3-2 Configuration for Mobile Communication Satellite System and Broadcasting Satellite Systems

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To realize S-band mobile satellite communications and broadcasting systems, onboard mission systems and equipment were designed for the Engineering Test Satellite VIII (ETS-VIII). Voice communication is performed using handheld terminals, high-speed data communications, and multimedia broadcasting through a geostationary satellite. To enhance the efficiency and flexibility of the communication system, the onboard mission system features phased-array-fed reflector antennas with large antennas and baseband switching through onboard processors.

Keywords
Engineering Test Satellite VIII, Mobile satellite communication, Mobile satellite broadcasting, S-band, Ka-band, Large deployable antenna, On-board processor, Onboard packet switch

1 Introduction

In the future, we can expect to see the development of a personal mobile communication system that enables users to communicate with anyone, anytime, anywhere, using handheld terminals. Today, in urban districts and other populated areas, this sort of personal mobile communication system has virtually come to be realized, through allocation of terrestrial cellular systems and the establishment of “hot spots” of ground-based wireless LAN systems. However, the radio frequencies used in such communications represent limited resources, and the benefits of personal mobile communications should be made equally available to the whole nation.

Satellite-based services would represent a valuable step forward because satellite communication systems can provide service to areas not covered by ground systems, and provide new service ground systems cannot provide. Use of a geostationary satellite would be the most economical choice in such case, as a single geostationary satellite could service all of Japan. In addition, such a satellite communication system could contribute to the implementation of a truly personal mobile communication system, in collaboration with existing terrestrial mobile communication systems, through the use of the S-band frequencies less prone to the effects of weather and thus better suited to mobile communications.

In our country, mobile voice satellite communication is currently performed using portable Earth stations at frequencies in the S-band. It is expected that in the near future, a highly convenient mobile voice satellite communication system will develop out of the current system, permitting the use of small, portable Earth stations (i.e., handheld terminals). In particular, in view of the rapid popularization of the Internet in recent years, it is expected that such demands for a satellite communication system integrated with the Internet environment will increase.

With the aim of developing the technologies required for such a system, the ETS-VIII incorporates a transponder for experiments in mobile communications and broadcasting (the transponder system) enabling high-speed packet communication for multimedia, including voice and image data, among mobile users via handheld terminals using frequencies in the S-band.

This paper outlines the configuration, features, functions, and performance of the transponder system.

2 Development of the transponder system

The transponder system is an essential element of the main mission of the ETS-VIII, and is intended for the development and experimental verification of the technologies described below [1]-[4]. Fig.1 shows the configuration of the experimental mobile-communications and broadcasting system and lists the agencies responsible for its development. Table 1 illustrates the design features of several items of equipment constituting the transponder system.

- Large-scale Deployable Reflectors, the World's Largest and Most Advanced
- Mobile satellite communication system technology to realize audio/data communications with handheld terminals
- Mobile satellite multimedia broadcasting system technology for CD-level sound and image transmission

In order to develop the technologies described above, the following basic requirements have been adopted in the design of experimental equipment for mobile communications and broadcasting.

(1) A communication link (either between the feeder link and the service link or between service links) must be able to be established by route switching of the transponder.

(2) The onboard satellite antenna for service links shall be of the multi-beam type and shall be constructed such that service may be provided throughout Japan with approximately five beams. The number of antenna beams in projected communications experiments is set to three in order to allow for experiments on frequency sharing

