4-6 Portable Earth Station

4-6-1 RF Unit for Portable Earth Station

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For the purpose of verifying the in-orbit electrical characteristics of the Engineering Test Satellite VIII (ETS-VIII) on-board antenna, we plan to measure the receiving signal power at multiple points in the beam area of it. We developed the portable earth station for measuring the receiving signal power and measured the electrical performance. The measurement results show that the expected performance can be achieved for the portable earth station.

Keywords
Engineering Test Satellite VIII, On-board antenna, In-orbit electrical characteristics, Portable earth station.

1 Introduction

The Engineering Test Satellite VIII (ETS-VIII) will be equipped with a large deployable antenna (with an effective aperture diameter of 13 m) to maintain sufficient antenna gain for mobile satellite communication experiments, including voice communications with hand-held terminals and high-speed data communications [1] [2]. The evaluation of ground and in-orbit characteristics of the large deployable antenna is essential to the development of the future satellite on-board antennas necessary for future satellite communications systems. The results of deployment tests and evaluations of electrical characteristics on the ground have been reported already [3] [4]. On the other hand, the evaluation of the in-orbit characteristics of the onboard antennas is scheduled to begin following the launch of the ETS-VIII.

To evaluate the characteristics of the ETS-VIII onboard antennas, such as in-orbit radiation patterns and reflector surface distortion, the CRL has designed experiments to measure the receiving signal power at multiple-locations in the coverage area of a single satellite beam. The newly developed portable earth station discussed herein will be used for measuring the receiving signal power.

The portable earth station is also designed as an RF unit, which will enable communication experiments through modem connection for IF signal input and output. This paper discusses the configuration and electrical characteristics of the developed prototype portable earth station.

2 Configuration of the portable earth station

2.1 Circuit configuration

Fig.1 shows a block diagram of the portable earth station. The design specifications of the station include a transmission EIRP of 20 dBW or greater at an antenna gain of 12 dBi, a G/T of −15 dB/K or greater (at the output terminal of the low noise amplifier (LNA)), a dynamic range in measurement of 30 dB or greater for receiving signal power, a transmission frequency band of 2657.5 ±2.5 MHz, and a receiving frequency band of 2502.5 MHz ±2.5 MHz.

The portable earth station consists mainly of the antenna unit, transmission unit, receiving unit, measurement and control unit, and

