4-2 S-band Earth Station for Mobile Communication

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Engineering Test Satellite VIII (ETS-VIII) is scheduled for launch in the summer of 2004. The Communications Research Laboratory (CRL) is planning various mobile satellite communications experiment using On-Board Processor, On-Board Packet Switch etc., which were carried in the satellite, and the satellite broadcasting experiment. An S-band earth station was installed in the Kashima Space Research Center, in order to measure characteristics which serve as a basis in the communication and the broadcasting experiment, between ETS-VIII and a mobile station.

This paper describes the outlook of an S-band earth station and the electric characteristic.

Keywords
Personal satellite communication, ETS-VIII, S-band earth station, Service link

1 Introduction

The Engineering Test Satellite VIII (ETS-VIII) is scheduled for launch from Tanegashima Space Center aboard the H-IIA rocket in summer 2004. The Communications Research Laboratory (CRL) loaded an on-board processor (OBP) for voice communications [1], an on-board packet switch (PKT) for high-data-rate communications [2], and a high accuracy clock (HAC) [3]. These devices will be used to carry out mobile satellite communication and broadcast experiments [4], as well a time comparison experiment [5].

An S-band earth station was installed at the Kashima Space Research Center to form a service link between the ETS-VIII and ground, and is used as a standard station for various satellite communication experiments.

This paper reports on the performance and electrical characteristics of several units constituting the S-band earth station.

2 Configuration of S-band earth station

A block diagram of the S-band earth station is shown in Fig.1.

The major components of the S-band earth station consist of an antenna unit, an RF unit, an IF unit, a monitor and control subsystem, and a standard frequency unit.

It is assumed that the satellite uses the large-scale deployable reflector (LDR) for communication with this earth station. However, if for some reason the LDR cannot be used, the satellite employs a small (1.1-mϕ) S-band antenna normally used in time comparison experiments instead. Since the performance of this link becomes significantly lower than the link which used LDR, the earth station has sufficient performance so that an experiment can be performed.

As shown in Fig.1, in the experiment which used the LDR, attenuators (ATT (LDR)) are inserted in the output side of the power amplifier and the output side of the

