4-7-6 Portable S-band Terminal for ETS-VIII Communication Experiments

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National Space Development Agency in Japan (Japan Aerospace Exploration Agency since Oct. 2003) has developed test models of S-band portable terminal to conduct experiments; such as large deployable reflector (LDR) antenna pattern measurement experiment and utilization experiments. These test models work as through repeaters and have a TCP/IP accelerator to compensate the decrease of the TCP/IP throughput caused in a satellite link. Practical models will be manufactured in FY 2003 based on the test model.

Keywords
Satellite communication, Terminal, S-band, Through repeater, TCP/IP accelerator

1 Introduction

Two types of experiments are to be performed under the auspices of the Engineering Test Satellite VIII (ETS-VIII) project: basic experiments conducted by the satellite developing institutes and utilization experiments solicited from the public [1].

Each of the large deployable reflectors aboard the ETS-VIII features outside dimensions of 17 m × 19 m—too large to perform measurement of antenna characteristics in a radio anechoic chamber prior to launch. The satellite is therefore to be launched into orbit before these characteristics are directly assessed.

After launch, radio waves are transmitted from orbit to measure transmission characteristics at multiple ground locations, and transmitted from the ground to the satellite to evaluate characteristics of reception. This requires a certain number of portable ground stations featuring continuous wave (CW) transmission and reception.

Many of the proponents of specific utilization experiments lack the funds or techniques to prepare their own ground terminals. Thus, it would be preferable for the satellite developer to make general-purpose terminals available for loan to users. These terminals must be portable, as they will be used in various locations throughout Japan.

To respond to these needs, the National Space Development Agency of Japan (NASDA; reorganized to the Japan Aerospace Exploration Agency in October 2003) undertook the development of suitable S-band portable ground station terminals. NASDA began developing two test models at the beginning of 2001; development was complete in February 2003. Based on the success of these test models, eight functional models are scheduled for development in fiscal year 2003.

2 Terminal configurations and functions

2.1 General configuration

Fig.1 shows the external appearance of the terminal. Fig.2 shows the general terminal configuration.

The terminals were designed to incorporate a number of features: specifically, requirements (1) to (3) are aimed at the needs of

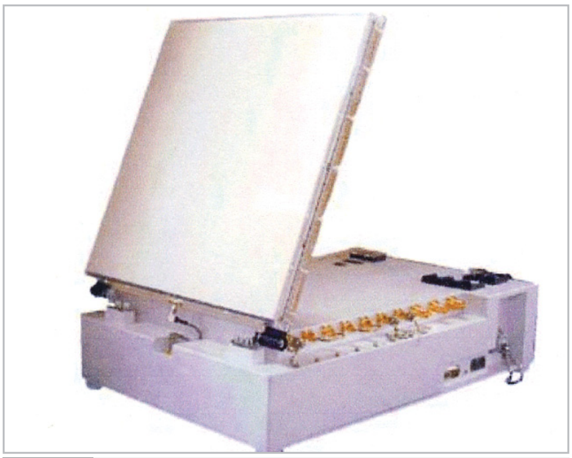

Fig.1 *External appearance of the terminal*

users performing application experiments and (4) is required for experimental antenna pattern measurement.

(1) The terminals must be able to communicate with each other in one hop via the satellite, without a base station relay.
(2) The terminals should use the satellite as a through repeater. Several transmission rates should be supported.
(3) The terminals must be as small and light as possible, to ensure portability.
(4) The terminals must feature CW transmission and reception functions.

To minimize dimensions and weight, the transmission power is set to 2 W and the internal antenna gain is set to 16 dBi achievable with B4 size. The internal antenna consists of 16 elements, each consisting of a 64-mm ϕ patch antenna (the structure of a single element is shown in Fig.3). The antenna is installed in the upper cover of the terminal. This internal antenna can transmit and receive up to 384 kbps of data. Users who wish to employ a higher transmission rate (up to 1.5 Mbps) can connect an external high-gain antenna to the terminal. Two types of standard external antennas are prepared: a 21-dBi