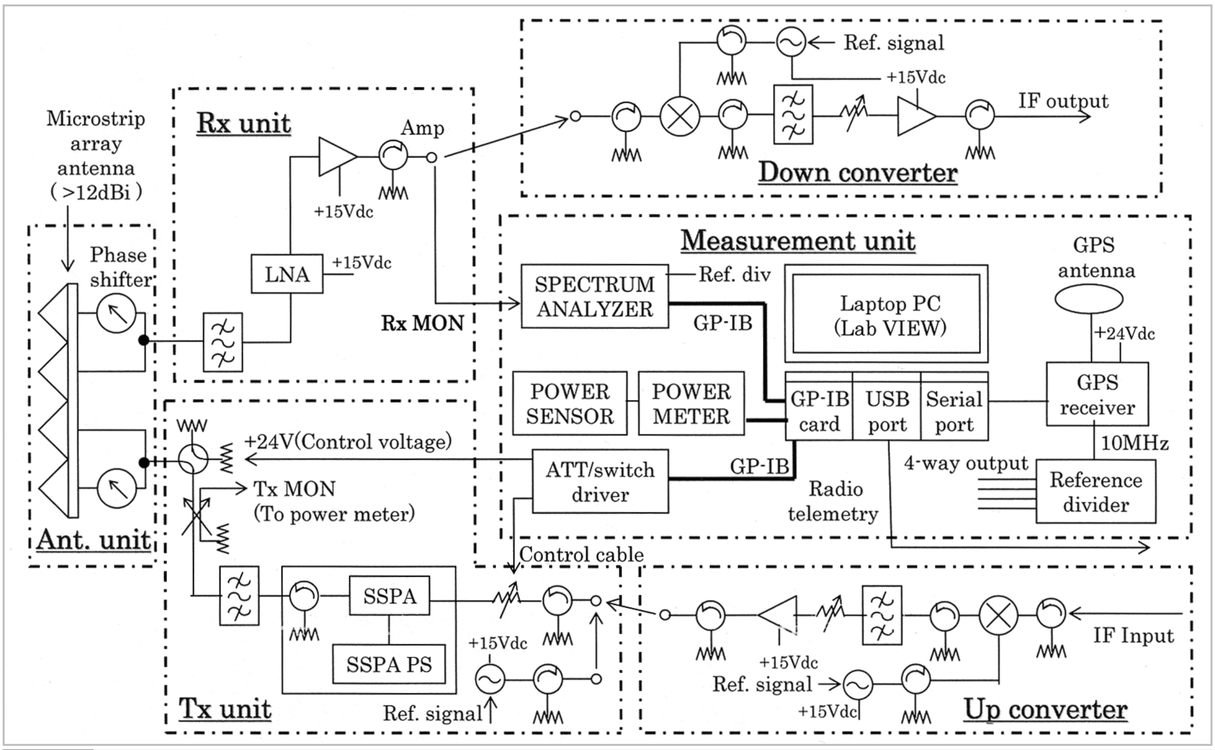

Fig. 1 Block diagram of the portable earth station

frequency conversion unit. The configuration of each of these units is described below.

(1) Antenna unit (Ant. unit)

The antenna unit consists of an S-band stair type array antenna (also used for automobile-based mobile stations), in addition to the power divider and phase shifter required to operate the antenna. The antenna consists of 4 rows of sequentially rotated 1×4 element arrays, in which the two front rows are used to transmit signals and the two rear rows are used to receive signals. Experimental results show that the antenna gain is 12 dBi or greater in both transmission and reception. The configuration and electrical characteristics of the antenna unit are described in more detail in 4-5, "Land mobile station for ETS-VIII mobile satellite communications experiments."

(2) Frequency conversion unit (Up/Down converter)

The frequency conversion unit will not be used to measure the onboard antenna characteristics but instead will be used solely for communication experiments, which will be performed through a modem connection enabling input and output of IF signals at 140 MHz and −10 dBm. The frequency conversion unit consists of an up converter and a down converter.

The up converter is designed to convert input IF signals at 140 MHz and −10 dBm into output RF signals at a frequency of 2657.5 MHz and at power of 0 dBm or greater. The down converter is designed to convert input RF signals at 2502.5 MHz and −30 dBm into output IF signals at 140 MHz and power of −10 dBm or greater. Tables 1 and 2 show the main specifications of the up and down converter components, respectively.

(3) Transmission unit (Tx unit)

As the frequency conversion unit is used only for communication experiments, another CW signal source is required to supply transmission signals when measuring the characteristics of the onboard antenna. Thus, a crystal oscillator and a filter featuring performance equivalent to that of the band-pass filter (BPF) in the up converter are installed in the transmission unit to measure these characteristics.

Table 1 *Main specifications of the up converter components*

Local OSC.	Output Freq.: 2517.5 MHz,
	Output power: 17.4 dBm,
	DC current: 450 mA (MAX)
	@ 15V
Mixer	Triple balanced mixers
	Freq. Range:
	LO/RF: .005 to 3.0 GHz
	IF: .005 to 2.0 GHz
	Conv. Loss: -7.5 dB type
BPF	f_0 : 2657.5 MHz,
	Pass band: $f_0 \pm$ 2.5 MHz,
	Rejection: < -70 dB @ $f_0 \pm$ 150 MHz,
	Pass band ripple:
	< 0.5 dBp-p @ $f_0 \pm$ 3 MHz,
	Power handling: 1 W
Var. ATT.	Freq. Range: 2 - 4 GHz,
	ATT. Range: > 20 dB,
	VSWR: < 1.5:1,
	Insertion loss: < 0.2 dB
AMP	Freq. Range: 0.1 - 3 GHz,
	Gain: 32.8 $\pm$ 0.9 dB,
	1dB Comp.: 21 dBm,
	NF: 4.77 dB,
	DC current: 364 mA @ 15 V

