Development Reports

Radio Base Stations Equipments toward Economical Expansion of FOMA Coverage Areas

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This article describes the development of the series of radio base stations equipments applicable to various implementation areas, to economically expand the indoor and outdoor areas covered by FOMA services.

1. Introduction

To expand the areas covered by Freedom Of Mobile multimedia Access (FOMA) services economically in the shortest possible time, it is necessary to select appropriate equipment size according to the traffic, improve ease of installation when building base stations, and reduce initial implementation costs when introducing equipment and running costs after implementation. Moreover, it is essential to design the optimal base station for each area because the design conditions are significantly different between outdoor areas and indoor areas.

Figure 1 shows the implementation areas for each type of Base Transceiver Station (BTS) and Multi-drop Optical Feeder (MOF).

For the types of BTS that are mainly used in the center of urban areas, smooth installation of large-scale base stations was made possible by implementing accommodated channels with a high density and reducing power consumption. For suburban areas with low traffic, the size of the BTS can be reduced and peripheral devices are made into an all-in-one unit for simpler construction of base stations. For areas with lower traffic, several functional units of a BTS can be integrated to achieve a compact and all-in-one structure to realize an easy-to-install and inexpensive BTS. When constructing indoor areas, costs of building equipment and running costs of transmission lines are reduced by expanding the coverage area and each equipments put together into a single station.

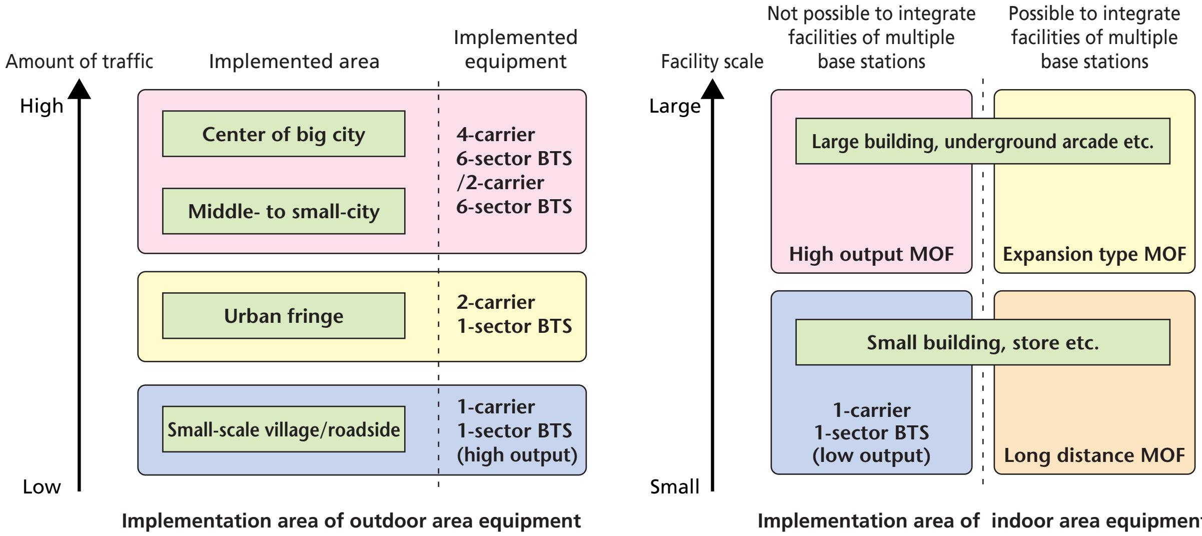

Figure 1 Implementation areas of radio base stations

This article provides an overview of such radio base stations and related equipment, and explains their characteristics.

2. 4-carrier 6-sector BTS

2.1 Overview

This is a successor model of the 2-carrier 6-sector BTS [1], which was developed to be available in time for the start of FOMA services in October, 2001. The capacity of this BTS equipment has increased further (**Photo 1**).

It is housed in a standard frame, just like the conventional 2-carrier 6-sector BTS, and is installed mainly in urban areas where traffic is heavy. **Table 1** shows its main specifications.

Photo 1 4-carrier 6-sector BTS (example)

2.2 Achieving Large Capacity

The conventional 2-carrier 6-sector BTS has the capacity to accommodate 720 or more voice channels per frame. The 4-carrier 6-sector BTS, on the other hand, can accommodate four times that capacity, i.e., 2,880 channels. It is also possible to increase the amount of packet data communication by improving the turbo coding [2]/decoding throughput of the Base Band signal processing unit (BB).

