Antenna-Assembling Mechanism Test on ETS-VII

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KEY WORDS AND PHRASES

Engineering test satellite, large space antenna, antenna assembling, teleoperation, telerobotics

ABSTRACT

The Communications Research Laboratory plans to test an antenna-assembling mechanism on the Engineering Test Satellite VII. The test is one of the application missions for the space robotics experiments that will be conducted mainly by the National Space Development Agency of Japan (NASDA). The purpose of the test is to verify the ability of the antenna assembling mechanism to function in space and to experiment on the teleoperation of a space robot to develop antenna-assembling technology. In this paper, we present the test experiment plans and the outline of the onboard assembling mechanism.

INTRODUCTION

Assembling antennas by means of a robot is one method to build large-scale dish-type space antennas for high frequency applications. Assembling-type antennas have possible advantages over deployable-type antennas to achieve highly accurate reflector-surface construction and is appropriate for high-frequency applications. [1] The Communications Research Laboratory (CRL) planned the antenna-assembling experiment on the Japanese Experimental Module (JEM) of Space Station and started developing assembling-type antennas in 1986. At first, we developed the assembling mechanism which couples the center panel with the divided peripheral panels. The mechanism is a key component for assembling antennas easily in space. A smart mechanism makes antenna construction possible using a robot arm instead of Extra Vehicular Activity (EVA). Two antenna scale models with different types of mechanisms are developed [2] and tested first on the ground using a robot arm. Before the experiment on JEM, we planned a precursor experiment to test the mechanism on the Engineering Test Satellite-VII (ETS-VII) [3], which will be launched in 1997. The purposes of the test on the ETS-VII are to verify the ability of the assembling mechanism to function in space and to experiment on the teleoperations of a space robot to develop antenna assembling technology.

ASSEMBLING-TYPE ANTENNA

Figure 1 shows the configuration of the assembling-type antenna. The main reflector is divided into 8 peripheral panels and a center panel. A sub-reflector is attached to the center panel with four stays. The assembling mechanism is used to couple the center panel and the divided peripheral panel, as shown in the figure.

In the JEM experiment, construction of a 2- to 5-meter diameter antenna is planned as the first step. Initially, the center part attached behind the center panel, which contains RF compartment and pointing equipment, will be assembled on the exposed facility of the JEM. Next, divided panels will be attached to the center panel, one by one, by using the Japanese Remote Manipulator System (JRMS).

EXPERIMENTAL SYSTEM FOR ETS-VII

CRL plans to test the antenna-assembling mechanism on the Engineering Test Satellite VII (ETS-VII). In this experiment, only the assembling mechanism is to be tested because it is the key component of the assembling-type antenna. Testing the assembly performance under various conditions (described later) as well as its durability in space is an important objective of the experiment.

Another objective is testing the teleoperation technology under the effects of communication delay and the limited communication capacity caused by the long distance from the operator on earth to the assembly site in space.

Figure 2 shows the experimental system block diagram including the onboard system and the earth control system. CRL will develop hatched equipment: an onboard antenna-assembling mechanism and a ground auxiliary teleoperation system for the experiment.

Assembling Mechanism

The antenna-assembling mechanism is composed of a fixed part (FP) which contains the mechanism for the center panel and a coupling part (CP) which contains the mechanism for the divided panel as shown in Fig. 3. The FP is attached to the satellite main body structure. The coupling mechanism used is a rotary hook-type latch actuated by a spring force (Fig. 4).

To make the assembly procedure easy and secure, we introduced both a mechanical guide system and a visual guide system. The mechanical guide system consists of a guide cone and a cone receptacle which mechanically compensates for the positioning error in the assembling process. The visual guide system uses a three-dimensional target mark (Fig. 5) attached to the FP and a hand camera system attached near the robot hand. The image of the target is transmitted to the ground control system and is used to determine the relative position and attitude of the CP to the FP. This information is used to teleoperate the onboard robot arm. The compliance mechanism in Fig. 3 is introduced to absorb the possible reaction force induced by the mechanical contact of the FP and the CP.

Teleoperation System

The teleoperation equipment consists of a workstation and an image processor, and functions as the robot arm control, image processor and robot operation simulator. Teleoperation commands generated in the equipment are transmitted to the satellite via NASDA's satellite control facility.