Table 2 *Main specifications of the down converter components*

Local OSC.	Output Freq.: 2363.5 MHz,
	Output Power : 14.4 dBm,
	DC current: 450 mA (MAX)
	@ 15V
Mixer	Refer to the mixer in the up converter
LPF	f_0 : 140 MHz,
	Pass Band : 150 MHz,
	Rejection: < -70 dB @ 300 MHz,
	Pass band ripple:
	< 0.5 dBp-p @ $f_0 \pm$ 3 MHz,
	Power handling: 1 W
Var. ATT.	Freq. Range: DC - 250 MHz
	ATT. Range: > 15 dB
	VSWR: < 1.5:1
	Insertion loss: < 0.9 dB
AMP	Freq. Range: 10 - 200 MHz
	Gain: 45.7 dB (MIN)
	1dB Comp.: 24.4 dBm
	NF: 2.5 dB
	DC current: 176 mA @ 15 V

The transmission unit consists of a step attenuator, a solid-state power amplifier (SSPA), a band-pass filter (BBF), a directional coupler having a coupling factor of 30 dB, an RF switch, and a coaxial fixed termination, arranged in this order from the input terminal. The circuit is designed to output signals at 2657.5 MHz and 40 dBm (10 W) or greater in response to input signals from the up converter of the frequency conversion unit or from the crystal oscillator installed in the transmission unit.

The Switch/Step attenuator driver of the signal measurement and control unit controls the step attenuator and the RF switch, the former adjusts the power level of the transmission signals and the latter switches the transmission signals between the fixed termination and transmission output terminal. The transmitted signals are monitored by measuring the coupled power of the directional coupler using the power meter installed in the signal measurement and control unit. Table 3 shows the main specifications of the transmission unit components.

(4) Receiving unit (Rx unit)

The receiving unit consists of a BPF (band-pass filter), an LNA (low noise amplifier), and an AMP (amplifier), arranged in this order from the input terminal. The circuit is designed to produce output signals at −30 dBm or greater following input of a signal at 2502.5 MHz and −100 dBm. Table 4 shows the main specifications of the receiving unit components.

Table 3 Main specifications of the transmission unit components

Local OSC.	Output Freq.: 2657.5 MHz, Output Power : 15 dBm, DC current: 450mA (MAX) @ 15V
BPF	Refer to the BPF in the up converter
Step variable ATT.	Freq. Range: 2 - 4 GHz ATT. Range: 0 - 81 dB, VSWR: < 1.5:1, Insertion loss: < 0.2dB
SSPA	Freq. Range: 2.6 - 2.7 GHz, Gain: > 40 dB, MAX. Output power: 10 W, 1dB Comp.: > 39 dBm, NF: < 12 dB, AC: 100 V, 50/60 Hz, 3 A
BPF	f_0: 2657.5 MHz, Pass Band: f_0 ± 2.5 MHz, Rejection: < -70 dB @ f_0 ± 150 MHz, Pass band ripple: < 0.5 dBp-p @ f_0 ± 3 MHz, Power handling: 20 W
Coupler	Freq. Range: 2 - 4 GHz, Coupling level: 30 dB, Power handling: 50 W
RF Switch	VSWR: < 1.2:1, Insertion loss: < 0.2 dB, Isolation : 80 dB (MIN)
Termination	Freq. Range: DC - 18 GHz, Power handling: 20 W

