4-7 Experimental Communications and Broadcasting Terminals

4-7-1 Functional Model of a Hand-held Terminal for OBP Experiments

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We developed an experimental terminals used with on-board processor (OBP) for a mobile satellite voice-communication experiment. It consists of rack-mounted experiment equipment, in addition to an antenna for hand-held terminals. We made terminals with S band RF transmitters and terminals for base stations without S band RF transmitters. These terminals handle a fixed communication mode and a normal OBP operational mode and respond to pre-assigned channels as well as the demand assignment access method. In addition to their function as communication terminals, they load operational programs and control and observe OBP with the assistance of attached equipment. We checked all the functions using a combination of tests with the OBP installed on the engineering test satellite VIII (ETS-VIII).

Keywords
Satellite communication, Regenerative transponder, Digital signal processing, Hand-held Terminal

1 Introduction

The ETS-VIII (Engineering Test Satellite VIII) onboard processor (OBP) for voice communication has been developed as a switching board for a mobile-satellite voice communication system using hand-held terminals. To enable the deployment of such terminals, the ETS-VIII is equipped with a large deployable antenna, and the OBP is assigned a range of functions: filtering, line switching, modulation, demodulation, and more, capitalizing on improvements made possible by developments in digital signal-processing technology.

In satellites employing conventional bent pipe systems, communication interfaces (other than radio interfaces) were checked by terminal-to-terminal testing. Since the OBP is equipped with a communications protocol (specifically to control communications) in addition to its role as a modulator and demodulator, the OBP must also execute verification of the interfaces for modulation and demodulation; consequently, advance verification of the connection between the onboard equipment and the terminal is essential. We thus conducted performance testing of the entire ETS-VIII communication system, confirming that the system worked as anticipated and was capable of stable communication.

This paper reports on the configuration and performance of a test terminal for OBP experiments.

2 Overall configuration

Although the OBP is targeted for use with hand-held terminals, a large portion of the cost of development is expected to be devoted to the construction of a very small aperture terminal, similar to the terminals employed in ground-based cellular phone systems. Experimental factors for evaluation must include propagation characteristics, method of modulation, characteristics of the communications protocol, and others. In particular, antenna and terminal shapes also have an effect on propagation characteristics. Based on the assumption that the form of the antenna has a significant effect on performance, we developed an antenna model for a hand-held terminal. On the other hand, since the form of the antenna does not affect the characteristic of the modulation scheme and the communication protocol, we thus adopted a rack-mount structure to hold these components. Figs.1 and 2 show photographs of the antenna unit and experimental terminal.

Fig.3 shows a block diagram of the experimental terminal. The terminal is made up of the antenna unit, equipped with a low noise amplifier (LNA), and a rack-mounted terminal section. This section consists of an S-band RF unit incorporating an S-band 20-W SSPA, a modulation and demodulation unit, and a power supply. Three sets of the experimental terminals were manufactured. One of these sets consists of a base station terminal without the S-band RF unit, but with a device to control and observe the OBP.

