4-7-2 Terminals for High-Data-Rate Satellite Communications Experiments

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The Communications Research Laboratory has been studying the mobile satellite communications network and developing an onboard packet switch. An onboard switch makes satellite communications systems with a multi-beam structure more efficient. In this communications system, a compact mobile earth station that can be installed in a mobile system or that is easily portable is assumed. The terminal equipment for the mobile station and the feeder link station has already been developed. This paper describes the characteristics of terminal equipment, which performs well enough to meet the requirements of experiments to evaluate the mobile satellite communications system and onboard packet switch.

Keywords
Engineering Test Satellite VIII, Mobile satellite communication, Packet signal, Mobile terminal

1 Introduction

Two ground-based terminals are used in high-data-rate satellite communications through a packet switch installed aboard the Engineering Test Satellite VIII (ETS-VIII): a base terminal connected to a Ka-band feeder-link earth station, and an S-band mobile terminal mounted to a vehicle or connected to other portable earth station. The base terminal is composed of two MODEM/controller sets, and the mobile terminal is composed of a MODEM and a controller. This report gives a general description of this equipment.

2 Earth station for high-data-rate satellite communication experiments

The S-band mobile earth station for high-data-rate satellite communication via onboard packet switch is designed to be an in-vehicle mobile station capable of installation in a compact passenger car and an easily portable small-sized earth station. Since the packet signal includes the information for switching control, all packet signals transmitted to the satellite undergo onboard regenerative repeating. Based on the control information obtained by demodulating the signal from the earth station, a transmission signal is sent to a modulator, which converts the signal to a beam directed to the appropriate earth station [1].

In the high-data-rate communication experiments, a base terminal is connected to a Ka-band feeder-link earth station, and an S-band mobile station terminal is mounted to a vehicle or other portable station. The mobile terminal is composed of a MODEM and a controller. The onboard packet switch has two I/O ports for the Ka-band feeder link, and the base terminal is composed of two MODEM/controller sets, each set corresponding to each port. The transmission signal frequency in the S-band mobile link is set to 2656 MHz or 2657.5 MHz for uplink and to 2501 MHz or 2502.5 MHz for downlink, and the terminal equipment is configured to offer selectable input/output signal frequency: 138.5