Table 4 Main specifications of the receiving unit components

BPF	f_0: 2520 MHz Pass Band: f_0 ± 20 MHz, Rejection: < - 90 dB @ f_0 ± 150 MHz, Pass band ripple: < 0.5dBp-p @ f_0 ± 20 MHz, Power handling: 1 W
LNA	Freq. Range: 2.3 - 2.7 GHz, Gain: 45 dB (MIN), 1dB Comp.: 16.4 dBm, NF: 0.38 dB, DC current: 200 mA @ 15 V
AMP	Freq. Range: 2 - 4 GHz, Gain: 31 dB (MIN), 1dB Comp.: 19.3 dBm, NF: 1.7 dB, DC current: 251 mA @ 15 V

(5) Signal measurement and control unit

The signal measurement and control unit consists of a spectrum analyzer, a power sensor, a power meter, a laptop PC, an Switch/Step attenuator driver, a GPS antenna and receiver, and a 4-way lumped element power divider. This unit monitors the transmitted and received signals and controls the signal measurement equipment.

The spectrum analyzer measures the received signal power and the power meter monitors the transmitted signals. The Switch/Step attenuator driver controls the step attenuator and the RF switch within the transmission unit. The GPS antenna and receiver is installed to supply the reference signal (10 MHz) used to synchronize the signal measurement equipment and the local oscillator and to determine time and position data. The reference signal is supplied to the signal measurement equipment and other devices through the 4-way lumped element power divider. The laptop PC is outfitted with a GPIB card and a serial port. A GPIB card is used to control the signal measurement equipment and to record measurement data. A serial port is used to record the GPS receiver position and time data.

(6) Other (data collection system)

To evaluate electrical characteristics (such as radiation patterns, for example) of the satellite onboard antennas, we will build portable earth stations, arrange them discretely within the ground area irradiated from a single satellite beam, and measure the receiving signal power. We will prepare a host computer, outfitted with an ADSL modem, for remote control of the separate portable earth stations and for the simultaneous collection of data obtained at each station, and will also prepare mobile terminals, such as portable phones and PHS devices, to be installed in the portable earth stations in order to export measurement data to the host computer. The host computer and the portable earth stations will be linked via Internet to form a data-collection system capable of managing all portable earth stations in a unified manner. (See 4-6-4, “Data collection system,” regarding the methods of remote control and data collection.)

2.2 Configuration of the RF unit of the portable earth station prototype

Fig.2 shows the cabinet rack-mounted equipment and configuration diagram of the portable earth station prototype built according to the configuration shown in Fig.1. The antenna unit, the receiving unit, and the GPS antenna are not shown in Fig.2, as we are now considering a variable configuration for the installation of these components. For example, they may be installed away from the cabinet rack for a clearer line of sight or they may be installed on top of the cabinet rack, depending on the position of the rack and on the specific application.

The cabinet rack is 1100 mm high, 570 mm wide, and 750 mm deep. There are 6 shelves in the cabinet rack with fans mounted on the back to release heat.

The topmost sub-rack within the cabinet rack contains the components for the transmission unit (except for the SSPA, which is too large to install in the sub-rack, as it is equipped with an integrated DC power supply and a cooling fan; this device is installed on the second shelf). When the transmission unit is in use, an RF cable connects the RF signal

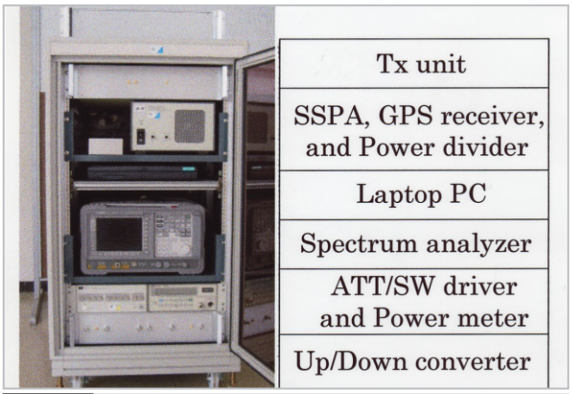

Fig.2 *Appearance and configuration diagram of the portable earth station prototype*
((a) photograph of the portable earth station; (b) configuration diagram)

input/output terminals on the front panel of the transmission unit sub-rack and those on the front of the SSPA.

