4-5 Development of Network Management Center for WINDS

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JAXA is developing an earth station which has communication controller and circuit-switched capabilities for WINDS communication experiment system. This station is installed in the JAXA Tsukuba Space Center, and operates as a control center for the experiment system. This paper describes the characteristics and the functions of this station.

Keywords
WINDS, Earth station, Ka-band, Satellite communications

1 Introduction

The Network Management Center (NMC) for the Wideband InterNetworking Engineering Test and Demonstration Satellite (WINDS) is installed at the Tsukuba Space Center of the Japan Aerospace Exploration Agency (JAXA) and plays a central role in communication experiments as the center for control and management of the WINDS communication missions.

As the base station for regenerative satellite communication experiments with the onboard switch as well as for bent-pipe non-regenerative satellite communication experiments, the NMC manages and controls system operation, including timing synchronization between the WINDS satellite and ground systems and communications between the user stations.

This article reports on the functions of the WINDS Network Management Center (specifically, its role within the WINDS experimental system) and the functions and performance of the components of the NMC.

2 Functions and structure of Network Management Center

2.1 Functions of Network Management Center

The WINDS Network Management Center (NMC) is installed at the JAXA Tsukuba Space Center to provide various control functions, including communication control and switching control for the WINDS communications network experimental system. The NMC provides a pilot signal and transmits and receives remote-control and monitoring signals for the communications network (thus serving as a network information link). A control interface is provided for the experimental communication links. The NMC also provides remote control and monitoring of the baseband switch (the asynchronous transfer mode baseband switch subsystem, or ABS), which provides the satellite's regenerative functions. By controlling synchronization between the WINDS satellite and user earth station systems, and through its control of system operations (including communications between user stations), the NMC plays a central role in the communication experiments, as a center for control and management of the various communication missions. The major functions of the WINDS NMC are listed below.

(1) Transmission and reception functions for network information link

Among the control and monitoring items relating to mission equipment, the NMC transmits and receives control and monitoring information (excluding so-called "housekeeping" information) to and from the WINDS satellite. These data include information relating to APAA and ABS control and monitoring.

(2) Pilot signal transmission function

The NMC transmits a Doppler-compensated 28.8-GHz pilot signal (using unmodulated continuous waves) to the WINDS satellite. The satellite uses the pilot signal as the standard local signal source. The NMC also provides frame timing control for the experimental communication links based on the transmission frequency control of the pilot signal.

(3) Beam-pointing calibration function for MBA for Southeast Asia

The NMC receives unmodulated continuous waves transmitted from an earth station within the coverage area of the multi-beam antenna (MBA) for Southeast Asia via the WINDS satellite and measures the reception level to enable calibration of beam-pointing operations for Southeast Asia.

(4) Regenerative link control function

Based on the operation plans formulated for the various experiments, the NMC assigns communication beams, communication areas, frequencies, control slots, and information slots within the TDMA frame of the regenerative link. The NMC generates control information (including TDMA correction information and satellite station status) from the WINDS operation information for users in each communication area and transmits this information to the WINDS satellite. Based on this data, the WINDS satellite issues to users the notification information via the notification slot—i.e., the control slot within the TDMA frame of the regenerative link.

The NMC responds to requests for assignment of wireless links (i.e., provides the association function) from user stations and assigns communication areas, frequencies, and TDMA time slots. Based on this information, the NMC generates and transmits the control information to the WINDS satellite. The NMC updates the ATM routing table for the ABS, including requests for the route addition or removal, based on the association request.

(5) Bent-pipe link control function

Based on the operation plans for the various experiments, the NMC pre-assigns communication areas, frequencies, control slots, and information slots.

Referring to the frame synchronization timing of the network information link, the NMC generates the reference burst signal for the bent-pipe links for each communication area and transmits this reference burst signal to user stations via the WINDS satellite.

The user station receives this signal, enabling it to frame-synchronize with the WINDS communications network.

(6) ABS onboard software loading function

The NMC rewrites the ABS onboard software by uploading the software data to the WINDS satellite using the regenerative link.

(7) Operation plan management function for experimental communications links

The NMC formulates the experimental communication link operation plans, inputs operational restrictions, registers communication profiles, sets communication configurations, and edits and displays the operation plans.

