Portable Earth Station

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ETS-VIII is equipped with a large deployable antenna of S-band, which launched in December 2006, it is possible to provide performance equivalent to that of the parabolic antenna with a diameter of 13 m in on-orbit. Therefore, satellite communications using a small terminal can be performed on the ground. NICT was developed portable earth station, which is possible to voice and data communications, and acquired the transmission characteristics and connection performance using the ETS-VIII. As part of the communication experiments using a mobile terminal that was developed, participated in the disaster prevention drills that the local government carried out, and confirmed that transmission of the disaster information by satellite communications was effective means.

1 Introduction

Satellite cellular phones are very effective as a means of communication to be used at such locations where communication networks on the ground or cellular phones are not available, and as a means of emergency communication when communication line and telephone circuit on the ground are disconnected when a disaster occurs.

The Engineering Test Satellite VIII (hereafter referred to as ETS-VIII) is equipped with one set of S-band large deployable antennas for transmission and reception, and performances equivalent to those of parabolic antennas with 13 m in diameter could be presented in orbit. Installation of such a large-sized antenna on the satellite improves transmission and reception performances of the satellite, and on the ground, can provide communication services using a small-sized terminal with excellent portability are made possible, thereby it contributes to a personal satellite communication and secures communication in the event of an emergency such as a natural disaster.

The small-size portable earth station (hereafter referred to as mobile terminal) used in this experiment is based on practical specifications of shape, weight and transmission power similar to those for cellular phones on the assumption that a large deployable antenna mounted on the satellite is used, and consumption of power or the like were investigated to allow for battery-power, and a prototype was produced[1][2][5].

Although ETS-VIII succeeded in deployment of the large reflector of antenna after launch, the large deployable antenna for reception could not be used due to problems with a low-noise amplifier of receiving unit[3]. Then, in the communication experiment, a parabolic antenna of 1 m in diameter had to be used as the reception antenna of the satellite, and a parabolic antenna was used as a transmission antenna of the mobile terminal on the ground to compensate for the reduction of the receiving performance of the satellite, followed by communication experiments. This paper describes the results of the communication experiment that use the mobile terminal prototype.

2 Outline of mobile terminal

Outline of the mobile terminal used in the experiments is described here. Figure 1 shows the external appearance

(1) Handheld type (2) PDA type

Fig.1 Appearance of a portable terminal of the prototype mobile terminal to be used in the communication experiments, and Table 1 shows the principal particulars of the same.

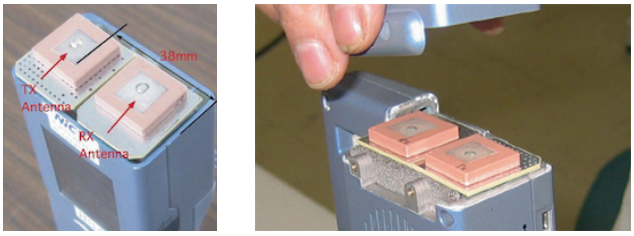
Mobile terminal falls into two types of handheld and PDA devices. The PDA type is characteristic in that its LCD for display is large, while internal circuits are almost identical. To realize miniaturization of the terminal and the exterior is free from protrusions, the transmission and receiving antenna has such a construction as shown in Fig. 2 to be built into the upper part of the housing.

The built-in antenna is a ceramic patch antenna and is provided separately for transmission and reception. Peak gain of the antenna including losses of housing cover at upper plane is about 3 dBi. Looking toward the terminal, right side is for reception and left side is for transmission. The size of the antenna element is 30 mm × 27 mm, and a band-pass-filter is coupled directly beneath the antenna. Figure 3 shows the external appearance of the patch antenna.

Figure 4 shows a block diagram of the mobile terminal.

Table 1 Main specifications of the portable terminal

Frequency band	2.5GHz (RX)/2.65GHz(TX)
Transmit Power	1W
Antenna (Both TX and RX)	Gain: 3dBi (peak gain, Built-in case) Polarization: LHCP
Modulation	8kbps BPSK
Connection method	FDMA
Channel spacing	12.5kHz
Voice coding	PSI-CELP (5.6kbps)
Power supply	Six NiMH batteries (A size AA or AAA batteries)
Continuous talk time	30min or more (when AA batteries)
Weight, Volume (Handheld type)	266g・264cc (Without batteries)