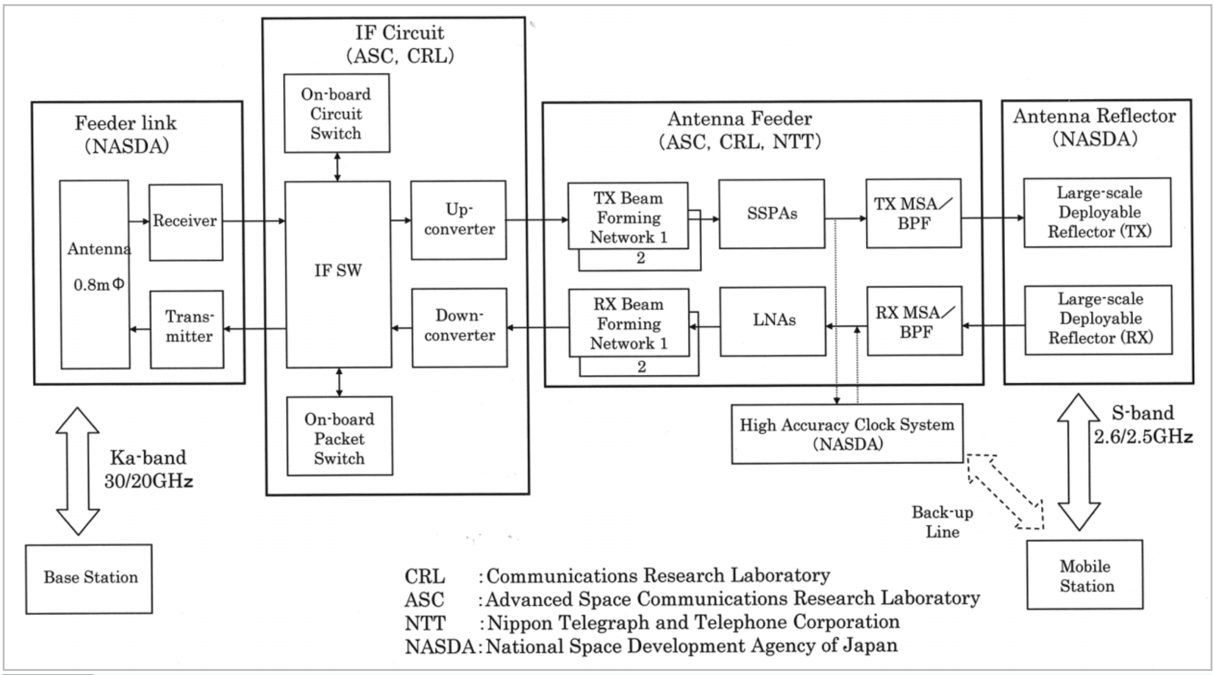

Fig.1 Configuration of experimental mobile communications and broadcasting system and list of development agencies

Table 1 *Design features of experimental mobile communications and broadcasting equipment*

Mission	Feature
Large-scale Deployable Reflector (LDR)	- The number of reflector: two (for Tx and for Rx) - Surface accuracy: 2.4mm RMS - Reflector type: Modular mesh deployable - The number of modules: 14 modules - Reflector size: about 19 m x 17 m - Aperture diameter: 13 m
Large Deployable Antenna Feed (LDAF)	- Type: active phased array with 31 elements - Total output power: 400W
S-band Converter (SCNE)	- The number of up- and down-converter: each three - Gain- and frequency- adjustment function
On-board Circuit Switch (OBP)	- Multi-carrier TDMA - Regenerative repeating function for cross link - Non-regenerative repeating function for forward-return link - The number of channel: 400 channels
On-board Packet Switch (PKT)	- Access scheme: Slotted ALOHA, Reserved packet - The number of ports: 2 ports for feeder link, 2 ports for mobile link
Feeder Link Communications Equipment (FLCE)	- Offset parabola antenna (0.8mΦ) - Gain- and frequency-adjustment function

between beams. On the other hand, one antenna beam is to be used for the broadcasting experiments. Beam direction must be controllable via command. Further, transmitted and received antenna beams shall be sufficiently isolated from each other.

(3) The equipment must be capable of evaluating the passive intermodulation (PIM) likely to occur in the transmitting service link antenna.

(4) The equipment shall feature a backup function that enables portions of the mobile satellite communications and broadcasting experimentation to be conducted using an onboard antenna (other than the large service link antenna) and a transmitting/receiving apparatus.