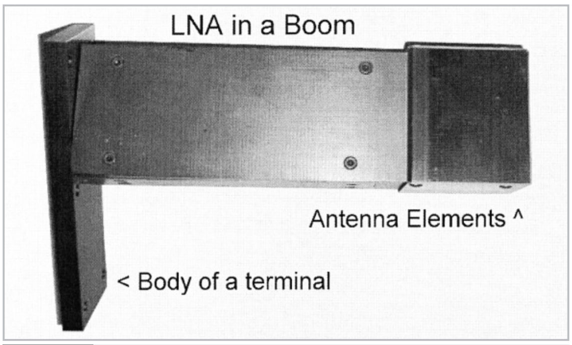

Fig.1 *Photograph of antenna unit*

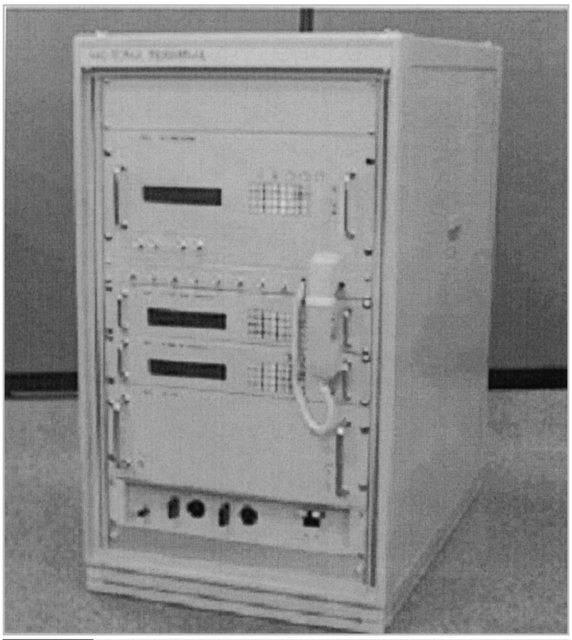

Fig.2 *Photograph of experimental terminal*

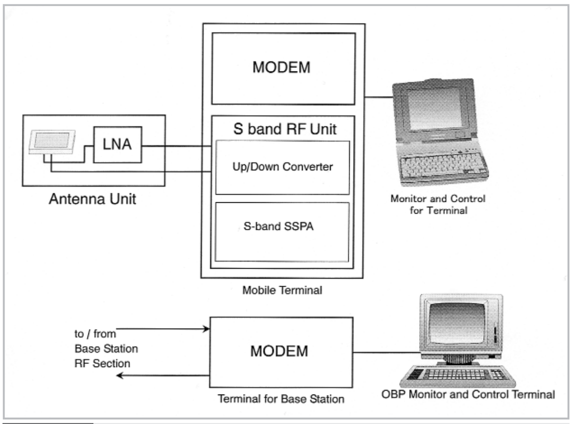

Fig.3 *Block diagram of experimental terminal*

3 Antenna unit

A transmitting and receiving common patch antenna was developed for the hand-held terminals. Fig.4 shows the structure of the antenna developed. With a two-layer configuration composed of an upper patch and a lower patch, the antenna is capable of both transmission and reception [2][4]. The antenna is attached to a boom extending from a dummy hand-held terminal body. The effects of the transmission waves on the human body are reduced by orienting the antenna away from the user. Moreover, the LNA and filter are built into the boom itself, to minimize the size of the antenna. Elevation can be changed by rotating the boom, but the azimuth is dependent on the user's position [3]. It is difficult to direct the antenna toward the satellite at all times during a call; nevertheless, the satel-

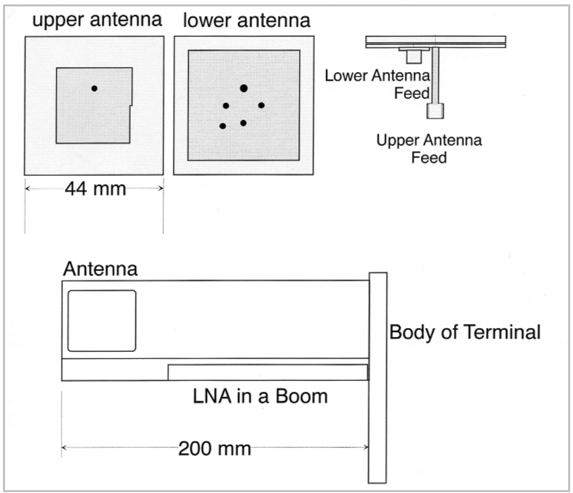

Fig.4 Structural drawing of antenna unit

lite's elevation is restricted to approximately 45 degrees (within Japan) by maintaining the antenna surface on a horizontal plane, even with a changing azimuth. The gain for an elevation of 45 degrees is approximately 0 dBi, and allows for stable communication. In addition, since the antenna is positioned away from the user, the antenna pattern is only minimally affected by the body [1].

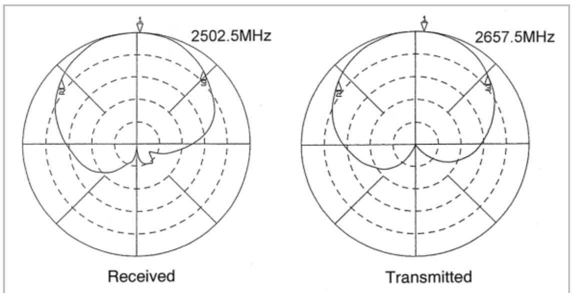

Fig.5 Antenna pattern

Fig.5 shows the antenna pattern without the boom. Table 1 the shows main specifications of the antenna unit.

Table 1 Main specifications of antenna unit

Frequency	TX: 2.6 GHz, RX: 2.5 GHz
Gain	3 dBi
Axial ratio	less than 4 dB
Isolation	more than 14 dB
Antenna type	Self-diplexing stacked patch antenna
G/T	more than -25 dBK

4 S-band RF unit

The S-band RF unit consists of a transmission frequency converter, a reception frequency converter, and a solid-state amplifier. Fig.6 and Table 2 show the configuration of the S-band RF unit and its main specifications.