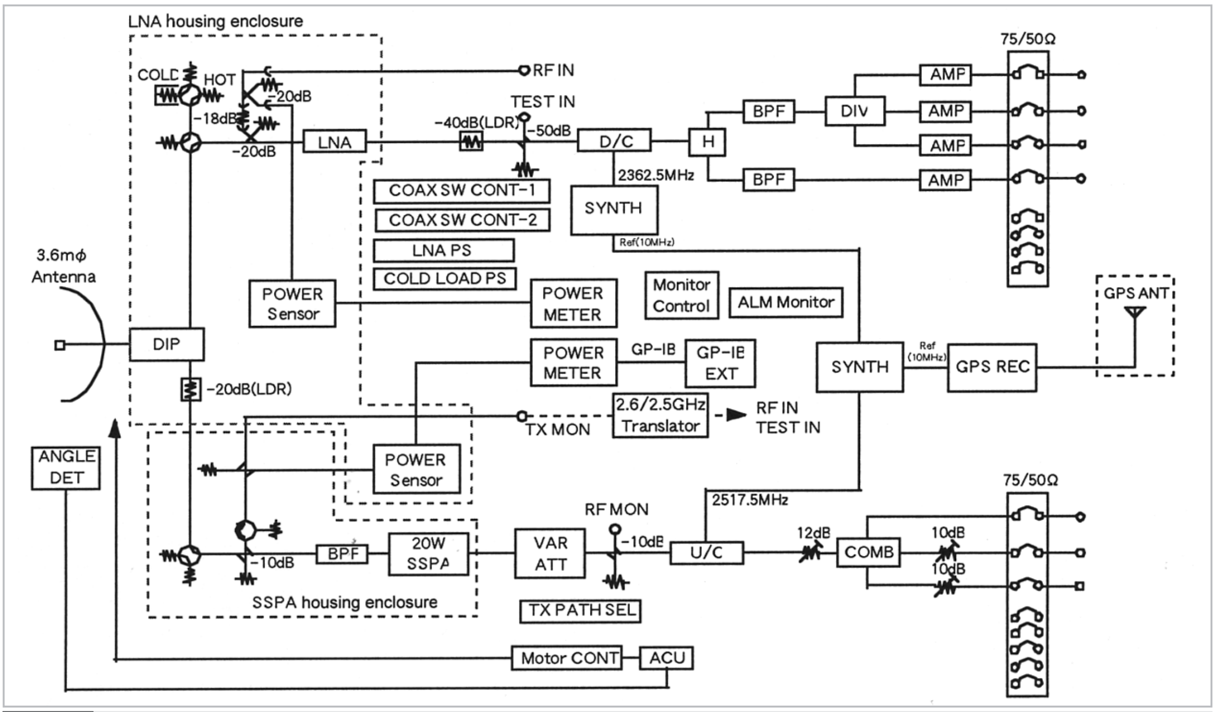

Fig.1 Block diagram of S-band earth station

low-noise amplifier (LNA), and adjust the input and output level.

Fig.2 shows the antenna unit and the RF unit.

Antenna unit RF unit

Fig.2 Appearance of S-band earth station

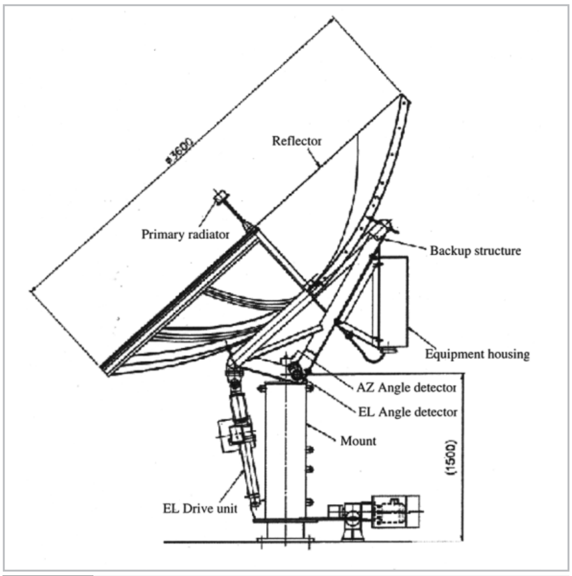

Fig.3 Appearance of antenna unit

2.1 Antenna unit

The antenna unit consists of an antenna apparatus and an antenna drive control subsystem.

Fig.3 shows the antenna appearance, and Table 1 shows the mechanical performance of the antenna unit.

The antenna receives the S-band signal (2500–2540 MHz) from the satellite and passes it to the low-noise amplifier (LNA) of the next stage, and transmits an S-band signal (2655–2660 MHz) output from the 20-W S-band solid state power amplifier (20-W SSPA) of the RF unit to the satellite.

The antenna diameter is 3.6 m, and the feed system is the front-feed type which used a cross dipole for the primary radiator.

Table 1 Mechanical performance

Item	Performance
Antenna aperture diameter	3.6 m (Nominal)
Antenna type	Parabola
	(Primary radiator: cross dipole)
Mount type	AZ - EL
Drive range	Elevation : 27.32°～ 62.47°
(software limit)	Azimuth : 155.85°～ 187.44°
Drive speed	Elevation 0.24°/s
	Azimuth 0.21°/s
Operable wind velocity	30m/s (Momentary maximum)
Nondestructive wind velocity	60m/s (Momentary maximum)

The antenna drive control subsystem performs remote direction adjustment of the antenna, and is composed of an antenna control unit (ACU) and a motor control unit (MOTOR CONT). There are three antenna drive modes: slew, manual, and preset, operated via the ACU. The ACU displays data of various types, including the antenna direction angle. The antenna is also provided with limiter switches to protect against excessive drive.

Table 2 shows the electrical performance of the antenna unit.

Table 2 Electrical performance

Item	Performance	
	Transmission	Reception
Frequency band	2657.5MHz±2.5MHz	2520MHz±20MHz
Polarization	LHCP	
Gain	35.80 dBi (DIP input)	34.54 dBi (LNA input)
Noise temperature (LNA input)	—	113.01 K (Elevation:45°)
VSWR	1.26 or less (DIP output)	1.04 or less
Axial ratio	1.12 dB	0.82 dB
Isolation	90 dB or more	
G/T	—	9.29 dB/K

G/T is calculated based on the performance of the antenna unit and the LNA.

