Special Article on IMT-2000 Services (2)
– Launch of FOMA, the Pioneer of the New Mobile Age –

# Link Equipment Technologies

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*NTT DoCoMo has developed ATM multiplexers and other devices that enable paths at various speeds to be efficiently multiplexed, edited and converged in relay transmission lines and base-station transmission lines in IMT-2000 networks. It has also developed an entrance microwave system that allows the capacity of IMT-2000 entrance transmission lines to expand.*
*This article reviews the functions and characteristics of these link equipment.*

New Technology Report

## 1. Introduction

International Mobile Telecommunications-2000 (IMT-2000) adopts the Asynchronous Transfer Mode (ATM) technology to transmit various types of services efficiently, ranging from speech, data, to video. As this gives rise to the need to further expand the transmission capacity of multiplexers and entrance transmission lines that support IMT-2000, NTT DoCoMo developed new link equipment to meet such requirements, namely, the ATM-Cross Connect equipment (ATM-XC), the ATM multiplexer and the 11/15G-26MD radio system. Efforts to make improvements in economy were also made upon the development of the ATM multiplexer: when building an IMT-2000 base station next to a Personal Digital Cellular (PDC) base station, the existing PDC services were converted to ATM and laid over IMT-2000 dedicated lines.

The newly developed devices ATM-XC and the ATM MUltipleXer for node station (ATM-MUX) were introduced in the relay transmission lines and the base station transmission lines, respectively. The 11/15G-26MD radio system is applied to the entrance transmission lines (**Figure 1**).

This article reviews the functions and characteristics of link equipment in IMT-2000 networks.

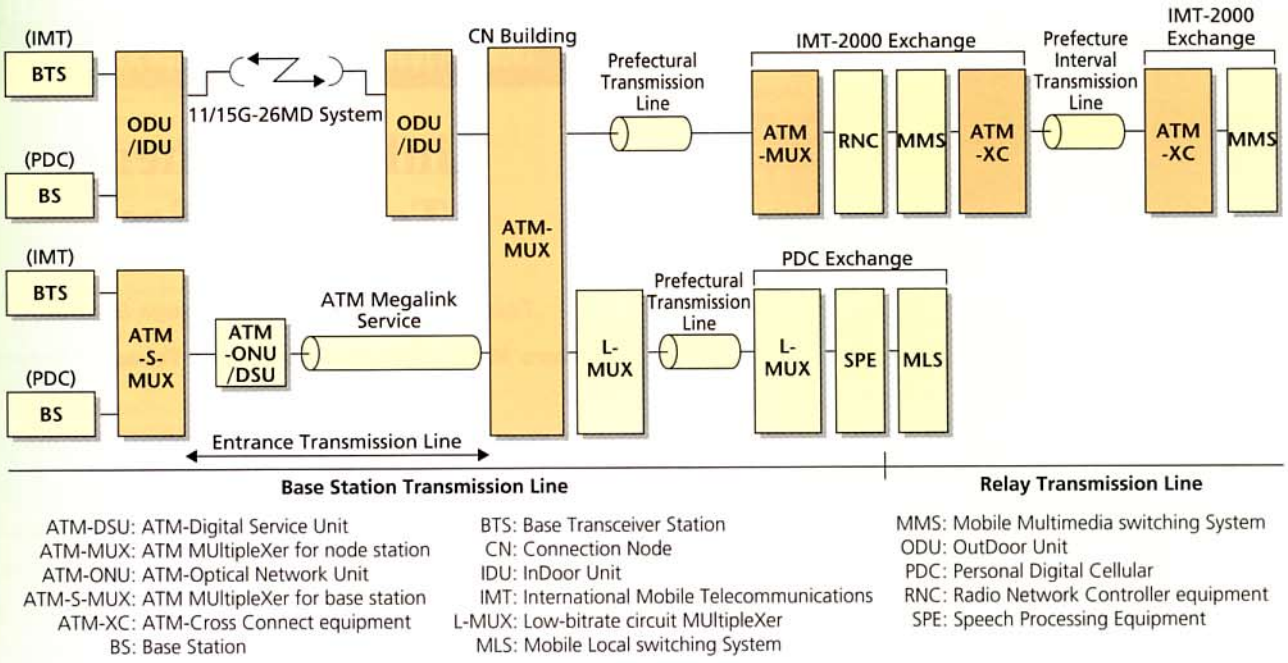



**Figure 1 Applications of Link Equipment**

## 2. ATM-Cross Connect Equipment (ATM-XC)

### 2.1 Overview

ATM-XC is mainly applied to a relay transmission line interconnecting Mobile Multimedia switching Systems (MMS), and its internal 50M and 150M interfaces are connected to MMS, etc. ATM-XC cross-connects the Virtual Path (VP) between the MMS and the relay transmission line equipment Module-A (Mod-A), etc. which are connected to the interface at discretion. Equipment and Operation-System (OpS) costs have been minimized by making VP as the unit of cross connection rather than the Virtual Channel (VC).

The cross connection capacity per ATM-XC is 20Gbit/s, and the device is able to perform unlimited cross connections even when the maximum number of interface boards are mounted (150M×128) [1].

