4 Development of Earth Stations

4-1 Ka-band Feeder-link Earth Station

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Engineering Test Satellite VIII (ETS-VIII) is schedule to be launched in the summer of 2004. The Communications Research Laboratory (CRL) is planning various mobile satellite communication experiment using On-Board Processor, On-Board Packet Switch, etc. which were carried in the satellite, and the satellite broadcasting experiment.

A Ka-band feeder-link earth station is installed in the Kashima Space Research Center, forms a feeder-link in the communication and the broadcast experiment between ETS-VIII, and carry out the central role of an experiment.

This paper describes the outlook of a Ka-band feeder-link earth station and the electrical characteristic.

Keywords
Satellite communication, ETS-VIII, Ka-band feeder-link earth station

1 Introduction

With a central role in various planned communication experiments, the Ka-band feeder-link earth station installed at the Kashima Space Research Center represents a feeder-link between the Engineering Test Satellite VIII (ETS-VIII) and the ground.

The ETS-VIII is scheduled for launch from Tanegashima Space Center aboard the H-IIA rocket in summer 2004. The Communications Research Laboratory plans to load an on-board processor (OBP) [1], an on-board packet switch (PKT) [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].

The Ka-band feeder-link earth station will be used as a base station for voice and data communications with mobile stations through the OBP, and for High-Data-Rate communications through the PKT. The station will also transmit CD-quality audio signals for mobile stations as a broadcast experiment.

This paper reports on the performance and electrical properties of several units that make up the Ka-band feeder-link earth station.

2 Configuration of Ka-band feeder-link earth station

Broadly speaking, the Ka-band feeder-link earth station consists of an antenna unit and an RF unit. Fig.1 shows its appearance. Fig.2 is a block diagram of the Ka-band feeder-link earth station.

2.1 Antenna unit

The antenna unit is composed of a Cassegrain antenna 5 m in diameter, a feed unit, a drive control subsystem (M&C), and a dehydrator.

The antenna unit has seen previous use, playing a role in communication experiments of the Engineering Test Satellite VI (ETS-VI).