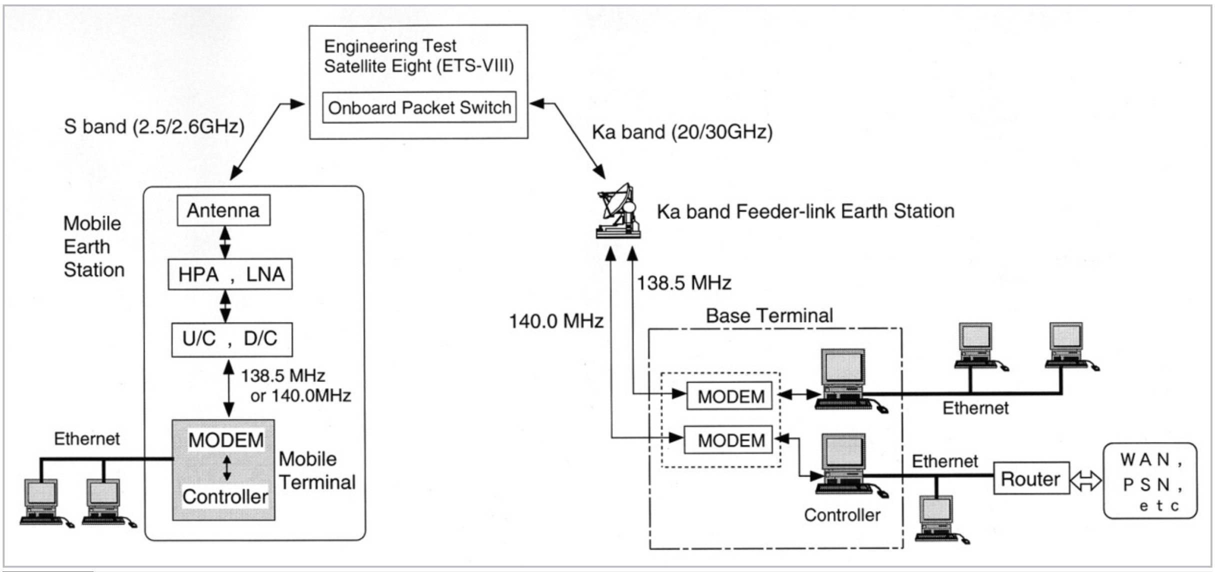

Fig. 1 *Block diagram of packet communications system*

MHz or 140 MHz. Fig.1 shows a block diagram of the communications system.

Both the in-vehicle mobile earth station and the portable small-sized earth station have an EIRP of 18 dBW or more and a G/T of approximately −22 dBK or more.

Table 1 shows an example of the link budget in the S-band assuming installation of an omni-directional antenna with 6 dBi gain and a high-power amplifier featuring 20W transmission output in the mobile earth station and the small-sized earth station. On the other hand, the use of a high-gain directional antenna in the above two earth stations would enable a reduction in the output of the high-power amplifier. Components of the mobile earth station and the small-sized earth station to be used in experiments after the launch of the satellite include an omni-directional antenna (gain of approx. 6 dBi), a phased array

Table 1 *Example link budget (for mobile link)*

Up-link (2.6 GHz)		Down-link (2.5 GHz)	
Mobile station		Satellite	
HPA output power	43.0 dBm	HPA output power	47.3 dBm
Feed loss	1.0 dB	Feed loss	1.5 dB
Antenna gain	6.0 dBi	Antenna gain	40.1 dBi
Mobile station EIRP	48.0 dBm	Satellite EIRP	85.9 dBm
Propagation loss	192.6 dB	Propagation loss	192.1 dB
Satellite		Mobile station	
Rx antenna gain	42.7 dBi	Rx antenna gain	6.0 dBi
Feed loss	1.1 dB	Feed loss	1.0 dB
Rx power (at LNA in)	-103.0 dBm	Rx power (at LNA in)	-101.4 dBm
System noise temp.	520 K	System noise temp.	450 K
System G/T	14.6 dBK	System G/T	-21.5 dBK
Up-link C/No	68.5 dBHz	Up-link C/No	70.7 dBHz
Required C/No	64.2 dBHz	Required C/No	64.2 dBHz
Link margin	4.3 dB	Link margin	6.5 dB

antenna and a portable antenna (each featuring gain of approx. 12 dBi), and a high-power solid-state amplifier featuring output of up to 50 W.

3 Terminal equipment for high-data-rate satellite communication experiments

The base terminal and the mobile terminal to be used in the high-data-rate satellite communication experiments offer nearly equivalent electrical performance, as both perform communications through the onboard packet switch. Table 2 shows the performance characteristics common to the two terminals, and Table 3 and Table 4 show characteristics specific to their respective MODEMs. Commercial personal computers are used as controllers for both terminals; any personal computer offering the performance shown in Table 5 may be used as a controller. Table 2 and Table 3 include configuration diagrams of the mobile terminal and of the base terminal, respectively, and Fig.4 and Fig.5 show photographs of the respective terminals. Desktop personal computers are used as the two controllers (shown in the left of each photograph).

"Maximum allowable input" in Table 2 refers to the maximum allowable input level that does not result in equipment failure. Under normal operations, the maximum input level is −9 dBm. When the input level exceeds this value, the bit error rate (BER) increases rapidly. Fig.6 is a graph of BER versus input level, with forward error correc-

Table 2 Main performance characteristics common to base terminal and mobile terminal