ATM-XC enables the construction of reliable transmission lines due to its VP operation and maintenance function (alarm transfer, transmission quality measurement, continuity property test and loop-back test), VP switching function, internal monitoring function, internal switching function, etc. **Table 1** shows the basic specifications, and **Photo 1** shows the exterior of the device.

**Table 1 Basic Specifications of ATM-XC**

| Item | Specifications |
|---|---|
| Capacity | 128HW inside (assuming 150M) |
| Interface Type | 51.84Mbit/s: 1.3 μm, 400m (inside), 1HW/PKG<br>155.52Mbit/s: 1.3 μm, 400m (inside), 1HW/PKG |
| Interface Switchover | 1+1 switching system |
| Switching Capacity | 20Gbit/s (non-blocking) |
| Traffic Administration Function | 2 classes, each VP can be set at priority/non-priority. |
| OAM Function | Alarm transfer, transmission quality measurement, continuity property test and loop-back function |
| Test Function | VC3/4 path test |
| Equipment Redundancy Function | Clock and Switch: 1+1 switching system |

OAM: Operation And Maintenance
PKG: PacKaGe
VC: Virtual Channel
VP: Virtual Path

**Photo 1 Exterior of ATM-XC (Example)**

### 2.2 Configuration

The dimensions of ATM-XC are 800m(W)×600mm(D)×1800mm(H). Each ATM-XC can accommodate 128HW when none of the 50M interfaces or 150M interfaces are in a redundant configuration, or 64HW when they are all in a redundant configuration.

The main functions of ATM-XC can broadly be divided into 4 groups (**Figure 2**).

(1) Interface

The interface, which is connected with MMS, relay transmission line equipment, etc., is in charge of the transmission and reception of optical signals at 51.84Mbit/s or 155.52Mbit/s, the conversion of optical signals to electric signals, Synchronous Transfer Mode (STM) frame termination and cell termination.

(2) Switch

The switch assigns channels for signals accounting for 128HW from the interface with respect to each VP.

(3) Clock

The clock receives the reference clock (64kHz+8kHz or 64kHz+8kHz+400kHz) from the internal clock supply module, generates a clock internally with reference to the clock received, and distributes it to each package.

(4) Supervisory and Control

The Supervisory and Control gathers alarms in the device and outputs those alarms by displaying them in the front panel of the device, by earth output, and through notification to the OpS.

It also sets the software strap and the header conversion table for each package in the device.

### 2.3 Characteristics

(1) Circuit Test for Determining Faulty Zones in the SDH Layer

ATM-XC can conduct a circuit test on VC-3 and VC-4 Synchronous Digital Hierarchy (SDH) paths, including the equipment used along the relay transmission lines.

The circuit test makes it easier to determine the faulty zones even in transmission lines that consist of more than one piece of relay transmission line equipment.

(2) VP Loop-back Test for Checking Continuity of Each VP

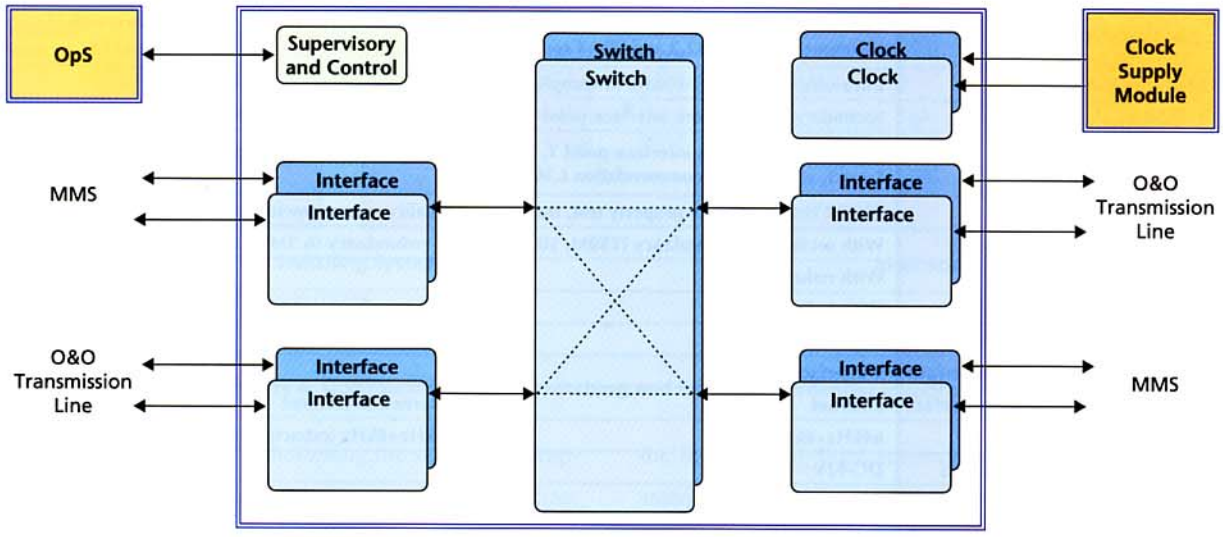
ATM-XC has the function to generate and detect segment loop-back cells and end-to-end loop-back cells, and execute loop-back processes.

