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DEPLOYMENT DYNAMICS OF MESH ANTENNAS WITH A NOVEL MULTISCALE MODELING APPROACH

Abstract

Deployable mesh antennas have been of increasing interest to the aerospace industry in recent decades because of their high packaging efficiency and low areal densities. Structurally, an antenna is constructed primary of a cable network attached to metallic mesh to reflect electromagnetic signals and a foldable truss that unfolds the antenna from its stowed state for launch to its deployed state in orbit. Failure of the truss to unfold the antenna may result in an immediately fatal failure of the satellite task. Therefore, understanding the deployment dynamics of mesh antenna is of great concern for designing purpose. A flexible multibody simulation is supposed to be a promising methods to study the deployment dynamics. And, in the past decades, great progress do have been achieved on modeling three-dimensional moving flexible bodies, such as cables and beams. However, fulfilling a system-level deployment simulation of a large antenna remains an extraordinarily challenging task. In our opinion, the bottleneck problem is the inherent multiscale nature in both length scale and time scale. Taking the Astromesh-I or Astromesh-II as an example, the length scale spans four orders of magnitude because the pulleys are 10mm, trusses are 1m and the driving cable is 100m; the time scale spans five orders of magnitude because the contact event is 1ms and the entire unfolding process last for 100s. In simulation, those problems conventionally demands fine finite element mesh and small integration time step, resulting in extremely low calculation efficiency. Fortunately, the central multiscale problem comes from the contacts between the pulleys and the driving cable since it is the common source of small length and small time duration. To speed up the simulation, we proposed a novel model method of the pulley-cable system. The basic idea is using a variable-length cable element to model the driving cable, a constraint to locate the contact point between a pulley and the driving cable, and an equivalent force to account for the friction effect. This modeling approach significantly reduced the level of multiscale, reduced the number of generalized coordinates, improved the simulation efficiency, and made a full-scale antenna simulation feasible. Based on it, we fulfilled the deployment simulations of a 12-m Astromesh-I and a 6-m Astromesh-II. Detailed deployed kinematics, dynamics and energetics were systematically investigated. The obtained understanding on deployment dynamics is helpful on antenna design, and the developed multiscale modelling technique can also be applied to other applications.