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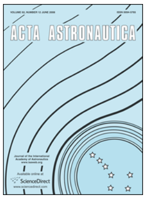

# Modeling and analysis of a large deployable antenna structure

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ABSTRACT

One kind of large deployable antenna (LDA) structure is proposed by combining a number of basic deployable units in this paper. In order to avoid vibration caused by fast deployment speed of the mechanism, a braking system is used to control the spring-actuated system. Comparisons between the LDA structure and a similar structure used by the large deployable reflector (LDR) indicate that the former has potential for use in antennas with up to 30 m aperture due to its lighter weight. The LDA structure is designed to form a spherical surface found by the least square fitting method so that it can be symmetrical. In this case, the positions of the terminal points in the structure are determined by two principles. A method to calculate the cable network stretched on the LDA structure is developed, which combines the original force density method and the parabolic surface constraint. Genetic algorithm is applied to ensure that each cable reaches a desired tension, which avoids the non-convergence issue effectively. We find that the pattern for the front and rear cable net must be the same when finding the shape of the rear cable net, otherwise anticlastic surface would generate.

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## 1. Introduction

With the increasing outer space activities nowadays, the large deployable antennas play a significant role in the space missions such as telecommunication, earth observation and different types of remote sensing missions [1–3]. Among various kinds of large deployable antennas, the mesh deployable antenna is one of widely used antennas because of its high stowability and light weight. Japan Aerospace Exploration Agency (JAXA) proposed one kind of large deployable reflector which is consisted of more than 10 modules [4]. Each module is made up of mesh surface, cable network and deployable structure which is composed of six basic deployable units. The cable network that makes the mesh surface become a parabolic shape is subdivided into the front cable net, the rear cable net, stand-offs that connect the front cable net to the deployable structure, and tension ties. Two LDRs which consist of 14 modules were mounted on the Engineering Test Satellite VIII, and launched on December 18th, 2006. Their aperture and the weight are 13 m and 170 kg, respectively. Astro Aerospace Corporation developed the AstroMesh deployable antenna which has over 15 years of continuous development history [5,6]. In the AstroMesh, two symmetrical parabolic cable nets are attached to a deployable ring structure and the mesh surface is attached to the front net. The first AstroMesh which had 12.25 m aperture and 55 kg weight was launched on December 5th, 2000.

To achieve communication between satellites and ground effectively in the near future, the aperture of deployable antenna has to be more than 30 m, because the antenna gain of mobile phones is small [7–9]. An intuitive approach to develop such large antenna is to increase the diameter of the deployable unit of LDR, however, it gets much heavier than its predecessor. Similarly, the natural frequency of AstroMesh gets much lower with increase of the structure diameter.

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Therefore, considering the advantages and disadvantages of above two kinds of large deployable antennas, we present one novel large deployable antenna which has lighter weight than LDR and higher natural frequency than AstroMesh in this paper. It is constructed by a number of basic deployable units in LDR, and can be deployed from a bundle compact configuration to a large expanding truss.

It is extremely important to study the form-finding of the cable network when the antenna is built, because the accuracy of the mesh surface depends on the form of the cable network. The force density method (FDM) was first proposed by Linkwitz and Schek to find forms of architectural structure without solving any nonlinear equations [10,11]. In past 25 years, FDM and its improvements have been used widely in form-finding of tensegrity structures due to its validity [12–14]. However, anticlastic surfaces would generate when FDM is introduced to form-finding of parabolic shape of the cable network. To solve this problem, a modified form-finding method combining the FDM with parabolic geometric constraint is presented in this paper.

The rest part of this paper is organized as follows: firstly, the large deployable antenna structure constructed by the basic deployable units in LDR is proposed and its geometric model is built in Section 2. Secondly, the form-finding method of the cable network with a desired tension is presented in Section 3, which is also founded based on the initial force density method and subjected to the parabolic surface constraint. Finally, an illustrative antenna model is developed by the aforementioned method, and the errors of the cable net are analyzed to show the effectiveness of the method in Section 4.

## 2. Proposal of deployable structure

### 2.1. Deployable structure

The basic deployable unit in the LDR is shown in Fig. 1 [4], which consists of a center beam, an upper radial beam, a lower radial beam, a longitudinal beam and a deployable diagonal beam. Apart from the sliding pair shown in Fig. 1, the rest of kinematic pairs are revolute pairs. The unit can be deployed through moving the slider along the center beam to the upward position and folded as the slider moves downward. The slider is driven by a driving spring, one end of which is attached to the slider but the other end attached to the bottom of the center beam. Fig. 2 shows the CAD model of the basic deployable unit. More than one basic unit can be connected by sharing the center beam and the sliding pair, therefore, the CAD models of the two deployable units and the three deployable units are obtained, as shown in Figs. 3 and 4, respectively.

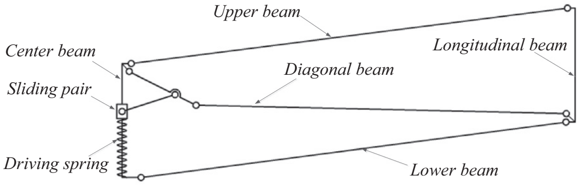

**Fig. 1.** Basic deployable unit.

**Fig. 2.** CAD model of the basic deployable unit.

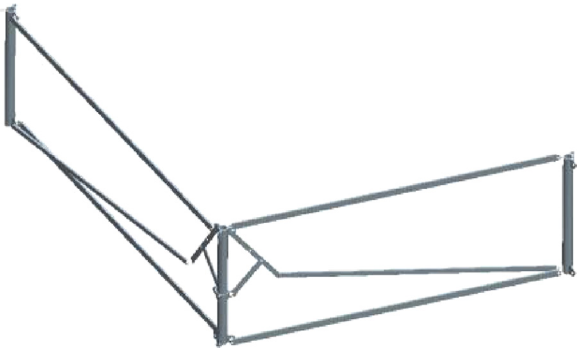

**Fig. 3.** CAD model of the two deployable units.

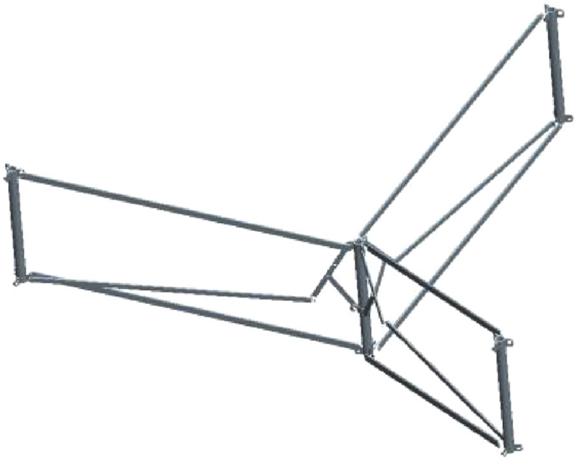

**Fig. 4.** CAD model of the three deployable units.

The CAD model of a three-modules large deployable antenna (LDA) structure which is constructed by connecting the two deployable units and three deployable units is shown in Fig. 5. When fully deployed, it becomes a large deployable truss which covers a very large area and supports the cable network of the antenna. When fully folded, it becomes a bundle with small volume and all the links are nearly parallel with each other.

Because the spring-actuated system leads to fast deployment speed of the deployable structure in practice, serious antenna vibration could be induced and would affect the accuracy of the mesh surface. To solve this problem, a braking system including ropes and a motor

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