(5) The onboard feeder link satellite antenna shall be of the single beam type and shall be directed to the Kanto area.

(6) The onboard satellite transponder establishing communication links shall be operated in a linear manner.

(7) In each communication link, degradation of quality caused by the feeder link shall be minimized (contribution of total C/No: target of 1 dB or less), with onboard equipment and Earth-station facilities subject to stipulated performance levels.

(8) Feeder link communications equipment shall provide a beacon signal in the 20-GHz band, coherent with a local-oscillator signal, such that the base station can use this signal for automatic frequency control.

(9) Local-oscillator signal frequency of the transponder shall be fine-tunable via command.

(10) The feeder link communications equipment will have two frequencies (high and low) with shared intermediate frequencies in the 30-GHz and in the 20-GHz bands, respectively, for frequency-sharing experiments in the service link.

(11) The transponder shall have a gain-adjustment function.

(12) The onboard processor for mobile voice communication shall allow channel switching corresponding to multi-carrier TDMA (MC-TDMA). Moreover, the equipment shall support regenerative relaying and non-regenerative relaying.

(13) The onboard packet communication switch shall enable high-speed data communications directed to mobile Earth stations by establishing connections between the service links as well as connections between the service link and the feeder link, using the slotted Aloha method.

(14) The equipment shall enable additional communication experiments, such as quadrature phase shift keying (QPSK) testing using the through-repeater relay system.

3 Configuration of the transponder system

The transponder for experiments in mobile satellite communications and broadcasting (the transponder system) is composed of feeder link communications equipment (FLCE), an onboard switching equipment section [comprised of an onboard processor (OBP) and an onboard packet switch (PKT)], an S-band converter (SCNE), a mission integrator (MI), a large deployable antenna feed (LDAF), large deployable reflectors (LDRs), and a feed system radiation panel (RPNL). Fig.2 shows a block diagram of the transponder system.

The feeder link communications equipment amplifies the uplink signals in the 30 GHz band with low noise, converts them to intermediate frequencies (IFs) in the 140-MHz band and the 176-MHz band, and outputs the IFs to the experimental equipment. The feeder link communications equipment converts IF signals in the 140-MHz band output from the experimental equipment to the 20-GHz band, amplifies the electrical power of the signals, and transmits them to the Base station as downlink signals. At the same time, the equipment transmits a beacon signal (synchronized with a local oscillator signal within the feeder link communications equipment) to the Base station as a downlink signal.

The onboard processor performs connection control and channel switching of communication signals in mobile voice communication experiments. The processor has three operational paths: a forward link directed to mobile stations from the base station, a return