Even though the numbers of channels and carriers that can be accommodated per frame have been increased significantly with the 4-carrier 6-sector BTS, the same size and weight and a power consumption have been achieved, equivalent to that of the conventional 2-carrier 6-sector BTS. This means that the installation conditions of the conventional 2-carrier 6-sector BTS can be applied; the installation method of BTS equipment can be used without modification. This was made possible by making the AMPlifier (AMP) more efficient, lowering the power consumption of BB and reducing the number of cards installed by integrating cards of common control systems (signal processing, clock processing, bus processing, etc.). These three points are explained specifically in the following. In order to prevent the power consumption caused by 4-carrier amplification from increasing, new technologies such as digital predistortion [3], which generates an input signal that takes the AMP's distortion component into consideration in advance, have been implemented in the AMP. This way, an output power of approximately 1.5 times the output of the 2-carrier 6-sector BTS AMP was made possible with the same power consump-

Table 1 Main specifications of BTS

	2-carrier 6-sector BTS	4-carrier 6-sector BTS	2-carrier 1-sector BTS	Low output 1-carrier 1-sector BTS	High output 1-carrer 1-sector BTS
Number of channels	From 720 channels	Up to 2,880 channels	From 240 channels	From 80 channels	From 80 channels
Power supply voltage	–48 ± 6 V DC	–57 to –40.5 V DC	–57 to –40.5 V DC	100 V ± 10% AC	–57 to –40.5 V DC
Weight	310 kg or less	310 kg or less	300 kg or less	20 kg or less	50 kg or less
Power consumption	10 kW or less	10 kW or less	2.2 kW or less	400 W or less	650 W or less
Size	W: 795 mm D : 600 mm H : 1,800 mm	W: 795 mm D : 600 mm H : 1,800 mm	W: 900 mm D : 900 mm H : 1,800 mm	50 L or less (Example) W: 500 mm D : 500 mm H : 200 mm	80 L or less (Example) W: 500 mm D : 500 mm H : 320 mm
Transmission line type	1.5 M: Up to 6 lines 6.3 M: Up to 4 lines ATM mega link: Up to 2 lines MDN*: Up to 2 lines	1.5 M: Up to 4 lines 6.3 M: Up to 4 lines ATM mega link: Up to 2 lines MDN*: Up to 2 lines	1.5 M: Up to 4 lines 6.3 M: Up to 2 lines ATM mega link: Up to 2 lines MDN*: Up to 2 lines	1.5 M: Up to 2 lines MDN*: 1 line	1.5 M: Up to 2 lines MDN*: 1 line

* MDN (Mega Data Netz): The network service based on the ATM technology, flexibly providing a communication method that is best optimized for each user.

tion. This allowed amplification of 4 carriers with a power consumption of only about 1.5 times the previous consumption.

The BB uses new devices for Digital Signal Processor (DSP), Large Scale Integration circuit (LSI) etc. As a result, the signal throughput per card was improved three to four times, the power consumption per channel was reduced to half and the size was reduced due to the higher density.

For the common control systems, the functions were integrated by up to approximately 30% in order to reduce power consumption and implementation space.

2.3 Other Features

It has a shelf structure consisting of the AMP shelf where the AMP is installed, the Modulation and Demodulation Equipment (MDE) basic shelf where the MDE for 2 carriers is installed, and the MDE extension shelf. With this structure, a flexible arrangement that can be changed according to installation form became possible; for example, the MDE extension shelf is not implemented for base stations installed in areas where the traffic can be accommodated by only 2 carriers, and the AMP rack is not implemented if it is not necessary.

For the HighWaY-INTerface (HWY-INT), the redundant configuration was reviewed; it is now possible to support not only the conventional configuration where the load is distributed among two cards, but also a configuration where two cards, one for the active system and one for the standby system, are used and the systems are switched as necessary. This change was made in order to avoid interruption of services in case a card fails. That is, in FOMA, a usage form where connection is established using a single broadband transmission line (Asynchronous Transfer Mode (ATM) mega link etc.) can be considered. Moreover, when transmission lines of ATM mega link are used, redundancy is secured by allowing to set control signals with the Radio Network Controller (RNC) for each Virtual Pass (VP), even if connection is established with a single transmission line.

With the conventional 2-carrier 6-sector BTS, updating of office data and control software (call control and Operation and Maintenance (O&M)) at implementation sites was executed by writing configuration files to the Personal Computer Memory Card International Association (PCMCIA) card using a PC, installing the PCMCIA card in the applicable equipment and then transferring the data to the memory inside the BTS. In order to simplify this process for the new BTS, we have developed a system where a PC can be connected to the BTS with a cable, and the configuration files can be transferred directly to the memory via the File LoaDer Maintenance Tool (FLD-MT), a dedicated file operation maintenance software tool. In this way, it is possible to update files easily at sites and the maintainability is improved.

Moreover, to lower the costs of the power supply system and meet the global specification, the operable power supply voltage of this equipment was changed to –57 to –40.5 V DC from the previous –48 V ± 6V DC.

