Large Deployable Reflector (LDR) onboard Engineering Test Satellite VIII (ETS-VIII)

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INTRODUCTION

In a new mobile communication service, the communication satellite is expected to achieve the capability equivalent to the existing terrestrial network. One of the key objectives of the Engineering Test Satellite VIII (ETS-VIII) is to establish a new mobile satellite communication system by using hand-held terminals. To achieve such a system, we need innovations in developing onboard equipment technologies, such as beam forming technology, beam control technologies and onboard switching technologies, as well as satellite bus technologies. Large deployable reflector (LDR) is one of a key technology in the beam forming technologies to improve communication capacity and to downsize ground terminals.

Two LDRs (TX-LDR for transmitting and RX-LDR for receiving) are installed on Engineering Test Satellite VIII (ETS-VIII). Several ground tests had been performed using a modular nature to advantage. ETS-VIII was launched by H-IIA launch vehicle on 18 December 2006. After the successful injection into Geo Synchronous Orbit, the RX-LDR and the TX-LDR were successfully deployed on December 25th and 26th, respectively. We confirmed adequacy of the proposed design and ground verification methodology.

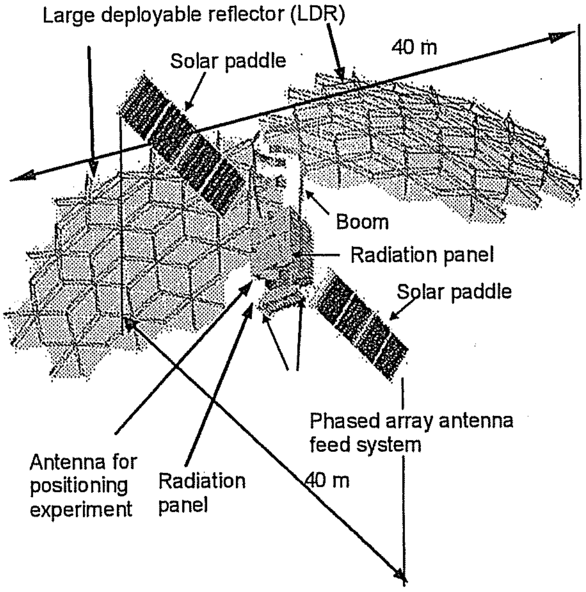

Fig. 1 In-orbit configuration of the ETS-VIII

DESIGN FEATURES

Reflector Design

The aperture diameter of the antenna reflector is 13 m (mechanical dimension of 19m x 17 m). To construct such a large antenna reflectors, we developed a design method for a modular mesh deployment antenna. As shown in Figure 2, the antenna reflector consists of fourteen basic modules, each of which is about 5 m in diameter. Each module is a hexagonal truncated pyramid, whose dimension is optimized by considering some design requirement such as weight, natural frequencies, a stowed size, and rigidity. Modular structures are easy to handling, testing and adjusting. If we use seven modules, we can easily obtain a 10 m aperture antenna reflector.

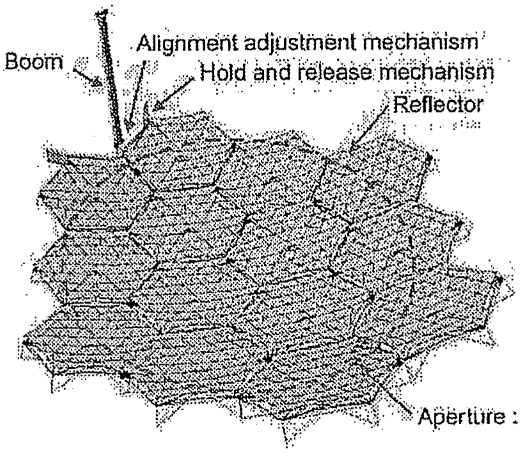

Fig. 2 Large Deployable Reflector

Cable Network System

As shown in Figure 3, the basic modules consists of a gold-plated molybdenum mesh surface, spatially determined cable network, and a deployable truss structure which is used as a supporting structure. A surface error is created during some manufacturing processes. We can correct the surface error by adjusting cable length. A system of cables forms a mesh into a parabolic shape. The deployable support structure is designed to have a spherical shape which is best fitted to a given parabolic surface. Therefore, stand-offs are needed in between the cable-mesh structure and the top surface of the deployable support structure to connect a parabolic surface and a spherical surface [1][2].

