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ROBUST SHAPE DESIGN OF TENSION TRUSS ANTENNAS ON VARIATION OF TENSION TIE FORCES

Abstract

In recent decades, the rapid development of Earth observations and satellite communications gives a great impetus to research on high-gain space antennas. A possible way of obtaining high-gain is building a large aperture reflector while maintaining enough parabolic-shape precision, with surface error smaller than 1/50 of the wavelength. A foldable tension truss antenna provides a profitable solution to accomplish large aperture, benefited from its flexible surface design: the surface is not rigid but rather approximated by a triangulated cable network that is attached with a metallic mesh to reflect signals. However, the design poses great challenges on achieving high shape precision. One challenge is that the cable must be tensioned by a group of tie forces and form a parabolic shape under various force uncertainties such as manufacture error, in orbit working environment – orbital thermal and satellite spinning, and on ground measurement of surface error. Or else, the cables might be slack, which in turn cause large surface deformation. The importance of force uncertainties has been realized for a while. Monte Carlo simulations have been used to check whether the cables are slack with a given deviation of the tie forces. Nevertheless, the reverse problem, which is calculating the allowable deviation of the forces that can guarantee all of the cables are tight, has not been addressed yet. This might be caused by lack of efficient method on formulating and solving the force tolerance problem. As a result, no effort has been further done on optimizing the cable network to get a larger force tolerance. This study aims to design a robust shape for tension truss antennas accounting for variation of the tie forces. We first introduced a quantitative definition of the force tolerance. Then, an analytical method of formulating and calculating the force tolerance was developed. This method was then exploited to optimize the cable network to achieve a wider force tolerance. Using a 2-m mesh antenna as an example, we shown that the force tolerance was enlarged three times after optimization, comparing with the original design. Such a great extent of improvement is beneficial to reduce the requirement on manufacture error, expand the allowed working environment, and cover the gravity difference between on ground test and in orbit usage. The proposed method is efficient and simple and is ready to be applied in the design of the antennas.