In the loop-back test that involves segment loop-back cells, the continuity of VP from ATM-XC to ATM-XC is checked. On the other hand, the loop-back test that involves end-to-end loop-back cells is able to check the continuity up to the end of VP, including MMS. These two types of loop-back tests make it possible to check the continuity of VP end-to-end.

## 3. ATM Multiplexer

### 3.1 Overview

ATM multiplexers can be divided into ATM-MUX and ATM MUltipleXer for base Station (ATM-S-MUX). ATM-MUX is installed in the Connection Node (CN) and the node




ATM: Asynchronous Transfer Mode
MMS: Mobile Multimedia switching System
OpS: Operation System

**Figure 2 Block Diagram of ATM-XC Functions**

building (exchange) via owned-and-operated (O&O) transmission lines. ATM-S-MUX is installed in the base station, and constitutes the entrance transmission line in combination with ATM-MUX installed in CN buildings and node buildings.

The equipment has a CeLl Assembly/Disassembly (CLAD) interface to apply ATM to circuits for PDC base stations and an in-channel based to control ATM-S-MUX supervisory and control function. Furthermore, it has been designed to occupy under 300mm in height.

### 3.2 Configuration and Functions

(1) Interface

Interfaces accommodated in ATM-MUX and ATM-S-MUX may be high-speed or low-speed. There are two types of high-speed interfaces: the 150M interface and the 50M interface, which are connected to relay transmission line equipment (e.g. module-A), Radio Network Controller equipment (RNC), and NTT-dedicated lines (e.g. ATM mega-ink). On the other hand, there are three types of low-speed interfaces: the 1.5M interface and the 6.3M interface, which can be connected to entrance microwave equipment and NTT-dedicated lines, and the 1.5M CLAD interface, which can be connected with PDC. **Table 2** shows the basic specifications.

(2) ATM Switch

ATM-MUX and ATM-S-MUX support cell switching in VP unit in order to efficiently administer and edit the channels of ATM cells from other equipment.

ATM-MUX has a cell switching function that exceeds 4.8Gbit/s per unit, and is able to accommodate more than thirty-two 150M interface boards. ATM-S-MUX has a cell multiplex conversion function that exceeds 1Gbit/s per system, and can accommodate more than seven 150M interface boards. **Figure 3** shows the equipment configuration.

(3) OAM Function

The Operation And Maintenance (OAM) function of ATM-MUX and ATM-S-MUX supports alarm transfer in VP unit, transmission quality measurement, continuity property test and loop-back test. Specifically, the transmission quality measurement and the continuity property test involve the assessment of cell loss from ATM-MUX to ATM-MUX from OpS without affecting the service, whereas the loop-back test is capable of identifying the faulty zone with reference to the loop-back cell in the Base Transceiver Station (BTS) and RNC connected to ATM-MUX and ATM-S-MUX.

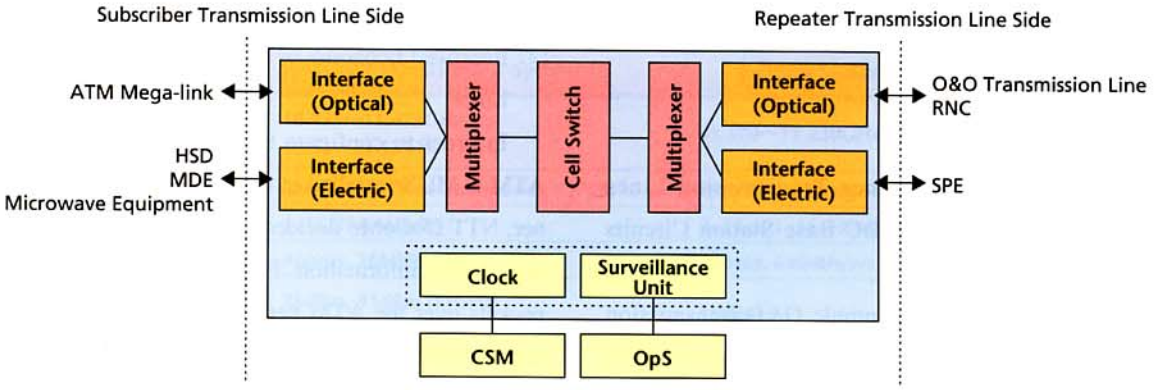
(4) Transmission Line Switching (Interface Switching and VP Switching)