(8) NMC control and monitoring function

The NMC controls, manages, and monitors the status of its component equipment. The NMC also stores NMC status information.

(9) Remote control and monitoring of beacon station

The NMC monitors and controls the beacon station installed in the Okinawa Tracking and Communication Station, enabling pointing control of the multi-beam antenna (MBA) for transmission and reception in Japan.

(10) WINDS monitoring function

The NMC displays the status of each

Table 1 Performance factors of regenerative link

Transmit characteristics	
Link	Fixed Beam Regeneraive Link (FRL) Fixed Beam Non-Regeneraive Link (FNL)
Transmit frequuency	Regeneraive Link : 27.5925/27.7775/27.9625GHz Non-Regeneraive Link (Reference Burst) : 28.33GHz
Polarization	Horizontal (revolvable)
EIRP	Regeneraive Link : >63.7dBW Non-Regeneraive Link : >70.5dBW
Modulation	QPSK
Data rate	Regeneraive Link : 51Mbps Non-Regeneraive Link (Reference Burst) : 155Mbps
Error-correcting	RS (255, 223)
Receive characteristics	
Link	Fixed Beam Regeneraive Link (FRL)
Received frequency	Regeneraive Link : 17.7925/17.9775/18.1625GHz
Polarization	Horizontal
G/T	>35.0dB/K
Modulation	QPSK(MF-TDMA)
Data rate	Regeneraive Link : 155Mbps
Error-correcting	RS (255, 223)

Table 2 Performance factors of network information link

Transmit characteristics	
Link	Network Information Link (NIL)
Transmit frequuency	28.9000GHz
Polarization	horizontal
EIRP	44.5dBW 以上
Modulation	PCM(NRZ-L)-PSK-PM
Data rate	4kbps
Data format	CCSDS Packet
Receive characteristics	
Link	Network Information Link (NIL)
received frequency	18.9000GHz
Polarization	Right-handed circularly polarized wave received by vertical polarization anttenna
G/T	>36.0dB/K
Modulation	PCM(NRZ-L)-PSK-PM
Data rate	10kbps
Data format	Fixed Frame

experimental payload aboard the WINDS satellite and stores status data for the mission equipment.

(11) External organization I/F function

The NMC delivers information such as network information telemetry to an external organization (i.e., the NICT Kashima earth station)

Table 3 Performance factors of pilot link

Transmit characteristics	
Link	Pilot Link(PIL)
Transmit frequuency	28. 8000GHz
Polarization	horizontal
EIRP	>62.2dBW

Table 4 Performance factors of communication network management and control functions

Communication Controle characteristics	
Maximum number of Stations	Regeneraive Link : >10,000stations Non-Regeneraive Link : >50satations
Maximum concurrent connection (Regeneraive Link)	765Stations
MAX data size	Data of 8days

As the major performance factors of the NMC, Table 1 shows the performance factors of the regenerative link, Table 2 shows the performance factors of the network information link, Table 3 shows the performance factors of the pilot link, and Table 4 shows the performance factors of the communication network management and control functions.

2.2 Structure of component units

The structures of the component units are indicated below. The WINDS NMC mainly consists of the antenna unit, the RF unit, the IF unit, and the monitoring and control unit. Figure 1 shows the structure of the WINDS NMC.

2.2.1 Antenna unit

The antenna unit mainly consists of a 9.2-m Cassegrain antenna and a drive control unit. Figure 2 shows the external appearance of the antenna unit. This antenna unit is developed based on the antenna used in the communication experiments for COMETS (Communications and Broadcasting Engineering Test Satellite, Kakehashi), with modifications to frequency range and polarization orientation. Table 5 shows the major performance factors of the antenna unit.