Modulation / Demodulation : π/4 shift QPSK / Coherent detection
Transmission rate : 1024 kbps
Access scheme : Slotted ALOHA , Reserved packet
Forward error correction : Convolution coding (Constraint length K=7, Coding rate = 1/2) / Viterbi decoding (3bit soft decision)
Packet signal length : 8 msec (normal) [32 msec at maximum]
Input/Output frequency : 138.5MHz, 140MHz
Input frequency shift : < ±30kHz
Output frequency stability : < ±2ppm
Input level : -19 ～ -9dBm (-12dBm (normal))
Maximum allowable input level : 0dBm
Output level : -10dBm (normal)
Output spurious : < –63dB
Input/Output impedance : 50Ω
VSWR : < 1.5
Input/Output connector : BNC
LAN interface : 10BASE-T
Other functions for experiments
- ON/OFF switch for output of signal
- ON/OFF switch for forward error correction
- ON/OFF switch for modulation
- ON/OFF switch for differential coding

Table 3 Additional specifications of mobile terminal MODEM

Input/Output frequency : 138.5MHz or 140MHz (selective)
Interface for MODEM : 50pin D-sub connector (RS422)
Power supply : 100VAC (±5V) or DC12V (±4V)
Size : 48 (width)×15 (height)×50 (length) cm
Weight : 11 kg
Power Consumption : 86 W (at maximum)
Operational temperature : 0 deg ～ 40 deg
Operational humidity : < 80%
Input/Output signal : Serial data (RS422)
Input/Output connector : D-sub connector (50pin)

Table 4 Additional specifications of base terminal MODEM

Input/Output frequency : 138.5MHz, 140MHz (2port)
Interface for MODEM : 50pin D-sub connector (RS422)
Power supply : 100VAC (±5V)
Size : 48 (width)×31 (height)×51 (length) cm
Weight : 19 kg
Power Consumption : 200 W (at maximum)
Operational temperature : 13 deg ～ 33 deg
Operational humidity : < 80%
Input/Output signal : Serial data (RS422)
Input/Output connector : D-sub connector (50pin)

Table 5 Main specifications of baseband switch controller

Clock frequency : >10MHz
Main memory : > 32Mbyte
Hard disk : > 1Gbyte
OS : Windows 2000 professional
Interface for MODEM : PCI card (26pin half-pitch connector)
Size, Weight and Power consumption : depending on specifications of the personal computer for controller