ATM-MUX and ATM-S-MUX support two transmission

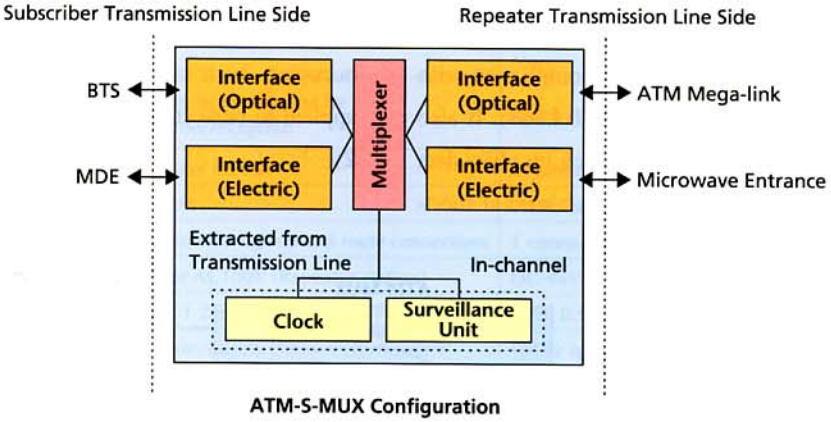
**Table 2 Basic Specifications of ATM-MUX and ATM-S-MUX**

| Item | | Basic Specifications | |
|---|---|---|---|
| | | ATM-MUX | ATM-S-MUX |
| Cell Switch Capacity | | 4.8Gbit/s or more (per unit) | 1.05Gbit/s or more (per system) |
| 150M Interface | | Intra-office(1.31 μm, 400m/1.31 μm, 2km), inter-office (1.31 μm, 40km), in compliance with ITU-T recommendation I.432.2 and ITU-T recommendation G.707 | |
| 50M Interface | | Intra-office (1.31 μm, 400m), in compliance with ITU-T recommendation G.707 | |
| 6.3M Electric Interface | | Secondary user network interface point T, in compliance with ITU-T recommendation G.703 | |
| 1.5M Electric Interface | | Primary user network interface point T, in compliance with ITU-T recommendation I.431-a, AAL Type 1, and ITU-T recommendation I.363.1 | |
| Test Function | | Circuit test, continuity property test, transmission quality measurement, and loop-back test | |
| Redundant Configuration | Interface | With section/VP redundancy (150M, 50M), without redundancy (6.3M, 1.5M) | |
| | Clock | With redundancy | |
| | Multiplexer | With redundancy | |
| | Cell Switch | With redundancy | |
| Supervisory and Control Interface | Logical Interface | S-interface | |
| | Physical Interface | Ethernet | Ethernet, in-channel |
| Reception Clock | | 64kHz+8kHz | 64kHz+8kHz (extractable from transmission channel) |
| Power Supply Requirements | | DC-42V~-54V | |
| Tower Configuration (H×W×D (mm)) | | 1800×800×600 | 300×500×500 or smaller |
| Cooling System | | Forced cooling | |
| QoS Function | | CBR, UBR support | |

ATM-MUX: ATM MUltipleXer for node station
ATM-S-MUX: ATM MUltipleXer for base station
CBR: Constant Bit Rate
ITU-T: International Telecommunication Union-Telecommunication Standardization Sector
QoS: Quality of Service
UBR: Unspecified Bit Rate
VP: Virtual Path



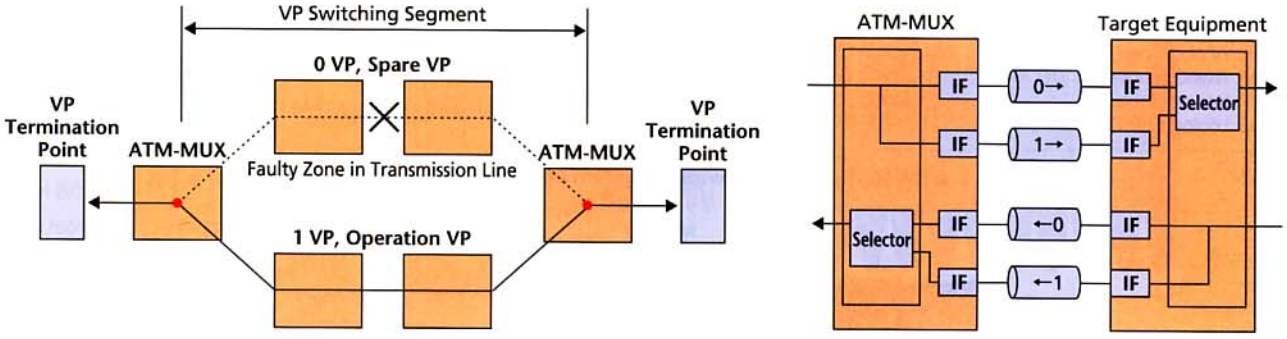

**ATM-MUX Configuration**




**ATM-S-MUX Configuration**

BTS: Base Transceiver Station
CSM: Clock Supply Module
HSD: High Super Digital
MDE: Modulation and Demodulation Equipment
OpS: Operation System
RNC: Radio Network Controller equipment
SPE: Speech Processing Equipment

**Figure 3 Configuration of ATM Multiplexers**




**VP Switching System**

**Interface Switching System**

ATM-MUX: ATM MUltipleXer for node station
IF: Interface
VP: Virtual Path

**Figure 4 Configuration of VP Switching and Interface Switching Equipment**

line switching systems aimed at shortening the service interruption time due to faults in the equipment or the transmission line: interface switching and VP switching (ATM-MUX only). Interface switching is based on a 1+1 switching system that controls switching according to the switching control information with reference to the target equipment, in compliance with the International Telecommunication Union-Telecommunication standardization sector (ITU-T) G.784. It is used when a redundant configuration is applied in combination with the existing Network Node Interface (NNI) equipment. On the other hand, VP switching adopts a redundant configuration in VP unit, and can carry out switching control based on the Automatic

Protection Switch (APS) cell information in the network (**Figure 4**).