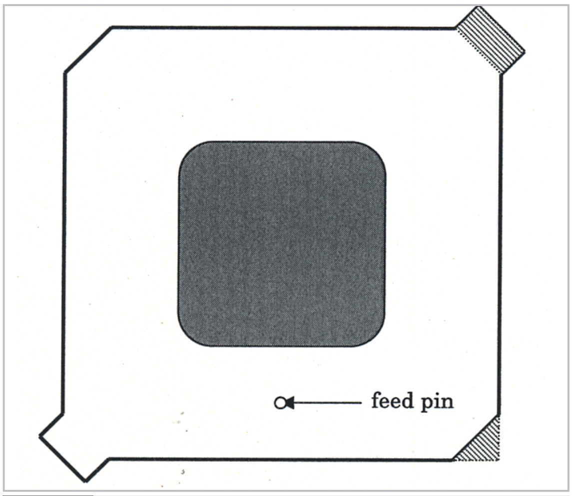

Fig.3 *Internal antenna element*

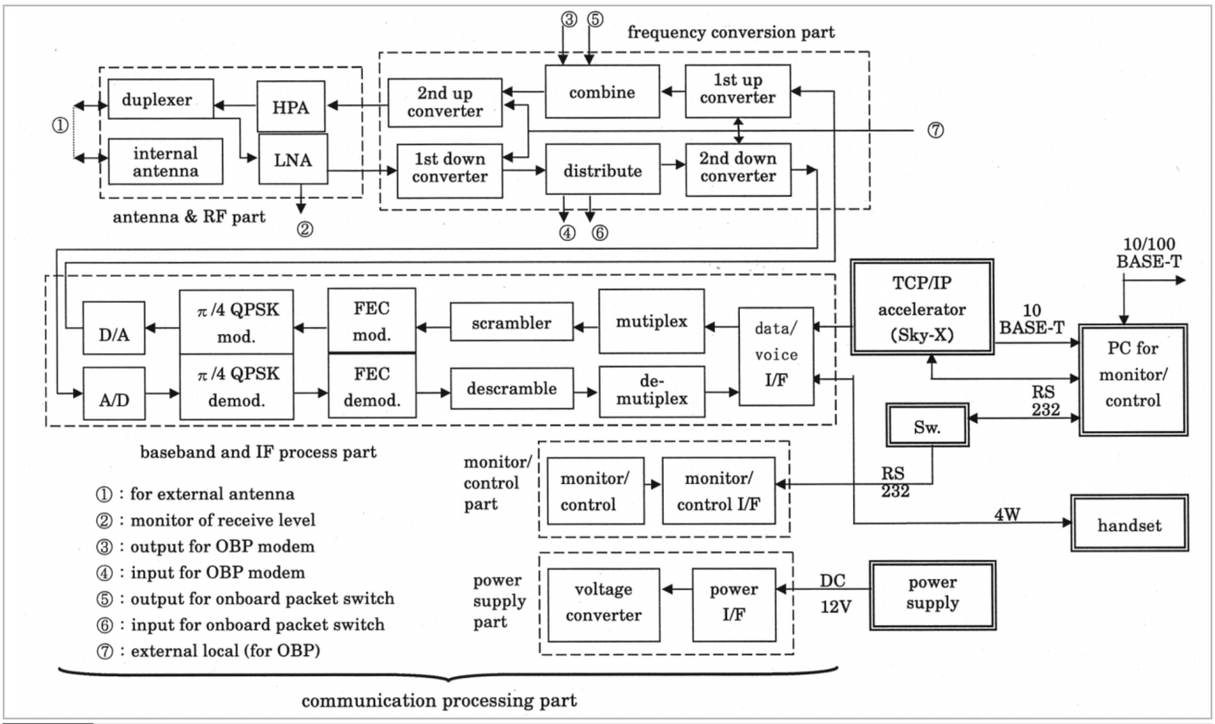

Fig.2 *General terminal configuration*

folding antenna [2] and a 26-dBi parabolic antenna (diameter of 1.2 m).

As most of the proposed utilization experiments do not make direct use of the functions of the onboard switches, the terminal supports a through-repeater function. Data is input to and output from the user's personal computer via Ethernet. The modulation method applied consists of $\pi/4$ shift Quadrature Phase Shift Keying (QPSK), a standard method of digital modulation. Frequency Division Multiple Access (FDMA) is used for the access method, and convolution coding (code rate: 1/2) is used for error correction.

