Abstract

High-bandwidth satellite-based telecommunication demands large-diameter antenna reflectors (LDR). Launching of monolithic LDR antennas of sizes 6m or more is limited by the launch vehicle’s payload fairing space. A foldable antenna with space deployment mechanisms is hence used. The deployment process of the antenna is the process of transition from folded and strapped structure to a locked structure, which is complicated because of the presence of backlash, friction, and misalignment due to manufacturing accuracy. An attempt has been made to explore the various foldable configurations reported in the literature for smooth and effective deployment motion with a focus on configurations with space heritage. Mesh antennas are preferred for large-size deployable reflectors due to low manufacturing complexity, ease in deployment operation, and high deployed-to-stowed ratio. The AstroMesh configuration is seen to be the simplest configuration to investigate further through kinematics and dynamic analysis. The spatial configuration is converted to planar by introducing a transformation relationship between two adjacent bays to solve the kinematics. The 12m diameter configuration is analyzed for the given position, velocity, and acceleration parameters, which are used as an example. The deployment cable pull force, which estimates the amount of force required to achieve a fully deployed configuration, is predicted through dynamic analysis. Design parameters are identified and parametric optimization of configuration with the objective of achieving a compact stowed configuration is carried out. The parametric optimization study for a prototype configuration of 3m diameter leads to a volumetric efficiency of 99.7%. The optimized design configuration is then evaluated for structural requirements of space launch environmental specifications. A linearized formulation for support net
analysis is carried out and an efficient numbering scheme was evolved to save memory and computation. Dynamic stiffness of stowed and deployed configurations is computed using the finite element method. The first fundamental mode of the stowed configuration of the 12m diameter truss structure is predicted to be 40 Hz. A prototype of a 3m diameter is realized to demonstrate the concept of the deployment mechanism. An SMA-based hold-down and release mechanism is also evaluated for functional aspects and hold-down capacity. Demonstration of deployment on 3m antenna reflector with support net and mesh configuration showed up issues with smooth deployment. To mitigate some of the problems, the use of tape flexure-based hinges is investigated. The buckling behavior of curved tapes is studied analytically with corresponding experimental strain measurement for equal sense and opposite sense bending cases under transverse loading. The absolute error between analytical formulation and experiments is found to be 9% and 19% for equal and opposite senses within the elastic limit. Characteristics of opposite and equal sense bending with combinations of a single and a double layer of tapes are analyzed in FEM for varying material options with CRFP and Ni36CrTiAl alloy seen to have benign stresses for $90^\circ$ rotation hinges. The feasibility of the concept is demonstrated with prototypes of joints incorporating tape flexures.