### 3.3 Characteristics

(1) Improved Efficiency of Entrance Transmission Lines accommodated by IMT-2000/PDC Base Station Circuits through CLAD Interface

For the purpose of building economic O&O transmission lines, ATM-MUX and ATM-S-MUX are equipped with a 1.5M CLAD interface that converts ATM cells from 1.5M circuits for PDC base stations, so that they can be efficiently accommodated in ATM mega-link circuits at IMT-2000/PDC juxtaposition stations. The CLAD in the equipment is in compliance with ATM Adaptation Layer (AAL) Type 1 (ITU-T I.363). It also adopts Unstructured Data Transfer (UDT), which involves data forwarding including 1.544Mbit/s frame signals, aimed at shortening the delay time.

(2) Improved Economy by In-Channel Supervisory and Control Lines

In order to configure the supervisory and control lines of ATM-S-MUX installed in the base station in an economic manner, NTT DoCoMo decided to resort to the in-channel forwarding of OpS information. Forwarding of Internet Protocol (IP) packets over the ATM network was achieved by applying the capsule technique standardized under RFC1483 (**Figure 5**).

(3) Minimal Space Configuration (Less than 300mm in Height)

ATM-S-MUX is configured in a manner that mounts the PacKaGe (PKG) horizontally, so as to minimize the space it occupies. As it takes up less than 300mm in height, it can be applied to base stations with limited installation space (**Photo 2**).

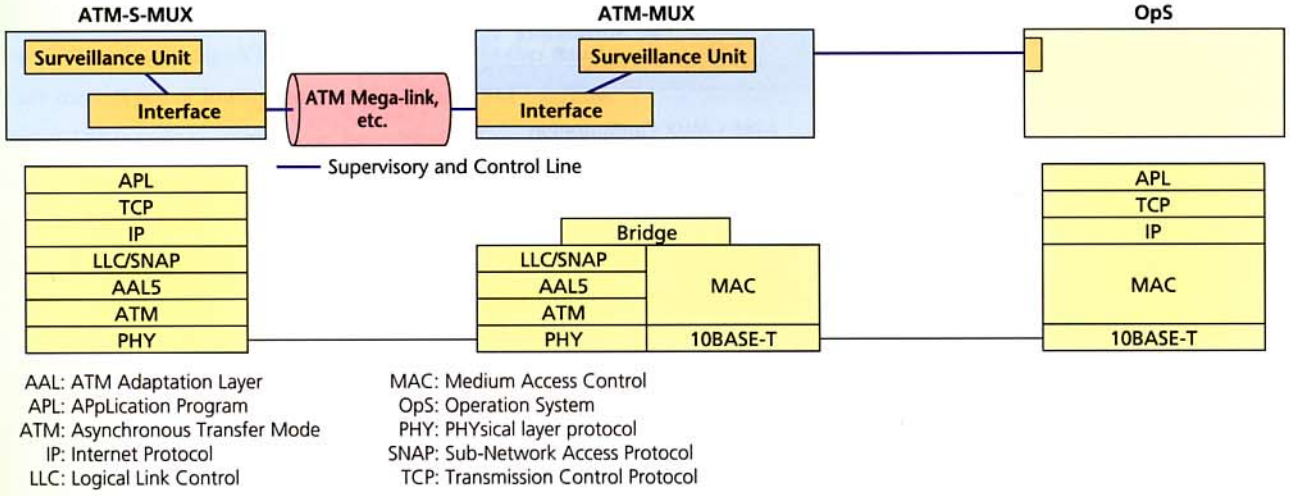



**Figure 5 ATM Multiplexer's Operation System and In-channel Protocol Stack**


**ATM-MUX (Example)** **ATM-S-MUX (Example)**

**Photo 2 Exterior of ATM Multiplexers**

Table 3 Main Parameters of 11/15G-26MD System

| Item \ System | 11/15G-26MD System | Existing System (11G-6M System) |
|---|---|---|
| Frequency Band | 10.725～11.475GHz<br>14.51～15.12GHz | 11.170～11.230GHz |
| Modulation Scheme | Quadrature Phase Shift Keying (QPSK) | Quadrature Phase Shift Keying (QPSK) |
| System Configuration | 1+1S (Hot-standby) | 2+1S or 1+1S (Hot-standby) |
| Transmission Capacity | Approx. 26Mbit/s/sys | Approx. 6Mbit/s/sys |
| Transmission Power | 28dBm, 31dBm [11GHz]<br>24dBm, 28dBm [15GHz] | 28dBm |
| Standard Reception Power | -37dBm±3dB | -40dBm±3dB |
| Radio Clock Frequency | Approx. 14MHz | Approx. 3.5MHz |
| Noise Figure | 5.0dB or less | 5.0dB or less |
| Error Correction | Reed-Solomon code (204, 188) | BCH (255, 239) |
| Equalizer | DFE | None |
| Circuit Switchover | Switchover by station and by transmission/reception | Route switchover en bloc |
| Repeat Scheme | Regenerative Repeat | Regenerative Repeat |
| Transmission Interface | 1.5M, 6.3M | 1.5M, 2M, 6.3M |
| Operation Connection | 1 connection through up to 3 route connections | 1 connection per route |
| Power Supply Type | DC-48V or AC100V (Repeater station) | DC-48V or AC100/200V (Repeater station) |
| Standard Antenna | 0.75, 0.9, 1.2m $\phi$ offset antenna | 0.75, 0.9, 1.2m $\phi$ offset antenna |
| Frequency Allocation | 20MHz interval, co-channel allocation | 5MHz interval, co-channel allocation |
| Standard Repeater spacing | 15km [11GHz]<br>7.5km [15GHz] | 15km |