With communication links featuring significant delay and a high error rate, as is the case with satellite communications, TCP/IP throughput decreases substantially, particularly when the transmission rate is high [3]. The example shown in Fig.4 illustrates simulation

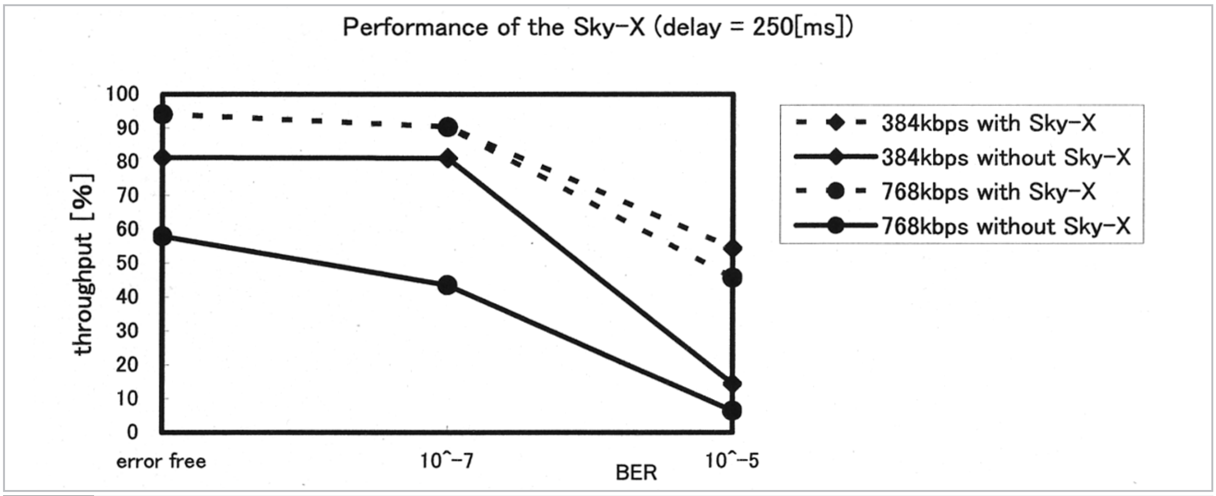

Fig.4 Degradation in TCP/IP throughput in satellite link

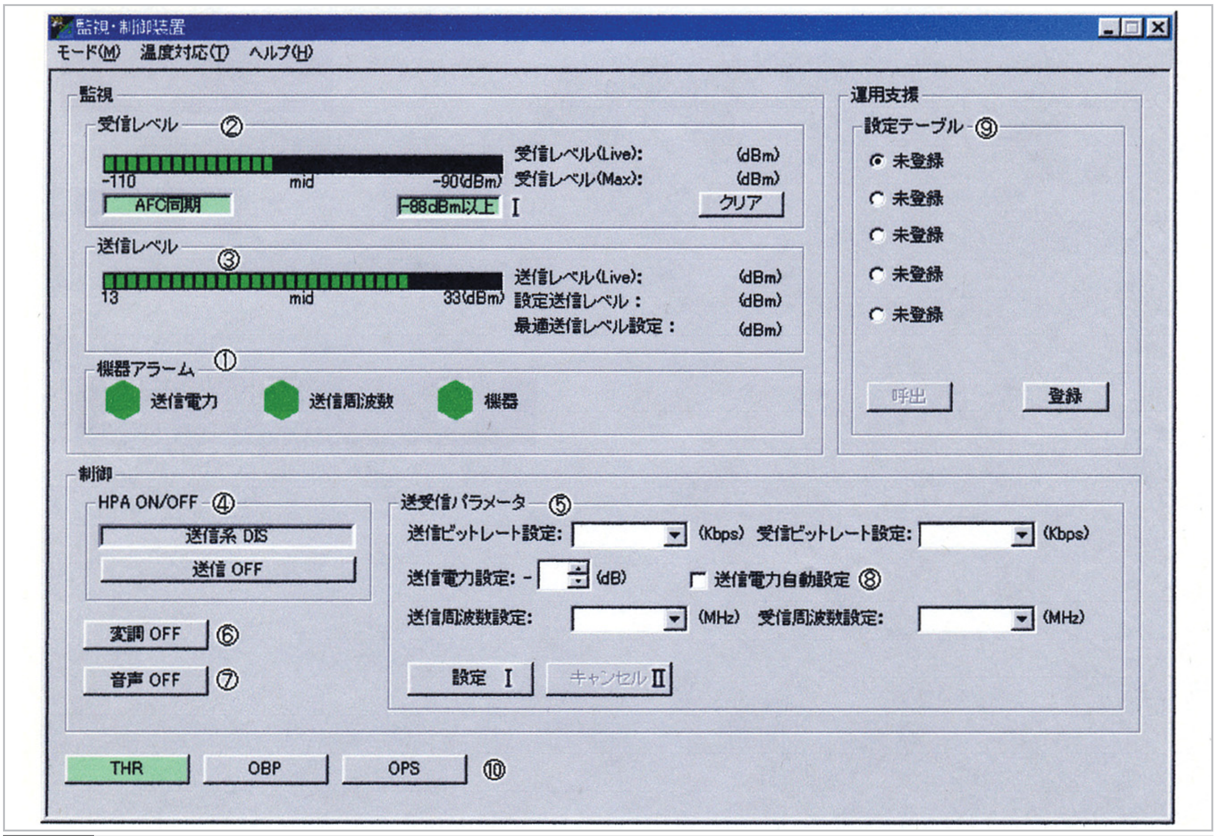

Fig.5 Monitor and control screen

of a communication link with a 250-ms delay (assuming one-hop communication). As indicated by the solid lines in the figure, throughput decreases significantly with increases in transmission rate and error rate. This reduction in speed can be moderated using methods such as protocol conversion within the satellite link. The dashed lines in the figure reflect performance with a Sky-X Gateway XR-10 (a Mentat TCP/IP accelerator) installed in the prototype terminal. Additionally, this apparatus incorporates an improved Xpress Transfer Protocol (XTP) [4]. Practical models will provide protocol conversion with software, to accommodate restrictions on size and weight.

An external personal computer (PC) connected to the terminal via RS232 will monitor transmission and reception levels and additional items relating to terminal status. The PC will also control transmission and reception parameters. Fig.5 shows the monitor and control screen.

It should be noted that the terminals were completed in February 2003, prior to the scheduled launch of the ETS-VIII. Thus it is assumed that the terminals were tested using a satellite link emulator, up and down converters, and two terminals. The emulator was equipped to add IF noise and delay.

