4-2 Earth Stations for WINDS High-Speed Network

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High-speed network is developed for the high-speed communication of user data rate over 622 Mbps using WINDS bent-pipe relay mode. We are developing a super high-data rate-VSAT with 2.4 m diameter antenna and a large earth terminal with 4.8 m diameter antenna. SDR-VSAT is used for high-speed communication of 622 Mbps and installed the vehicle. LET is used for high-speed communication of 1244 Mbps and set up at the NICT Kashima space technology center.

The earth station for the high-speed network is required the 1.1 GHz wideband transmitter and receiver as same as the on-board transponder of WINDS.

Keywords
LET, SDR-VSAT, SS-TDMA, Bent-pipe relay, Satellite switch

1 Introduction

We are currently developing two types of earth stations for high-speed network experiments using the Wideband InterNetworking Engineering Test and Demonstration Satellite (WINDS) bent-pipe relay links. The Large Earth Terminal (LET) features an antenna with a diameter of 4.8 m and supports communications at a user data rate of 1,244 Mbps. The Super-high Data-rate Very Small Terminal (SDR-VSAT) is equipped with an antenna having a diameter of 2.4 m and supports communications at a user data rate of 622 Mbps. The Large Earth Terminal will be installed at the NICT Kashima Space Research Center located in Kashima, Ibaraki; construction of the terminal is now underway. (This terminal is referred to below simply as the “Kashima earth station”). The SDR-VSAT is installed on a vehicle to enable experiments throughout Japan. (The device is thus referred to as the “vehicle-mounted station” below.)

The Kashima earth station and the vehicle-mounted station differ in their antennas and the number of communication terminals that can be connected. Their RF facilities, on the other hand, feature similar structures. The structures and characteristics of the Kashima earth station and the vehicle-mounted station are described below.

2 Structure of each unit

Figure 1 shows the structures of the Kashima earth station and the vehicle-mounted station. Table 1 shows the major specifications of each. Each of the earth stations consists of an antenna, a low-noise amplifier, a high-power amplifier, a frequency converter unit, and an antenna tracking system. Functioning as a high-speed network terminal, a high-speed burst modem is connected in the intermediate frequency (IF) band at 3-GHz. The Kashima earth station is also equipped with a 155-MHz reference burst receiver.

At the Kashima earth station, the high-power amplifier is placed outdoors directly below the antenna to minimize transmission loss. The low-noise amplifier is installed in