BCH: Bose Chaudhuri Hocquenghem code
DFE: Decision Feedback Equalizer

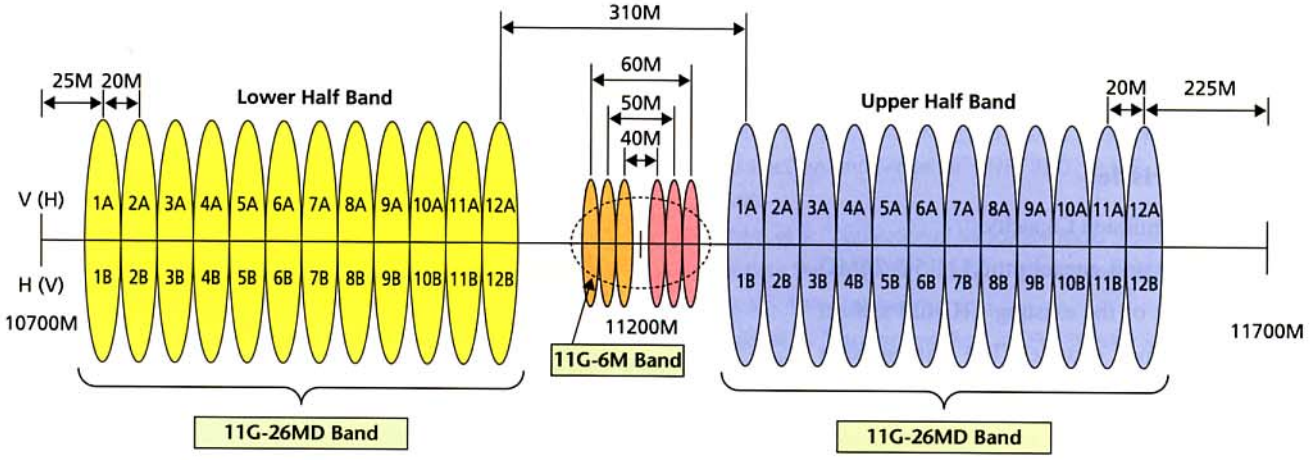



Figure 6 Frequency Channel Arrangement (Example: 11GHz Band)

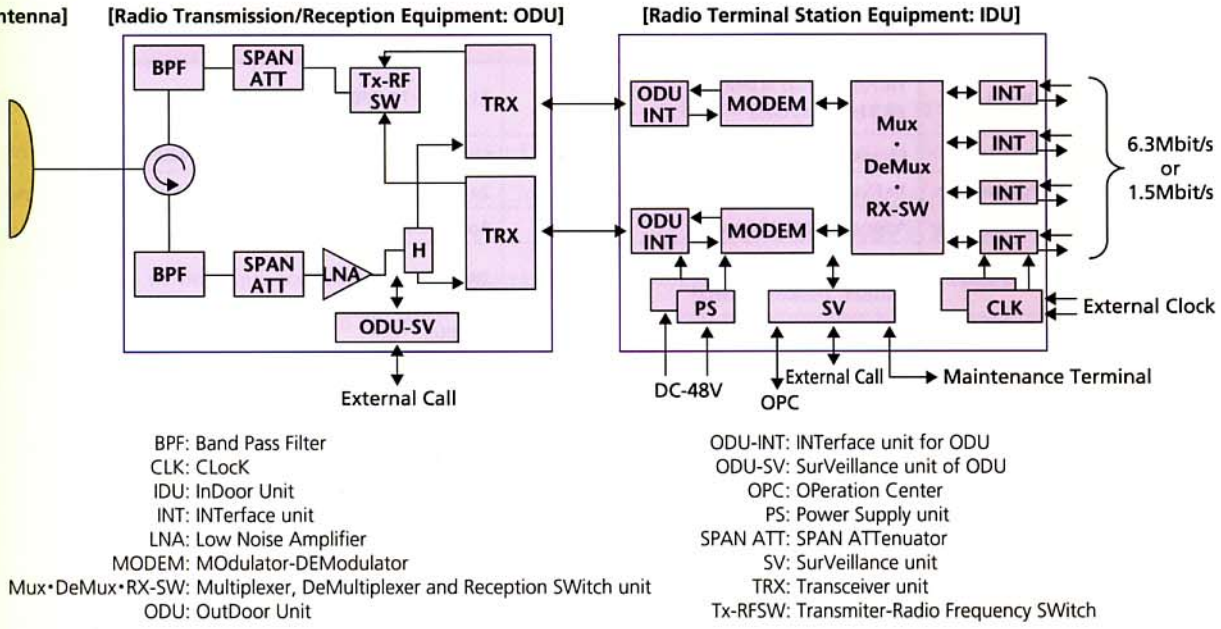
# 4. Entrance Microwave Systems (11/15 G-26MD Radio System)

