5 Plan of Experiments

5-1 Plan of Experiments for Mobile Satellite Communications and Broadcasting

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Mobile satellite communications and broadcasting experiments using the Engineering Test Satellite VIII are planned. The experimental plan has two categories. One is a fundamental experiment which will be carried out by National Space Development Agency of Japan, Nippon Telegraph and Telephone Corporation and Communications Research Laboratory. These organization has been developing the Engineering Test Satellite VIII. The other is application experiments which will be conducted by several selected organizations. The Communications Research Laboratory's experimental plan includes evaluating the performances of the onboard equipment, the earth station, and the mobile satellite communications and broadcasting system.

Keywords

Engineering Test Satellite VIII, Mobile satellite communication, Mobile satellite broadcasting

1 Introduction

Included among the planned mobile satellite communication and broadcasting experiments using the Engineering Test Satellite VIII (ETS-VIII) are basic experiments to be performed by the National Space Development Agency of Japan (currently the Japan Aerospace Exploration Agency), the Nippon Telegraph and Telephone Corporation, and the Communications Research Laboratory. These are in addition to application experiments proposed by universities and various other organizations. This paper gives a summary of the mobile satellite communication and broadcasting experiments, and mainly describes the experimental plan by the CRL.

2 Basic Experiments

The basic experiments will be conducted by NASDA—the National Space Development Agency of Japan (reformed as JAXA—the Japan Aerospace Exploration Agency—in October 2003), the Nippon Telegraph and Telephone Corporation (NTT); and the Communications Research Laboratory (CRL), which are involved in development of the ETS-VIII. These will include experiments to evaluate onboard equipment performance, the basic characteristics of earth stations, mobile satellite communication and broadcasting system performance, and some application systems performance.

Although the Advanced Space Communications Research Laboratory (ASC) was among the organizations participating in the

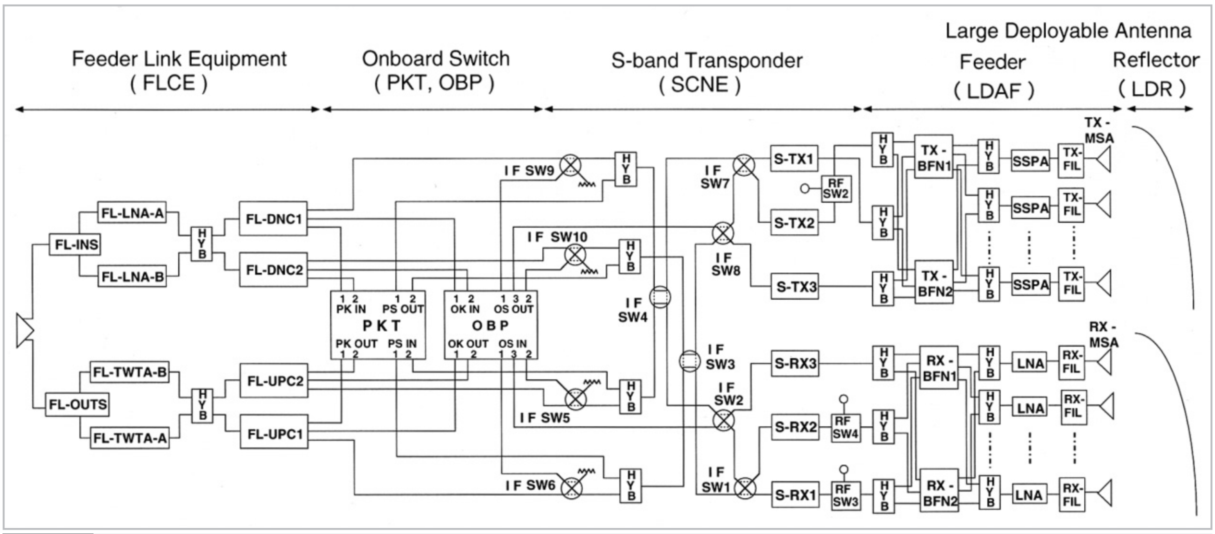

Fig. 1 *Block diagram of the ETS-VIII for mobile satellite communications and broadcasting experiments system*