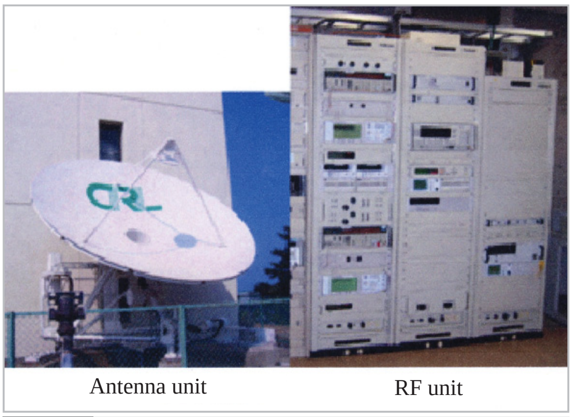


Fig.1 Appearance of Ka-band feeder-link earth station

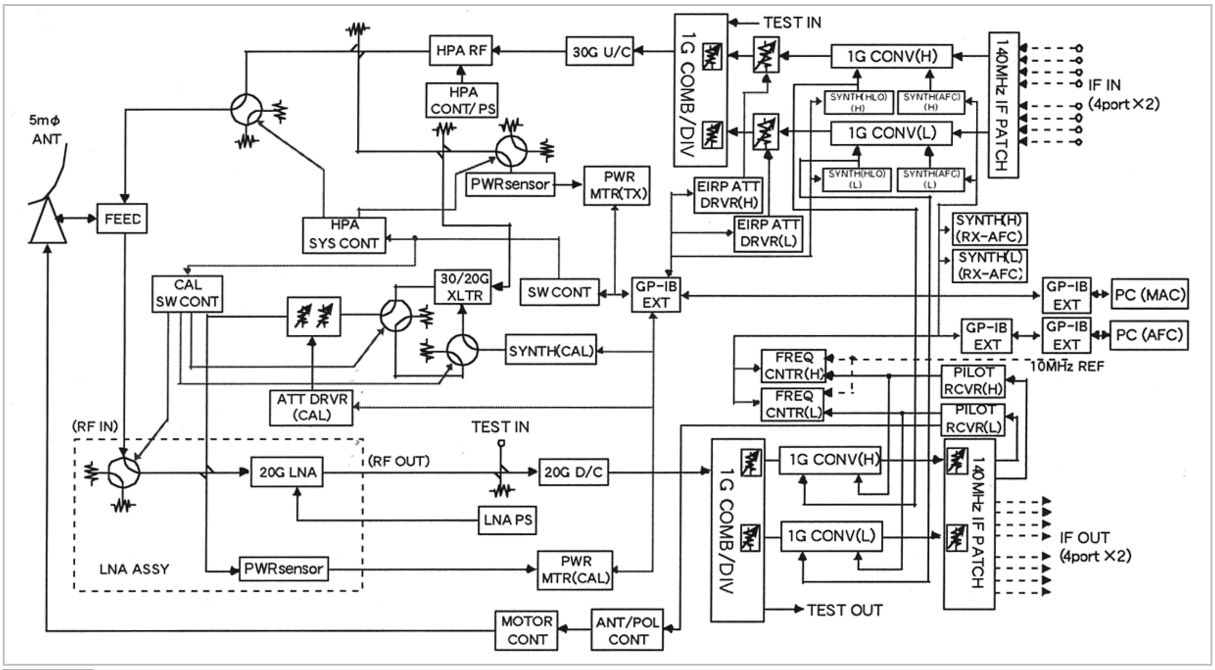


Fig.2 Block diagram of Ka-band feeder-link earth station

An antenna reflector, an AZ-EL drive structure, and a remote control console for the antenna were used after inspection and maintenance. The feed unit, waveguide, control cables, and dehydrator are new. Fig.3 shows the structure of the main reflector and a primary radiator.

The structure is identical to that of the antenna unit for the ETS-VI, except that the base plate of the AZ drive structure has been modified to accommodate a different antenna direction [6].

Composed of a corrugate horn antenna and the primary reflector, the primary radiator receives and transmits signals to and from the sub-reflector through a tube in the central ring.

Table 1 shows the mechanical performance of the antenna unit. Table 2 gives its electrical performance.

The G/T in Table 3 is a value calculated from the performance of the antenna unit and a low noise amplifier.

Fig.4 shows transmitting/receiving antenna patterns.

The figure shows a sidelobe characteristic with sidelobe suppression equal to or better than 96.6% for both transmission and receiving, an excellent showing.

Fig.5 is a block diagram of the feed unit.

The isolation between transmission and reception components determines the amount of leakage from a transmission terminal to a reception terminal.

The low noise amplifier is installed immediately after the reception terminal of the feed unit (details of the low noise amplifier will be given later.). Antenna motion is controlled by switching an AC motor ON or OFF. The antenna has three drive modes: AUTO, MAN, and PRESET. AUTO mode is an automatic stepwise tracking mode, whereby the antenna

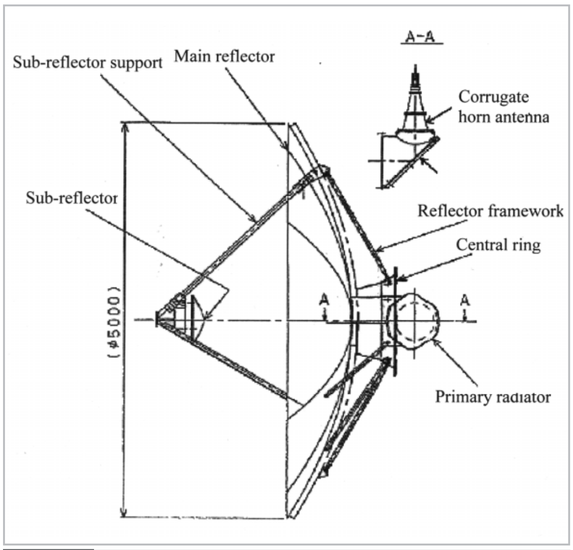


Fig.3 *Structures of main reflector and primary radiator*

Table 1 *Mechanical performance*

Item	Performance
Antenna aperture diameter	5.0m (Effective diameter)
Antenna type	Cassegrain
Mount type	AZ - EL
Drive range	EL: Initial set angle ±5°
	AZ: Initial set angle ±10°
Drive speed (Nominal value)	Elevation 0.005° /s
	Azimuth 0.007° /s
Tracking accuracy (at a mean wind velocity of 20m/s)	0.002° rms (for both AZ and EL)
Main reflector accuracy	0.25mm rms (at installation)
Wind velocity for operations	Mean 20m/s
	Max. instantaneous 30m/s
Wind velocity resistance	Max. instantaneous 60m/s