With the exception of the SSPA device, the second to the fifth shelves house the signal measurement and control unit. The second shelf holds the GPS receiver and the 4-way lumped element power divider (in front of the output terminal of the GPS receiver). The third shelf contains the laptop PC, the fourth shelf holds the spectrum analyzer, and the Switch/Step attenuator driver and the power meter are installed on the fifth shelf. The laptop PC on the third shelf is mounted on a sliding steel tray that can be pulled out for use and pushed in for storage. The bottom sub-rack contains the frequency conversion components for the up and down converters.

3 Electrical characteristics of the portable earth station

3.1 Electrical characteristics of the up converter

Fig.3 is a diagram of power levels at consecutive stages of the up converter. This diagram tracks the power level to be measured for an input IF signal of 140 MHz and −10 dBm with an attenuation value for the variable attenuator of 0 dB. The output signal of the measured up converter is at 2657.5 MHz and 13.6 dBm. The maximum gain of the measured up converter is 23.6 dB. The spurious response is −70 dBc or less at 2657.5 ±2 MHz, the amplitude-frequency characteristic is 0.41 dBp-p at 2657.5 ±3 MHz, and the variable range of the variable attenuator is 27 dB. As the up converter is used in the communication experiment, it is necessary to measure the phase noise of the local oscillator in advance. Fig.4 shows the results of this phase-noise measurement.

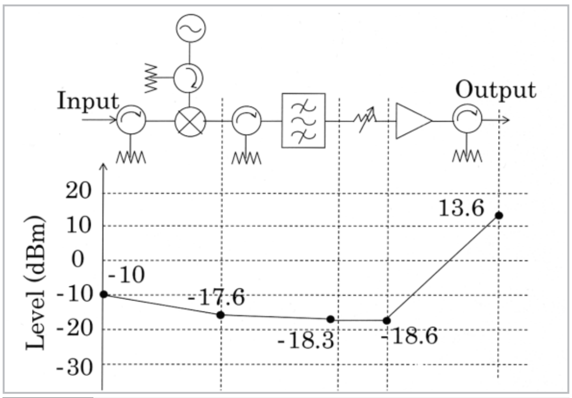

Fig.3 Diagram of power levels at consecutive stages of up converter

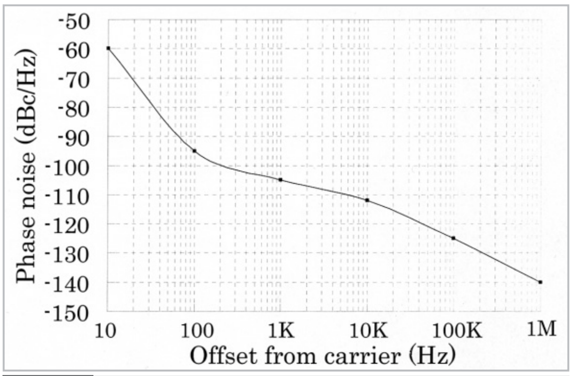

Fig.4 Phase noise of the local oscillator in the up converter at 2517.5 MHz

3.2 Electrical characteristics of the transmission unit

Fig.5 shows the input/output characteristics of the transmission unit. The values in the figure are measured at the coupled output terminal of the directional coupler for a frequency of 2657.5 MHz with the variable attenuator of the transmission unit set to 0 dB. The signal starts to saturate with input power of 0 dBm; the output power here is 41.5 dBm. Gain in the linear region is 41.5 dB.

As described in the discussion of the circuit configuration of the transmission unit (**2.2**), the input signal for the transmission unit consists either of the up converter signal or the transmission unit's oscillator signal. Thus, both of these signals are input into the transmission unit to measure spurious response and amplitude-frequency characteristics as the output power is adjusted to 40 dBm using the variable attenuator. The resultant spurious response values are −70 dBc or less at 2657.5 ±2 MHz for both signals. The amplitude-frequency characteristics values are 0.6 dBp-p at 2657.5 ±3 MHz for the up converter signal and 0.5 dBp-p at 2657.5 ±3 MHz for the oscillator signal.