The S-band solid-state amplifier (SSPA) is

Table 2 Main specifications of terminal section

S band RF section	
Frequency	TX: 2655.5 to 2658.0 MHz RX: 2500.5 to 2503.0 MHz
Transmission power	20 W (saturation)
Frequency stability	less than +/- 3E-7
DEMOD section	
Access method	MC-TDMA (FDD)
Time slots	5 slot / carrier
Number of carrier	50 carrier / 2.5 MHz (50 kHz separation)
Modulation	π/4 shift QPSK
Information rate	Voice: 5.6 kbps (/slot) Data: 32 kbps (/carrier)
Channel assign	Demand assign random access (slotted ALOHA)
Voice codec	PDC half rate codec (5.6 kbps)

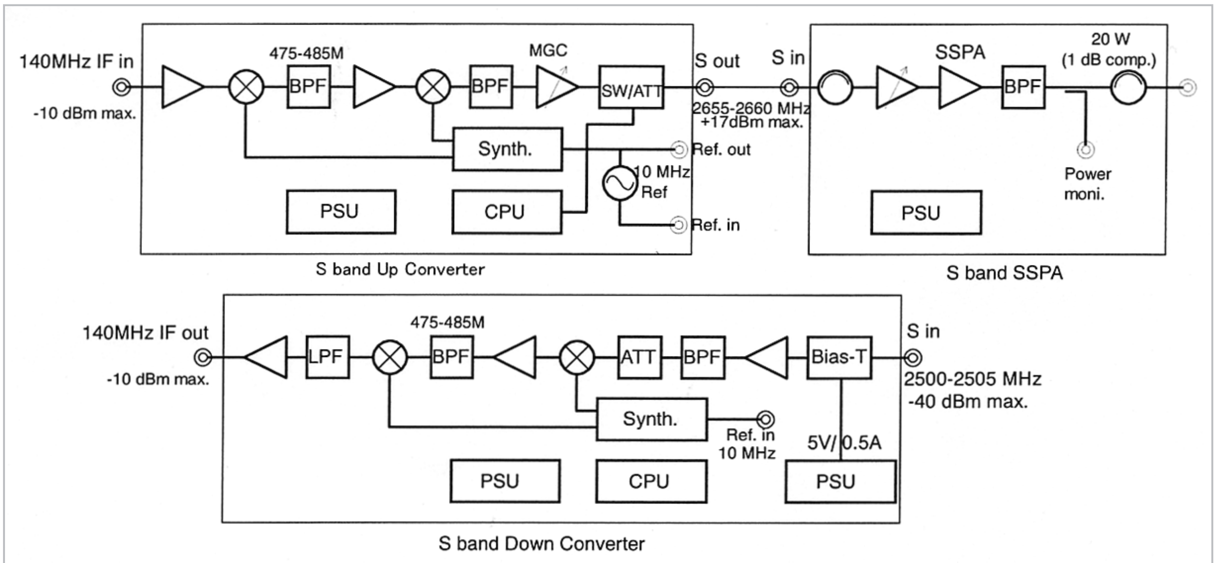

Fig.6 Block diagram of S-band RF unit

capable of 20-W output (with 1-dB suppression), and can emit 10 W in linear operation. The SSPA is provided with gain compensation to account for temperature change, restricting gain deviation to ±0.3 dB or less from 5 to 35℃.

The transmission frequency converter converts a 140-MHz band IF signal input into a 2.6-GHz band transmitted signal for output to the SSPA. This converter is part of a double-conversion system, in which a local signal is created by a quartz crystal oscillator or generated from an external frequency reference signal by a synthesized oscillator. The converter features a 10-dB variable attenuator (1-dB steps) in its output section, enabling adjustment of transmitted power. The operator can set the output level and the RF frequency via front-panel key operations.

The reception frequency converter converts a 2.5-GHz band received signal input from the antenna unit into a 140-MHz band IF signal. This converter is part of a double conversion system, as with the transmission frequency converter; here a local signal is generated from the frequency reference signal of the transmission frequency converter or from an external frequency reference signal provided by a synthesized oscillator. The RF input terminal is equipped with a bias T circuit; the converter can thus supply power of +5 V/0.5 A to the LNA of the antenna unit.