Table 2 *Electrical performance*

Item	Performance	
	Transmission	Reception
Frequency band	30.56-30.68 GHz	20.78-20.84 GHz
Polarization	RHCP	LHCP
Gain	62.1 dBi (feed unit output)	59.1 dBi (feed unit output)
Noise temperature (EL: 45°, fair)	—	57.4 K (feed unit output)
VSWR (Feed unit)	1.07 or less	1.04 or less
Sidelobe characteristics	96.6%	99.5%
Axial ratio	2.7 dB or less	2.3 dB or less
Isolation	-100 dB or better	
G/T	-	35.8 dB/K

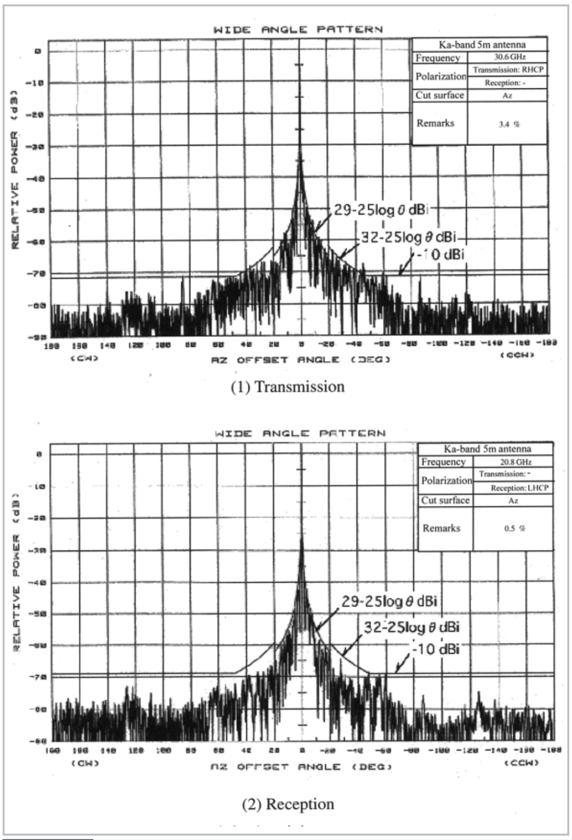


Fig.4 *Transmitting/receiving antenna patterns*

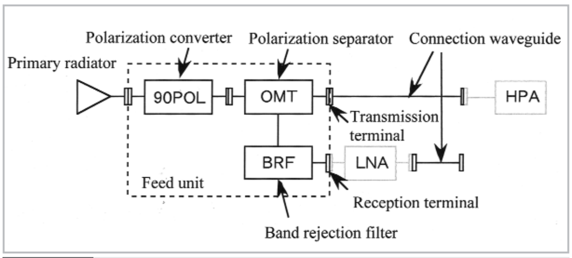


Fig.5 *Block diagram of feed unit*

is driven toward the direction in which the received beacon level is at its maximum value to track the satellite. The MAN mode drives the antenna up/down and clockwise/counter-clockwise. The PRESET mode drives the antenna by issuing positioning instructions. The antenna can be driven manually using a handle. In addition, the movement mechanisms are provided with limit switches that correspond to the limits of the range of motion for AZ and EL, respectively.

2.2 RF unit

The RF unit is composed of an L-band frequency converter, a Ka-band frequency converter, a high power amplifier subsystem (HPA), a low noise amplifier, an AFC control subsystem, and a monitor and control subsystem.