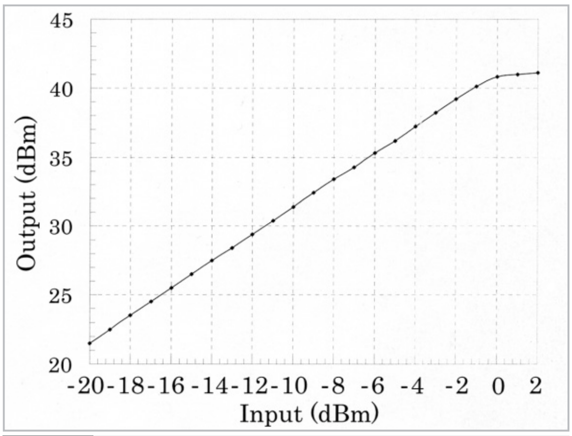

Fig.5 Input/output characteristics of the transmission unit at 2657.5 MHz

3.3 Electrical characteristics of the receiving unit

Fig.6 is a diagram of power levels at consecutive stages of the receiving unit. The measured values in the figure correspond to an RF input signal of 2502.5 MHz and −100 dBm. The gain of the receiving unit is 84.8 dB and the output power is −15.1 dBm. The amplitude-frequency characteristic is 0.6 dBp-p at 2502.5 ±3 MHz, and the C/N ratio is 32 dB or more at 2502.5 ±3 MHz (when the RBW of the spectrum analyzer is 3 kHz). The C/N value indicates the output dynamic range of receiving signal power.

Fig.7 shows the input/output characteristics of the LNA in the receiving unit. The gain of the LNA is approximately 50 dB. The figure noise is 0.4 dB. Assuming an antenna gain

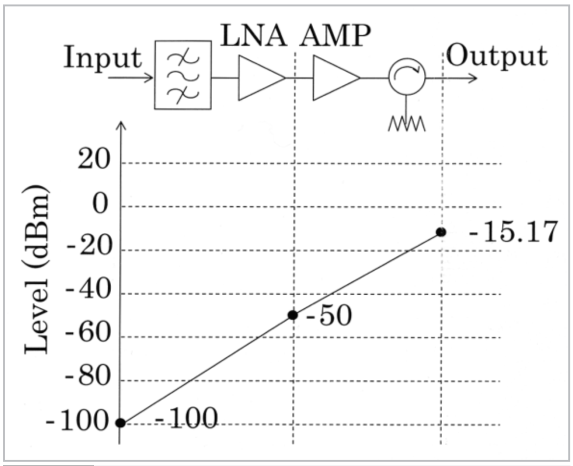

Fig.6 *Diagram of power levels at consecutive stages of receiving unit*

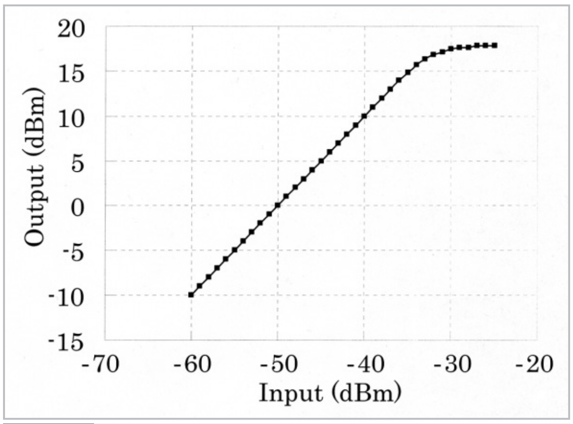

Fig.7 *Input/output characteristics of the LNA at 2502.2 MHz*

of 12 dBi, a feed line loss of 1 dB, antenna noise temperature of 300 K, and environmental temperature of 300 K, G/T is calculated as −14.17 dBK.