## 4.1 Overview

11/15G-26MD is a radio system designed for constructing the base station entrance transmission link of IMT-2000 networks. In contrast with existing entrance microwave systems (e.g. 11G-6M radio system) [2], 11/15G-26MD has a larger transmission capacity and superior workability, and is easier to maintain. **Table 3** shows the main parameters of 11/15G-26MD as a comparison against the existing system. **Figure 6** illustrates an example of frequency channels arrangement (11GHz Band).

## 4.2 Configuration

11/15G-26MD consists of an antenna, radio transmission/reception equipment (installed on the antenna pole), and radio termi-




BPF: Band Pass Filter
CLK: CLocK
IDU: InDoor Unit
INT: INTerface unit
LNA: Low Noise Amplifier
MODEM: MOdulator-DEModulator
Mux·DeMux·RX-SW: Multiplexer, DeMultiplexer and Reception SWitch unit
ODU: OutDoor Unit
ODU-INT: INTerface unit for ODU
ODU-SV: SurVeillance unit of ODU
OPC: OPeration Center
PS: Power Supply unit
SPAN ATT: SPAN ATTenuator
SV: SurVeillance unit
TRX: Transceiver unit
Tx-RFSW: Transmiter-Radio Frequency SWitch

**Figure 7 System Configuration (11/15G-26MD Radio System)**

nal station equipment (indoor unit: mounted in steel rack). The repeater station consists of a repeater modem and power supply unit (both are outdoor units), in addition to the radio terminal station equipment.

**Figure 7** shows the system configuration of 11/15G-26MD. **Figure 8** shows the exterior of the equipment.

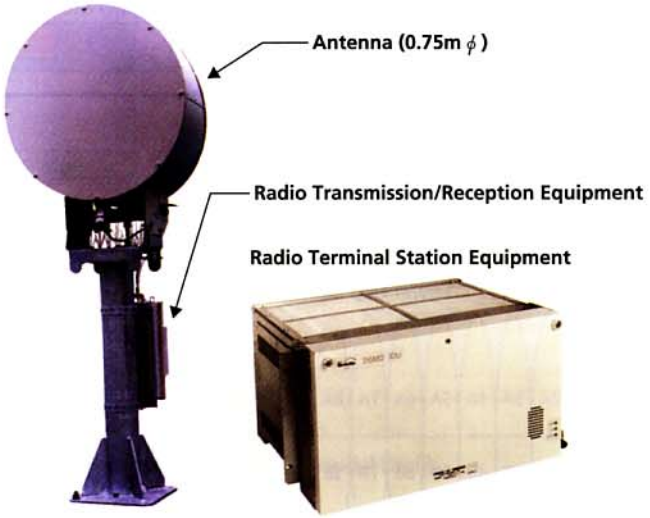



**Figure 8 Exterior of 11/15G-26MD Radio Equipment (Example)**

### 4.3 Characteristics

(1) Larger Transmission Capacity

The transmission capacity of 11/15G-26MD is quadruple that of the existing 11G-6M system per radio frequency channel. The transmission interface of the equipment is flexible in terms of combinations: up to 4 units can be mounted, assuming that one unit is 6.3M ×1 or 1.5M ×4.

(2) Improved Workability

In the existing system, the outdoor unit and the indoor unit had to be connected with 2 signal cables (for transmission and reception) for each system, and more cables were required for the power supply and surveillance control systems.

11/15G-26MD requires only 1 Intermediate Frequency (IF) cable for each system by overlaying transmission IF signals, reception IF signals, power supply and surveillance control signals over coaxial cable, which improves workability.

(3) Easier Maintenance

In the existing switchover system with hot-standby system, circuit switchover operations upon maintenance could lead to burst error in transmission signals. As the impact of such burst error would be larger in the 11/15G-26MD system, in which the clock frequency is about 4 times as that of the existing 11G-6M system, the 11/15G-26MD system has to be taken to minimize the effects.

The 11/15G-26MD system realizes no transmission-signal errors when the radio circuit is switched over upon the maintenance of the transmission side and the reception side. This has

been achieved by accelerating the RF-band switch on the transmission side, synchronizing the frequency on the transmission side, synchronizing the radio frame, adopting forward error correction for burst error, accelerating pull-in speed in the demodulator, and adopting a reception hitless switch [3].

(4) Concentration of Surveillance Control Signals in Connection Routes

In the existing system, the surveillance control information was connected to the operation center in route unit. The 11/15G-26MD system concentrates surveillance control signals accounting for 3 connected radio routes and reduces the operations connection transmission line to a third, taking into account the form of the entrance route connection and the operations connection.