Handheld type PDA type

Fig. 2 Built-in patch antenna

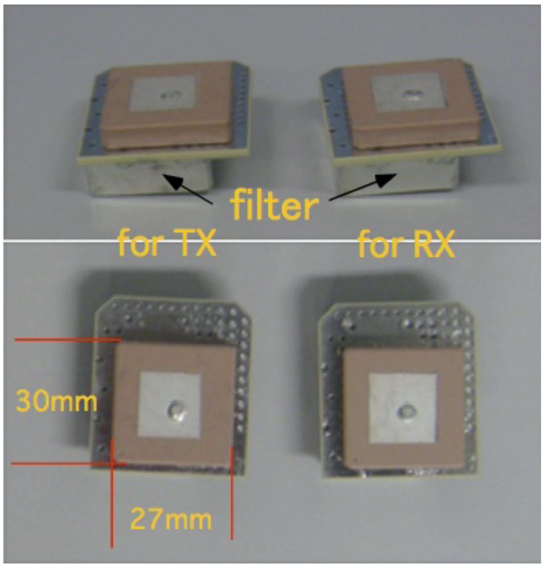


Fig. 3 Appearance of the patch antenna

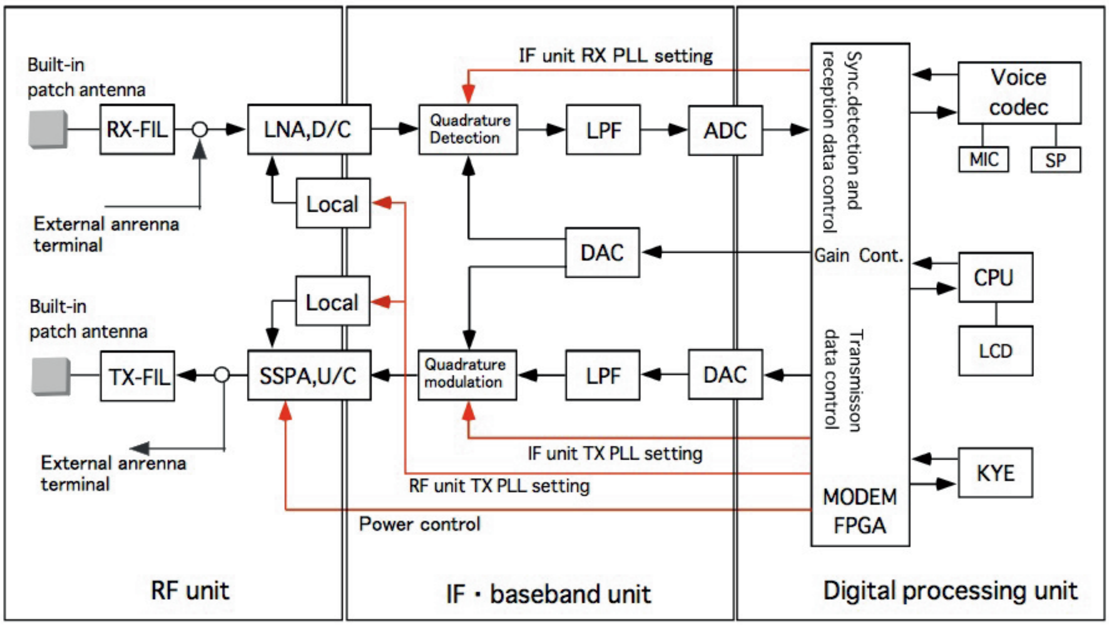


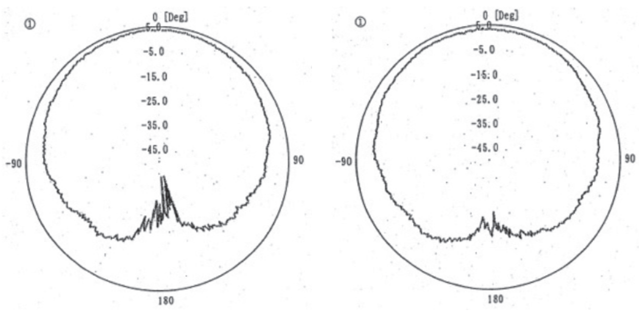
Fig. 4 Block diagram of a portable terminal

It is largely divided into three sections of RF unit, IF and the base band unit, and digital processing unit. The antenna which is constituting the RF unit has such a construction that an external antenna could be connected for both transmission and reception.

Figure 5 shows radiation patterns of a single patch antenna to be built. Figure 6 shows radiation patterns when patch the antenna is accommodated in the housing. The radiation pattern for incorporated cases is distorted as compared with the single case since the antenna is influenced by the place of mounting the transmission and reception antenna and metals in the housing.

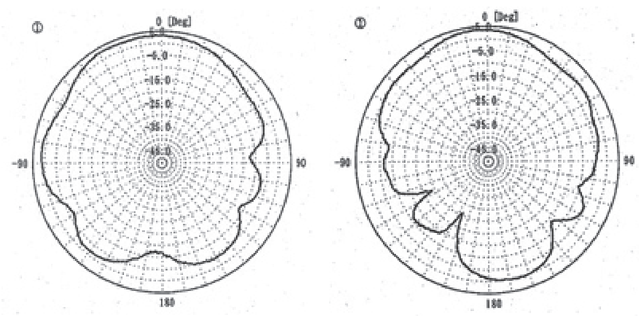
Power consumption of handheld types is about 18 W at transmission. Power consumption of PDA types is slightly greater than that of handheld types. To lengthen the operation time of the battery, investigation was made to provide lower power consumption. As a result, for solid state power amplifiers (SSPA) that consume a comparatively large of power, one using the pulse dope type FET was newly produced. Power consumption of this SSPA is 5.2 W when output power is 1.78 W (earth station transmission power 1 W) and its efficiency is 34.2%.