3.4 Down converter

Fig.8 is a diagram of power levels at consecutive stages of the down converter. The values in the figure are measured for an RF input signal of 2502.5 MHz and −30 dBm with the variable attenuator set to 0 dB. The measured output signal of the down converter is 140 MHz and 11.6 dBm, and the maximum gain is 41.6 dB. The spurious response is −30 dBc or less at 140 ±3 MHz, the amplitude-frequency characteristic is 0.6 dBp-p at 140 ±3 MHz, and the range of the variable attenuator is 21 dB.

Fig.9 shows the input/output characteristics of the amplifier in the down converter. The gain in the linear region is 49.3 dB and the signal starts to saturate with input power of −22 dBm.

The phase noise of the local oscillator in the down converter is measured similarly to that of the local oscillator in the up converter. Fig.10 shows the results.

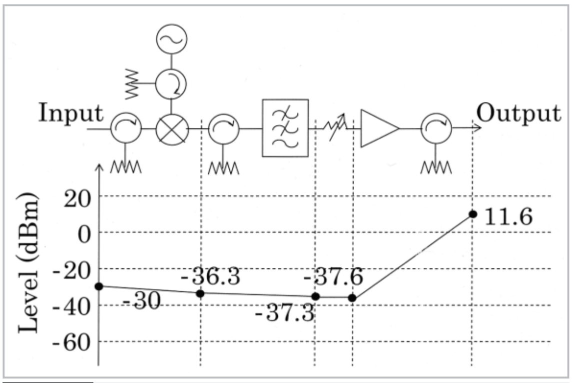

Fig.8 *Diagram of power levels at consecutive stages of down converter*

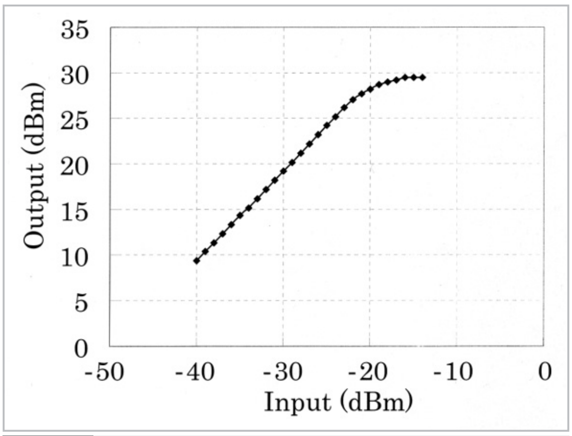

Fig.9 *Input/output characteristics of amplifier in the down converter at 140 MHz*

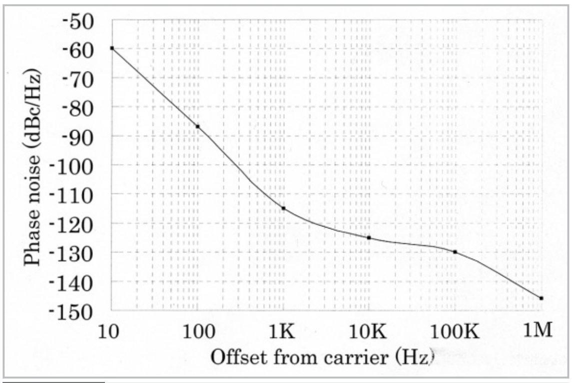

Fig.10 *Phase noise of the local oscillator in the down converter at 2363.5 MHz*

4 Summary

We have discussed the circuit configuration and the electrical characteristics of the prototype portable earth station built to measure the electrical characteristics of the ETS-VIII onboard antennas and to facilitate communication experiments. The ETS-VIII is planned to be launched in the near future, and the portable earth stations will be used for initial verification of the onboard antennas after launch. The portable earth stations will then be used in the basic experimental phase in which the electrical characteristics of the onboard antennas are evaluated and communication experiments are performed. We planned to build five portable earth stations by the end of 2003. At the same time, we will conduct extensive preparations for post-launch experimentation, including studies on methods of evaluation of the onboard antenna, the placement of the portable earth stations, and calibration methods for the individual stations.

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