Table 1 shows the main specifications and characteristics of the prototype terminal model.

Table 1 *Terminal specifications*

Dimenions (WxDxH)	330x510x146 [mm]
Weight	15.7 kg *1 (without external PC)
Frequency and Polarization	TX: 2.6555–2.658 GHz (LHCP) RX: 2.5005–2.503 GHz (LHCP)
Information rate	64k, 128k, 256k, 384k, 768k, 1.5Mbps *2
Internal antenna	16 dBi patch antenna
External antenna	26 dBi parabolic 1.2mϕ antenna, 21 dBi folding antenna, etc.
G/T	−10.5 dB/K (El = 40°) (with internal antenna)
Communication	SCPC/FDMA $\pi/4$ shift QPSK
Applied FEC	Convolution coding and Viterbi decoding
Error rate	$< 1\times10^{-5}$ (after error correction)
User interface	Ethernet Connectable with the OBP and the onboard packet switch
TCP/IP throughput compensation	Hardware-based communication protocol conversion (Sky-X)
Monitor and control functions	Installed in the external PC
Antenna pattern measurement function	CW transmission (frequency variable) (with monitoring of TX level)
Satellite link emulator	Equipped to add IF noise and delay

*1 External AC/DC power supply and TCP/IP accelerator weighing 10kg
*2 768 kbps and 1.5Mbps require an external antenna

Table 2 *Principal results of stand-alone test*

Items	Specifications	Test results	
		Terminal A	Terminal B
TX antenna gain	16dBi	16.85dBi	16.96dBi
RX antenna gain	16dBi	16.83dBi	17.05dBi
TX antenna axial ratio	3dB	< 1.09dB	< 1.27dB
RX antenna axial ratio	3dB	< 0.38dB	< 0.09dB
Modulation accuracy	12.5% rms	< 7.91% rms	< 7.72% rms
Spurious	−50dBc	<−61.98dBc	<−61.61dBc
AFC frequency acquisition range	+8kHz −8kHz	+17kHz −12kHz	+16kHz −12kHz

2.2 Performance test

The two terminals were first tested on a stand-alone basis. Table 2 shows the principal results.