We made a prototype of the mobile terminal which performs voice communication of information at a rate of 5.6 kbps as noted above, and also a prototype of the mobile terminal which performs a data communication transmission at a rate of 64 kbps and the modulation method of QPSK. Size and external appearance of the terminal are the same as those of the PDA type mobile terminal shown in Fig. 1.



TX (at 2655MHz) RX (at 2500MHz)

Fig. 5 Antenna pattern of the patch antenna (antenna only)



TX (at 2655MHz) RX (at 2500MHz)

Fig. 6 Antenna pattern of the patch antenna (Built in the housing)

3 Communication experiments

In the communication experiments using the satellite, the large deployable antenna of the satellite for reception could not be used due to problems with a low-noise amplifier (LNA), so a parabolic antenna with 1 m in diameter constituting a high accuracy clock (HAC) was used. G/T of this receiving system, is - 8.4 dB/K or more (-2 dB area: the area where the antenna gain is 2 dB down when the reception antenna pattern is projected on the earth, which covers nearly all of Japan). G/T (design value) of the receiving system using large deployable antenna for reception is +13.8 dB/K, and reduction in receiving performance of the satellite is compensated by using a folding type parabolic antenna 68 cm in diameter when using a voice mobile terminal of 5.6 kbps. Further, compensation for transmission is made by using a parabolic antenna (3.6 mϕ) when using a data communication mobile terminal of 64 kbps.

Table 2 shows an example of link budget when using a built-in patch antenna for the reception antenna of 5.6 kbps voice mobile terminal. Transponder gain of the satellite is set to 150 dB.

Figure 7 shows a block diagram that conducted communication experiments. Figure 8 shows an aspect of communication experiments. Table 3 shows main specifications of the folding type parabolic antenna.

In the communication experiments, transponder ETS-VIII is made to the cross link connected to the S-band from S-band, and used single hop (mobile terminals are connected directly) as shown in Fig. 7.

3.1 Voice mobile terminal

Outgoing and incoming calls of the mobile terminal are direct calls between mobile terminals. Specific ID numbers and transmission/receiving channels for each terminal are assigned to all of the mobile terminals. After the opponent ID number is set to the mobile terminal, calling is initiated by pressing the call button in a similar manner as a cellular phone. The setting of the ID number of the opponent address, is done in four ways as shown below, and can be operated in the same way as cellular phones.

Table 2 Example link budget

	Up-Link	Down-Link
Frequency (GHz)	2.65	2.50
TX power (dBW)	0.0	0.8
feeder loss (dB)	1.4	1.8
ANT Gain (dBi)	22.4	40.4
EIRP (dBW)	21.0	39.4
Propa. loss (dB)	192.4	191.9
RX ANT Gain (dBi)	25.0	2.9
pointng loss (dB)	0.0	0.0
feeder loss (dB)	2.8	1.5
RX power(dBW)	-149.2	-151.0
system Noise temp. (K)	-	600
G/T (dB/K)	-8.4	-26.3
C/No(dBHz)	48.8	49.9
C/No total (dBHz)	46.3	
Bit Rate (kbps)	8.0	
Eb/No (dB)	7.3	
Threhsold Eb/No (dB)	5.6	
margin (dB)	1.7	

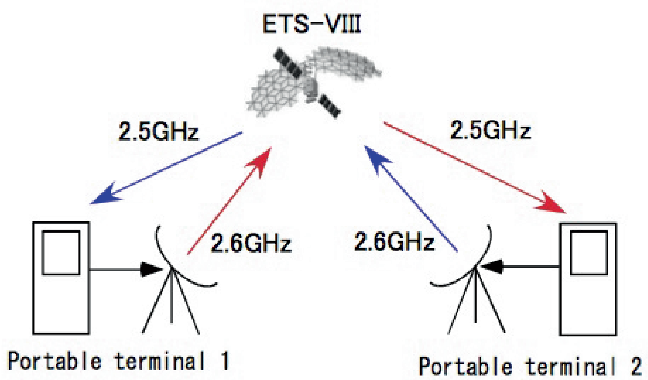


Fig. 7 Block diagram of a portable terminal experiment

Fig. 8 State of the communication experiment

1. Direct key input
2. Selection from address book
3. Selection from outgoing call history
4. Selection from incoming call history

Figure 9 shown is a screen to configure settings from the address book.

The sequence of incoming and outgoing calls is performed in the following procedures:

1 Set the opponent ID number to the mobile terminal and press the call button. Call using a common calling channel.

2 The mobile terminal in waiting state is always receiving a calling channel. The station when confirmed a calling of its own station and the ID number of the calling station, responds to the individual receiving channel of the calling station.

3 The calling terminal is receiving the individual own receiving channel, and after response from the terminal being called is confirmed, and return the response to the individual receiving channel of the terminal being called, and proceeds to communicate without change.

