3-3 On-board Baseband Switch

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NICT and JAXA had developed Wideband InterNetworking engineering test and Demonstration Satellite (WINDS). NICT is in charge of developing the ATM-based baseband switching subsystem (ABS) for the WINDS satellite. The ABS enables high-speed, highly efficient regenerative switched connections between several beams. In the ABS, the demodulator part can process multiple data rate from 1.5 Mbps to 155 Mbps. The baseband switching part can be ATM based switching data. We aim for efficient use of wireless link resource by statistical multiplexing effect.

Keywords
WINDS, On-board Switch, ABS, Regenerative mode

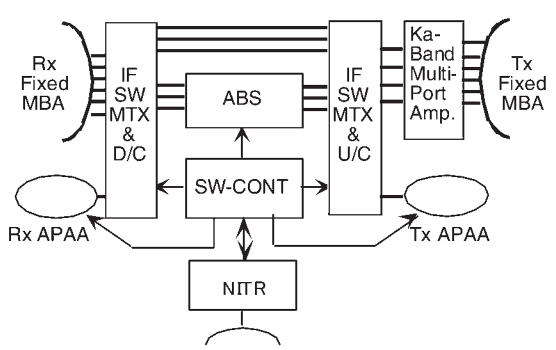
1 Introduction

NICT is in charge of an on-board regenerative switching subsystem (specifically, an ATM-based baseband switching subsystem, or ABS) in the context of the development of the Wideband InterNetworking engineering test and Demonstration Satellite (WINDS). The ABS consists of a digital signal-processing demodulator, an on-board baseband switch, and an analog signal-processing modulator. The digital signal-processing demodulator can process multiple transmission rates from 1.5 Mbps to 155 Mbps. The on-board baseband switch is designed to be compatible with the ATM switch used on earth.

This article describes the structure and characteristics of the on-board regenerative switching subsystem.

2 Overview of WINDS satellite system

Figure 1 presents a schematic diagram of the mission system functions within the WINDS satellite system. The WINDS mission payloads consist of an on-board regenerative switching subsystem (ABS), an IF switch system (IFS, or intermediate frequency switch matrix subsystem), two antenna systems (one involving an APAA, or active phased-array antenna, and another employing an FMBA, or fixed multi-beam antenna), and a multi-port amplifier (MPA). NICT is in charge of developing the ABS among the on-board mission payloads.



APAA: active phased array antenna
MBA: multi-beam antenna
ABS: ATM based switching subsystem
NITR: network information transmitter and receiver

Fig.1 *Schematic diagram of WINDS mission system functions*

WINDS functions within three major modes of operation: regenerative mode, bent-pipe mode, and regenerative/bent-pipe hybrid mode. The ABS, which NICT is developing, is used in regenerative mode. The regenerative mode aims at high-speed full duplex communication at a maximum rate of 155 Mbps, while the bent-pipe mode is designed for ultra-high-speed full duplex communications at a maximum rate of 1.2 Gbps. MF-TDMA is adopted as the method of satellite access. Figure 2 shows the TDMA frame structure for WINDS. This configuration is referred to as a “super frame” structure. A super frame consists of 16 basic frames, and a basic frame consists of 20 slots. This slot is the minimum unit of the physical link between the user and the satellite. A slot corresponds to a communication period of 2 ms. This TDMA frame structure is common to the three modes. In regenerative mode, the first slot of each basic frame is used in uplink communication as the signaling slot for the association of the user station to join the WINDS network, and in the downlink communication as the notification slot for transmitting the reference burst, which contains TDMA synchronization information, association response information, and satellite status notification. The remaining slots are used as traffic slots.

Figure 3 shows the frequency allocation in the RF band used in regenerative mode.