The L-band frequency converter is comprised of a 1 GHz converter (1G CONV), a 1 GHz combiner and divider (1G COMB/DIV), and a 140 MHz IF patch (140M IF PATCH). The 1G CONV has a transmitting frequency conversion function to convert 140 MHz band IF signals from the 140M IF PATCH to 1.2 GHz band signals for transmission to a 30 GHz up-converter. It also has a received frequency conversion function that converts received 1.2 GHz band signals into 140 MHz band IF signals to the 140M IF PATCH. The 1G CONV has two systems: 1G CONV (H) and 1G CONV (L), corresponding to the HI and LOW bands, respectively, within the transmitting/received frequencies.

The 1G COMB/DIV adjusts levels of 1.2 GHz band signals output from the transmit units of the 1G CONV (L) and (H) with variable attenuators, respectively, subsequently combines them with two test signals from two input ports in a combiner to obtain a combined signal, and outputs them to the 30 GHz up-converter. Moreover, the 1.2 GHz band input signal output from a 20 GHz down-converter is divided into four signals, of which two are output to receiving units of the 1 GHz CONV (L) and (H), respectively, after levels of the two signals are adjusted with variable attenuators. The two remaining signals are output for monitoring.

The 140M IF PATCH combines four 140 MHz band signals input from terminal equipment into one signal and outputs it to the transmit unit of the 1G CONV. Input terminals are prepared independently for each of the (L) and (H) systems. The input level is −10 dBm typ./wave. Received 140 MHz band signals output from the 1G CONV receiving unit are divided into five signals by a divider, and four signals thereof are output to the terminal equipment, while the remaining signal is output to a beacon receiver. The output terminals including the terminal for the beacon receiver (PILOT RCVR) are prepared independently for (L) and (H) systems on a system basis.

Table 3 shows the main performance of the L-band frequency converter.

Table 3 *Main performance of L-band frequency converter*

Item	Performance
1. 140M IF PATCH	
Input-Output frequency range	140MHz±38MHz
Passing loss	6.6 dB or less (TX) 3.7 dB or less (RX)
Amplitude frequency characteristics	0.4 dBp-p or less (TX) 0.7 dBp-p or less (RX)
2. 1G CONV.	
2-1 Transmitting frequency converter	
Input frequency range	137.5−177.5 MHz
Output frequency range	1167.9−1207.9 MHz (LOW) 1235.1−1275.1 MHz (HIGH)
Conversion gain	0 dB ±1.1 dB
Spurious	-61.5 dBc or better
Amplitude frequency characteristics	1.7 dBp-p or less／±38MHz
2-2 Received frequency converter	
Input frequency range	950−1450 MHz
Output frequency range	140 MHz ±38 MHz
Conversion gain	36 dB ±0.6 dB
Spurious	-60.3dBc or better
Amplitude frequency characteristics	0.9 dBp-p or less／±38 MHz
3. 1G COMB/DIV	
Input-output frequency range	1167−1276 MHz
Number of combination (TX)	4
Number of division (RX)	4
Passing loss (TX)	10 dB or less (at a min. attenuation)
Passing loss (RX)	10 dB or less (at a min. attenuation)

The Ka-band frequency converter consists of a 20 GHz down-converter (20G D/C), a 30 GHz/20 GHz translator (30G/20G XLTR), a receiving system calibrator, and a calibration signal switching controller (CAL SW CONT).

The 20G D/C converts a 20 GHz band RF signal input from the low noise amplifier (LNA) into a 1.2 GHz band signal, then outputs the result.

The 30G/20G XLTR converts part of a 30 GHz band RF signal taken out with a directional coupler on the high power amplifier subsystem output side into a received 20 GHz band signal and outputs it to a calibration path switch (CAL SW ASSY) in the next stage.

The receiving system calibrator is composed of a synthesizer (SYNTH (CAL)), the CAL SW ASSY (including an attenuator), and a power meter (PWR MTR (CAL)).

Two signals of a loop signal from the 30G/20G XLTR and a calibration signal from the SYNTH (CAL) are input to the CAL SW ASSY. Either signal is then output from a CAL OUT terminal as output by a switching signal from the CAL SW CONT after output levels are adjusted with an attenuator for calibration. The output signal is passed to the low noise amplifier and is used to calibrate the LNA. When the loop signal is selected, a signal from the SYNTH (CAL) serves as a local signal for the 30G/20G XLTR.