(5) Improved Stability based on Switchover System by Station

In contrast with the existing system, which executes circuit switchover for routes en bloc, the 11/15G-26MD system executes circuit switchover for each transmission system and reception system on an individual basis at each station, which makes it possible to shorten the time consumed in circuit switchover and fix multiple faults.

(6) Enhanced Redundancy of Equipment Clocks

The 11/15G-26MD system's clock may either be based on transmission signals or be externally supplied. In order to apply the same terminal station equipment in each terminal station, the transmission-signal clock can be set to extract or not to extract the signals with respect to each HW. It also has the automatic selection switchover and priority-switchback functions with respect to multiple clock sources.

(7) Layer Configuration that can Accommodate Existing Circuits

Under IMT-2000, information is transmitted in the form of ATM cells. While the aforementioned ATM-MUX, etc. carries out up to VP processes in the ATM layer, the 11/15G-26MD system performs processes up to the physical layer (link layer). The 6.3M interface is in compliance with TTC standard JT-G 703a, whereas the 1.5M interface is compliant with TTC standard JT-I 431 a. This makes it possible to transmit over IMT-2000 circuits and accommodate PDC-dedicated circuits with NTT leased lines.

(8) Saving Space required for Equipment

This equipment is 10-40% smaller in terms of volume compared to the existing equipment, owing to the accumulation of circuits and the integration of panel functions.

## 5. Conclusion

In May 2001, NTT DoCoMo launched its IMT-2000 service called Freedom Of Mobile multimedia Access (FOMA) on an introductory basis in Tokyo and Yokohama. The service is due to be rolled out fully in October 2001. In line with FOMA's expansion to cover Nagoya, Osaka and other parts of the country, link equipment reviewed in this article will gradually be introduced. We strongly believe that the link equipment will facilitate the efficient, economic operation of networks.

We intend to conduct further studies to develop and implement link equipment that can adapt to increases in subscriber capacity in the future.

REFERENCES

[1] Tsuboi, Yoshida, Ohta, Iwase and Adachi: "Development of ATM Cross-Connect System (Model B)", NTT R&D, Vol.48, No.5, pp.439-445, 1999.

[2] Chiba, et al: "Application of Microwave Radio Systems to Entrance Lines for Base Station", NTT DoCoMo Technical Journal, Vol.3, No.4, pp.11-15, Jan. 1996 [Japanese Version].

[3] Endo, et al: "Errorless Switching for Hot-Standby Systems", Proceeding of The 2001 IEICE General Conference, B-5-292.

## GLOSSARY

AAL: ATM Adaptation Layer
APL: APpLication program
APS: Automatic Protection Switch
ATM-DSU: ATM-Digital Service Unit
ATM-MUX: ATM MUltipleXer for node station
ATM-ONU: ATM-Optical Network Unit
ATM-S-MUX: ATM MUltipleXer for base station
ATM-XC: ATM-Cross Connect equipment
ATM: Asynchronous Transfer Mode
BCH: Bose Chaudhuri Hocquenghem code
BPF: Band Pass Filter
BS: Base Station
BTS: Base Transceiver Station
CBR: Constant Bit Rate
CLAD: CeLl Assembly/Disassembly
CLK: CLocK
CN: Connection Node
CSM: Clock Supply Module
DFE: Decision Feedback Equalizer
FOMA: Freedom Of Mobile multimedia Access
HSD: High Super Digital
IDU: InDoor Unit
IF: Intermediate Frequency
IMT-2000: International Mobile Telecommunications-2000
INT: INTerface unit
IP: Internet Protocol
ITU-T: International Telecommunication Union-Telecommunication standardization sector
L-MUX: Low-bitrate circuit MUltipleXer
LLC: Logical Link Control
LNA: Low Noise Amplifier
MAC: Medium Access Control
MDE: Modulation and Demodulation Equipment
MLS: Mobile Local switching System
MMS: Mobile Multimedia switching System
Mod-A: Module-A
MODEM: MOdulator-DEModulator
Mux·DeMux·RX-SW: Multiplexer, DeMultiplexer and Reception SWitch unit
NNI: Network Node Interface
OAM: Operation And Maintenance
ODU-INT: INTerface unit for ODU
ODU-SV: SurVeillance unit of ODU
ODU: OutDoor Unit
OPC: OPeration Center
OpS: Operation System
PDC: Personal Digital Cellular
PHY: PHYsical layer protocol
PKG: PacKaGe
PS: Power Supply unit
QoS: Quality of Service
RNC: Radio Network Controller equipment
SDH: Synchronous Digital Hierarchy
SNAP: Sub-Network Access Protocol
SPAN ATT: SPAN ATTenuator
SPE: Speech Processing Equipment
STM: Synchronous Transfer Mode
SV: SurVeillance unit
TCP: Transmission Control Protocol
TRX: TRansceiver unit
Tx-RFSW: Transmiter-Radio Frequency SWitch
UBR: Unspecified Bit Rate
UDT: Unstructured Data Transfer
VC: Virtual Channel
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