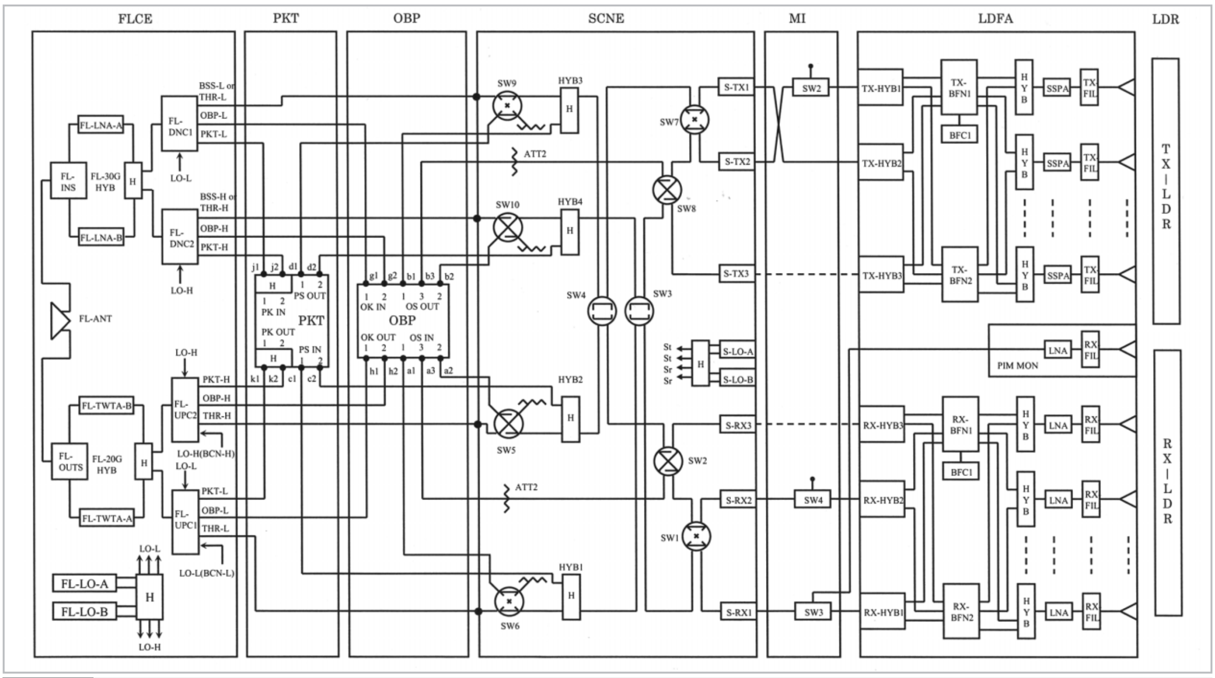

Fig.2 Block diagram of the transponder system

link directed to the base station from mobile stations, and a cross link connecting mobile stations. The service links can be operated within all three beams. In the forward links and return links, only filtering and switching are conducted, because the base station circuit quality can be high in these cases. In the cross links, regenerative relaying is also conducted, in order to increase the circuit quality of the mobile stations.

The onboard packet switch performs switching control for packet signals. This switch is composed of a modulation/demodulation section and a switching control section, with two input/output ports for the feeder link and two input/output ports for the service link; the switch interfaces with the feeder link communications equipment and the S-band converter using IF signals in the 140-MHz band. Since control information used for switching operations in the switching control section is included in the packet signal, all packet signals to be transmitted undergo regenerative relaying and are subject to controlled switching based on the obtained control signals.

The S-band converter is composed of up converters (S-TX) and down converters (S-RX), both for three beams, and of change-over switches (IF-SW); this device performs switching of the switches according to the operational mode.

The mission integrator performs switching between highly accurate time reference equipment (serving as a backup system) and the communications mission system, in addition to switching between the PIM system and the feed system, using switches employed at the RF band (the S-band).

The large deployable antenna feed is composed of two types of beam-forming networks (BFNs), each consisting of 31 high-power solid state power amplifiers (SSPAs), 31 low noise amplifiers (LNAs), and 31 transmission/reception antenna elements, each unit serving one BFN. Total output power is as high as approximately 400 W, with eight 20-W SSPAs and twenty-three 10-W SSPAs. For the antenna elements, a cup micro strip antenna (cup MSA) is used, resulting in a lightweight, rigid structure with low coupling between adjacent elements.

For the beam-forming networks, the satellite carries two types of BFNs: a collective control BFN and an independent control BFN. The collective control BFN can easily correct directional errors generated by mechanical, thermal, and electrical phenomena on the satellite by collectively controlling common excitation amplitudes and phases involved in the formation of two or more beams. Further, the Earth station can control each beam freely by allowing the independent variable BFN to control the directional pattern of each beam separately.

For the large deployable antenna, two panels of large deployable reflectors (one for transmission and one for reception), each with a diameter of 13 mΦ are deployed on the satellite to minimize the size of the mobile stations. The adoption of the phased array feeding method allows for flexible antenna beam setting. The satellite can use three beams in the S-band. The satellite can also perform experimental relaying via the conventional bent pipe method.