3.1.1 Connection performance

Connection performances were confirmed using the call sequence and used C/No of the received signal of the

Table 3 Main specifications of the folding type parabolic antenna

Frequency band	S-band (2.50GHz to 2.65 GHz)
Primary radiator	quadrifilar helical antenna
Gain	21.6 dBi (RX 2.50GHz) 22.4 dBi (TX 2.65GHz)
Size	667×732 mm
Weight	2.2 kg

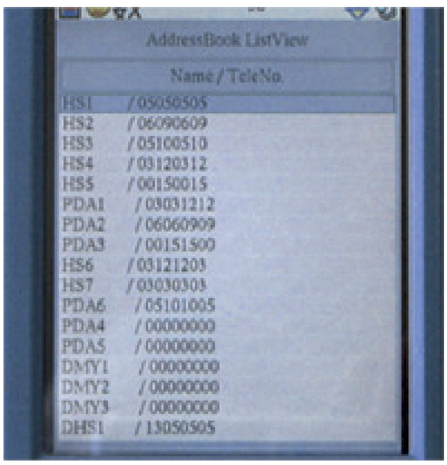


Fig. 9 Select the ID number from the address book

called station as the parameter. Figure 10 shows the composition diagram of the experiments.

In the experiments, a folding type parabolic antenna was used as the reception antenna and C/No was made variable by adjusting a variable attenuator (ATT) which is placed front of LNA of receiving unit of the mobile terminal, to investigate the connection with response to the calling. Figure 11 shows the results of the experiments. As for the mobile terminals, five sets are handheld types and three sets are PDA types, in Fig. 11, HS means handheld types and PDA means PDA types. Numerals attached to them are for identification purposes.

X-axis represents the value of ATT which was placed front of LNA, and y-axis represents the value of C/No which was measured at the called station side. These values were measured at intermediate frequency (IF).

The green line shows a range where connection was possible, when a PDA type #1 (PDA1) was called from a handheld type #4 (HS4), in the range of about 7 dB (from 44.7 dBHz to 51.4 dBHz) of C/No of the reception station side. The red line shows a range where connection was possible, when a handheld type #2 (HS2) was called from HS4, in the range of about 6 dB (from 43.6 dBHz to 49.7 dBHz) of C/No of the reception station side.

When C/No of the received signal is less than 44 dBHz, although connection was possible, loss of synchronization occurred during communication, and it was not possible to continue communication in a stable manner.

It is shown from the results of the experiments that connection of mobile terminals and stable continuation of the communication could be performed in the range of C/No of the received signal at about 44 dBHz to 51 dBHz, although there was an individual difference of terminals.

When transmission power is 1 W, the folding type parabolic antenna is used for the transmission antenna, and the built-in patch antenna is used for a reception antenna of the mobile terminal, C/No of received signal is about 46 dBHz for PDA1 and about 48 dBHz for HS2. Although there are individual differences, both are in the range of C/No of received signal that allows stable connection and communication.

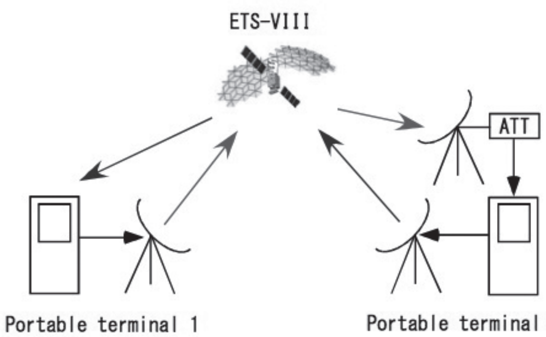


Fig. 10 Block diagram of the link connection performance experiment

3.1.2 Communication quality

To evaluate communication quality between mobile terminals, Bit Error Rate (BER) characteristics were obtained. Figure 12 shows a block diagram for BER characteristics measurement. A PDA type mobile terminal (PDA #3) was used for transmission side and two types of handheld types and PDA types were used for reception, and connected to BER measuring device, and BER was

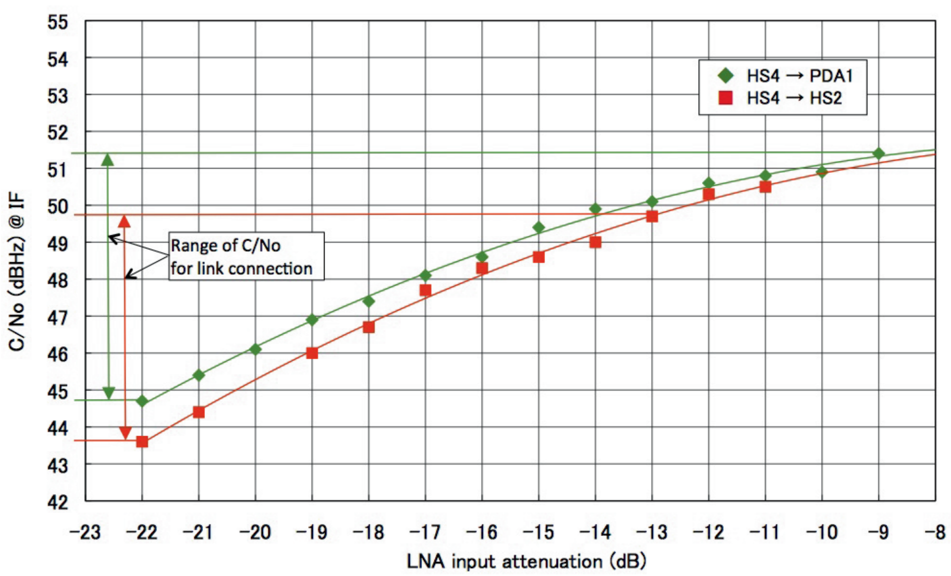


Fig. 11 Link connection performance

measured. The mobile terminal at transmission side has a function of output of the pseudo random noise (PN) code which was used at the measurement. Meanwhile, the voice mobile terminal uses PSI-CELP for voice coding and error correction is also made using the function of PSI-CELP. For this reason, error correction is not performed at BER measurement.