development of onboard equipments, this organization closed its research and development activity in February 2001. The onboard equipments developed by the ASC were transfered to the CRL, and the performance tests of these equipments in orbit will be conducted by the CRL. Fig.1 is a block diagram of the onboard equipments in ETS-VIII mobile satellite communications and broadcasting system, and Table 1 indicates the organizations responsible for the development of the respective components.

Table 1 *Onboard equipments in mobile satellite communication and broadcasting system, and organizations responsible for development*

Onboard equipments	Development organizations
Feeder link communications equipment (FLCE)	: NASDA
Onboard switch	
Packet switch (PKT)	: CRL
Onboard processor (OBP)	: ASC
S-band Transponder (SCNE)	: ASC
Large deployable antenna feeder (LDAF)	
Beam-forming network 1 (BFN1)	: CRL
Beam-forming network 2 (BFN2)	: NTT
Other feeder components	: ASC
Large deployable antenna reflector (LDR)	: NASDA

2.1 Experiments Performed by the Communications Research Laboratory

Planned experiments to be conducted by the CRL include performance tests to evaluate the onboard equipments, mobile satellite communication and broadcasting experiments system, and the basic characteristics of the earth station.

2.1.1 In-Orbit Experiments to Evaluate Characteristics of Onboard Equipments

Most of the in-orbit experiments assigned to evaluate the characteristics of onboard equipments are planned to take place in the initial stages of experimentation, after the initial check of the onboard equipments. Evaluations will be performed on the newly developed onboard equipments such as the beam-forming network [1] and the onboard packet switch [2], as well as on the transponder and the large deployable antenna feeder [3]. The main components of this evaluation are as follows.

a. Experiment to Evaluate Characteristics of the Large Deployable Antenna

Five default radiation beam patterns will be employed for the link between the satellite and mobile terminals (mobile link) for the communication experiments (Fig.2). A maximum of three beams may be used simultaneously in these experiments. The use of a phased-array antenna allows for the generation of an arbitrary beam through control of the amplitude and phase of the beam-forming network.

a-1. Measurement of antenna radiation pat-

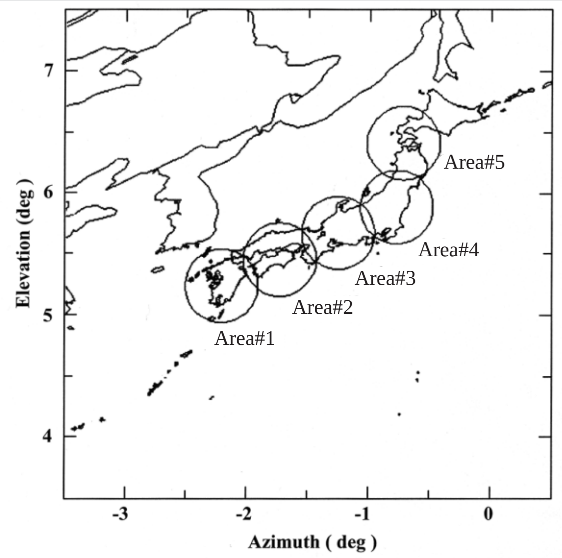

Fig.2 S-band antenna radiation pattern (for communication)

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To measure the radiation pattern, a basic antenna characteristic, variations in satellite attitude and received signal power will be measured simultaneously at multiple earth stations to obtain a two-dimensional pattern. The transmitted pattern will be measured by the received level of a continuous wave which is output from the onboard switch on the ETS-VIII. The received pattern will be measured through transmission of a continuous wave from the earth station; this wave is subsequently received by the satellite and then transmitted back to earth. Corrections will then be made to received signal power to arrive at a final satellite transmission pattern.