Figure 6 shows the block diagram of CRL's teleoperation equipment. The basic system consists of a teleoperation computer, an image processor, a video processor, and a monitor. The teleoperation computer is used for arm control calculations and data communication. The video processor is used for processing the target-mark image. The image processor is used for overlaying the camera image on the CRT.

The teleoperation auxiliary computer is used only for the predictive bilateral control experiment described later.

The basic system software consists of a teleoperation manager, a simulation module, a visual simulation module, and an interface module. Each module works as an independent parallel process. The teleoperation manager communicates with other modules and exchanges parameters and data. Almost all operations such as the menu selection, parameter change, and command transmission, can be done by using a mouse on a graphical user interface (GUI).

The teleoperation manager functions are
*robot teleoperation,
*data management, and
*controlling other modules.

The simulation module functions are
*robot movement simulation
*3-D wire frame simulation-image display of the robot and the assembling mechanism, and
*pre-operation check.

The visual simulation module functions are
*image processor control, and
*video processor control.

The data which will be acquired from the experiment are
*torque and force data of the arm,
*position of the arm (angle of the joints),
*video image of the CCD camera,
*target position calculated from the video image, and
*operation duration time.

TEST EXPERIMENT PLAN

Several kinds of assembling and disassembling experiments are planned:

Basic Assembly and Disassembly Experiment

Repeating the assembly and disassembly operation while changing the following parameters:
* Operation mode of the arm (teaching/manual mode)
* Operational speed of the arm
* Insertion force of the coupling
* Control mode of the arm (position control/force control mode)

Allowable Positioning Error

The FP and the CP can be assembled even with a certain positioning error using the mechanical guide cone. In this experiment, the allowable positioning error is measured.

Assembling and Disassembling with Intentional Disturbance

Sine-wave/random positioning error will be added to the robot command to simulate the assembly using a long-armed manipulator with excess vibration.

Fully-Automatic Assembling Experiment

The relative position of the FP and the CP is calculated using visual feedback of the target mark images. The position data enables automatic assembly of the FP and the CP.

Predictive Bilateral Control

A virtual model of the operation target is constructed in real-time. The virtual image and the reaction force calculated from the model is supplied to the operator who controls the master arm while watching the virtual image with the superimposed real image delayed by the distance.

CONCLUSION

The plans of the assembling mechanism test on ETS-VII and the outline of the onboard mechanism is presented in this paper. The experiment will demonstrate the possibility of constructing large-scale dish-type antennas using a space robot controlled by a ground operator. The actual antenna construction in space with this type of assembling mechanism is planned for the space station using JEM's remote manipulator system.

The onboard mechanism for the ETS-VII is now under the critical-design stage and a BBM is under construction. Before the ETS-VII experiment, a ground simulation test using the BBM and the NASDA's test bed system will be done.

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REFERENCES

[1] T. Iida, K. Okamoto, Y. Ohkami, S. Kibe, H. Koshiishi, M. Naka, and H. Yamamoto, : "A Space Station Experiment on Large Antenna Assembly and Measurement," Acta Astronautica Vol.12. No. 5, pp.335-344, 1985.

[2] Y. Suzuki, T. Takahashi, M. Tanaka, T. Iida, S. Yokota, and K. Ohshima, : "Scale Model Development of Assembling Type Space Antenna," 42nd Congress of the International Astronautical Federation, IAF-91-314, October 5-11, 1991, Montreal, Canada.

[3] M. Oda, Y. Wakabayashi, S. Ichikawa, R. Imai, and T. Anzai, : "ETS-VII, The World First Telerobotic Satellite (Mission and Its Design Concept)," Artificial Intelligence, Robotics and Automation, in space, Toulouse, September 92, pp307-318.

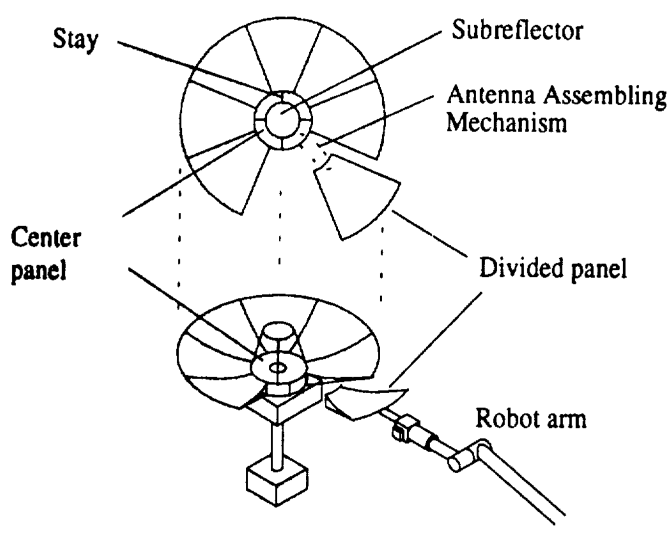

Fig. 1 Assembling-type antenna and assembling mechanism.