Table 4 shows the main performance of the Ka-band frequency converter.

Table 4 *Main performance of Ka-band frequency converter*

Item	Performance
1．20G D/C	
Input frequency range	20.77 - 20.85 GHz
Output frequency range	1170 - 1250 MHz
Conversion gain	35 dB ±5.4 dB／80 MHz
Spurious	-66.8 dBc or better
Amplitude frequency characteristics	0.5 dBp-p or less／80 MHz
2．30G/20G XLTR	
Input frequency range	30.56 - 30.6312 GHz 30.5728 - 30.6528 GHz
Output frequency range	20.7788 - 20.85 GHz 20.77 - 20.85 GHz
Conversion loss	19.8 dB or less
Amplitude frequency characteristics	0.4 dBp-p or less

The high power amplifier subsystem consists of a 30 GHz up-converter (30G U/C), a high power amplifier (HPA), and a transmit signal switching controller (HPA SYS CONT).

The 30G U/C converts the 1.2 GHz band IF signal input thereto to a 30 GHz band transmit signal and outputs it to the HPA in the next stage. The gain can be adjusted using a dial on a front panel.

The HPA amplifies the 30 GHz band RF signal sent from the 30G U/C to the required strength, achieving a gain of 50 dB with a two-stage configuration consisting of a solid state amplifier and a TWT (Traveling Wave Tube) amplifier.

The HPA SYS CONT is used to control switching of the HPA system and to display status. HPA SYS CONT has the following functions.

1 Switches transmitting output to the antenna or a dummy load, then displays the output.
2 Switches of ON/OFF of the transmitting power measurement using power meter, then displays the output.
3 Setting REMOTE/LOCAL control modes
4 Outputs the operating conditions of the HPA and changes in the location status of the waveguide switches to the monitor and control subsystem.

Table 5 shows the main performance of the high power amplifier subsystem.

Table 5 *Main performance of high power amplifier subsystem*

Item	Performance
1. 30GHz U/C	
Input frequency range	1220 MHz ±60 MHz
Output frequency range	30.56 - 30.68 GHz
Conversion gain	22 dB or more (at a maximum setting)
Output 1 dB compression point	+16.5 dBm or more
Amplitude frequency characteristics	0.2 dBp-p or less
2. HPA	
Output frequency range	30.56 - 30.68 GHz
Saturated output power	+50.6 dBm or more
Gain	50 dB or more (at saturation)
Gain fluctuation	0.1 dB/h or less (at an output of 50W)
Amplitude frequency characteristics	0.9 dBp-p or less
Spurious	-61.2 dBc or better

Fig.6 shows an example of the input-output characteristics of the HPA alone.

The saturation output power of the HPA is 51.2 dBm. Although not shown for the input-output characteristics of 30G U/C, the saturation output power is +17 dBm at the maximum gain setting and +16.5 dBm at an output 1 dB compression point (input power: −5 dBm).

The low noise amplifier is installed in an RF unit housing enclosure directly under the feed unit of the antenna, and consists of an

LNA and an input switching waveguide circuit. Fig.7 gives a block diagram.

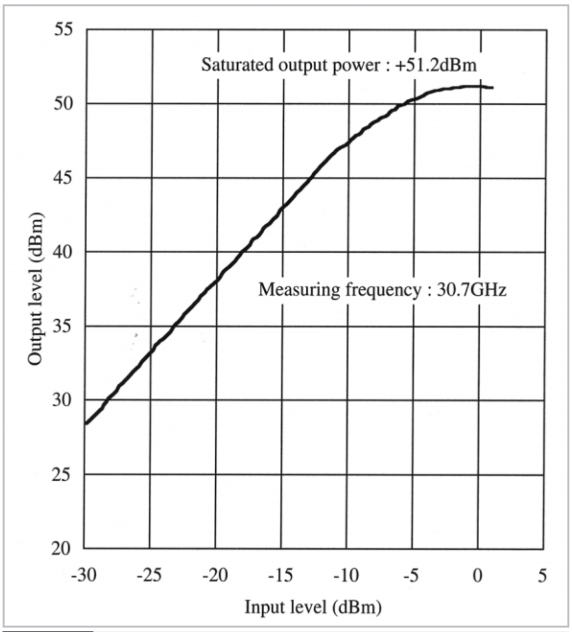


Fig.6 HAP input-output characteristics (@30.7 GHz)