Two feed system radiation panels, installed in the north and south orientations, respectively, radiate the heat generated by the transmission feed unit into space.

4 Functions and performance of the transponder system

The major specifications of the transponder system are shown in Table 2. The transponder supports the following communication modes: a packet switching relay system, an onboard switching relay system, and a through-repeater relay system. Fig.3 shows the circuit configuration of the transponder system. The circuit configuration includes: forward links (each using a 30-GHz feeder link from the base station and a 2.5-GHz service link for mobile stations); return links (each using a 2.6-GHz service link from mobile stations and a 20-GHz feeder link for the base

Table 2 *Major specifications of the transponder system*

Freq. Range	· Communication	2655.5MHz～2658.0MHz(UP)
	· Communication	2500.5MHz～2503.0MHz(down)
	· Broadcasting	2537.5MHz～2540.0MHz
	· Feeder link	31G/21GHz
Polarization	LHCP	
Antenna	13mΦ	
EIRP	63.8dBW (Peak)	
	61.8dBW (Beam Area Edge)	
Data Rate	· Voice	5.6 kbps
	· Data	32 kbps
	· Packet	～1,024 kbps
	· Broadcast	220 kbps×6ch (OFDM)
Feeder	Active phased Array with 31 Elements	
MOD Access Method	· Communication	π/4 QPSK MC-TDMA
	· Packet	π/4 QPSK Slotted ALOHA, Reserved packet
	· Broadcast	π/4 QPSK, OFDM, and so on
G/T	12～14 dB/K	

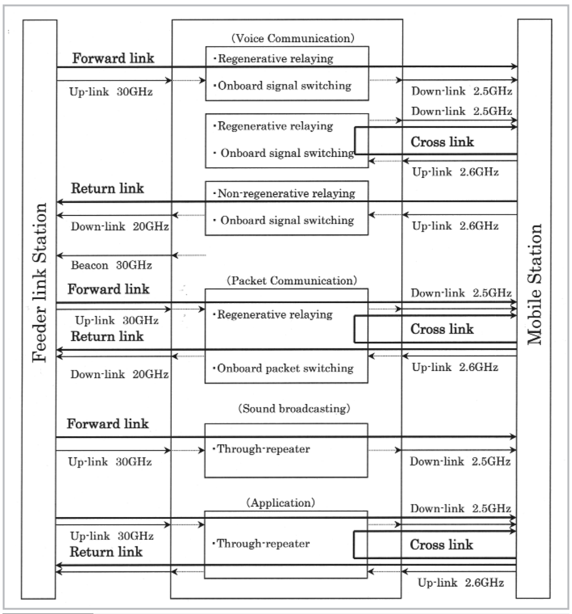

Fig.3 *Circuit configuration of the transponder system*

station); and cross links (each using a service link between mobile stations).

The onboard packet switch and the onboard processor are connected to an RF device for the Ka-band (20/30-GHz) dedicated base station feeder link and to an RF device for the S-band (2.5/2.6 GHz) dedicated mobile station service link, using IF signals in the 140-MHz band.

Due to the configuration of the packet switch housing on the satellite, mobile stations can perform high-quality communication with less propagation delay. Further, the enlargement of the onboard satellite antennas allows for a reduction in size of the Earth stations. Additionally, in preparation for cases in which the large deployable reflectors cannot be deployed, the equipment is provided with the ability to connect to a transmission/reception system, on the high accuracy clock system (HAC) used to establish the service link.

Table 3 *Experimental operation mode*

Operation mode			Voice	Packet	Broadcast	Application
Onboard signal switching	Communication	Voice	○			
		Packet		○		
Through repeater	Communication					○
	Broadcast				○	

Table 3 illustrates an experimental operation mode. The three modes of voice communication, packet communication, and broadcasting are not performed simultaneously; instead, individual experiments are conducted for each. Simultaneous operation of the onboard switching mode and the through-repeater mode is not conducted. A beacon signal is always output.