2.2.2 RF unit

The RF unit mainly consists of a traveling

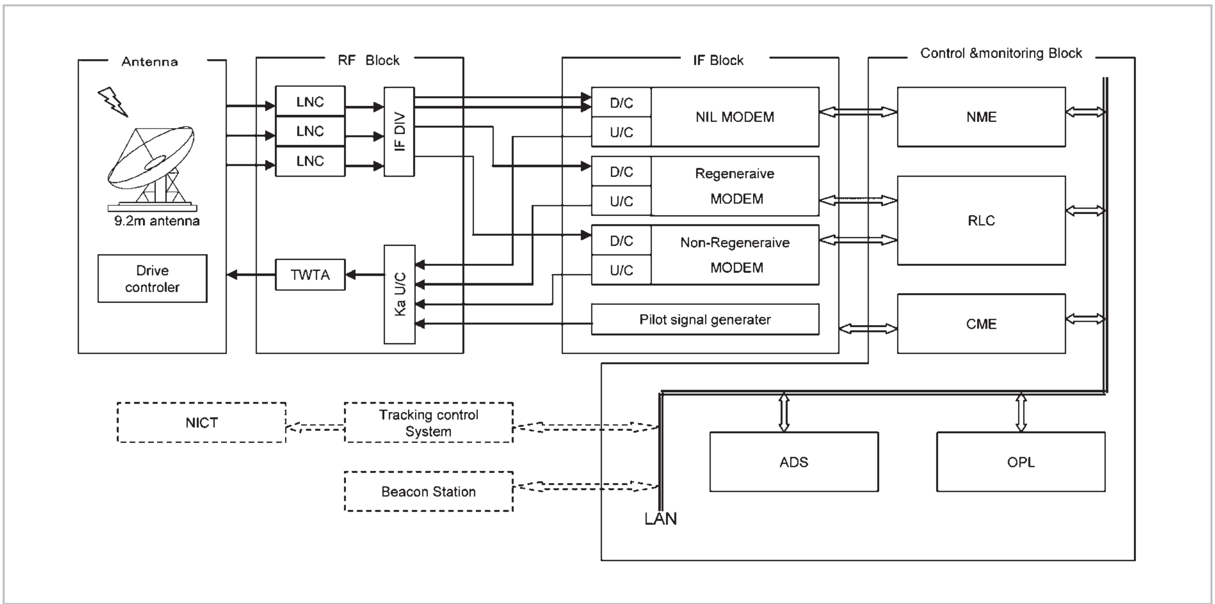

Fig. 1 Structure of WINDS NMC

Fig.2 External appearance of WINDS NMC antenna unit

Table 5 Major performance factors of antenna unit

Item	characteristics
Aperture	9.2m
Antenna	Cassegrain
Frequency	Transmit 27.5GHz～28.9GHz
	Receive 17.7GHZ～18.9GHz
Antenna Gain	Transmit >64.9dBi
	Receive >61.5dBi
Polarization	Linear (revolvable)
Pointing	Pointing loss < 0.5dB

wave tube amplifier (TWTA), low noise frequency converters (LNCs), and an intermediate frequency signal divider (IF DIV). The unit provides transmission power control and can control the EIRP of the uplink signals (e.g., network monitoring and control, pilot, regenerative, and bent-pipe signals) from the NMC based on the level of the downlink network information signal transmitted from the satellite. Through this function, the NMC ensures the availability in rain of the network monitoring and control link, the pilot link (providing 99.99 % availability), and the regenerative and bent-pipe links (providing 99.5 % availability).

2.2.3 IF unit

The IF unit modulates and demodulates signals in each link. This unit consists of a network modem, a regenerative modem, and a bent-pipe modulator. The network modem provides an interface between the RF unit and the network monitoring and control unit, receives the network information signals from the WINDS satellite, and transmits the network control signals to the WINDS satellite. The regenerative modem provides an interface between the RF unit and the regenerative link control unit. In communications with the ABS of the WINDS satellite, the IF unit transmits the TDMA signaling burst signals (i.e., notification information and signaling data) for the regenerative link, receives the reference burst signals (i.e., notification information and association data), transmits and receives ABS software, and receives link status information. The bent-pipe modulator provides an interface between the RF unit and the regenerative line control equipment and transmits the bent-pipe reference burst signals to the WINDS satellite. In the future, when bent-pipe demand assignment is incorporated within the system, a new non-regenerative line control equipment (NLC) will be installed to control the bent-pipe modulator to be added with the demodulation function.

To reduce pointing deviation in the MBA for Southeast Asia, WINDS regularly acquires data for the pointing error correction table, including at the start of use of the corresponding beam. In connection with this pointing error calibration operation for the MBA for Southeast Asia, the IF unit receives signals transmitted from an earth station installed overseas via WINDS and measures and stores the measured reception levels.