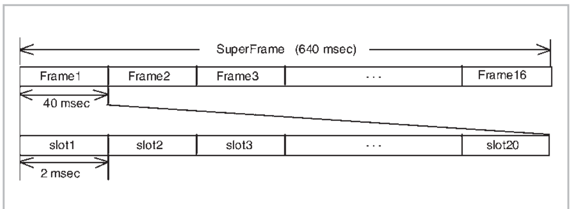


Fig.2 TDMA frame format

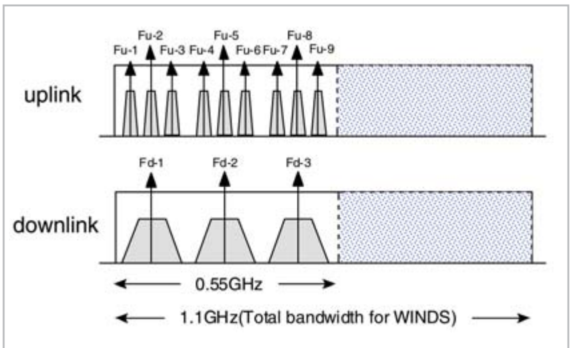


Fig.3 Frequency allocation in regenerative mode

3 Structure of ABS

The ABS consists of three types of components: a digital signal-processing demodulator (DDEM), an analog signal-processing modulator (MOD), and an ATM baseband switch (ATMS). WINDS is equipped with three DDEMs, three MODs, and two ATMS units, including components included as part of a redundant system. Figure 4 shows a structural block diagram of the on-board ABS.

Two out of the three DDEM and MOD units operate only with fixed frequency channels. The remaining units (DDEM 3 and MOD 3) can operate with all frequency channels. Figure 5 shows the TDMA burst format in regenerative mode. Four ATM cells constitute a data block. Error correction is performed

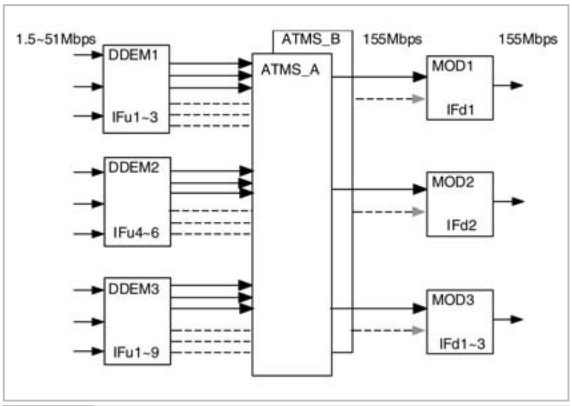


Fig.4 Structural block diagram of ABS

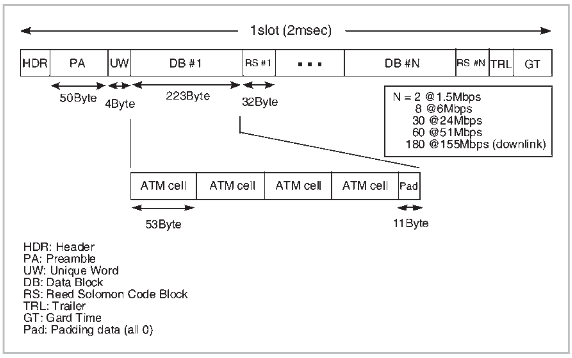


Fig.5 Overview of burst format in regenerative mode

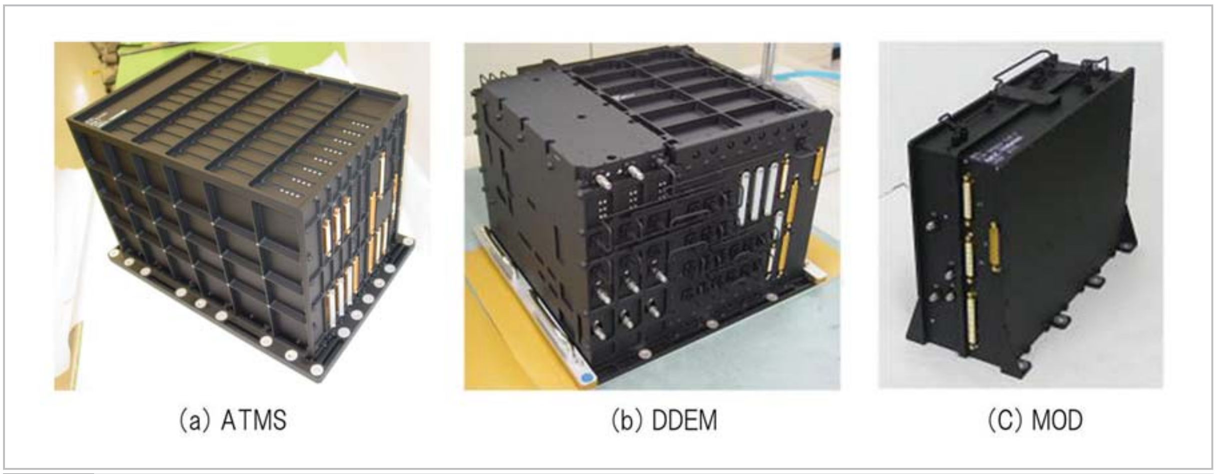


Fig.6 ABS components (External appearance)