a-2. Evaluation of antenna beam directional characteristics

To evaluate the effects of thermal distortion of the deployable antenna reflector surface and fluctuations in satellite attitude on the directional characteristics of the antenna beam, continuous measurements will be made of the received signal power for multiple antenna beams. The results will then be used by the beam-forming network to correct for fluctuations in beam direction caused by thermal distortion and variation in attitude, in order to confirm the effectiveness of the calibration procedure while in orbit.

a-3. Measurement of the beam-scanning pattern

The antenna beam will be scanned by controlling the amplitude and phase of the beam-forming network, followed by evaluation of the obtained beam-scanning pattern (i.e., plotting of antenna gain against beam-scanning angle).

a-4. Evaluation of antenna feeder excitation error

Amplitude and phase of the beam-forming network will be set to form a standard beam and a test beam for measurement. Excitation error will be evaluated by rotating the element phase, a process executed through application of the Rotating Element Electric Field Vector (REV) method to the array weight of the test beam. Received signal power is then evaluated against the phase rotation angle.

b. Experiment to evaluate transponder system characteristics

The evaluation of transponder characteristics will be performed in the initial stages of experimentation through in-orbit evaluations of onboard equipments. These measurements will be taken periodically (approximately once every year) to evaluate performance over time.

b-1. Basic characteristics

Basic transponder characteristics to be measured include the I/O characteristic, amplitude-frequency characteristic, and intermodulation characteristic. Measurements will be performed of the onboard equipments on the mobile link side (mainly involving the use of the S-band). Overall system characteristics, including those related to the feeder link component, will be evaluated in cooperation with NASDA.

b-2. PIM evaluation

The satellite features a dedicated antenna element and a low-noise amplifier on the transmitter side of the feeder to permit measurement of passive intermodulation (PIM). Multiple high-power signals will be transmitted at different frequencies and the respective intermodulation in the received frequency band will be measured to evaluate PIM.

c. Experiment to evaluate characteristics of the onboard switches

The onboard processor performs circuit switching, and the onboard packet switch performs packet switching. Since the methods of evaluating these respective functions are quite similar, they will be described here together in terms of the evaluation of onboard switch performance.

c-1. Evaluation of basic transmission characteristics

Analysis will be performed of the basic characteristics of digital equipment, including bit error rate and synchronous acquisition. The modem used for regenerative repeating will be checked independently for uplink to and downlink from the satellite so that modulation and demodulation can be evaluated separately. Furthermore, basic characteristics will also be measured in through-repeater mode, with the results to be compared to those obtained in onboard-switch mode.

c-2. Evaluation of switching characteristic

Switch control signals will be transmitted from the earth station to the satellite to confirm whether the onboard switch will follow the commands of the control signals. The time required for switch control, one of the basic parameters of the switch function, will also be measured.

c-3. Evaluation of the switch reprogramming function

To enable the onboard processor and the packet switch of the ETS-VIII to respond to switch control commands in accordance with a variety of protocols, these components have been designed to allow reprogramming of switch control from the earth stations. To prevent errors when loading the program, data subject to error in transmission will be retransmitted automatically. In the evaluation of the switch reprogramming function, a test will be conducted to confirm whether the onboard processor and packet switch can properly load programs, and to measure the time required for the loading procedure. The automatic retransmission function will also be evaluated.

c-4. Confirmation of the location registration function

The onboard switch performs multi-beam switch control by recognizing and keeping track of the beam corresponding to the target mobile earth station. The registered location of the mobile station will be confirmed by a base station that receives the tracking data from the onboard switch.

2.1.2 Evaluation of the Communication System

Communication experiments involving the onboard processor, packet switch, and corresponding earth stations will evaluate the communication system through analysis of voice, data, and image transmission characteristics.