3. 2-carrier 1-sector BTS

3.1 Overview

DoCoMo has developed a 2-carrier 1-sector BTS in order to meet the demands for economical and small-capacity BTS required to broaden the FOMA services coverage areas. The number of channels accommodated by this equipment is 240 or more, and it covers a suburban area. This is the first FOMA BTS with a cubicle supporting outdoors installation (**Photo 2**). Table 1 shows the main specifications.

3.2 All-in-one Structure with Cubicle Supporting Outdoors Installation

The 2-carrier 6-sector BTS and 4-carrier 6-sector BTS discussed above are standard frame-type equipment. For this reason, an appropriate cubicle for outdoor installing a radio base station required at the base station site, in which the BTS, IMT-2000 Multiprotocol Turn up Test (I-MTT), signal relay unit[*1], I/O port[*2] etc. were installed. For this reason, it was required to secure installation space of at least 8 m^2. With newly developed 2-carrier 1-sector BTS, the required installation space was successfully reduced to approximately 1/10, as it is equipped with a cubicle supporting outdoors installation and has an all-in-one configuration (**Figure 2**) that allows implementing the I-MTT, signal relay unit and I/O ports directly in the equipment. Due to the reduced installation space required, the foundation work costs were reduced, and as a result the initial introduction costs have been reduced to approximately 1/3 of the introduction costs of the conventional 2-carrier 6-sector BTS.

Photo 2 2-carrier 1-sector BTS (example)

3.3 Other Features

This equipment utilizes most of the cards of the 4-carrier 6-sector BTS and achieves size reduction by reducing the number of channels and carriers accommodated as well as the number of sectors. Moreover, the air conditioning equipment was changed from the conventional air conditioner to a heat exchanger[*3], which eliminated the needs for regular maintenance, and at the same time lowered the electricity consumption and operation noise.

The AMP and MDE of this equipment are implemented using a rack structure; it is possible to install the AMP and MDE directly in a frame when installed indoors. Inserting and removing only the AMP is also possible; it can be applied to Inbuilding Mobile Communication Systems (IMCS).

*1 A device that remotely controls the tilt angle of an antenna
*2 A device to combine or separate control signals that are transmitted between various external devices installed at a BTS and a base station
*3 A method of plate-based cooling that takes advantage of the convection within the cubicle box and external convection. It eliminates filter replacement etc. because it does not take outside air in directly.

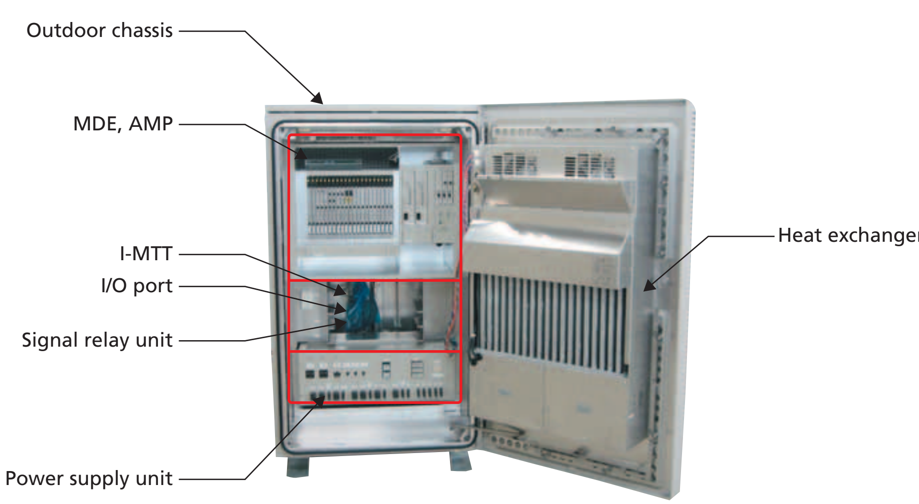

Figure 2 All-in-one configuration of 2-carrier 1-sector BTS

4. 1-carrier 1-sector BTS

4.1 Overview

The 1-carrier 1-sector BTS is available in two configurations. One is a low output 1-carrier 1-sector BTS for indoor areas, developed for the purpose of providing services in radio blind areas, such as event sites, inside buildings, underground arcades and subway stations (**Photo 3**). The other is a high output 1-carrier 1-sector BTS for outdoor areas, developed for the purpose of expanding the FOMA coverage areas, including suburban areas (less traffic areas) and out of service areas due to rough terrain etc. (**Photo 4**). Table 1 shows the main specifications. The basic number of channels that can be accommodated is 80 or more. The number of channels can be increased by adding cards according to the intended purpose. The number of transmission lines is limited to two 1.5 M lines or a single MDN 25 M line, which is of low cost, because the number of accommodated channels is small. The transmission output power of the low output type for indoor usage is set to 400 mW because the radius of an indoor area is smaller than that of an outdoor area.