by the data block. The number of data blocks differs depending on the transmission rate.

4 DDEM

A DDEM has three series of demodulation units. Each demodulation unit can demodulate at any of four data rates (1.5 Mbps, 6 Mbps, 24 Mbps, and 51 Mbps) per slot (multi-rate demodulation). Operating three series of units at 51 Mbps in parallel produces a transmission rate of 155 Mbps. With 1.5-Mbps transmission, each demodulation unit can provide 14 channels of multi-carrier demodulation. Figure 7 presents a conceptual illustration of DDEM frequency channel use.

The signal input into each DDEM demodulation unit is first band-limited and then quadrature-detected by the external local signal. The signal then passes through the processing units corresponding to each transmission rate, is A/D-converted, and then demodulated within the demodulation gate array (DEM G/A). With 1.5-Mbps transmission, the demultiplex gate array (FDMUX G/A) performs digital-filtering signal processing to convert the signal into time division data, and then the DEM G/A demodulates the signal.

The DEM G/A performs waveform shaping, carrier detection in the burst signal, clock recovery, unique word detection, and de-randomization. The demodulated data are subject to Reed-Solomon decoding and are then transmitted to the ATMS.

Figure 8 shows a functional block diagram of the demodulation unit. Table 1 lists the main specifications of the DDEM.

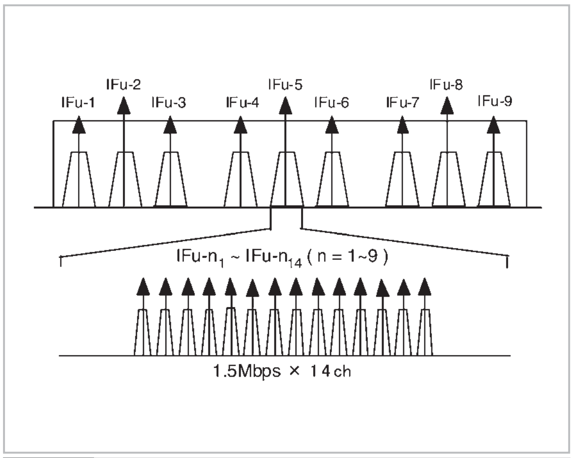


Fig.7 DDEM frequency channels

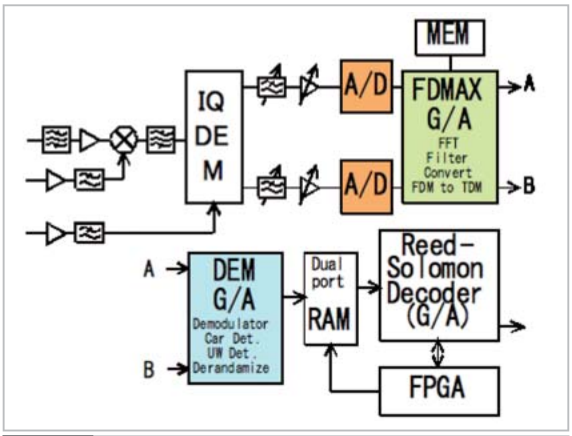


Fig.8 Functional block diagram of DDEM demodulation unit

Table 1 Main specifications of DDEM

Demodulator (DDEM)	Technology	Digital processing Frequency demultiplexing
	Data rate	1.5 / 6 / 24 / 51 Mbps (per 1 unit) 155 Mbps (3 unit parallel processing)
	Modulation	QPSK
	Error Correction Code	Reed-Solomon (255,223)
	Number of DDEMs	3 (1 D-DEM has 3 units.)
	Data rate switching interval	2 msec (one slot)

