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Space Structures II - Development and Verification (Deployable and Dimensionally Stable Structures) (2)

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A NEW DESIGN METHODOLOGY FOR ONBOARD ULTRA LIGHT-WEIGHT CABLE-MESH ANTENNA REFLECTORS

Abstract

The purpose of this study is to establish a new design methodology for light-weight cable-mesh antenna reflectors, whose areal density is less than 0.2 kg/m^2, for the future communication satellites. We propose a gossamer space structure which consists of a system of cables and a flexible supporting structure. Surface accuracy of less than 1 mmRMS can be realized against a large deformation of the supporting structure. We are expecting the antenna reflector to be designed simpler and lighter than current design. Additionally, this design methodology would be scalable and applicable in between small and large satellite systems.

A system of cables should be designed by changing initial length and extensional rigidity of cables, considering a whole surface accuracy and tensions. We confirmed that the surface accuracy is determined by high-rigidity cables which construct "tension-truss structure". We also confirmed that high-rigidity cables must be supported by low-rigidity cables to keep tensions stable. Additionally, low-rigidity cables allow large deformation of the supporting structure.

We employed the non-linear structure analyzer, "ORIGAMI/ETS" developed by Japan Aerospace Exploration Agency (JAXA). To obtain a desire equilibrium shape of a system of cables, we optimized the initial length of cables object to minimize a whole surface accuracy and tensions. These calculations have been performed under a given boundary condition for given rigidity of cables.

To demonstrate our design methodology, we've designed and manufactured bread board model, "umbrella antenna", whose diameter is 1.4 m, as well as high-rigidity cables made of carbon-fiber and silicone. We can conclude following remarks,

1. We've successfully designed an accurate system of cables on spokes of an umbrella, whose rigidity is extremely small.
2. Deformation modes on the umbrella can be divided into two groups, group A and group B. Group A degrade the surface accuracy but group B doesn't affect the surface accuracy.
3. Deformation modes in group A can be suppressed by adding some tendon-cables.
4. The influence of deformation in the supporting structure on the surface accuracy would be changed corresponding to the ratio of the rigidity of the system of cables to the rigidity of the supporting structure.
5. We confirmed that the aerial density of 0.4 kg/m^2 can be obtained in "umbrella antenna". Aerial density of less than 0.2 kg/m^2 is expected for large antenna reflector whose aperture diameter is more than 10 m, because the ratio of non-structural (mechanism) mass to structural mass would be greatly decreased.