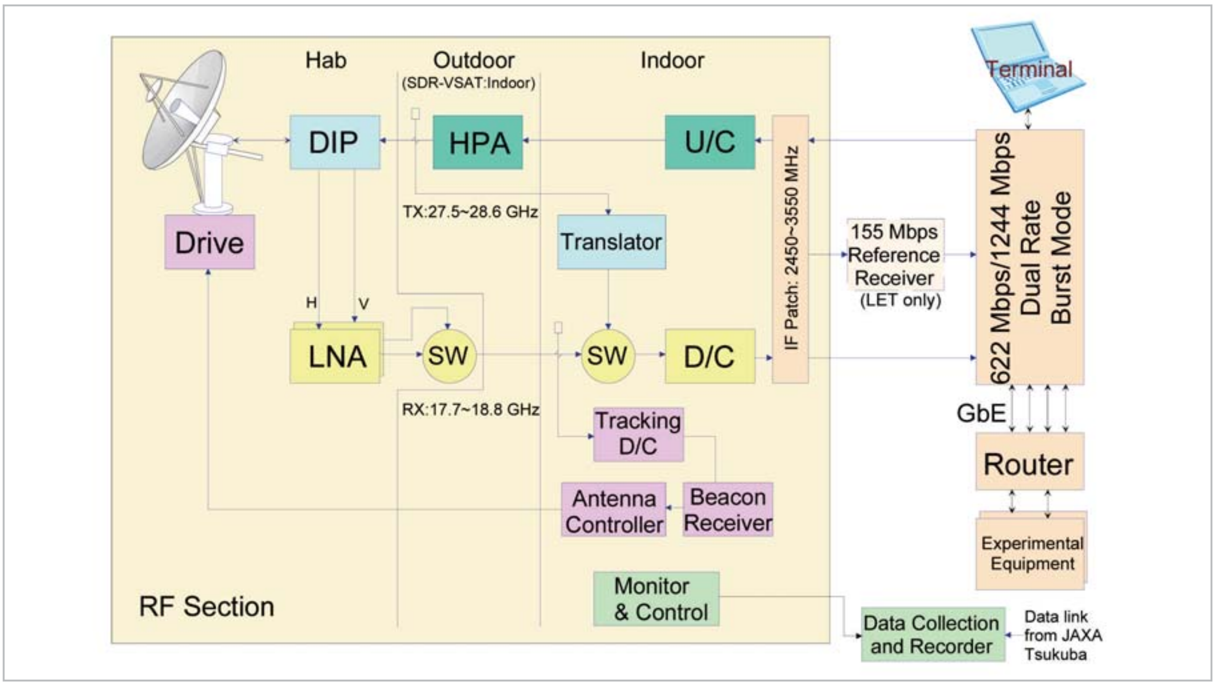

Fig. 1 Structure of experimental earth stations

Table 1 Major specifications of experimental earth stations

	Kashima earth station	Vehicle earth station
TX / RX frequency	18.25 GHz / 28.05 GHz	
IF frequency	3000 MHz / 1100 MHz bandwidth	
Antenna diameter	4.8 m	2.4 m
HPA output power	215 W	215 W
EIRP	79.3 dBW	73.1 dBW
G/T	32.7 dB/K	26.3 dB/K
Flatness (1100 MHz BW)	2.55 dBp-p (RF loop back)	
Spurious	Less than -60 dBc	
User data rate	1244 Mbps	622 Mbps

the antenna hub. The frequency converter and subsequent devices are installed in three consecutive racks in the indoor laboratory.

In the vehicle-mounted station, the high-power amplifier and the frequency converter unit are placed at the rear of the vehicle, with the exception of the IF connection unit (IF patch), which is installed in the operation room. The low-noise amplifier is installed in the antenna feed unit. The vehicle-mounted station is installed with an offset Gregory antenna featuring a diameter equivalent to 2.4 m. Due to the width of the vehicle, the antenna width is limited to this size. Figure 2 shows the external appearance of the vehicle-mounted station. Figure 3 shows the on-vehicle RF devices, including the frequency converter unit and the high-power amplifier.

(1) Frequency converter equipment

The frequency converter equipment consists of an IF patch, a transmission frequency converter, a transmission interface unit, a receiving frequency converter, a receiving interface unit, and a translator.

The IF patch interfaces with the communication terminal by an IF-band signal with a center frequency of 3 GHz. The patch adjusts the signal level with the IF-band amplifier. The patch also features a first-order amplitude equalizer in the transmitting and receiving circuits and can adjust amplitude characteristics in the satellite links. The Kashima earth station is equipped with a high-speed burst modem and a 155-Mbps reference burst receiver. In addition, this station is outfitted with additional input and output terminals for connecting measurement and other equipment. The transmission frequency converter converts an IF-frequency signal into a Ka-band (28.05 GHz) signal. The receiving frequency converter converts a Ka-band (18.25 GHz)

Fig.2 *External appearance of vehicle-mounted station*

Fig.3 *External appearance of RF devices of vehicle-mounted station*

signal into an IF-frequency signal. The transmitting and receiving interface units provide the signal interfaces in the Ka band, adjust the signal levels of various connected devices, and feature monitor terminals for measuring various signals.

(2) High-power amplifier

The Kashima earth station and the vehicle-mounted station use the same type of high-power amplifier. In the Kashima earth station, the high-power amplifier is placed outdoors directly below the antenna to suppress transmission loss. For the vehicle-mounted station, it is placed at the rear of the vehicle, directly below the antenna attachment.

The earth stations use the traveling-wave tube amplifier (TWTA), which can amplify signals in a wide bandwidth from 27.5 GHz to 30.0 GHz and can provide output power of up to 215 W.

(3) Low-noise amplifier

The low-noise amplifier consists of FET amplifiers yielding a noise figure of 2.1 dB. The WINDS communication signal is linearly polarized and transmitted as horizontally or vertically polarized waves. Thus, the earth stations are equipped with two sets of low-noise amplifiers for horizontally and vertically polarized waves. Toggling between these amplifiers is effected via a switch.