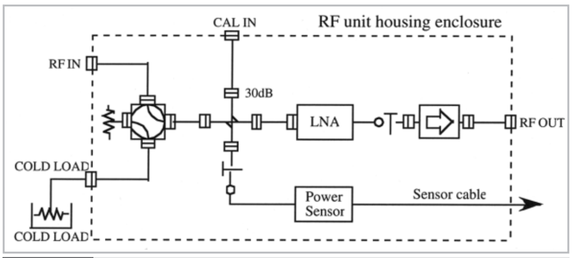


Fig.7 Block diagram of low noise amplifier

This low noise amplifier amplifies the received signal in the 20 GHz band input from the feed unit to the required level with low noise level and outputs it to the next-stage 20G D/C. It offers a COLD LOAD terminal for measuring the noise temperature of the receiving system and allows a standard noise source (nitrogen dummy) to be attached thereto. Moreover, a signal for receiving system calibration is input from a CAL IN terminal. This signal is passed to the LNA through a 30 dB coupler.

Table 6 shows the main performance of the low noise amplifier.

Fig.8 shows the input-output characteristic of the LNA.

The AFC control subsystem compensates

Table 6 Main performance of low noise amplifier

Item	Performance
Input-output frequency range	20.78 - 20.84 GHz
Noise temperature	157.1K or less（at Input point）
Gain	54.1 dB ±0.1 dB
Output 1 dB compression point	+6.5 dBm
Temperature characteristics	1.6 dBp-p or less／-10℃～+55℃

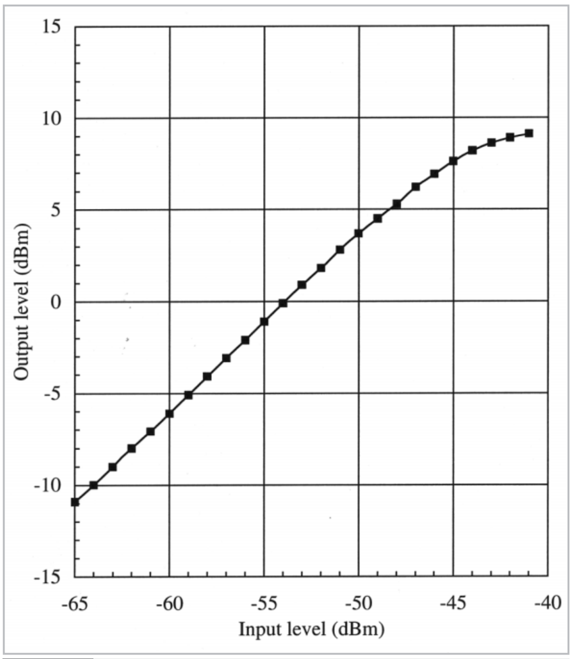


Fig.8 LNA input-output characteristics

for the effects of local frequency drift of the satellite station in an RF system of the feeder-link earth station.

It performs the following basic operations: receives a beacon signal transmitted from the satellite with the beacon receiver (PILOT RCVR); acquires error information on the frequency in a route from an oscillator to generate a beacon signal in the satellite to the PILOT RCVR of the feeder-link earth station, based on differences between the measured value of the received frequency and a nominal value of the beacon signal frequency; automatically adjusts the transmitting/received frequencies of the feeder-link earth station.

Note that this AFC control cannot compensate for frequency drifts arising from Doppler effects generated by satellite motion.

The monitor and control subsystem are used to monitor and control each component of the equipment with a monitor and control device (MAC), mainly through a GP-IB interface.

Fig.9 shows a monitor and control system diagram.