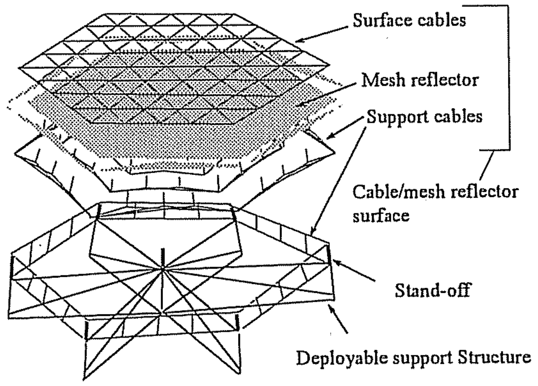

Fig.3 Detail of Basic Module

Deployment Mechanism

Figure 4 shows some detail of a basic frame structure. The structure consists of six basic frame structures each of which is arranged spoke-wise around the common central axis. The basic frame structure consists of an upper radial member, a lower radial member, a longitudinal member and a foldable diagonal member. Driving force is obtained by a coil-spring installed in a slide hinge to move the hinge along the center axis. The driving force is transformed from the slide hinge to the folding diagonal member thru the four-bar linkage mechanism. The basic frame structure can be stowed by moving the slide hinge to the upward position.

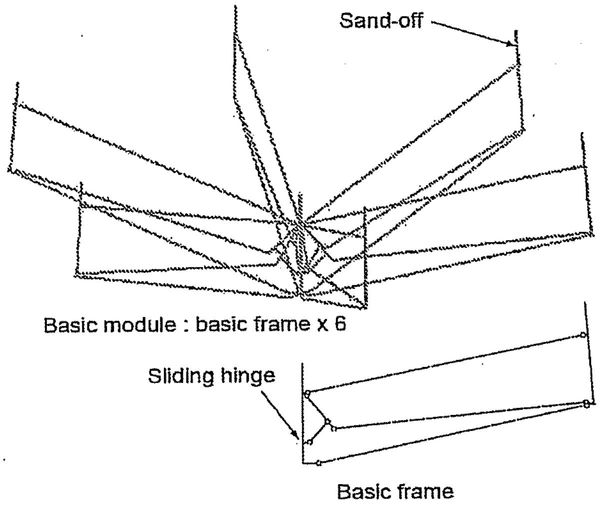

Fig. 4 Basic frame structure

GROUND DEPLOYMENT TESTING AND EVALUATION

Evaluation Method

Several ground tests had been performed using a modular nature to advantage. Single basic module, three combined modules, seven combined modules, and a fully-combined module were tested step by step [3]. The true characteristics of deployment structures were extracted from the test results by identifying an analysis model of the ground deployment test system. Analysis models were constructed by using SPADE (Simple coordinate Partitioning Algorithm based Dynamics of finite Element) developed by Nippon Telegraph and Telephone Corporation [4][5]. SPADE can analyze the deployment behavior of elastic structures that consist of beams, rods, plates, cables and membranes.