(4) Antenna

The Kashima earth station uses a limited-scan parabolic antenna with a diameter of 4.8 m. The vehicle-mounted station uses an omnidirectional offset Gregory antenna with an equivalent diameter of 2.4 m mounted atop the vehicle.

(5) Antenna drive unit

The antenna drive unit consists of a tracking frequency converter, a tracking receiver, an antenna controller, and an antenna driver. The antenna drive unit of the Kashima earth station is stored in the same rack as the frequency converter unit. In the vehicle-mounted station, it is stored in the same rack as the frequency converter, at the rear of the vehicle, with the exception of the antenna controller, which is installed in the control cabin.

The tracking frequency converter receives the residual carrier in the 18.9-GHz network information link transmitted from WINDS, converts it to a 70-MHz IF signal, and inputs the resultant signal into the tracking receiver. The tracking receiver detects the carrier level and outputs this level to the antenna controller.

The antenna controller normally tracks the satellite using the step track method. In addition, the controller can employ the functions listed in Table 2. The start modes indicated in the table direct the antenna roughly toward the satellite, the satellite search mode ("Box Scan") captures the satellite, and the operation modes track the satellite.

Here, the satellite capture function within the vehicle-mounted station acquires the position and direction of the vehicle-mounted sta-

Table 2 *Antenna drive control functions*

Function	Outline	mode
Optrack	Optrack is primary tracking mode of the antenna control unit. It provides for AZ, EL, and POL tracking of geosynchronous targets. Tracking data is gathered, normally via Steptrack, and stored. This data is used to form an ephemeris model. The combination of active tracking data and ephemeris model is used to optimally position the antenna in the presence of wind, fade and other disturbances	Operation mode
Position Track	Position Track is a hybrid tracking mode which allows entry of AZ, EL, and (optional) POL starting Coordinates. When the antenna arrives at the start coordinates, the control enters Optrack if a signal is found that is above the low signal threshold. If the signal is not above low signal threshold, then the control will enter BOX SCAN mode.	Operation mode
Geo Track	Satellite Longitude is entered instead of Satellite AZ/EL (The LON parameter only exists when GEO Track is selected). The control automatically computes AZ/EL starting coordinates based upon this longitude. Additional POL options are available.	Start mode
Steptrack	Steptrack is one of antenna control unit's secondary tracking modes. It is normally used only as part of Optrack's data gathering sequence.	Operation mode
INTELSAT	The INTELSAT mode provides selection of the desired target via Operator Input INTELSAT Ⅱ data set.	Start mode
Table Track	Table Track mode exists primarily to allow an operator to manually input time-tagged AZ/EL position angle data points.	Start mode and Operation mode
Memory Track	Memory Track mode is used for actively tracking geosynchronous satellites. It works on the principle that a geosynchronous satellite's trajectory does not differ significantly from day to day.	Start mode
Norad Track	This mode generates pointing angles that dynamically command the trajectory of a NORAD object as defined by a NORAD two-line element set.	Program mode
Satellite Track	Sat tracking allows the choice of 1 to 10 preconfigured satellite targets from a satellite database listing.	Start mode

tion using GPS and an electronic compass; given this configuration, care must be taken to ensure additional positional confirmation, particularly in terms of antenna direction.

(6) Monitor control

The monitor controller adjusts the transmission power and toggles the waveguide switch. The monitor controller is stored in the rack of the frequency converter and can be operated via touch panel. A personal computer (PC) is prepared to store a log of operation. This PC is able to store the log and also repeat the operations recorded therein. The monitor controller and the PC are connected via Ethernet, allowing other PCs connected to the Ethernet to monitor and control the equipment through a web browser.

(7) Vehicle

The original vehicle is an experimental vehicle prepared for the Communications and Broadcasting Engineering Test Satellite (COMETS or “Kakehashi”) project, modified for the WINDS project. This vehicle has a power-generater of 15 kW and can operate the equipment even in locations in which it is difficult to find a power supply. For the current project, we have newly developed the antenna, the RF, and the terminal facility. As we have increased the antenna diameter from 1.8 m to 2.4 m, we have moved the air-conditioning apparatus and adjusted the weight balance of the vehicle.