Fig.4 shows the transmitting antenna pattern, and Fig.5 shows the receiving antenna pattern.

The figure indicates that the sidelobe characteristics are excellent in both transmission and reception.

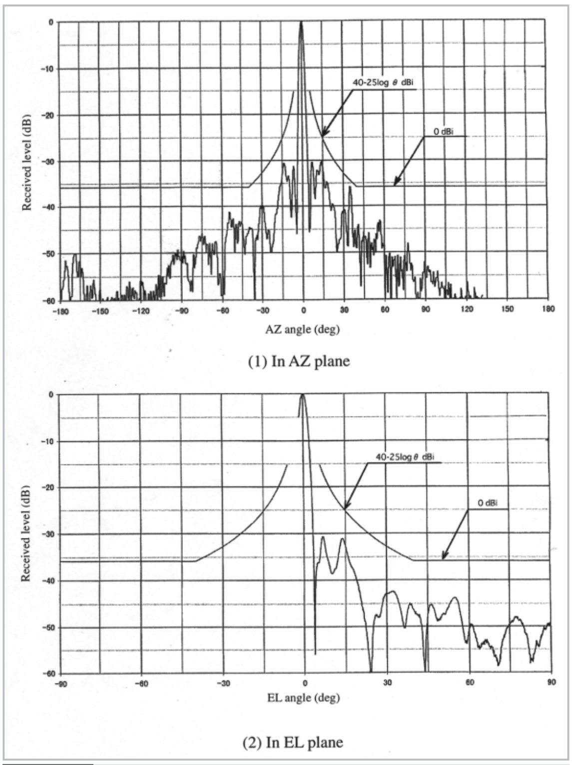

Fig.4 Transmitting antenna pattern

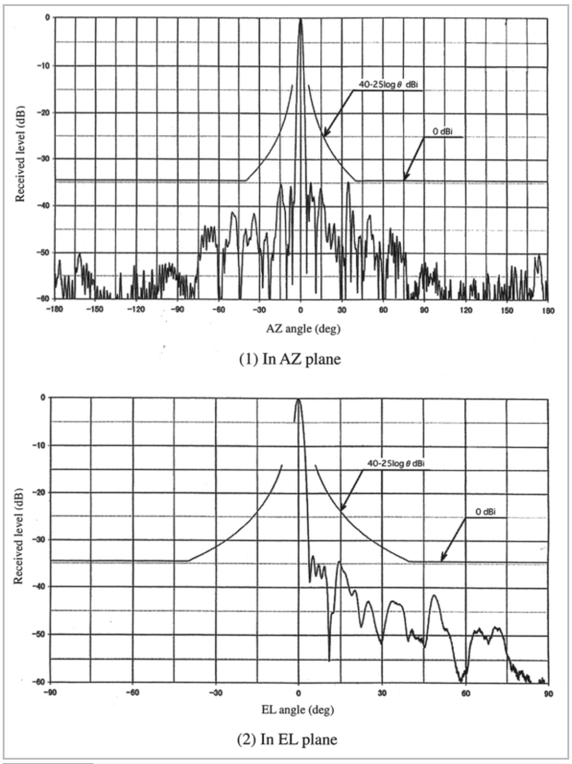

Fig.5 Receiving antenna pattern

2.2 RF unit

The RF unit consists of four subsystems: a power amplifier, a low-noise amplifier (LNA), an up converter (U/C), and a down converter (D/C).

Table 3 shows the main performance of the individual subsystems.