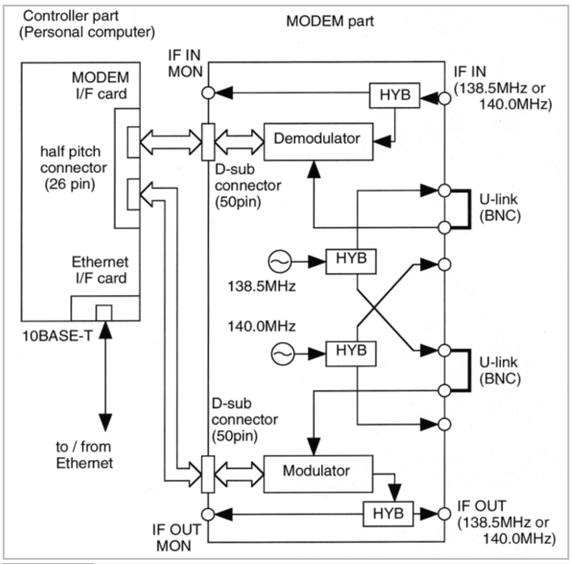

Fig.2 Block diagram of mobile terminal

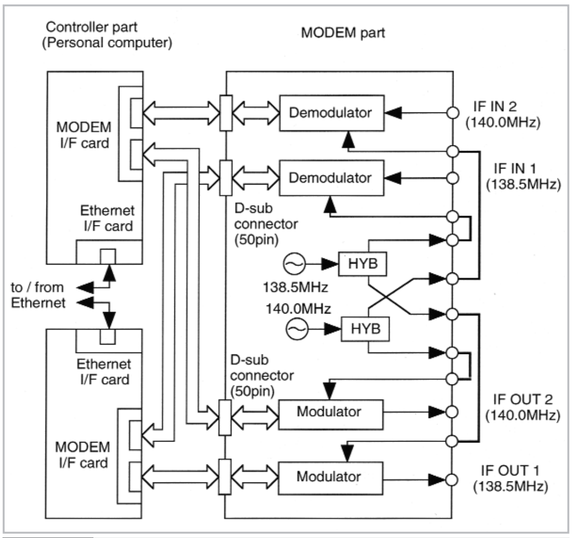

Fig.3 *Block diagram of base terminal*

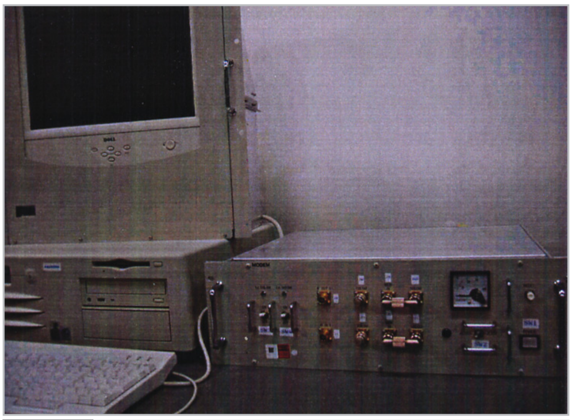

Fig.4 *Photograph of mobile terminal*

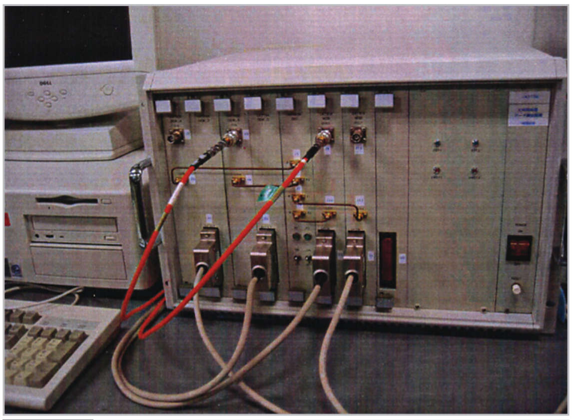

Fig.5 *Photograph of base terminal*

tion. When the Eb/No value was sufficiently large (Eb/No > 30 dBHz), no bit error arose during measurement with input from －19 dBm to －9 dBm, corresponding to a BER of 10^{-8} or less. When the input level reduces below －19 dBm or exceeds －9 dBm, the

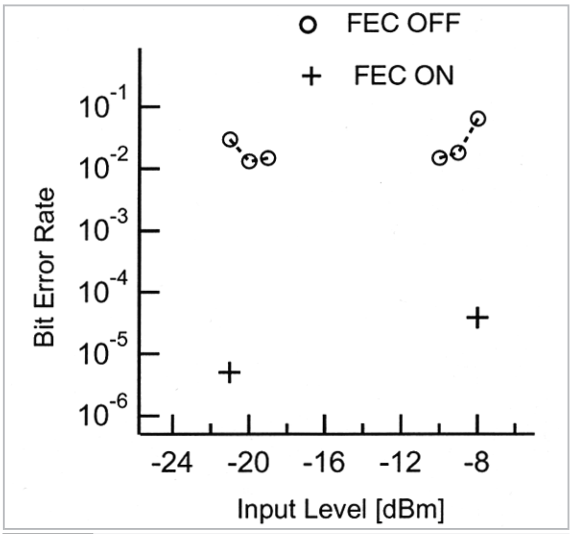

Fig.6 *BER versus input level*

BER increases abruptly. Input level thus should be maintained at the proper level in experimental operations.

Fig.7 illustrates the relationship between BER and Eb/No. Since the design of the MODEM is almost the same as that of the MODEM of the onboard packet switch (differing only in the environmental conditions of operation), the obtained results generally agree with the BER characteristics of the onboard packet switch.

