centrifugal force alone cannot keep all links simultaneously stretched because there is no force along the spin axis. Yet, a combination of spin with gravity gradient may be a solution. A regular tetrahedron i.e. that with all tethers having equal length and all masses equal, is known to lose its stability over a part of its orbital period, no matter what is its orbit and initial spin. To have the tetrahedron stretched despite the orbital motion, the spin axis should evolve so as to follow the geocentric radius vector. In other words, the rotation referred to the orbital frame will be permanent. Gravity torque should drive this fast evolution. Obviously it cannot do so at high spin rates. On the other hand, the spin has to provide a sufficient centrifugal force. Similar opposing constraints are put on the tetrahedron shape and angle between the radius vector and the spin axis. Nevertheless, the analysis presented in the paper revealed a narrow domain of tetrahedron stability.