Table 3 *Main performance of subsystems*

Item	Performance
1. Power amplifier (20W SSPA)	
Output frequency range	2657.5 MHz ±2.5MHz
Saturation output power	+43.5 dBm (2657.5MHz)
Gain	62.1 dB
Gain fluctuation	0.5 dBp-p or less（Fixed room temperature)
Amplitude-frequency characteristics	0.5 dBp-p or less
Spurious	-60.0 dBc or better
2. Low-noise amplifier (LNA)	
Input frequency range	2500 – 2540 MHz
Gain	38.3 dB
Noise temperature	221.6 K (LNA input)
1 dB compression point	-39 dBm (Input level)
Amplitude-frequency characteristics	0.57 dBp-p or less
3. Up converter (U/C)	
Input frequency range	140.0 MHz ±2.5MHz
Output frequency range	2655－2660 MHz
Conversion gain	20.0 dB（140 MHz）
Amplitude-frequency characteristics	0.19 dBp-p or less
Spurious	-63.3 dBc or better
4. Down converter (D/C)	
Input frequency range	2500 – 2505 MHz (Communication) 2537.5 – 2540 MHz (Broadcast)
Output frequency range	140.0 MHz ±2.5MHz (Communication) 176.25 MHz ±1.25MHz (Broadcast)
Conversion gain	56.0 dB（2502.5 MHz） 56.0 dB（2538.75 MHz）
Amplitude-frequency characteristics	0.09 dBp-p (Communication) 0.19 dBp-p (Broadcast)
Spurious	-57.0 dBc or better (Communication) -53.83 dBc or better (Broadcast)

The power amplifier is composed of a 20-W SSPA housed in an SSPA enclosure, a harmonic filter, a band pass filter, a coaxial switch unit with a dummy load, and a coaxial switch controller.

The S-band RF signal from the U/C passes through a directional coupler (for monitoring) and through a VAR ATT (for input signal adjustment), and is input into the 20-W SSPA. The SSPA has a gain 62 dB or more, amplifies the RF signal up to a required level, and passes it to the antenna or to the dummy load through the band pass filter and the coaxial switch.

The output of the 20-W SSPA is branched by a directional coupler, and this output is passed to a 2.6/2.5-GHz TRANSLATOR from the coupler’s TX MON terminal. This output is then used to perform the loop test.

The low-noise amplifier (LNA) subsystem is composed of a low-noise amplifier (LNA), a power supply for the LNA (LNA PS), a coaxial switch, and a cold load for calibration (HOT/COLD LOAD).

This system is mounted in an LNA housing enclosure attached to the antenna feed unit, and is used for low-noise amplification of the S-band (2500–2540 MHz) weak and wide-band signals received by the antenna; these signals are then sent to the D/C subsystem in the subsequent stage. The HOT/COLD LOAD is used when measuring the noise temperature of the receiving system, and it measures by switching a cold load (COLD) and a normal temperature load (HOT).

The up converter subsystem is composed of an up converter (U/C), a 10-dB directional coupler with an RF monitor terminal, and a programmable attenuator (VAR ATT). A 140-MHz band IF signal input into the U/C is converted into a 2.6-GHz band RF signal, passed through the directional coupler and the VAR ATT, and input into the 20-W SSPA. The VAR ATT adjusts the level of the transmitting RF signal.

The down converter subsystem is composed of a down converter (D/C), a 60-dB directional coupler with a TEST IN terminal, and a 40-dB attenuator for the LDR operation. As shown in Table 3, the D/C converts RF signals in the communication or broadcast bands into the appropriate IF signals.

The 2.5-GHz RF signal from the LNA is supplied to the D/C after passing through the 40-dB attenuator and the directional coupler. The D/C converts the input RF signal into an IF signal in the 140-MHz band or the 176.25-MHz band. The IF signal is then divided into two signals by a hybrid device, and the signals are output to the IF unit after passing through a bandpass filter.

2.3 IF unit

The IF unit is divided into a transmitting IF component and a receiving IF component. The transmitting IF component consists of an IF connection panel (IF PATCH) and an IF combiner (IF COMB). The receiving IF component consists of a bandpass filter (BPF) built into the D/C, an IF divider (IF DIV), an IF amplifier (IF AMP), and an IF connection panel (IF PATCH).

The IF PATCH for transmission has BNC connectors on the front panel, in order to input 140-MHz IF signals, a test signal, etc. from communication terminals.

The IF COMB combines three 140-MHz signal inputs into one output.

Two BPFs of the receiving IF component—one for communication in the 140-MHz band and the other for broadcast in the 176-MHz band—are built in to the D/C, and restrict the frequency band of these two IF signals.

The IF DIV splits one 140-MHz input signal into three output signals.

The IF AMP amplifies the 140-MHz band IF signal, and can carry out variable gain up to 40 dB.