5 ATMS

The ATMS performs ATM cell switching based on the set PVC table and the VPI/VCI contained in the ATM cell header. The PVC table is set by a command from the network management control station and can be updated during operation. The ATMS supports not only the unicast function but also the inter-area multicast function. The service classes handled are CBR (constant bit rate) and UBR (unspecified bit rate). The ATMS also features a congestion-control function based on the back pressure method. Further, the ATMS is equipped with a function to generate the reference burst used in TDMA synchronization. The reference burst is generated by editing the internal status of the ABS and of the information from the network management control station. This burst contains information concerning satellite status and association processing, in addition to synchronization information. The reference burst is distributed to each area using the first slot of each frame.

Figure 9 presents a functional block diagram of the ATMS. The ATMS consists of transmitting and receiving line interface units (TXLINF and RXLINF), a switch core unit (SWCORE), a buffer unit (TRXBUF), and a controller unit (CONT). The RXLINF multiplexes the data input from the DDEM (three series per DDEM) at 1.5 Mbps to 51 Mbps and transmits the data to the ATM core unit as a single 155-Mbps line. The TXLINF buffers the ATM cell for the duration of the period set for cell output to MOD, according to the transmission timing and the service class.

When the number of input and output lines of the ATM core unit needs to be increased, line interface boards may be added to the structure to handle the additional lines. This on-board ATMS has only three input and output lines, so its throughput aboard WINDS is 465 Mbps. However, the core switch itself features a capacity of up to 2.4 Gbps.

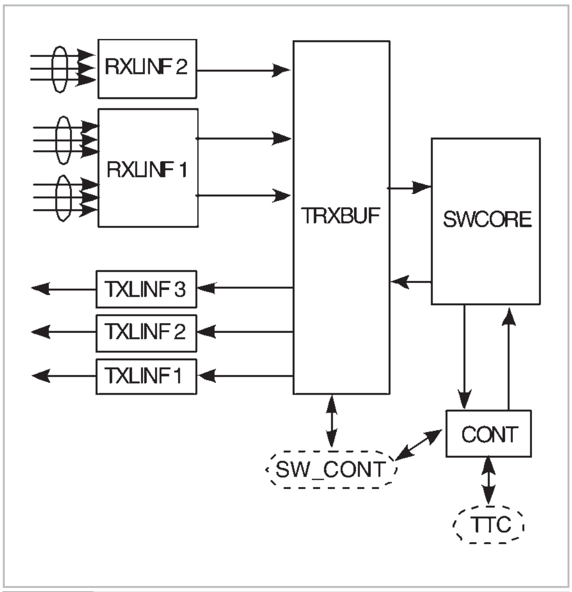


Fig.9 ATMS functional block diagram

Table 2 Main specifications of ATMS

ATM switch (ATMS)	Data rate	155 Mbps (per port)
	Port	3
	Throughput	More than 465 Mbps (actual throughput is 2.4 Gbps)
	Number of ATMSs	2 (including redundancy)
	Service Class	CBR, UBR
	Congestion Control	Back pressuer
	Software Function	Reference burst generation Program-loading Self check

The functions of CONT include PVC table update, program download, command processing from the TTC station, telemetry generation, and ATMS status monitoring. The program download function makes it possible to update the ATMS control program in orbit, which allows for easy modification of control procedures and addition of functions.

Table 2 shows the main specifications of ATMS.

6 MOD

The MOD outputs a 155-Mbps modulated burst. Here, the MOD transmits signals with different unique words attached to the reference burst and to the data burst between user stations. Using this rule, the user station can distinguish the data burst from the reference burst. In addition to ordinary burst modulation mode, MOD also has features CW (continuous wave) output and PN (pseudo noise sequence) output modes for measuring reception on the ground and the BER (bit error rate). These modes can be toggled via commands from the network management control station. On and off operations for RF signal output can also be controlled by command.

The MOD performs digital signal processing of the transmission data sequence in the FPGA (Field Programmable Gate Array) at the input stage — such as Reed-Solomon coding of the transmitted data sequence, randomization, and addition of preambles and unique words — and generates the transmission burst format. The data sequence is then converted to quadrature symbol data, band-limited, QPSK-modulated, up-converted to the 4-GHz band by the external local signal, and output to the IFS.