Next, the two terminals were connected via the satellite link emulator and subject to various tests. Compatibility testing was then conducted to verify compatibility with the communication equipment (flight model) onboard the ETS-VIII. Fig.6 illustrates the configuration of compatibility testing, which incorporated the tests described below.

2.2.1 RF reception test

This test determined whether reception levels were appropriate at high, medium, and low frequency values (in transmission and reception) along the path from terminal A via the practical satellite model to terminal B.

2.2.2 AFC test

The transmission frequency of terminal A was modified in 1-kHz increments as the range of Automatic Frequency Control (AFC) was measured for reception in terminal B. While the specification value was ±8 kHz, the measured values offered sufficient performance at an upper limit of +16 kHz and a lower limit of −12 to −13 kHz. These results were confirmed to agree with the results of the stand-alone test.

2.2.3 IP data communication test

The TCP/IP accelerator was activated for ftp data transmission, and throughput was measured as the C/N was varied. The throughput characteristics can be understood in terms of the ratio of average throughput to maximum speed at the TCP/IP accelerator of

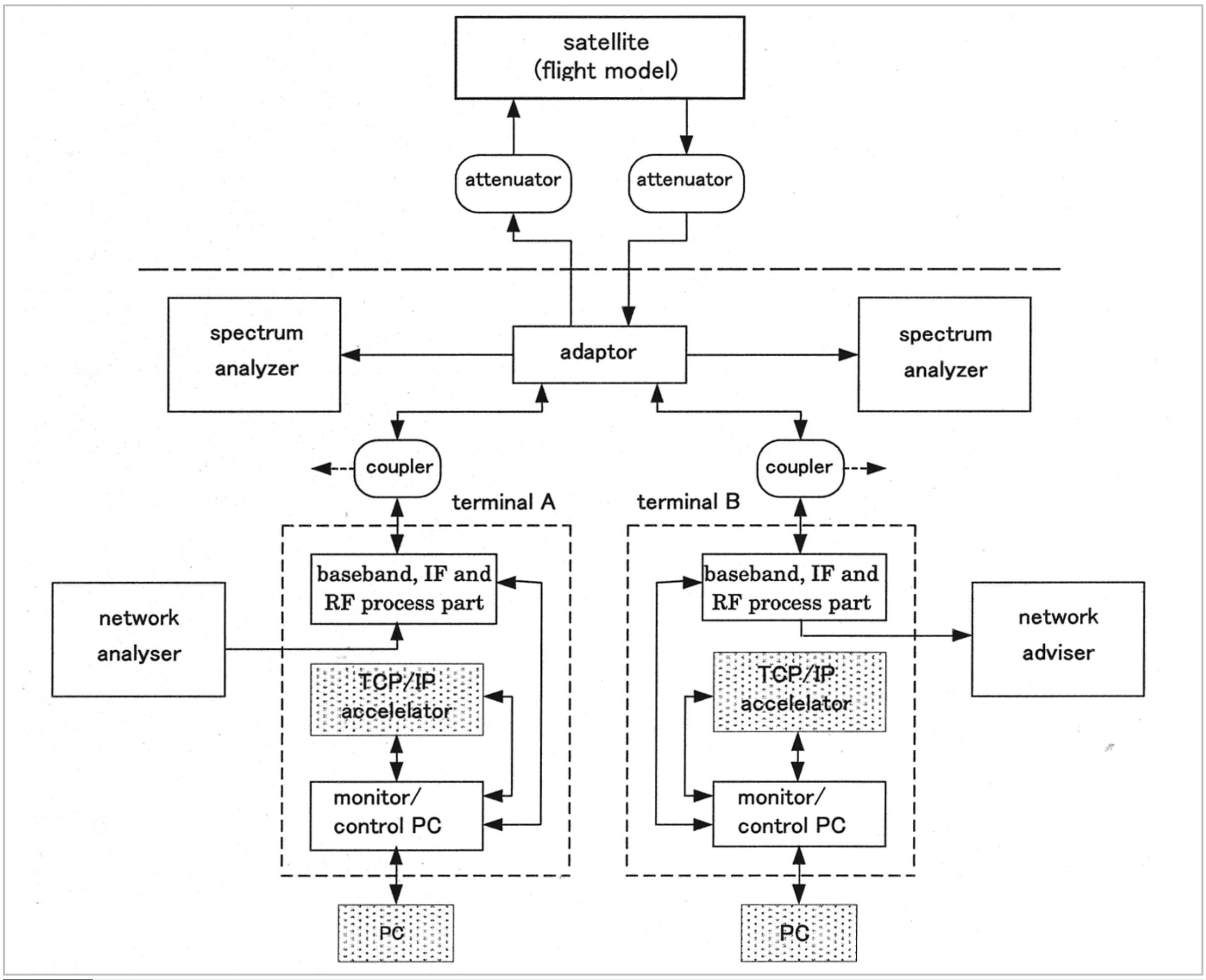

Fig.6 Configuration of the compatibility test, including the satellite

the transmitter terminal. Table 3 shows the results of this test. The determined values corresponded to the results of the previous standalone test. These values can also be used to predict the limit C/N value in actual communication.

2.2.4 Error rate test

PING packets were generated using the traffic generator function of the LAN analyzer and then transmitted. The attenuator along the signal path was adjusted to vary the magnitude of the signal, corresponding to varying the C/N value. Errors were measured using a net-

Table 3 Throughput characteristics with the TCP/IP accelerator

Information rate	Max. set rates in TX	C/N	Average throughput	Throughput characteristics	Data consistency
128 kbps	115 kbps	17.9 dB	74.67 kbps	64.9 %	OK
		14.8 dB	80.16 kbps	69.7 %	OK