5 Modulation and demodulation section

The configuration of the modulation and demodulation section is shown in Fig.7. Since the modulation and demodulation section operates at a 10-MHz band IF, the modulation and demodulation section features both a frequency converter to convert the 10-MHz band IF into a 140-MHz band IF and another to convert the 140-MHz band IF into a 10-MHz band IF. The modulator unit consists of two modulators: one for the communication control signal and another for data. The signals from each control processor are modulated by each modulator (both of which are $\pi/4$-shift QPSK modulators), and converted to an analog IF signal in the 10-MHz band through a digital-analog converter. The frequency converter on the reception side features gain control to optimize the modulator input level for signals from -10 dBm to -57 dBm. The demodulator unit uses an analog-digital converter to sample the analog 10-MHz band IF signal at a clock rate of 44.8 MHz. The demodulator unit holds two demodulators: one for the communication control signal and one for data. In each demodulator a $\pi/4$-shift QPSK signal is demodulated and processed by a DSP (Digital Signal Processor). In demodulating the $\pi/4$ shift QPSK signal, the sampling rate is reduced by half using a half-band filter and subsequently subject to quadrature detection via a digital down converter. The

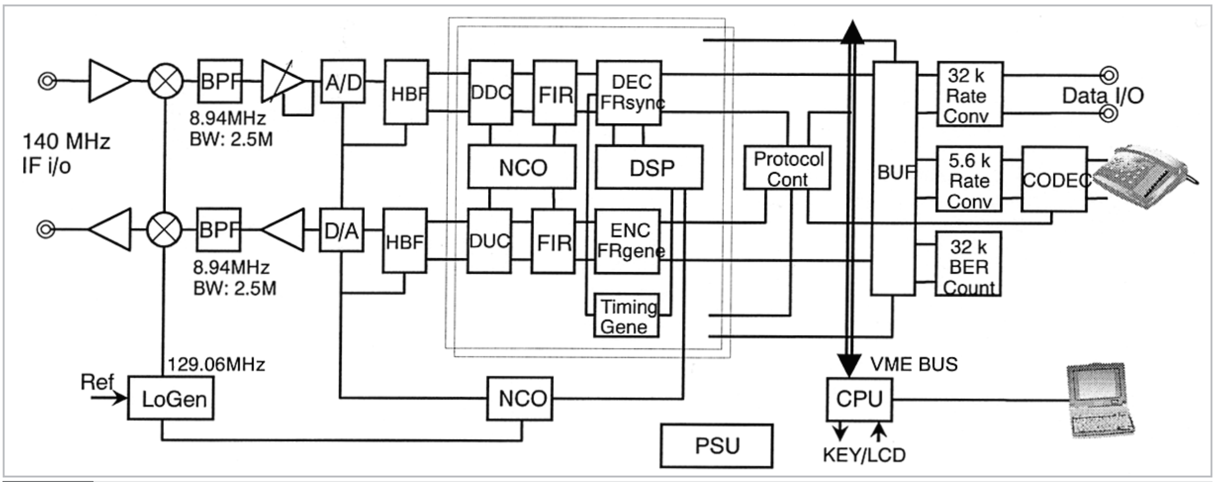

Fig.7 *Block diagram of modulation and demodulation section*

signals are then demodulated after passing through root Nyquist filters. The DSP provides symbol synchronization, carrier synchronization, and other functions. The CPU processes the communications protocol of the OBP.

The modulation and demodulation section allows external equipment to interface with the communication data through RS422, and permits the user to call using a built-in voice CODEC for PDC. Moreover, in BER measurement mode, the modulation and demodulation section can be connected to an error-rate measuring circuit for BER and FER measurement.

The OBP operates according to a demand assign method in which a reference signal, control signal, and communication signal are assigned to different frequencies, with the communication signal assigned to a frequency that features a burst position at the start of a call. The reference signal serves as a time and frequency reference to be output from the satellite OBP. In order to stabilize operation, the experimental terminal was designed to incorporate a dual-wave internal modulator/demodulator to eliminate frequency switching and to ensure stable receipt of the reference signal. In addition, it is possible to generate the reference signal in test mode within the experimental terminal and conduct a point-to-point test using the experimental terminals alone, thanks to the dual modulator/demodulator design.

6 Operation and protocol

The experimental terminal can be operated in two modes: a protocol mode for normal exchange control and a fixed mode corresponding to the test mode of the OBP. The test mode of the OBP involves channel pre-assignment without exchange control. This means that channel setting within the experimental terminal must conform to an MC-TDMA (Multi-Carrier Time Division Multiple Access) frame; further, adjustment of transmission timing is also required. Channel setting is performed by selecting a frequency and a TDMA slot for each communication beam. The transmission timing must be set such that the distance from the satellite is calculated, the transmission time per symbol is found, and the transmission signal agrees with the time determined based on the OBP reference signal.