3 Characteristics

(1) Example of link budget

Table 3 shows an example of the link budget in the WINDS bent-pipe relay mode. The Kashima earth station features a link margin of 7.4 dB for 1,244-Mbps transmission. The vehicle-mounted station demonstrates a link margin of 7.1 dB for 622-Mbps transmission.

Table 3 *Example of link budget*

		MBA		APAA	comments
		LET	SDR-VSAT	LET	
Frequency:	GHz	28.05	28.05	28.05	
Earth station:					
EIRP	dBW	79.3	73.1	79.3	3 dB back off
Pointing loss	dB	0.5	0.5	0.5	
Pass loss:					
Free space loss	dB	212.8	212.8	212.8	
Atmospheric loss	dB	0.5	0.5	0.5	
Satellite:					
G/T	dB/K	18.0	18.0	7.1	
Up-link C/No	dB	109.1	105.9	103.7	
EIRP	dBW	68.0	68.0	54.6	
Frequency:	GHz	18.25	18.25	18.25	
Pass loss:					
Free space loss	dB	201.9	201.9	201.9	
Atmospheric loss	dB	0.5	0.5	0.5	
Earth station:					
Pointing loss	dB	0.5	0.5	0.5	
G/T	dB/K	32.7	26.3	32.7	
Down-link C/No	dB	126.4	120.0	105.9	
Total C/No:	dB	109.0	105.7	101.7	
Transmission rate:	Mbps	1648	824	824	QPSK FEC codeing rate=0.879
Require C/No:	dB	101.6	98.6	98.6	Eb/No = 10 dB
C/No margin:	dB	7.4	7.1	3.1	

The antenna gain for the APAA is low, thus requiring an LET-class earth station, even with 622-Mbps transmission.

(2) RF characteristics

As the earth station for a high-speed network based on the WINDS bent-pipe relay link, the transmitter and receiver offer a bandwidth of 1,100 MHz, the same as the onboard transponder. The LNA also amplifies the 18.9-GHz network information link for antenna pointing. Figure 4 shows the loop-back characteristics of the translator for the vehicle-mounted station. The translator loop-back value is 2.55 dBp-p.

Construction of the Kashima earth station is now underway. In this context we plan to develop further devices of approximately the same design as those of the vehicle-mounted station, with equivalent characteristics.

The IF patch includes an amplitude equalizer and can correct first-order amplitude frequency characteristics. There are six WINDS bent-pipe relay links. Taking the destination earth stations into consideration, the link characteristics will differ among the connections; as a result, we will need to consider which combination should be selected for adjustment of the amplitude equalizer.

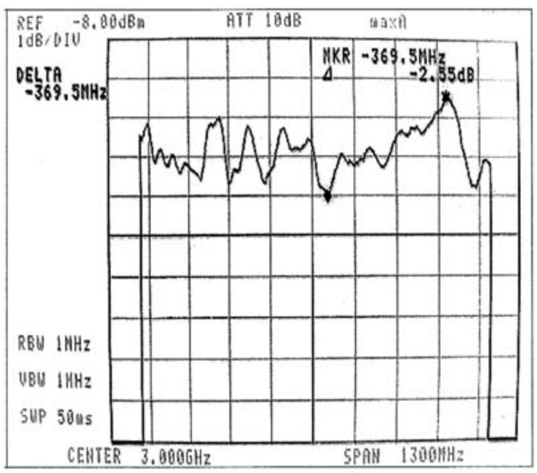

Fig.4 *Amplitude frequency characteristics (translator loop-back)*

4 Conclusions

We have developed a vehicle-mounted station as an earth station for the high-speed WINDS network. We are also developing the Kashima earth station and plan to complete construction by the time of the WINDS launch. We have developed a wideband transmitter and receiver that have been adjusted to the WINDS onboard transponder and have confirmed satisfactory results in terms of characteristics. The amplitude equalizer in the IF patch can adjust amplitude characteristics. However, adjustment differs depending on the combination of the six ports of the transponder and the destination earth stations; as a result we will need to perform average characteristic corrections for the links used in operations after the satellite is launched.

As the antenna gain of the APAA of WINDS is lower than that of the MBA, it is difficult to perform regenerative repeating experiments with VSAT, to resolve this problem we will need to consider how to perform these experiments using the Kashima earth station and the vehicle-mounted station.

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