		11.8 dB	64.69 kbps	56.3 %	OK
384 kbps	340 kbps	12.3 dB	218. kbps	64.1 %	OK
		10.1 dB	151.36 kbps	44.5 %	OK
		8.8 dB	not transmitted	—	—
768 kbps	650 kbps	13.0 dB	367.65 kbps	56.6 %	OK
		11.2 dB	216.88 kbps	33.4 %	OK
		9.9 dB	not transmitted	—	—

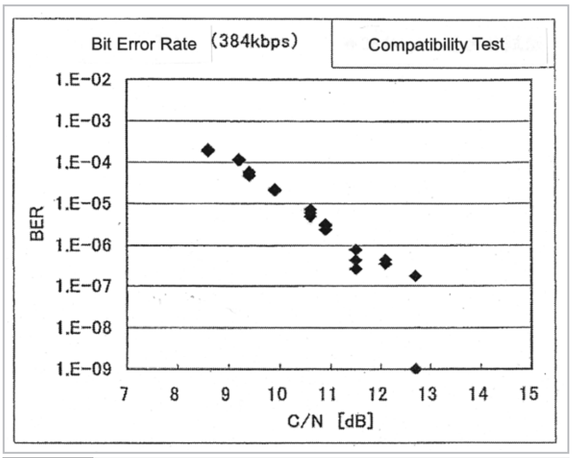

Fig.7 *Error rate characteristics*

work adviser connected to the reception terminal. Here, directly measurable errors included the number of erroneous frames detectable using the frame check function. A single frame consists of 960 signal bits subject to error detection; one-bit random error can be assumed per frame until the measured error rate reaches the level of 10^{-4}. Measurement was thus performed based on the following relation:

bit error rate (BER) = (frame error rate)/960

Fig.7 shows the results of compatibility testing conducted at a data rate of 384 kbps. (BER in the absence of detectable error is plotted as 10^{-9} in the figure, for reference.) The results basically reproduce the results of the previous stand-alone test.

3 Summary

This paper primarily describes the design of the ground terminal test models for the ETS-VIII communications experiments and the associated compatibility testing. The achievements were reflected in the practical models to be built in fiscal year 2003. Although the test model terminals were developed with an emphasis on functionality and verification of characteristics, the practical models must be smaller, lighter, and easier to use, including the implementation of a software-based protocol converter.

Stanley Electric Co., Ltd. and Tokimec Inc. produced the terminal test models, and we are grateful for the efforts of the participating engineers. We also received technical assistance from the engineers at the Communications Research Laboratory and the former National Space Development Agency of Japan. Mitsubishi Electric Corporation provided assistance in the compatibility testing. We would like to express our sincere gratitude to these and all participating individuals.

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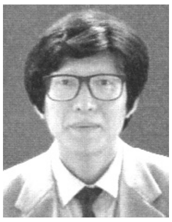

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