In protocol mode, a call can be made by dialing the telephone number of another party and originating the call, provided that the user has assigned an identification number to the experimental terminal and registered both this number and the device's position.

Switching from fixed mode to protocol mode is performed when the operator issues the relevant software to the OBP. The base station terminal allows the operator to conduct mode change after the fixed mode (e.g., program loading mode) and OBP operation (e.g., alteration of burst transmission timing information). Moreover, the base station terminal also allows for observation and monitoring of OBP status. Connecting the control/observation apparatus of the base station terminal to an experimental terminal featuring an S-band RF unit enables OBP control and monitoring with the experimental terminal. Note that OBP status and monitoring data is output to only one beam of the S-band service link, although it is also output to a Ka-band feeder link.

7 Voice and data transmission interfaces

Voice communication is performed in the OBP at a transmission rate of 5.6 kbps. The OBP uses a CODEC of the PSI-CELP (Pitch Synchronous Innovation-Code Excited Linear Prediction) system currently used in ground system hand-held terminals as a voice CODEC. The PSI-CELP performs error-correcting coding only for information that may significantly affect voice content in the encoding process. In the OBP communication system, error correction will be performed twice, through convolution coding and Viterbi decoding, and consequently it is assumed that the PSI-CELP system requires no further error correction functions. Since the voice CODEC is not optimized, evaluation of voice quality is omitted in this apparatus.

This interface enables data transmission at a rate of 32 kbps, and can input and output data at the TTL level. Further, the interface measures the error rate internally, and also enables BER and FER at transmission rates of 5.6 kbps (for voice transmission) and 32 kbps (for data transmission) in OBP test mode.

8 Testing and characteristics

Both when the OBP was delivered and when the OBP was installed on the satellite, a combination of tests were carried out on the experimental terminal and the OBP, including measurement of error rate, connection testing, and a call test [5]. The measured error rate attributable to non-regeneration relaying nearly agreed with the theoretical value, showing almost no degradation. The connection worked normally as well, enabling a call.

Since the OBP experimental terminal was designed based on the principle of regeneration relaying, in which the communication signal and the control signal are transmitted with the same frequency deviation, the signal from the Ka-band base earth station must be tuned to the appropriate frequency within the OBP. More specifically, the frequency deviation between the communication signal and the reference signal sent from the OBP must be limited to 120 Hz. In the ETS-VIII, the local signals of the Ka-band frequency converters are generated by a common oscillator. Further, the earth station provides frequency correction for both reception and transmission. The experimental terminal supports narrowband signal communications as a result. Note that the S-band side employs an independent local signal; consequently it is necessary to verify that the non-regeneration relaying signal frequency is within a range allowing for demodulation by a hand-held terminal.

9 Concluding remarks

The equipment under study, including the OBP and related components, was developed by the Advanced Space Communication Research Laboratory (ASC). As the research activities of this organization came to a close, development of the subsequent equipment was transferred to the CRL.

The CRL further developed the experimental OBP terminal under study and verified that the performance matched design criteria. In addition, the CRL conducted connection testing with an actual device to be installed on the satellite and confirmed normal operation.

The CRL has thus developed an experimental functional model of a satellite handheld terminal, though a significant amount of work still needed to be carried out to produce a more compact version. We would point out that our experimental OBP terminal corresponds to a BBM (Bread Board Model) of onboard satellite equipment. In addition, a number of features were omitted from the experimental terminal, such as the dual modulator/demodulator and the diversion of PSI-CELP as a voice CODEC; consequently several items remain to be developed before the hand-held terminal can be put to practical use.

References

1 H. Mitsumoto, et al, "Characteristics of an Antenna for Hand-held Phone Terminals of S-band Satellite Communications", IEICE General Conference, B-1-194, Mar. 1998. (in Japanese)

2 M. Yawata, et al, "Self-Diplexing Stacked Patch Antenna for Mobile Satellite Communication", IEICE A-P99-6, Apr. 1999. (in Japanese)

3 H. Mitsumoto, et al, "Antenna Section of a Satellite Comminication Handset", AP2000, 09-14, Apr. 2000.

4 H. Arai, et al, "Self-Diplexing Antennas of Small Mobile Satellite Phone Terminal for ETS-VIII", IEICE A-

P2000-156, Jan. 2001. (in Japanese)
5 S. Yamamoto, et al, "Mobile terminal for On-board Processor (OBP) on the ETS-VIII", IEICE General Conference, B-3-15, Mar.2003. (in Japanese)

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