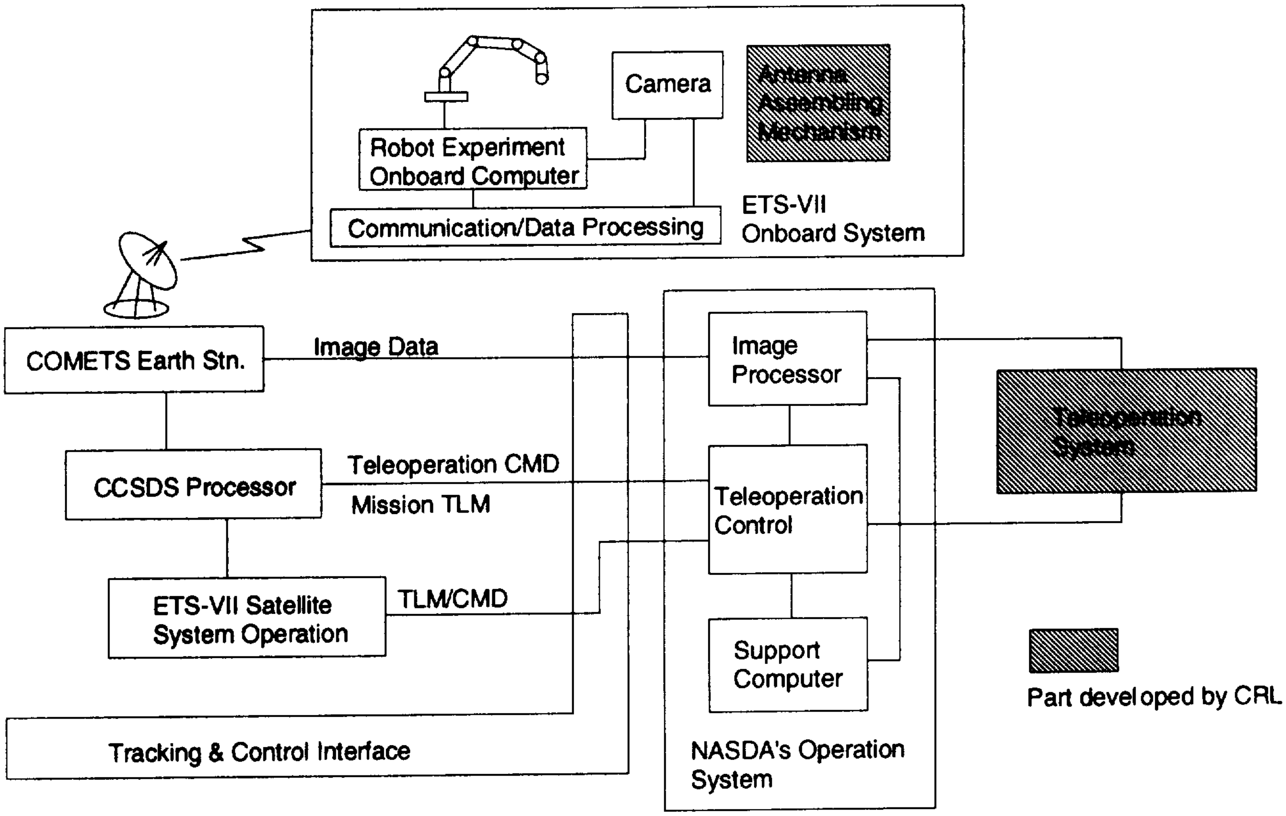

Fig. 2 ETS-VII robotics experiment system block diagram.