A built-in patch antenna was used for the mobile terminal of the reception side, and the EIRP of the satellite was varied by adjusting the gain of the transponder of the satellite to give the desired C/No at the reception side. C/No was measured at IF of the mobile terminal of the reception side.

Figure 13 shows the BER characteristics measured (without error corrections).

As a result of the measurement, it is shown that the deterioration of BER acquired by HS4 from the theoretical value is about 1 dB. In PDA2, there was a slight tendency for the signal to deteriorate when C/No of the received signal is 48 dBHz or more. The reason for this is that a cold cathode tube is used for a back light because the PDA type has a large LCD display and the inverter power supply for the back light generated noise. It was confirmed that when signals after AGC are observed in the indoor test, C/N deteriorated when the inverter power is ON as compared with when it is OFF. When using the PDA2 of reception side and C/No was 48 dBHz or more, a noise from the inverter power supply exceeds system noises and thereby deteriorates BER.

Since the handheld terminal's small LCD display uses an LED backlight, the effect of noise due to the backlight didn't occur.

In the communication experiments, C/No of received signal was about 46 to 48 dBHz when the built-in patch antenna was used for reception, and from Fig. 13, BER for no error correction case was about 2E^{-3} to 2E^{-4}. Mobile terminals use PSI-CELP for a voice coding, and so it obtained good voice quality in a voice communication by coding and an error correction, when C/No is 46 dBHz (BER = 2E^{-3}) or more.

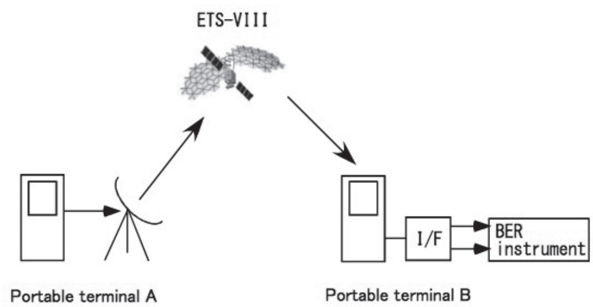


Fig. 12 Block diagram of the BER characteristics measurement

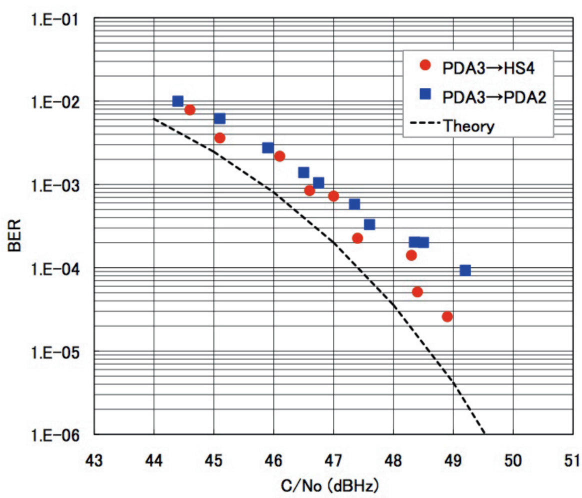


Fig. 13 BER performance of the portable terminal (Without error correction)

3.2 Mobile terminal for data communication

We developed a mobile terminal for data communication with the same profile as the PDA type mobile terminal, with a transmission rate of 64 kbps, and modulation method is QPSK. Figure 14 shows an external appearance of the mobile terminal. Table 4 shows the main specifications of the mobile terminal for the data communication prototype.

In the communication experiments, a parabolic antenna with 3.6 m in diameter was used for the transmission, and a folding type parabolic antenna 68 cm in diameter was used for the reception.

Figure 15 shows a block diagram of the communication experiments.

The parabola antenna (3.6 mϕ) for the transmission is used for mobile terminals A and B. The transmission signal is synthesized by hybrid (H) and is transmitted from the parabolic antenna (3.6 mϕ) via a filter (BPF). At the reception side, a folding type parabolic antenna (68 cmϕ) is connected to each of mobile terminals.

In this experiment setup, when a signal transmitted from mobile terminal A, and received by mobile terminal B, C/No of the received signal was about 57 dBHz.

3.2.1 Connection performances

Connection experiments were conducted with the composition shown in Fig. 15.