2.2.4 Monitoring and control unit

The monitoring and control unit configures the link settings based on experimental plans input in advance and distributes and manages the TDMA slots in response to association requests from user earth stations. This unit also transmits control commands to the mission equipment of the WINDS satellite and receives and processes status data for these equipment.

The monitoring and control unit consists of a network management equipment (NME), a regenerative line control equipment (RLC), a station control and monitor equipment (CME), an operation and planning equipment (OPL), an analysis-data storage equipment (ADS), and a pilot frequency control equipment. Among these equipment, all except the pilot frequency control equipment are implemented as application programs that run on five independent workstations.

(1) Network Management Equipment (NME)

The network management equipment controls and monitors the WINDS satellite mission equipment that use the network information link within the entire WINDS communications network (consisting of the WINDS satellite and the user stations). The major functions of the NME are listed below.

- Network monitoring signal processing
  The NME processes the real-time housekeeping telemetry required in the execution of experiments, including the status of mission equipment (downlinked as network monitoring signals), waveguide switch setting information (acquired from the tracking and control system), redundancy switching information, and various operational status messages for the mission-related facility.
- Network control function
  The NME controls the mission equipment employed in the execution of experiments.
- Management of experimental modes and experimental plans
  The NME provides configuration settings at the specified time based on experimental mode information and the experimental plan information generated by the OPL.
- Detection of abnormal operation during experiments
  When the satellite moves to low-load mode (LLM) due to the abnormal attitude of the satellite or a decrease in battery voltage, the NME detects the transition to LLM via real-time HK telemetry delivered from the tracking and control system. The NME causes the CME and the RLC to stop the NMC uplink operation and moves to mission standby mode.
  Figure 3 shows an example of the NME screen. This screen displays the information delivered by the network monitoring signal, and the operator can check the status of the communication mission equipment on the screen in list form.

(2) Regenerative Line Control equipment (RLC)

The regenerative line control equipment (RLC) controls the user stations and experiments related to the regenerative link based on ATM switching, within the entire WINDS communications network (consisting of the WINDS satellite and the user stations). The

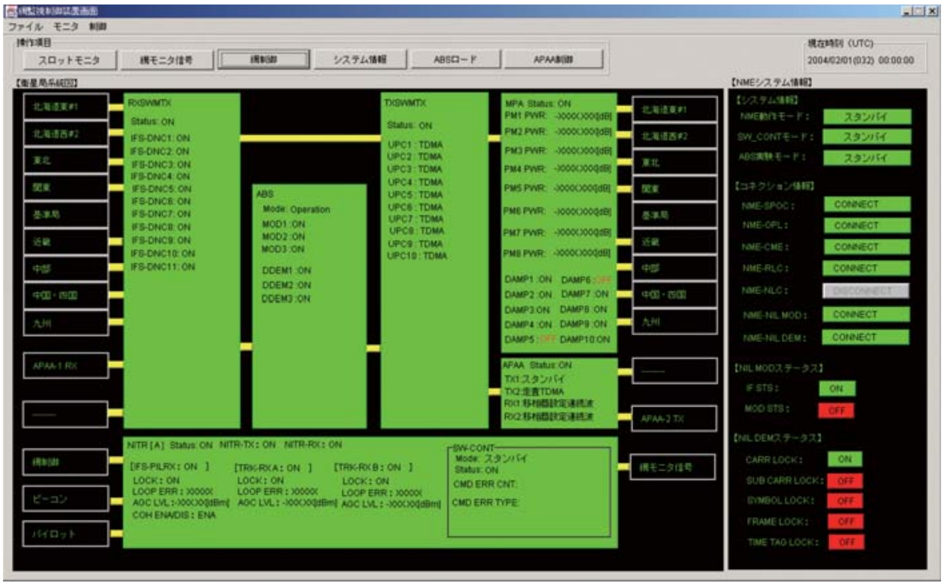

Fig.3 *Example screen of NME*

major functions of the RLC are listed below.

• Association processing
In response to an association request from a calling user station, the RLC registers the user station in the experiment, responds to the resource reservation request, and transmits an association notification to the receiving station. The RLC also processes the procedures related to the release of the association.