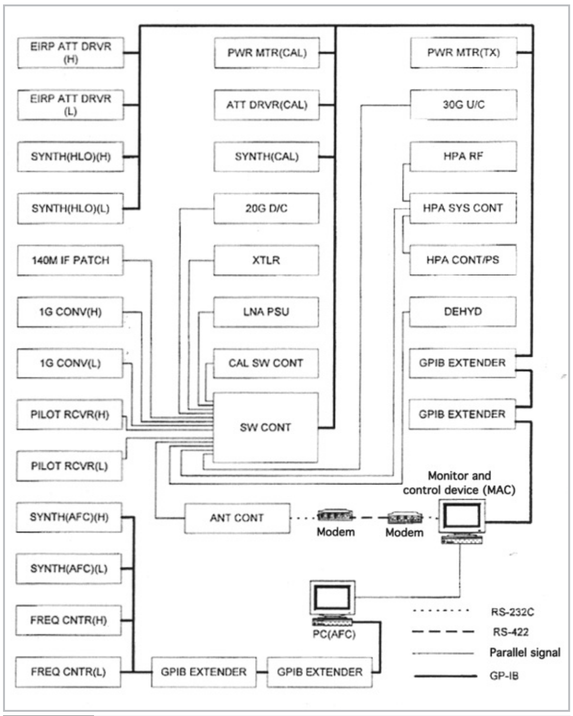
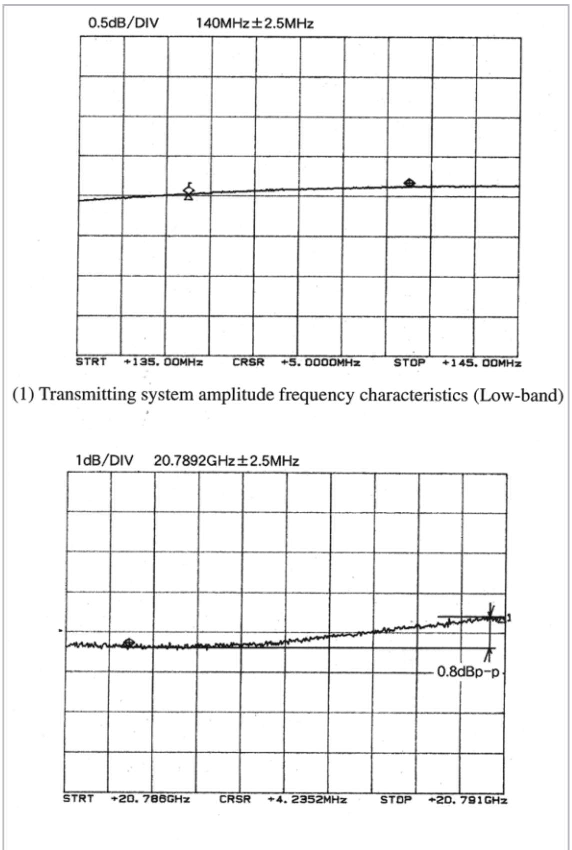


Fig.9 Monitor and control system diagram

Used to perform the following basic functions:

1 Status monitoring of satellite communication equipment
2 Individual control of satellite communication equipment
3 Function for switching ANT/DUMMY and ANT/TEST
4 Function for sounding/silencing a buzzer
5 History recording function
6 Transmission power logging function
7 Maintenance functions
   (1) Setting date and time
   (2) Setting a buzzer
   (3) Backing up a log
   (4) Validating/non-validating local operation of Individual equipment
   (5) Validating/non-validating AFC monitor and control of Individual equipment

Fig.10 shows an example of an RF unit overall amplitude frequency characteristic. A measurement route covers from the 140M IF PATCH to the HPA in the transmitting system, and from the LNA to the 140M IF PATCH in the receiving system.



(1) Transmitting system amplitude frequency characteristics (Low-band)

(2) Receiving system amplitude frequency characteristics (Low-band)

Fig.10 An example of RF unit overall amplitude frequency characteristics

An amplitude frequency characteristic for a Low-band is shown for both transmitting and receiving systems, as an example. The amplitude variance is 0.1 dBp-p for the transmitting systems and 0.8 dBp-p for the receiving system. In the Hi-band, the value is 0.1 dBp-p or less in the transmitting system and 0.8 dBp-p in the receiving system.