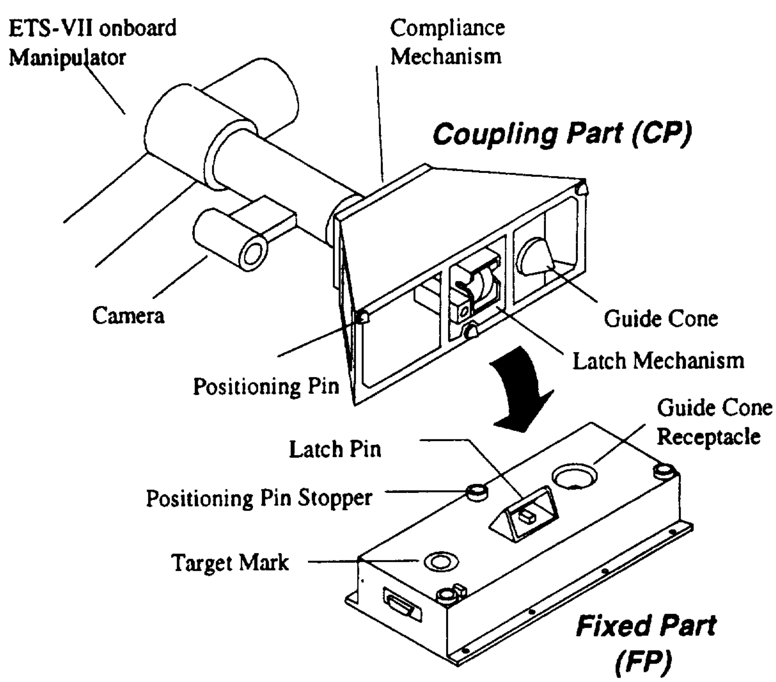

Fig. 3 Onboard antenna-assembling mechanism

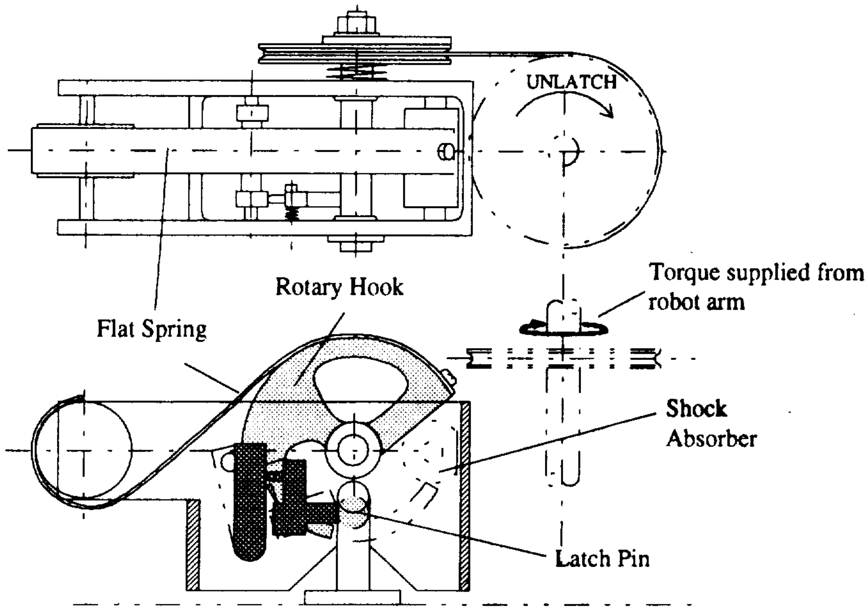

Fig. 4 Structure of the latch mechanism.

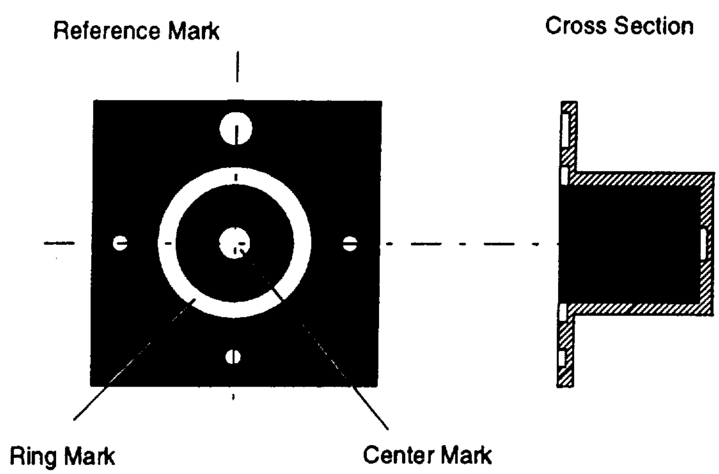

Fig. 5 Target mark for the visual guide