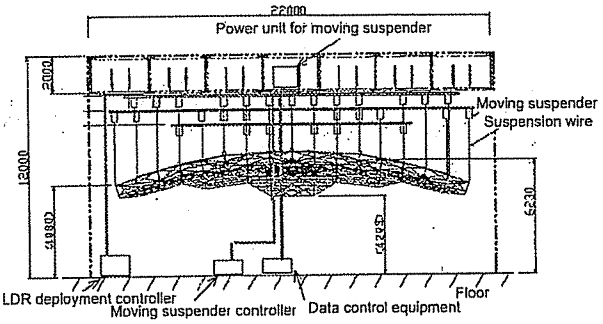

Fig.5 Moving suspension system for LDR

Ground Test Equipment

When we perform a ground deployment test for a large deployable structure, the structure is usually suspended from several discrete points to offset gravity loading. Because deployable space structures are designed to withstand in-orbit environment, gravity loads may swamp the deployment forces and cause structural damage. Therefore, we should perform a comprehensive and accurate fracture analysis of the entire deployment process before performing ground deployment tests. The suspension system consists of tracking rails constructed above the LDR and suspension units which move along the tracking rails. A suspension wire connects a suspension point on the LDR and a corresponding suspension unit. We had to measure tension of these wires as well as tracking position error of suspension units to update analysis model of the ground test equipment and to improve the accuracy of analysis model of LDR itself.

IN-ORBIT OPPERAITONS AND RESULTS

Deployment behavior both in a close-up and distant view was taken by two onboard cameras. Figure 6 shows a picture of TX-LDR taken during deployment in close-up view. The close-up view was used for observing HRM (Hold and Release Mechanism) releasing and the beginning LDR deployment. Figure 7 shows a picture of the full deployment position of TX-LDR in distant view respectively. Both TX-LDR and RX-LDR were successful deployment in orbit. Deployment forces and angles were also measured to evaluate the accuracy of analytical prediction obtained by ground deployment testing.

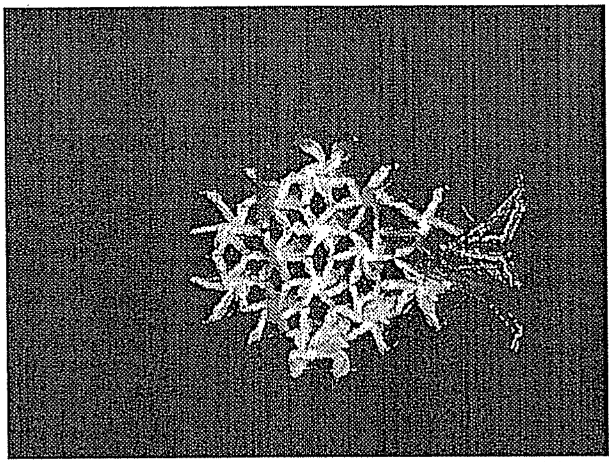

Fig. 6 TX-LDR successful deployment in orbit (During deployment in close-up view)

CONCLUSIONS

Two large deployable reflectors onboard ETS-VIII were successfully deployed in orbit. We confirmed the adequacy of the proposed design and ground verification methodology. Besides being successful results of LDR development, they promise future success of larger antenna reflectors. In addition, after the successful deployment in orbit, an initial on-orbit testing (IOT) was performed. Resulting electrical performance showed that LDR has sufficient surface accuracy (of less than 2.4 mmRMS) and alignment accuracy (difference of 0.1 degree from a prediction) as well. Now we are using the LDRs for some mobile satellite communication experiments.

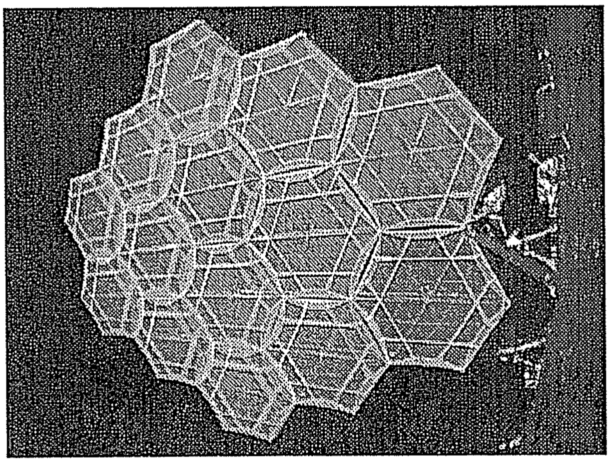

Fig. 7 TX-LDR successful deployment in orbit (Full deployment in distant view)

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