Fig.11 shows an example of spurious in the transmitting system.

The spurious was measured as in an HPA output (coupling output of the directional coupler) with a 140 MHz, −10 dBm signal (standard input) input from the 140M IF PATCH. There is no especially distinctive spurious.

Fig.12 shows a level diagram of the transmitting system. Fig.13 shows a level diagram of the receiving system.

In the transmitting system, a transmitting

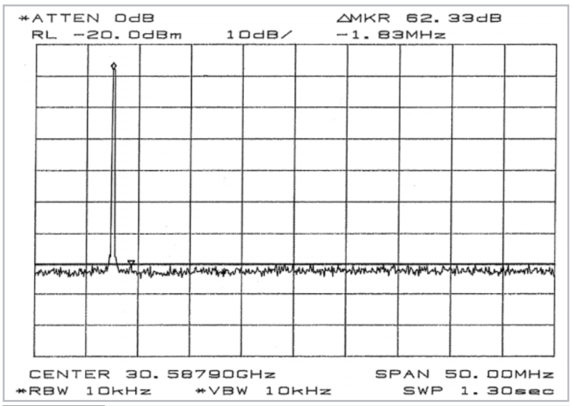


Fig.11 Spurious of transmitting system (Low-band)

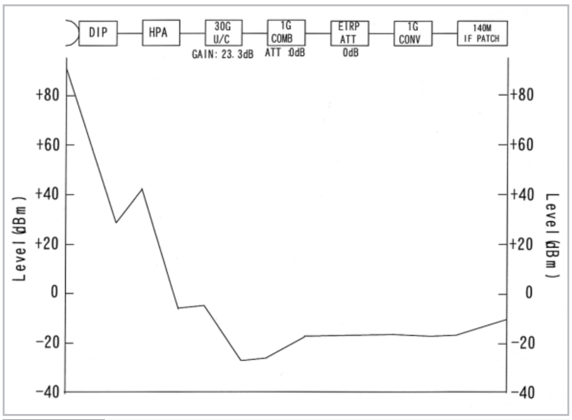


Fig.12 Level diagram of transmitting system

level can be varied by EIRP ATT and ATT in the 1G COMB. Moreover, in 30G U/C, its gain can be varied with the dial in the front panel. A variable range is 17 dB to 23 dB (catalog values). This level diagram is shown for an input of −10 dBm (standard), with both ATTs being set to 0 dB, and with a gain of 30G U/C being set to 22.3 dB (maximum gain), i.e., the maximum operation.

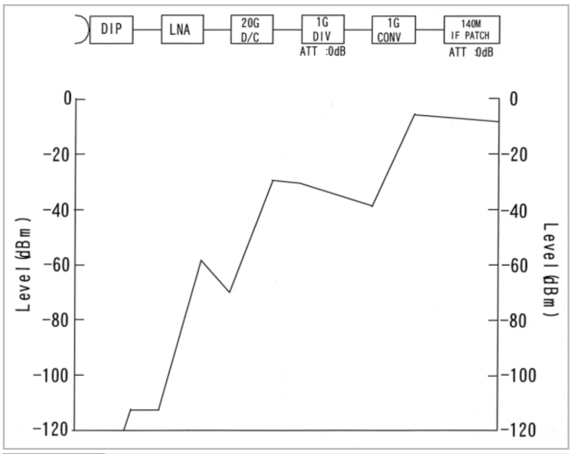


Fig.13 Level diagram of receiving system

In the receiving system, the output level can be varied by ATT in the 1G DIV and ATT in the 140M IF PATCH. This level diagrams are shown for cases with ATTs set to 0 dB.

3 Concluding remarks

This report introduced the configuration and performance of the Ka-band feeder-link earth station. The ETS-VIII launch is scheduled for summer 2004, and this earth station is expected to play a central role in various communication experiments. To ensure the smooth completion of the actual experiments, we plan to make various preparations, including confirming interfaces for the communication terminals to be used in the experiments and examining the system for Doppler compensation.

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