Table 3 shows the main specifications of the MOD.

Table 3 *Main specifications of MOD*

Modulator (MOD)	Data rate	155 Mbps
	Modulation	QPSK
	Error Correction Code	Reed-Solomon (255,223)
	Number of MODs	3

7 Functions of ABS

The ABS features four major modes of operation: Off (OFF), TTC standby (TTC STBY), diagnosis (DIAG), and network management control station operation (NMC OPR). Figure 10 shows the relevant state transition diagram.

The Off mode is the status before power is fed to all ABS devices. When the ATMS is switched on, the status moves to the TTC standby mode.

In TTC standby mode directly after the transition from Off mode, the ABS loads the ABS control software into memory from built-

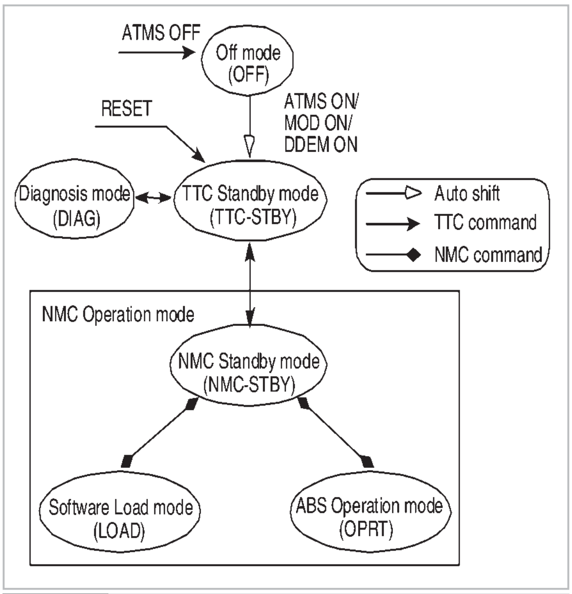


Fig.10 *State transition diagram of ABS*

in ROM and performs startup self-diagnosis. In this mode, only communication with the TTC station is possible, and the ABS does not accept control from the network management control station (NMC), which controls the network, nor does it transmit the reference burst. This mode is also activated by a reset command from the TTC station or an automatic reset request from the ATMS itself in abnormal ATMS operations.

The ATMS is the target of diagnosis mode; CW/PN output from the MOD is also performed in this mode. Also in this mode, the ABS can communicate only with the TTC station and cannot be controlled by the NMC. As in TTC standby mode, the ABS does not transmit a reference burst.

NMC operation mode is a collective term for modes of operation under the control of the network management control station (NMC), which controls the network. There are three sub-modes within the NMC operation mode, as follows. Switching takes place among the three modes in the NMC via control signal from the NMC. In this mode, the ABS transmits the reference burst.

- NMC standby mode (NMC STBY): This mode corresponds to standby status under NMC control. In this mode, diverse parameters can be set for communication services in regenerative mode (for example, PVC table configuration and inter-area multicast configuration). This mode does not allow transmission from user stations.

- Software load mode (LOAD): This mode allows for updating of ABS control software from the NMC. In this mode, the data switching function does not operate; only functions required to load the program are operational.
- ABS operation mode (OPRT): This is the operation mode of the ABS.

8 ATM cell switching in ABS

The WINDS system supports only PVC communication during the initial phases after launch; here, VPI/VCI is used in a rule unique to WINDS. Figure 11 shows how VPI/VCI is used in communication between the ABS (satellite station) and the user station (ES) or the network management control station (NMC).

The symbols used in the figure are defined as follows.

- LN#: 2 bits

Specifies the ABS input and output port in the 155-Mbps band.

- K: 1 bit

Specifies the service class of the ATM cell (CBR/UBR).

- AREA#: 5 bits

Specifies the area. Numbers 1 through to 16 indicate each area, and 0 and numbers 17 through to 29 are invalid. Number 30 indicates broadcast for all areas, and number 31 performs multicast operations based on BIX.

- ES#: 8 bits

Specifies the user station. Numbers 1 through to 255 indicate each of the 255 stations for each ABS port. In all, 765 stations can be specified.