Fig.3 is a conceptual diagram of the communication system. Data will be collected for each function, both with a stationary earth station and with a vehicle serving as a mobile earth station. The performances of the switches in orbit and on the ground will also be evaluated through measurement of switch characteristics using breadboard models (BBM). The satellite will be set in the through-repeater mode and the signals will be relayed through the ground BBM switch.

Since this communication system is designed for a multi-beam satellite (featuring the beam radiation pattern shown in Fig.2), tests will be performed to determine whether the registered location of a mobile earth station that has moved from one beam to an adjacent one are updated properly. A frequency re-utilization experiment is also planned, in which signals at the same frequency are used by different beams, as well as an experiment to verify the connection between the satellite communication system and other communication networks. The communication system also features a terminal performing multiple block-coded modulation, mainly for high-speed transmission of image data. This terminal will be placed on the measurement vehicle to evaluate its capabilities in a mobile environment within the present modulation-demodulation mobile satellite communication system. In this experiment, the satellite will be set to through-repeater mode, and the MPEG4 codec will be used for image coding.

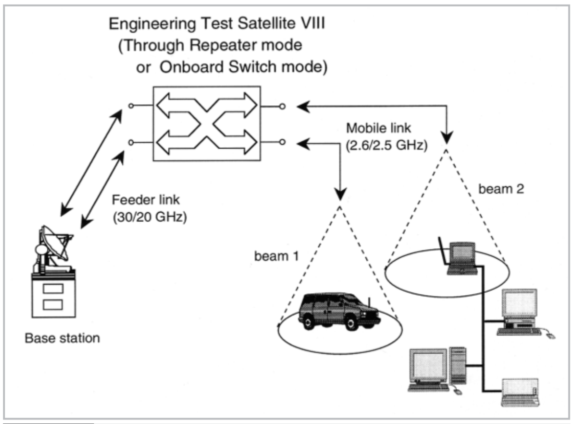

Fig.3 *Conceptual design of the communication system*

2.1.3 Evaluation of Broadcasting System Performance

The broadcasting system will be evaluated using an Orthogonal Frequency Division Multiplex (OFDM) terminal developed by the ASC [4]. The S-band antenna of the satellite incorporates a single-beam radiation pattern, as shown in Fig.4. In this experiment, a signal transmitted by the OFDM signal generator of the Ka-band feeder link base station (installed at the Kashima Space Research Center) will be sent via the ETS-VIII to a signal-evaluation component of the mobile vehicle station in order to evaluate high-speed data transmission and verify transmission of CD-quality sound. Evaluation of basic characteristics will also be performed, including bit error rate measurement and spectral analysis of the received signal, and data will also be collected to evaluate the effects of non-linearity in the transmission path and multipass propagation.

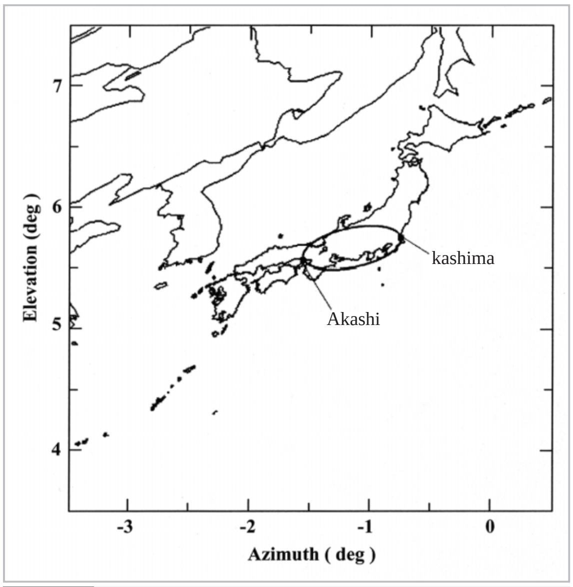

Fig.4 *S-band antenna radiation pattern (for broadcasting)*

2.1.4 Evaluation of the earth Station

a. Feeder Link Earth Station

The Ka-band feeder link earth station is one that will play a key role in the experiments. The basic characteristics of this earth station have already been confirmed. Important characteristics that remain to be evaluated after the launch of the ETS-VIII include the antenna's satellite-tracking function and automatic frequency calibration. The antenna features automatic step tracking as well as a manual tracking function. The frequency calibration function, on the other hand, corrects for the frequency variations resulting from instability in the onboard oscillator; calibration is performed with reference to the received beacon signal transmitted by the satellite. These characteristics will be evaluated by analyzing the received radio waves issued from the satellite.