The IF PATCH of the receiving IF component outputs 140-MHz and 176-MHz IF signals, and a monitor signal and a test signal from BNC connectors on the front panel.

2.4 Monitor & control subsystem

The monitor & control subsystem is composed of a TX path selector (TX PATH SEL), an RX coaxial switch controller (COAX SW CONT), a monitor & control device (M&C), and an alarm monitor (ALM MONITOR).

The TX PATH SEL and the COAX SW CONT each control coaxial switches to select the path of the transmitted signal and of the received signal. There are two control modes, local control and remote control, in this switch control, and remote control mode is normally selected, which is controlled by the M&C.

The M&C is monitoring the status of devices installed on the S-band earth station, and displays the status of the remote operation of the coaxial switches, and the transmission/reception routes, and NORMAL/FAULT of devices. Fig.6 shows the front panel of the M&C.

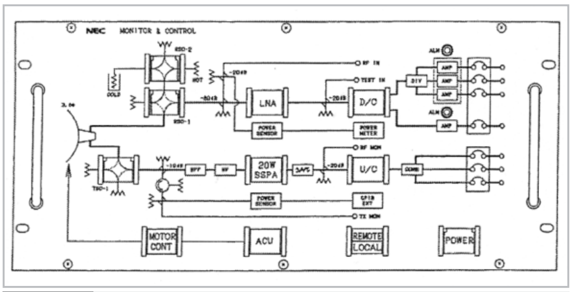

Fig.6 *Front panel of monitor & control device*

As can be seen in the layout of the front panel, the M&C is designed to monitor the status of each device along the signal path. In terms of the transmitting system, the panel allows visual confirmation of IF signal input to the IF PATCH, through the AMP, combination by the COMB, and connecting to the U/C and the 20-W SSPA. The LED indicates any fault occurring in the AMP. In the U/C and the 20-W SSPA, a green LED is activated during normal operation and a red LED lights in the event of fault. When a route switch button on the display is pushed, the COAX SW executes remote control of the PATH SEL to switch the signal route. The current route is displayed on the button.

In the receiving system and the antenna drive control subsystem, monitoring and control are similarly performed by M&C.

The ALM MONITOR indicates alarm output from any of the devices installed in the S-band earth station via lighting or flashing LEDs and activation of a buzzer. The ALM MONITOR also relays the alarm message to the M&C. Twelve alarms can be displayed and there is a function to memorize the generated alarm.

2.5 Testing device subsystem

This subsystem is equipped with a programmable attenuator (VAR ATT) and a 2.6/2.5-GHz test translator (TEST TRANSLATOR), which are used in various ways according to the specific test purposes.

The VAR ATT is installed between the U/C and the 20-W SSPA, and is used to attenuate the transmitted RF signal in accordance with the testing purpose. An attenuator can be varied, in increments of 1 dB or 10 dB, up to a maximum value of 85 dB.

The TEST TRANSLATOR carries out testing by looping an output signal back from the SSPA without establishing a communication channel to the satellite; this device converts a 2.6-GHz band input signal into a 2.5-GHz band output signal.

3 Overall electrical characteristics

The input-output characteristics of the 20-W SSPA are shown in Fig.7.

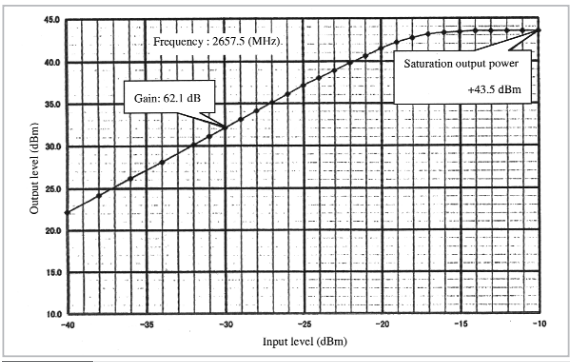

Fig.7 *Input-output characteristics of 20-W SSPA*

The component gain is 62.1 dB and a saturation output power is +43.5 dBm.

Fig.8 shows the amplitude-frequency characteristics of the transmitting system.

The amplitude-frequency characteristic of the transmitting system is measured along the route from the IF PATCH to the TX MON. An input signal of 140 MHz ± 2.5 MHz at −10 dBm results in an output signal fluctuation of 0.19 dBp-p.