After the address number of the mobile terminal of the

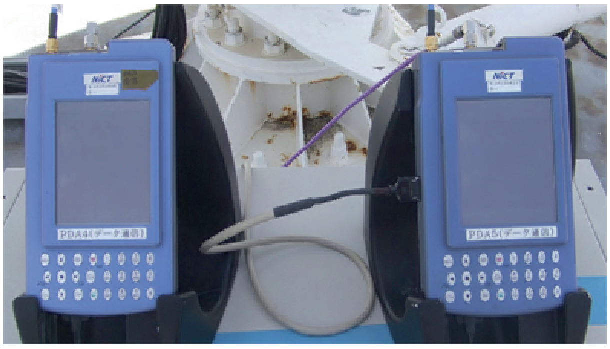


Fig. 14 Appearance of portable terminal for data communication

Table 4 Main specifications of portable terminal for data communication

Frequency band	2.5GHz(RX)/2.65GHz(TX)
Transmit Power	0.5W
Antenna	*1 Polarization: LHCP
Transmission rate Modulation method	64kbps QPSK
Connection method	FDMA
Channel spacing	100kHz
Error correction method	Convolution coding (R=1/2, K=7) Viterbi decoding
Power supply	DC 7.2V 2A built-in battery: NiMH battery
Operating time (using built-in batteries)	10min or more
Volume (mm)	105(W)×185(D)×45(H)
Weight	500g (Without batteries)

*1 for TX: 3.6mϕ parabolic antenna (Gain: 35.8dBi)
for RX: 68cmϕ folding type parabolic antenna (Gain: 21.6dBi)

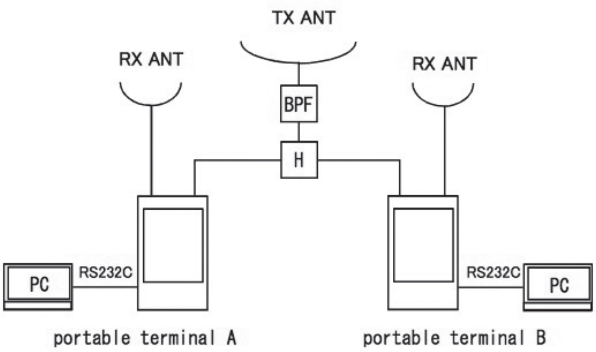


Fig. 15 Block diagram of a communication experiment

opponent is set and the call button is pressed, an outgoing call is made and if the opponent responded, connection is made.

According to results of the test, C/No of the downlink signal was 57.8 dBHz for a case of transmission from mobile terminal A and received by mobile terminal B, and was 56.3 dBHz for a case of transmission from mobile terminal B and received by mobile terminal A.

Next, receiving C/No of both terminals was reduced by inserting a variable attenuator between the transmission filter (BPF) and the parabolic antenna (3.6 mϕ) to reduce the transmission power, and C/No that allows connection was measured. An ATT of 1 dB was inserted into transmission of mobile terminal B to obtain the same conditions of C/No of the received signal at connection. It was confirmed by the experiments that connection was still possible even if C/No of received signal was reduced down to 50.8 dBHz. However, disconnection occurred frequently during communication, and C/No for stable continuation of the communication was 51.5 dBHz or more.

3.2.2 BER characteristics

BER characteristics were obtained by the composition shown in Fig. 16. It was transmitted from mobile terminal A, and down link signal was received by mobile terminal B and to measure BER.

C/No of signal of the reception side was made variable by regulating the transmission power by variable attenuator (ATT) connected to the transmission side. A BER measuring device was connected to mobile terminal B to take BER measurements. Mobile terminal A of transmission side has the PN code output function inside, and used it.

Figure 17 shows the result of the measurement. According to this composition, if PN code being outputted from mobile terminal was used, the error correction is not made. Therefore, measured BER is without error corrections.

BER measured in C/No of 57 dBHz was 1E^{-3}, which means that deterioration of about 2 dB from the theoretical level was seen. As the reason for deterioration, although influences of noises by back light for display LCD as observed in BER characteristics of PDA type for voice use (5.6 kbps) are conceivable, noises of the transponder of the satellite are received by the folding type parabolic antenna is used for the reception antenna at the data transmission mobile terminal, measurement of No are greater than those at experiments of 5.6 kbps mobile terminal for voice use, and in addition, there is no unnatural variation. Accordingly, the authors consider that there is no influence of noise from the back light.