4.1 Antenna coverage

The antenna pattern of the Ka-band feeder link antenna deployed on the satellite covers the Kanto area, as shown in Fig.4. For mobile communication service links, the equipment emits three beams simultaneously to any of the five areas covered by the multi-beam service (five beams) covering the main land of Japan, as shown in Fig.5. These three beams

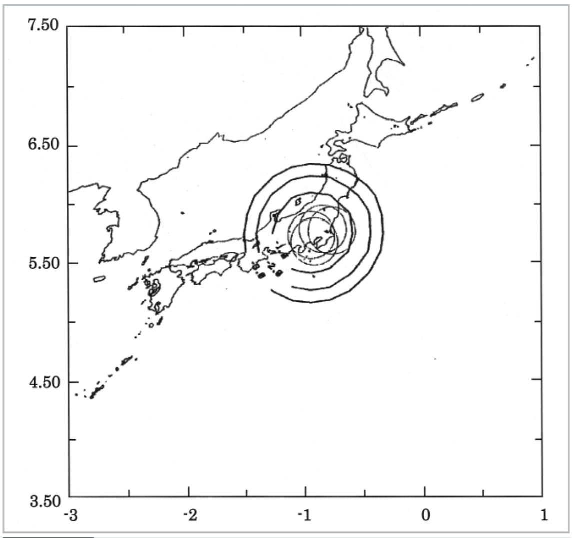

Fig.4 *Feeder link pattern*

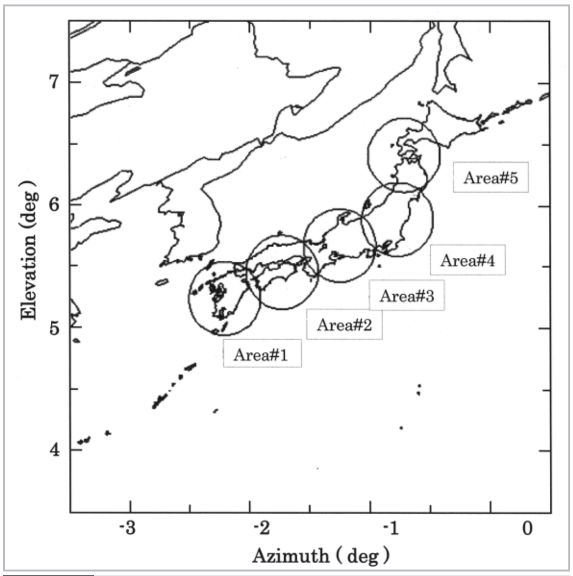

Fig.5 *Service link pattern (Communications)*

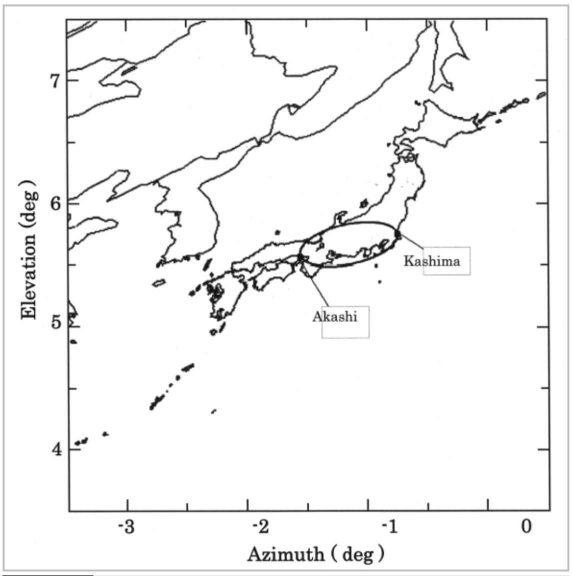

Fig.6 *Service link pattern (Broadcasting)*

consist of fixed beams and/or variable beams, and the variable beam can be adjusted to provide service to any location in the areas covered by the five beams. A single beam for mobile broadcasting covers the Kanto and Kansai areas, as shown in Fig.6.