b. S-band Earth Station

The S-band earth station will be used as a base station for the service link in the context of the mobile satellite communication and broadcasting experiments. This earth station will serve as the monitoring station in the course of the experiments, and will also be used in the experimental verification of the frequency calibration function (correction of fluctuations in the received signal frequency attributable to the motion of the satellite).

c. Evaluation of the Performance of Mobile and Portable Stations

Two types of high-gain antennas have been prepared for experiments relating to the mobile stations: an active-phased-array antenna and a stairs-type antenna. There are two antenna types for the portable stations as well: a case type and a foldable type. The satellite tracking functions of the active-phased-array and the stairs-type antennas represent essential characteristics that must be confirmed after the launch of the ETS-VIII. As with the onboard antenna of the ETS-VIII, the excitation error of the active-phased-array antenna will be evaluated by the REV method. In addition to these antennas, a simple omnidirectional low-gain antenna has been prepared for comparison. A multiple block-coded modulation unit will be used as the terminal for the mobile earth station, and the mobile terminals for the onboard swiching experiments will also be applied. Evaluation of bit error rate and measurements of received signal power will be performed to evaluate performance as a earth station.

2.2 Experiments to Be Performed by NASDA

Among the equipments for the mobile satellite communication and broadcasting experiment, NASDA has been in charge of developing the feeder link communications equipment (FLCE) and the large deployable antenna reflector (LDR). The basic characteristics (gain, radiation pattern, etc.) of the ETS-VIII antenna will be determined simultaneously for the LDR and the large deployable antenna feeder. Furthermore, measurements will be made not only of static antenna characteristics, but also of dynamic characteristics resulting from thermal environmental conditions and satellite motion, and a general evaluation will be provided of the overall structure. In-orbit evaluation will be performed of the FLCE as an component of the satellite's transponder system, along with the remaining onboard equipments. Each item will be measured once a year to evaluate performance over time.

2.3 Experiments to Be Performed by NTT

NTT developed the onboard beam-forming network (BFN2) [5]. In-orbit evaluation of the BFN2 is thus the main objective of NTT's experimental activities. The organization is planning to evaluate performance by measuring the antenna radiation pattern for a preset antenna excitation distribution, and through analysis of amplitude and phase value in beam formation.

3 Application Experiments

Various application experiments were selected from among responses to a public call issued by the Satellite Application Experiment Promotion Conference (Chairman: Professor YASUDA Yasuhiko of Science and Engineering, Waseda University) from October to December 2002. Final decisions were made in January 2003 [6], and in June of the same year, the ETS-VIII Application Experiment Execution Council (Chairman: Professor KONDO Kimio of the National Institute of Multimedia Education) was founded. Since then, numerous discussions have taken place to elucidate the details of the experimental plans and the required preparations for the earth station facility.

4 Conclusion

We have provided a summary of planned mobile satellite communication and broadcasting experimentation using the Engineering Test Satellite VIII. Since the design life of the satellite is three years (minimum), the experimental schedules of the associated organizations must be optimized to ensure the most efficient execution of the experiments to be performed.

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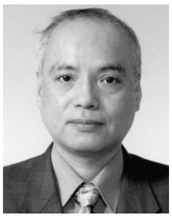

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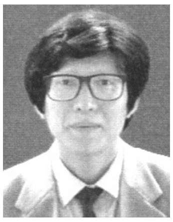

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