• User station management
The RLC determines whether the user station is allowed to join the experiment and designates the station either as VPI or VCI.

• Regenerative link resource management
According to the conditions at the time of the association request, the RLC assigns and manages resources, including frequencies, slots, areas, and transmission power.

• User station monitoring
The RLC monitors the connection to the user after the connection is established.

• Rain attenuation compensation processing
From the receiving margin information (the difference between the receiving C/N_0 of the reference burst and the receiving limit C/N_0 of the user station) regularly transmitted from the user station via WINDS, the RLC calculates the increase or decrease in MPA output power, based on the data for the user with the least margin within the relevant area.

• Notification information management
The RLC generates the notification information to be transmitted to the user stations and transmits this information to WINDS.

• ABS software loading
The RLC performs the procedures for loading the ABS software to the satellite.

• Plan management
According to instructions received from the NME, the RLC starts and ends a given experimental mode and starts and ends a given experimental plan. The RLC also sets the initial configuration of the PVC conversion table.

Figure 4 shows an example of the RLC screen.

(3) Control and Monitor Equipment (CME)

The station control and monitor equipment (CME) continuously monitors the status of the satellite link as well as the status of the equipment in the NMC and at the Okinawa beacon station.

The CME also monitors the operational status of the various operation-related equipment, including the NME, the RLC, the OPL, and the ADS. The major functions of these monitoring operations are listed below. Figure 5 shows an example of the CME screen.

(4) Operation and PLanning equipment (OPL)

As a planning tool to assist in the creation of operational plans for the experimental communication links, the OPL creates, displays,

Fig.4 Example screen of RLC

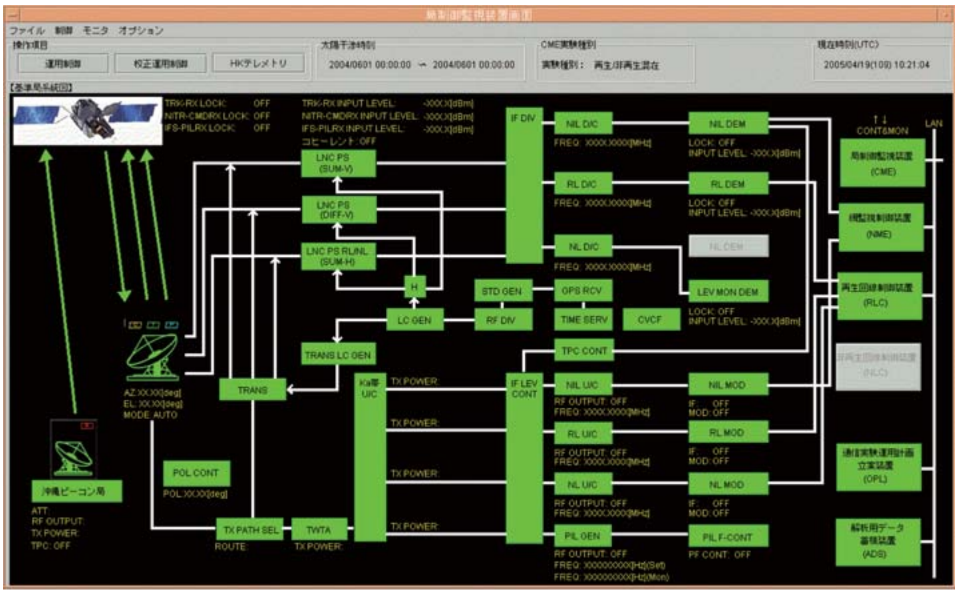

Fig.5 Example screen of CME

and distributes experimental plan information.

The major functions of the operation and planning equipment are listed below.

- Management of operation restriction/ limitation information

  The OPL inputs the periods during which operation is restricted due to the requirements of the NMC facilities and MBA/ APAA calibration as periods during which planning cannot be effected. The OPL calls the attention of the users to the shadow periods affecting the battery operations when setting experimental modes.

- Experimental mode setting

  The OPL sets the bent-pipe, regenerative, and bent-pipe-regenerative mixed modes to ensure that these modes do not overlap or extend into any restricted-operation periods. Assuming that waveguide switching is not allowed, the OPL assigns resource information to fixed routes in the satellite and to fixed target beams, thus enabling defined assignment of beams and areas for each slot.