- UC#: 4 bits

Specifies eight user channels (PVC connection), numbered 8 through 15. This symbol is used to identify connections when a single user station simultaneously uses two or more connections.

- BIX#: 5 bits

Specifies all-area broadcast or 31 types of multicast pattern. The multicast patterns are set at the network management control station for each experiment in advance, and the system is operated according to the patterns.

- Freq#: 6 bits

Specifies the frequency number employed by the user station in the signaling slot. As ES# is assigned after the association request is

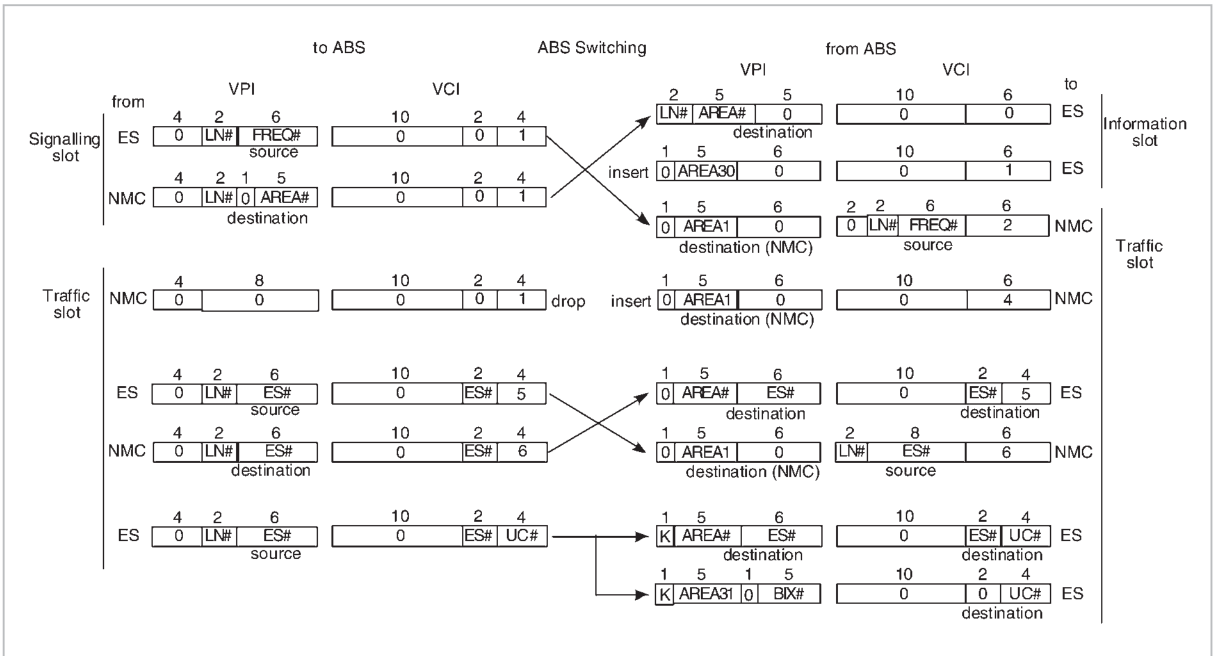


Fig.11 Usage of VPI/VCI in ABS

accepted, ES# is not available before association. Thus, Freq# is used to identify the source user station.

WINDS assigns the uplink slots to each user station but multiplexes ATM cells in the same area in downlink communication. Thus, VPI/VCI is specified to identify the source user station (source). In a similar rule, VPI/VCI is specified to identify the destination user station (destination) in the same area.

In uplink communication, the lower 8 bits of the 12 bits in VPI are effective, and the lower 6 bits of the 16 bits in VCI are effective. In downlink communication, all bits in VPI and VCI are effective.

Communication between NMC and ABS makes use of the traffic slot. The request for association from the user station uses the signaling slot, and the corresponding ABS response uses the notification slot. The ABS switches the cells based on the header conversion table and performs buffering separately for each area. The cell transmitted from the NMC to the ABS is dropped in the ABS.

9 Conclusions

The ABS is the core system of the WINDS regenerative function. We have verified in subsystem tests using the PFM that the required functions are provided and the necessary performance levels are achieved. After the launch, we will check performance in orbit, and the system will then be used in various experiments.

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