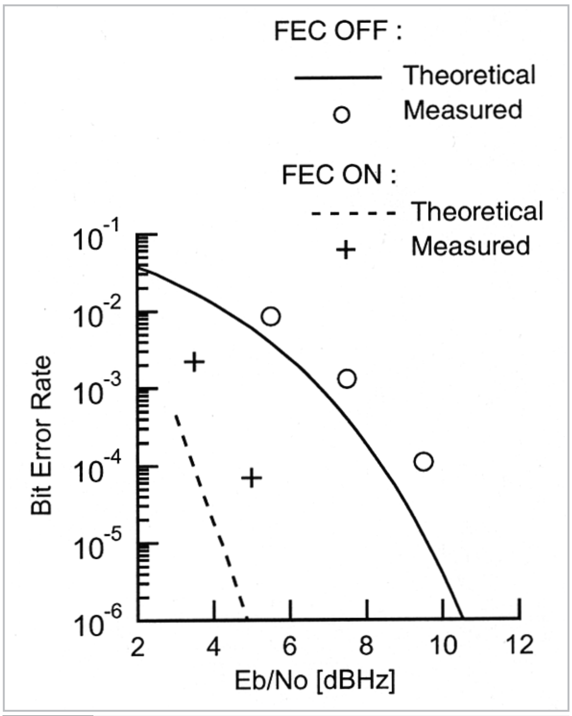

Fig.7 *BER versus Eb/No*

4 Base terminal switch control program loading

As described above, the base terminal and the mobile terminal feature nearly equivalent electrical performance. However, only the base terminal can upload the baseband switch control program used in the onboard packet switch. Although the onboard packet switch has a function of a bridge in the data link layer, the switch can operate in an upper layer when the relevant program is uploaded. The program is transmitted from the earth station to the satellite.

Fig.8 illustrates the operational mode of the onboard packet switch. When power is supplied to the onboard packet switch, the operational mode shifts automatically from “Off mode” to “Wait mode.” In order to shift to an “Operate mode” which is the usual mode in high-data-rate satellite communication experiments, the switch control program must be uploaded from the earth station. Specifically, the following procedures are required, entailing the use of a communication link and a telemetry and command system.

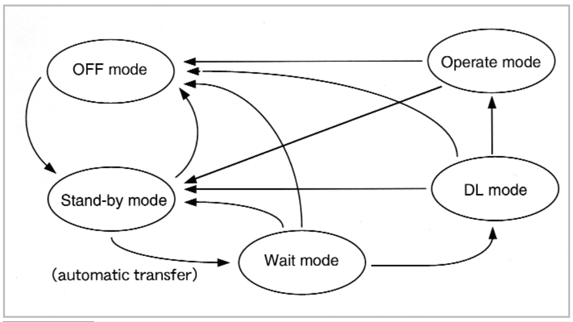

Fig.8 *State transition diagram of onboard packet switch*

(1) Confirmation via telemetry signal that the switch is in “Wait mode”
(2) Transmission of the command signal to the satellite from command equipment in order to shift from “Wait mode” to “DL mode.” “DL mode” means the state for uploading the switch control program.
(3) Confirmation via telemetry signal that the switch has been shifted to “DL mode”
(4) Communication-line transfer of the switch control program to the satellite from the base terminal via packet signal
(5) Confirmation via telemetry signal that program uploading is completed
(6) Transmission of the command signal from the command system in order to set the switch to “Operate mode”
(7) Confirmation via telemetry signal that the onboard packet switch has been shifted to “Operate mode”

The switch control program is divided into packet signals of a length set by the base terminal and then transmitted to the satellite. If an error occurs in transmitted packet signals, the signals are automatically transmitted again by the selective ARQ method, ensuring that the program to be uploaded is free from errors.

Although the base terminal is being developed on the assumption that it will be connected to the Ka-band feeder-link earth station, program uploading via the S-band mobile link is also possible. However, since ARQ retransmission is performed while the program is uploaded, if BER of packet signals goes above 10^{-5}, the time required for uploading will increase abruptly [2]. It is thus very important that the ratio of the carrier power to the noise power density (C/No) of the satellite link be sufficiently high.

5 Concluding remarks

We have provided a description of the mobile and base terminals for high-data-rate satellite communication experiments. This mobile terminal, which can be mounted in a 19-inch rack, will be installed in an experimental vehicle and used for mobile satellite communication tests.

References

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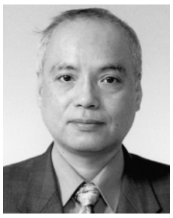

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