- Experimental planning

  The OPL defines the communication configuration for each experiment in advance as a template, links the predefined template to a user station group, and inputs a mission operation request specifying the period of the experiment and other information. Based on the defined configuration, the OPL checks and assigns the resources for each experiment and provides error information when the requisite conditions are not satisfied.

- Management of experimental user stations

  The OPL maintains a user station list and defines the participating user station group in each experiment.

- Output and distribution of planning results

  As information output to the tracking and control station, the OPL generates a mission experiment operation plan in which a variety of information is set forth, such as the period of each experimental mode and the beams involved in the experiments. The OPL conveys the experimental mode and the resource information for each experiment to the NME as operation information.

- Display of various planning information

  The OPL displays a list of the input operation restrictions, experimental modes, experimental plans, and time charts. It

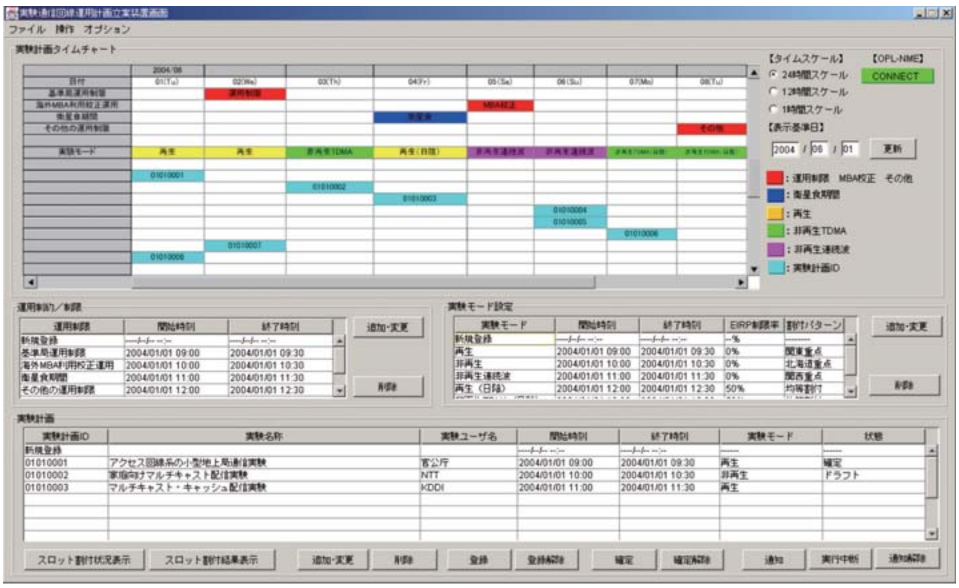

Fig.6 Example screen of OPL

also displays an operation log for operational events and various errors.

Figure 6 shows an example of the OPL screen.

The NMC registers each plan input to the OPL, assigns resources, and performs trial planning. Based on this trial planning, the NMC adjusts the operation of the experiments, and based on the results of this adjustment, finalizes the execution of each experimental plan.

(5) Analysis Data Storage equipment (ADS)

The analysis-data storage equipment (ADS) receives a succession of quasi-real-time data used to operate the relevant equipment (NME, RLC, CME) in the NMC and stores this information as log data. In addition, the ADS extracts certain necessary information according to a data retrieval request from the operator.

The ADS also functions as a data server when distributing information (such as network information telemetry) to an external organization (i.e., to the NICT Kashima earth station).

3 WINDS NMC networking protocol

The networking protocol employed by the WINDS NMC to control the equipment is outlined below.

3.1 TDMA management

The WINDS communications system, including the WINDS NMC, uses the TDMA frame based on a slot with a burst length of 2 ms as the minimum unit of communication. The time system standard is satellite-based TDMA. The system synchronizes signals by synchronizing the transmission and reception timing in the WINDS satellite. A reference burst (referred to below as the "RB") transmitted from the satellite is placed at the head of each basic frame. The user station first detects the RB in its beam area, and then calculates the position of the head of the super frame using the RB basic frame number and the RB slot number specified in the notification information. For the transmission timing of the user station, the NMC issues notification of the assigned basic frame number and slot number as association information (in regenerative mode) or as communication route information (in bent-pipe mode). Thus, the user station calculates the position of the transmission slot from the position of the head of the super frame. In addition, the user station estimates the transmitting timing by taking into account the round-trip delay time and the satellite-position information transmitted within the notification data.