4.2 Frequency allocation

Frequency allocation of the Ka-band and frequency allocation of the S-band are shown in Fig.7 and Fig.8, respectively. For feeder link frequencies, the 30.6-GHz band is used for uplink, and the 20.8-GHz band is used for

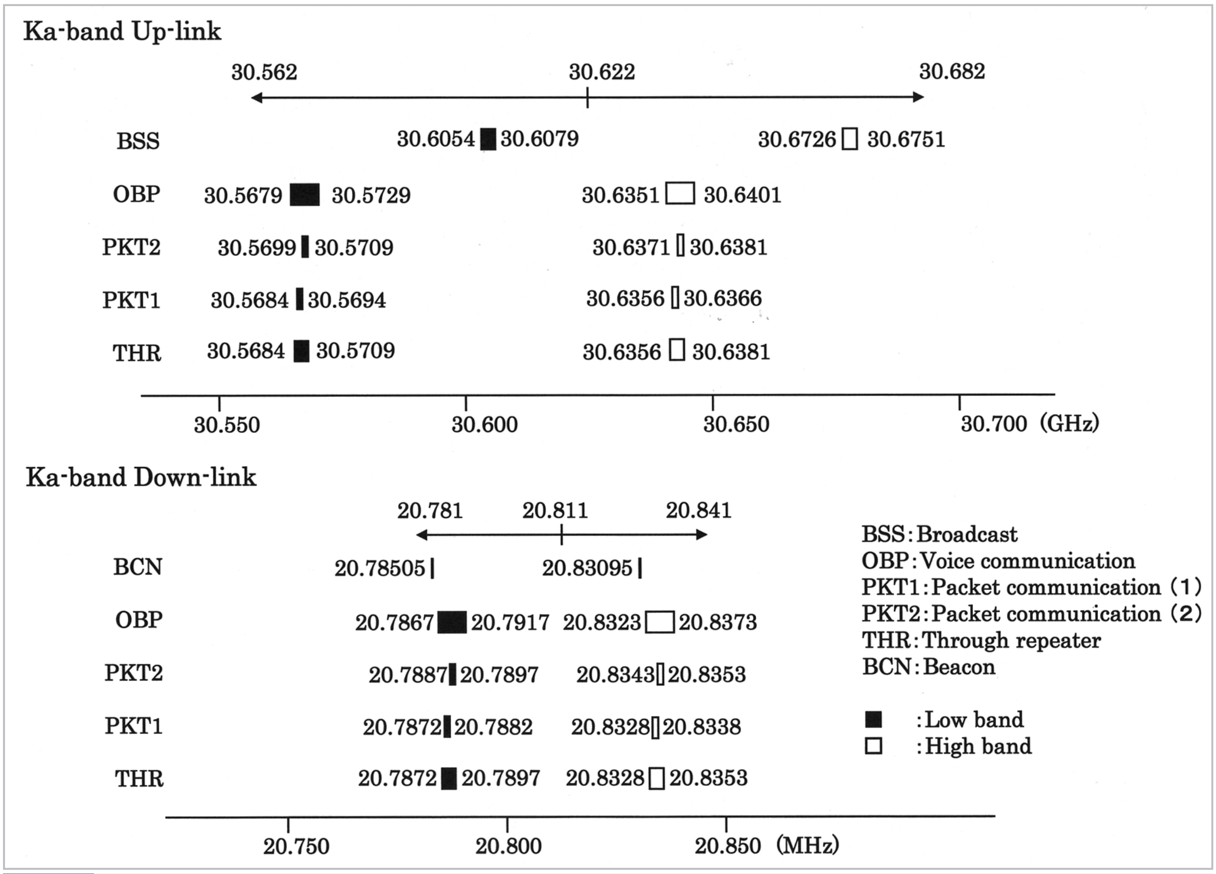

Fig.7 *Ka-band frequency allocation*

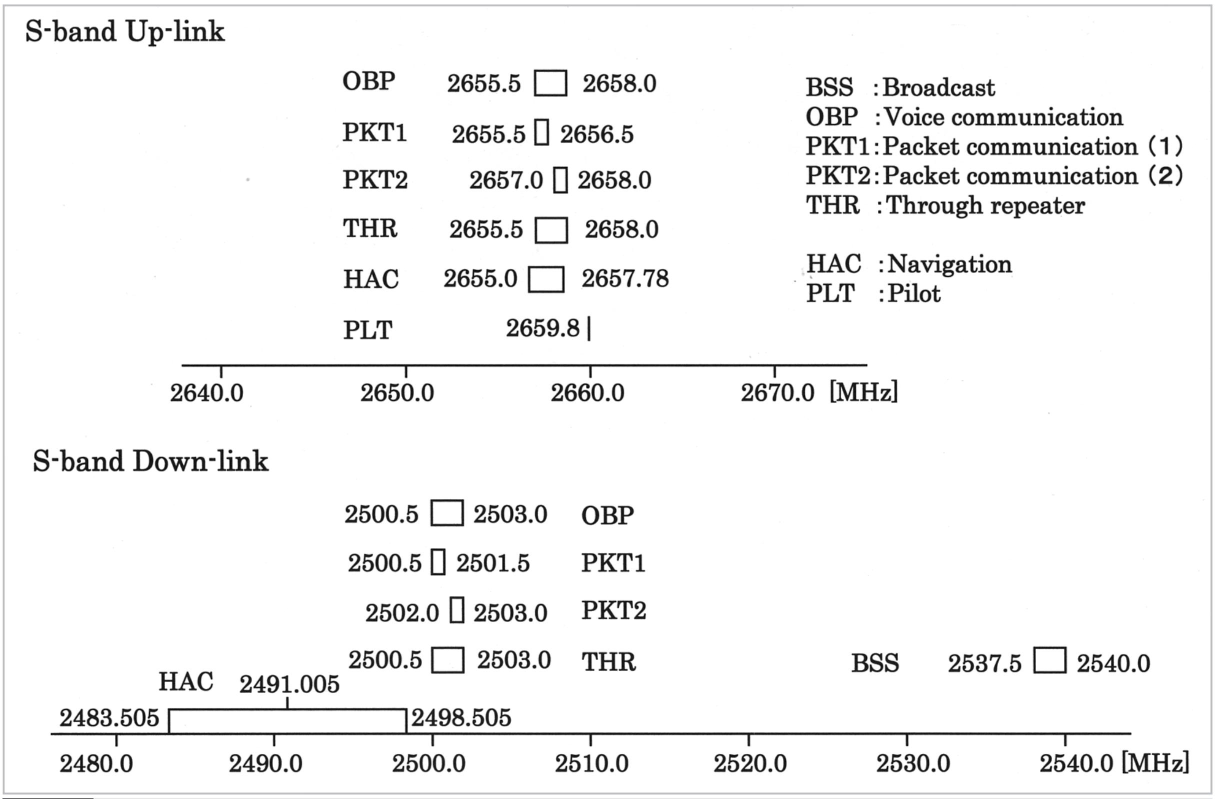

Fig.8 S-band frequency allocation

downlink. For service link frequencies, the 2.6-GHz band is used for uplink, and the 2.5-GHz band is used for downlink.

5 Concluding remarks

This paper described the configuration of a transponder for experiments in mobile satellite communications and broadcasting. Details of the functions and performance of constituent equipment (such as the onboard satellite antenna, the antenna feed system, and the onboard packet switch) will be described in subsequent papers.

Mobile satellite communications and broadcasting experiments by ETS-VIII are indispensable in the establishment of the technologies required in next-generation mobile satellite communications. We anticipate that these experiments will prove fruitful.

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