Fig.9 shows the spurious of the transmitting system.

The spurious of the transmitting system

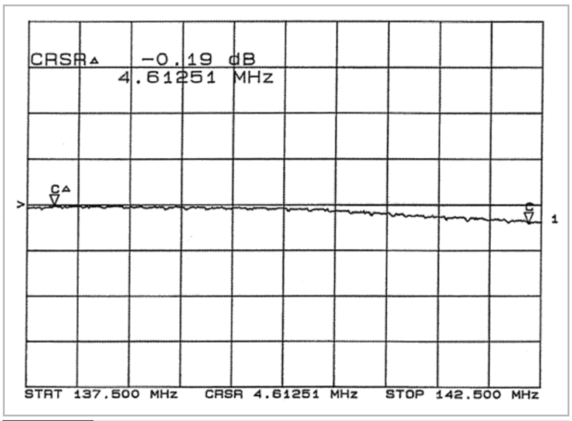

Fig.8 *Amplitude-frequency characteristics of transmitting system*

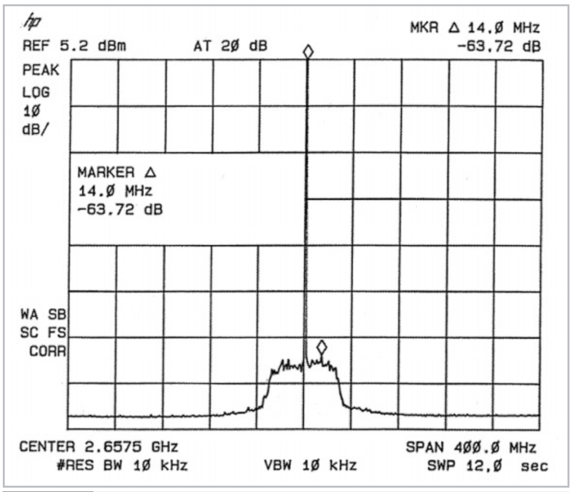

Fig.9 *Spurious of transmitting system*

input the signal of 140 MHz and −10 dBm from the IF PATCH, and measured it in the DIP input.

Fig.10 shows the input-output characteristics of the LNA.

The gain is 38.3 dB, and the 1-dB compression point is −39 dBm in input level.

Fig.11 shows the amplitude-frequency characteristics of the receiving system for communication band, and Fig.12 shows the amplitude-frequency characteristics of the broadcast band.

The amplitude-frequency characteristic of the receiving system for communication band was measured along the signal path from the LNA input to the IF PATCH. A signal of 2502.5 MHz ±2.5 MHz and −66.3 dBm input into the LNA resulted in an IF PATCH output signal fluctuation of 0.69 dBp-p.