3.2 Slot management and slot assignment method

In principle, both the regenerative and bent-pipe communication modes use the TDMA-based burst communication mode. In regenerative mode, the control processes for assigning the TDMA slot to a user station include association control, slot control table configuration, and ATM connection control. The setting of basic transmission parameters based on the plan and the loading of the regenerative repeater software are performed together before the satellite starts operation.

At the operation planning stage, the traffic slots are assigned to each area. In operation, these traffic slots are assigned according to association requests from the user stations. When parameters not specified in advance need to be modified, the slot control table is updated. The basic principle involved entails assignment to a given area by slot sequence. (See Fig. 7.) For communications requiring real-time transmission such as voice communication, assignment is performed by slot sequence.

3.3 Connection management

In a multi-beam mesh network, the standard station generally cannot directly monitor traffic between users or the status of the user stations. WINDS requires all regenerative user stations to transmit on a regular basis the C/N_0 margin information as described in ***2.2.4*** (2),

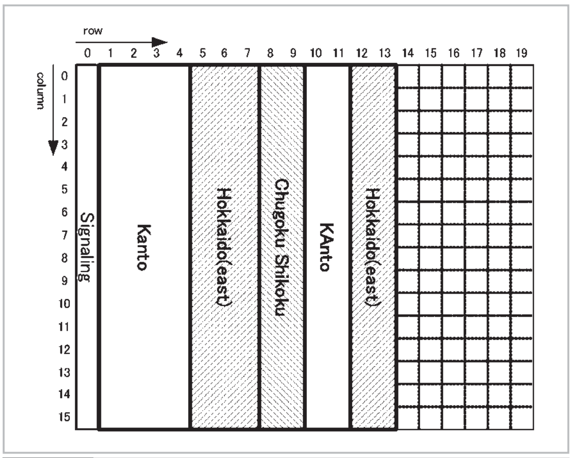

Fig.7 Example of slot arrangement

with or without compensation for attenuation due to rain. When the NMC cannot receive this C/N_0 margin information during communication, it assumes the abnormal operation of the corresponding user station and begins releasing the connection for the corresponding user station.

3.4 Link control

When the NMC receives an association request message from a user station (i.e., a calling station), the NMC adds the satellite station to the ATM connection table if the resources assigned to the corresponding area are available. At the same time, if it is necessary to modify the transmission parameters for the assigned slot, the NMC sets the slot control table accordingly. After these settings are made, the NMC specifies the position of the transmission slot and the remaining conditions in the association response. The NMC does not specify the receiving slot for the receiving station. The user station receives the downlink burst in its respective area. The receiving station that has received the association notification extracts the ATM cell from the downlink burst based on the specified connection information. To end the communication, the calling station initiates the procedures to release the connection.

3.5 Rain attenuation compensation

Control of rain attenuation compensation within the traffic link is performed both in the user uplink and downlink connection. The user station autonomously performs uplink compensation for attenuation due to rain. First, the station estimates the amount of downlink rain attenuation based on the state of reception of the RB (the difference between the receiving C/N_0 of the RB in clear weather as calculated from the EIRP of the satellite and the actual receiving C/N_0), predicts the amount of uplink attenuation based on the frequency correction, and controls its own transmission power accordingly. On the other hand, for downlink rain attenuation compensation, the NMC controls the satellite transmission power for each downlink area based on the reception level information described above, as issued from each user station, with reference to the station with the smallest C/N_0 margin within the given area. The NMC controls the power by updating the slot control table of the satellite station.

4 Conclusions

This article describes the functions and structure of the WINDS Network Management Center. WINDS will be launched in the winter of fiscal 2007. This earth station will play a central role in communication experiments. Going forward, we plan to verify the interfaces with the experimental earth stations to be used in the experiments and conduct full preparations to ensure the smooth operation of the various experiments.

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Satellite Communications