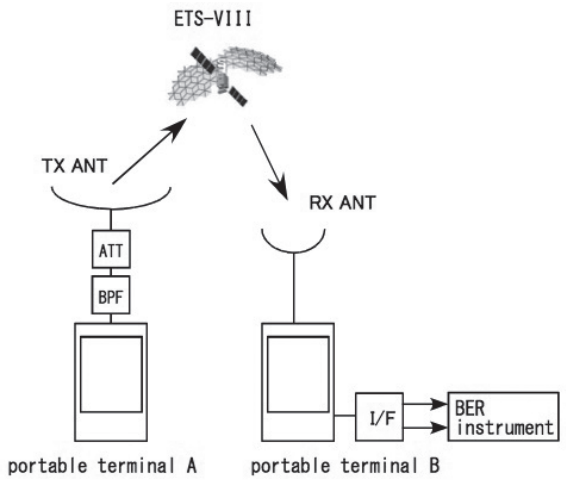


Fig. 16 Block diagram of the BER characteristics measurement

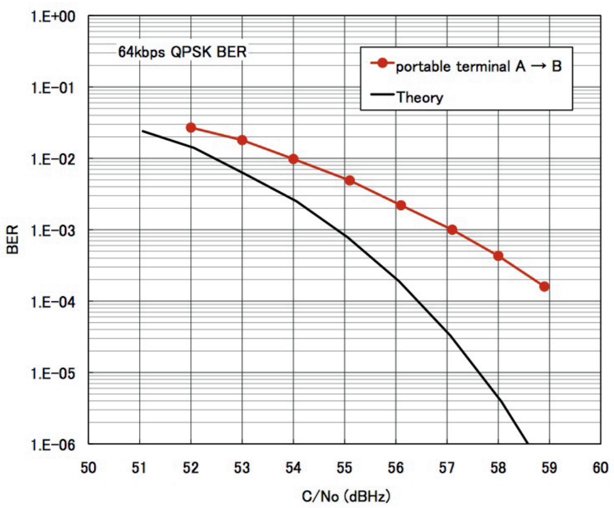


Fig. 17 BER performance of the portable terminal (Without error correction)

3.2.3 File transfer tests

When mobile terminals are in connected state with the composition shown in Fig. 15, data communication is made possible between personal computers (PC) connected to each of them.

When performance data communication is performed after connecting to the PC, an error correction is enabled.

In the experiment, the PC was connected to mobile terminals A and B, and a data file transfer test was carried out.

As with the BER measurement, the receiving C/No was changed by method of adjusting the transmission power, the received file was compared with the transmitted, file and the error rate was obtained from the transferred data. The data file as arranged 1 byte ASCII characters in random, the file size is 51.5 KB. And this file was transmitted 10 times continuously.

The result of experiment, when the data file is transferred from the mobile terminal A to B, confirmed that the transferred data is error free, when C/No is 56.0 dBHz or more. When C/No was 54.7 dBHz, the error rate of the data received was $2.9E^{-4}$. The error rate of the data was calculated from number of transferred characters and number of incorrect characters.

Further, it was confirmed that when the data file was transferred in reverse direction from the mobile terminal B to A, data transferred was error free, when C/No was 56.1 dBHz or more. When C/No was 54.5 dBHz, the error rate of the data received was $2.9E^{-4}$.

Actual measurement of time needed for transfer of the data file was about 2 min 53 to 55 sec.

1 frame is 40 msec in the frame format of data communication, and the number of bits is 2560 bits, and area for data storage is 2464 bits. When calculated as an 8 bit 1 byte of data, when using an error correction, the time it takes to transfer 10 times the file is 133.76 sec (about 2 min and 14 sec). About 3 sec are necessary, after the first file transfer is completed before the next file transfer is started, therefore it takes about 2 min 40 sec for transfer of 10 times the data file, and this time is approximately identical with the actual measurement. From the results thus obtained, it is confirmed that file transfer by the mobile terminal for data communication was performed normally without causing any delay in the processing in data transfer. And confirmed when C/No was 56 dBHz or more, the data being transferred has no error. Further, compared the results of data transfer and the BER characteristics (no error correction), confirmed that the gain due to the coding is obtained.

4 Others

4.1 Influences of electromagnetic wave to the head

When the large deployable antenna for reception of the satellite is operating normally, use of an ear speaker and microphone built in the handheld type mobile terminal, can be used like a cellular phones. In the development phase of the mobile terminal, we investigated the influences of electromagnetic waves on the head in the use of such[4].

As shown in Fig. 18, a handheld type mobile terminal was mounted close to the head phantom of the human body, and measured by the thermography method the electric power absorbed by the human body.

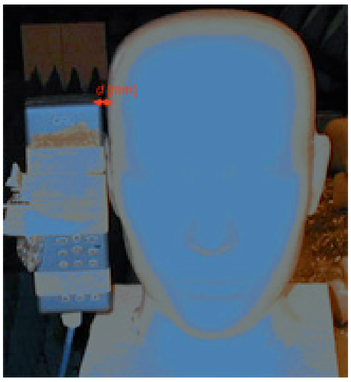


Fig. 18 Portable terminal attached to the phantom

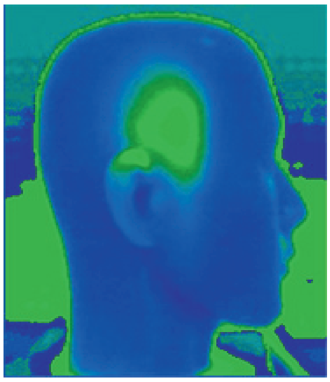


Fig. 19 Temperature rise of the head by an electromagnetic wave

Tokyo comprehensive disaster drill

Sakurajima volcano explosion comprehensive disaster drill

Tokyo islands comprehensive disaster drill

Fig. 20 State of communication experiments in disaster drills

It was confirmed from results of the measurement, that if the housing of the mobile terminal is set apart 5 mm or more from the head, 2 W/kg is an acceptable level of specific absorption rate (SAR) per 10 g of any in the ordinary environments are met[5][6].