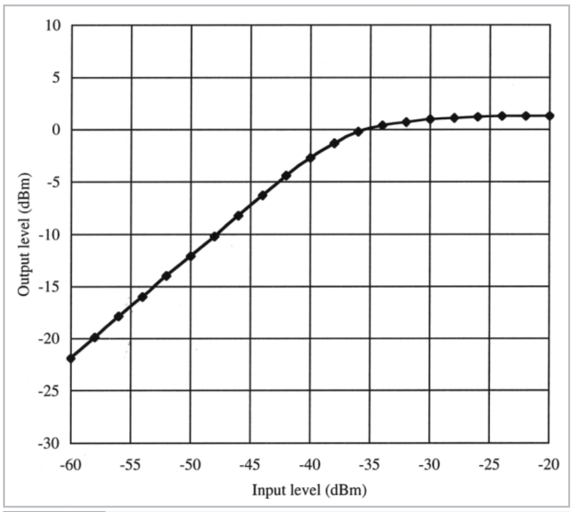

Fig.10 *Input-output characteristics of LNA*

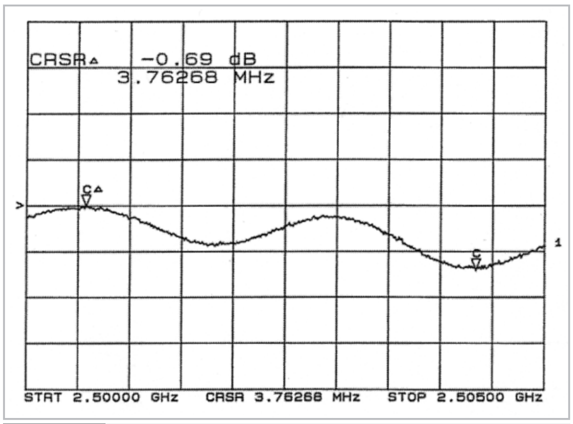

Fig.11 *Amplitude-frequency characteristics (communication) of receiving system*

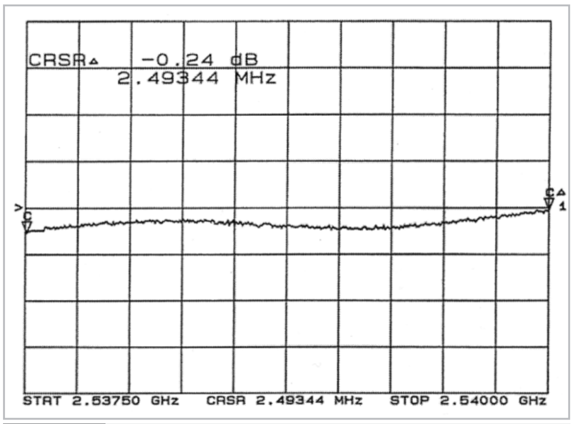

Fig.12 *Amplitude-frequency characteristics (broadcast) of receiving system*

The amplitude-frequency characteristic of the receiving system for broadcast band was measured along the signal path from the LNA input to the IF PATCH, as in communication measurement. A signal of 2,538.75 MHz ±1.25 MHz and −66.3 dBm input into the LNA resulted in an IF PATCH output signal fluctuation of 0.24 dBp-p.

Fig.13 shows a level diagram of the transmitting system.

When the LDR was used, the value of the VAR ATT was set to 12 dB. When the HAC was used, the value of the VAR ATT was set to 2 dB, and the 20-dB fixed ATT inserted in the stage following the 20-W SSPA was removed.

Fig.14 shows a level diagram for communication of the receiving system.

When using the LDR, a 40-dB ATT is inserted in the IFL. The broadcast band takes a different path in the IF PATCH. The gain of the AMP for the broadcast band differs from that of the communication band, the AMP is thus configured so that PATCH output level corresponds to the level of the communication band.

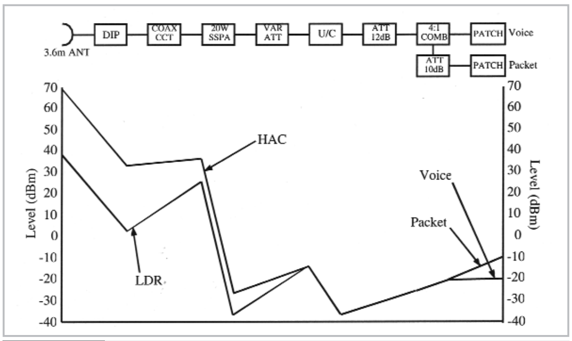

Fig.13 *Level diagram of transmitting system*

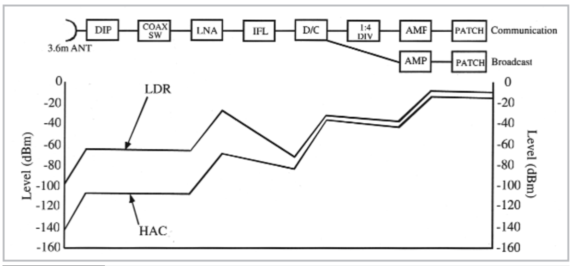

Fig.14 *Level diagram of receiving system (communication)*

4 Concluding remarks

We have discussed the configuration, performance, and electrical characteristics of an S-band earth station designed for mobile communication experiments. The launch of the

ETS-VIII is scheduled for the summer of 2004, and this earth station will play a central role in mobile communication experiments involving the satellite. Going forward, we will continue in our preparations, involving verification of the interfaces to be used in experimental communication terminals, to ensure that these experiments will proceed smoothly.

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