Figure 19 shows aspects of the elevation of the head temperature around the antenna, after test electromagnetic waves are radiated. The built-in patch antenna of mobile terminal used in this experiment is designed to reduce the absorption of electromagnetic waves to the head, when using the mobile terminal in near the head, and disposed the transmission antenna in a position distant to the head. However, since the transmission power of the satellite mobile terminal is greater than that of cellular phones, the terminal should be designed so that absorption of electromagnetic waves by the human body satisfies the allowable level.

4.2 Participation in disaster drill

We considered that the satellite mobile terminal is extremely effective to be used as a means of transmission of information when a disaster occurs and the communication network on the ground was damaged and disconnected. In the communication experiments, we participated in a disaster drill simulated by the local government, and installed mobile terminals assuming disaster occurrence, and connected communication links, and performed the training of transmission of information by voice, and was checked its effectiveness. In the experiments, we participated to the disaster drill that was conducted in Tokyo and Kagoshima Prefecture, and performed installation of mobile terminals, and performed transmission of information by voice. Further, the transmission of information by voice is performed using a mobile terminal by the general public and concerned parties who participated in drills, and a voice quality that can transmit accurate information was confirmed. In addition, they operated the mobile terminal and were able to experience the easiness of the connection between mobile terminals using the satellite links in the same operation as the cellular phones. Figure 20 shows the state of disaster drills.

4.3 Investigation of power supplying

In the event of a disaster, the supply of the electric power for operating such the communication system in the

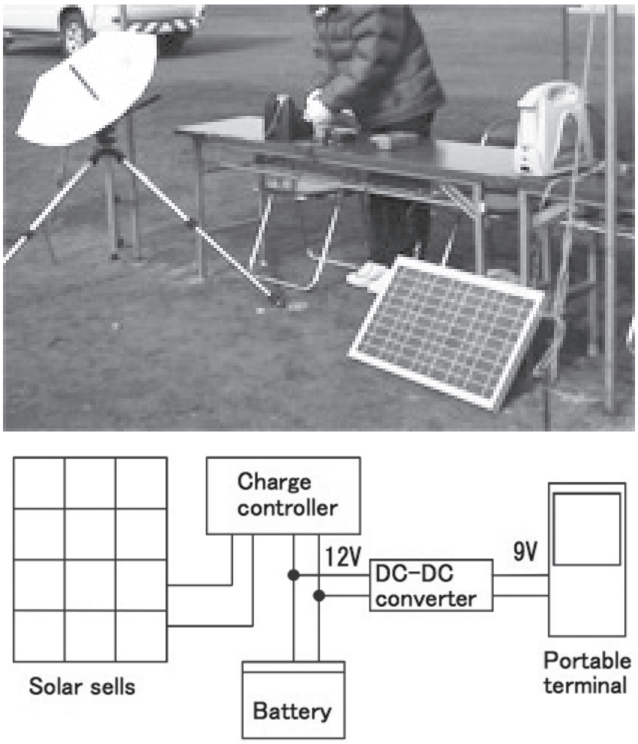


Fig. 21 Power supply system (Trial in disaster drill)

disaster area is assumed to become difficult. Although the mobile terminal could be operated by a battery, operation time is short. Therefore, to realize the information transmission for several days, it is necessary to consider the electric power supply system that combines an external battery and solar cell charge system. Figure 21 shows a power supply system that was used in the disaster drill. This system configured of battery (20 Ah), solar cell (generated power: max. 30 W), charge/discharge controller and DC/DC converter.

If power consumption of the handheld type mobile terminal at transmission is 18 W, and at reception (standby) is 5 W, the continuous operation is possible of about 20 hours by the battery alone while a battery (20 Ah) is used and ratio of transmission and reception is 1 : 1. A system for battery charge using the solar cell was considered. If average sunshine duration in Japan is estimated to be about 3 hours, and continuous operation of 24 hours is considered, it is difficult to obtain required power of a day for reception (standby state) even when using the 30 W solar cell. Therefore, when the continuous operation for several days in the disaster area is considered, supply of the electric power is an important investigation item.

5 Conclusions

Using ETS-VIII, satellite communication experiments by the mobile terminal were conducted, and were verified that voice and data communication was possible, and basic data including connection performance, transmission characteristics and the like were obtained. ETS-VIII could not use the large deployable antenna for reception by failure of the receiving system, so that we conducted the communication experiments using the parabolic antenna for transmission on the ground side.

We participated in a disaster drill performed by the local government, and confirmed that satellite communication is effective as an information transmission means in the event of a disaster, and good voice quality is obtained in communication using mobile terminals. We considered, if the general public could connect to the opponent easily by nearly the same operation as used for cellular phones, and used the terminal without being conscious of satellite communication.

Communication network and cellular phone circuits were damaged by the Great East Japan Earthquake occurred in March 2011, and it took more than 1 month to be restored. During this period, information communication using the satellite circuits was extremely useful and this is still fresh in our minds.

At present, the satellite communication service using mobile terminals is provided also in Japan, In the future, this may become more popular as a means of communication during disaster times.

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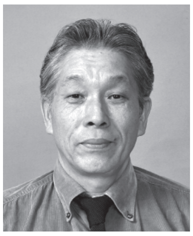

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