4.2 Achieving Size and Weight Reduction

To make the density higher, the common functions, which used to be handled by multiple cards in the conventional equipment, have been integrated. As a result, it has become possible to reduce the number of cards required to accommodate the same number of channels to approximately 1/5 compared to the conventional equipment. Moreover, the reliability of the equipment has been improved by reducing the number of parts to guarantee a Mean Time Between Failure (MTBF) of 30,000 hours or more without a redundancy configuration. This has made it possible to simplify the equipment configuration; the size of the low output 1-carrier 1-sector BTS was reduced to approximately 1/30 in volume compared to the 4-carrier 6-sector BTS, and the weight was reduced by 15 kg. For the high output 1-carrier 1-sector BTS a size reduction of approximately 1/15[*4] and a weight reduction of approximately 38 kg[*5] were achieved. This equipment uses the digital predistortion technology for the AMP for higher distortion compensation and efficiency while lowering the power consumption.

*4 The smallest equipment configuration among the developed equipment
*5 The lightest equipment configuration among the developed equipment

Photo 3 Low output 1-carrier 1-sector BTS

Photo 4 High output 1-carrier 1-sector BTS (example)

4.3 Other Features

In spite of its small-scale equipment configuration, a maintainability equivalent to that of the 4-carrier 6-sector BTS is secured by allowing to exchange each card or each unit which houses multiple functions in an all-weather cubicle. For this reason, the service time required to bring the system back online in case of failures is dramatically reduced and service interruption time can be suppressed to a minimum. The following shows the features of the low output 1-carrier 1-sector BTS and high output 1-carrier 1-sector BTS, respectively.

1) Low Output 1-carrier 1-sector BTS

To ensure that the BTS can be installed flexibly, this BTS has a structure that allows both floor-mounting and wall-mounting, by integrating positions for connecting external interfaces such as the power supply and antenna terminals on the same surface. It can operate with an AC power supply as well; thus, it can be installed in places where supply of DC power is difficult.

Considerable improvement was made in terms of the operation noise as well; it was reduced from the 65 dB of the conventional equipment to 40 dB, by controlling speed of the fan according to the temperature inside the cubicle; the fan is driven at low speed at normal operation. This improvement has thus made it possible to install the equipment in offices etc. where the operation noise of the conventional equipment can be annoying, and has made expansion of coverage areas easier.

2) High Output 1-carrier 1-sector BTS

This equipment is an outdoor cubicle integrated unit that can be installed outdoors. An Open Air Receiver Amplifier (OA-RA) and an Open Air Receiver Amplifier Supervisory Controller (OA-RA-SC), which were required in the conventional equipment, are no longer required because a Low Noise Amplifier (LNA), DUPlexer (DUP) and Band Pass Filter (BPF) are built in.

5. Multi-drop Optical Feeder (MOF)

5.1 Overview

The MOF [4] discussed here is configured with base unit, which is connected to a BTS via a coaxial cable, as well as multiple access unit and antennae sets, which are connected to the base unit via fiber optic cable (**Figure 3**). Radio Frequency (RF) signals transmitted from the BTS and a mobile terminal are received by base unit and access unit, respectively. The received RF signals are converted to optical signals and then transmitted via the fiber optic cable. The optical signals are converted to RF signals at the opposing access unit and base unit, and transmitted to the BTS and mobile terminal, respectively. In indoor areas, where building structures are complicated and radio signals have difficulties to reach their targets, the MOF can be used to expand the coverage areas economically as well as flexibly because it uses small-diameter and light-weight fiber optic cable for the transmission lines and allows extending the transmission lines to multiple antennae. Moreover, MOF can transmit RF signals for both Second-Generation Personal Digital Cellular (PDC) and FOMA services at the same time with one system.

MOFs that make use of fiber optic cable to relay RF signals of BTSs have been used in the past as well. However, further economization has become possible by enabling to increase the transmission output of Wideband Code Division Multiple Access (W-CDMA) radio signals and increase the transmission distance of fiber optic cable. This time, we have developed three types of MOF, a high output type, a long distance type and an extension type, which can be used according to the area of implementation, in order to expand indoor coverage areas economically and flexibly (Fig.3).

- High output MOF: Applied mainly to large-scale indoor areas (e.g., in a business complex). Installed and used together with a BTS.
- Long distance MOF: Applied mainly to isolated indoor areas and small-scale areas. It is possible to integrate base station equipment with the MOF in a remote building.
- Extension type MOF: Applied mainly to large-scale indoor

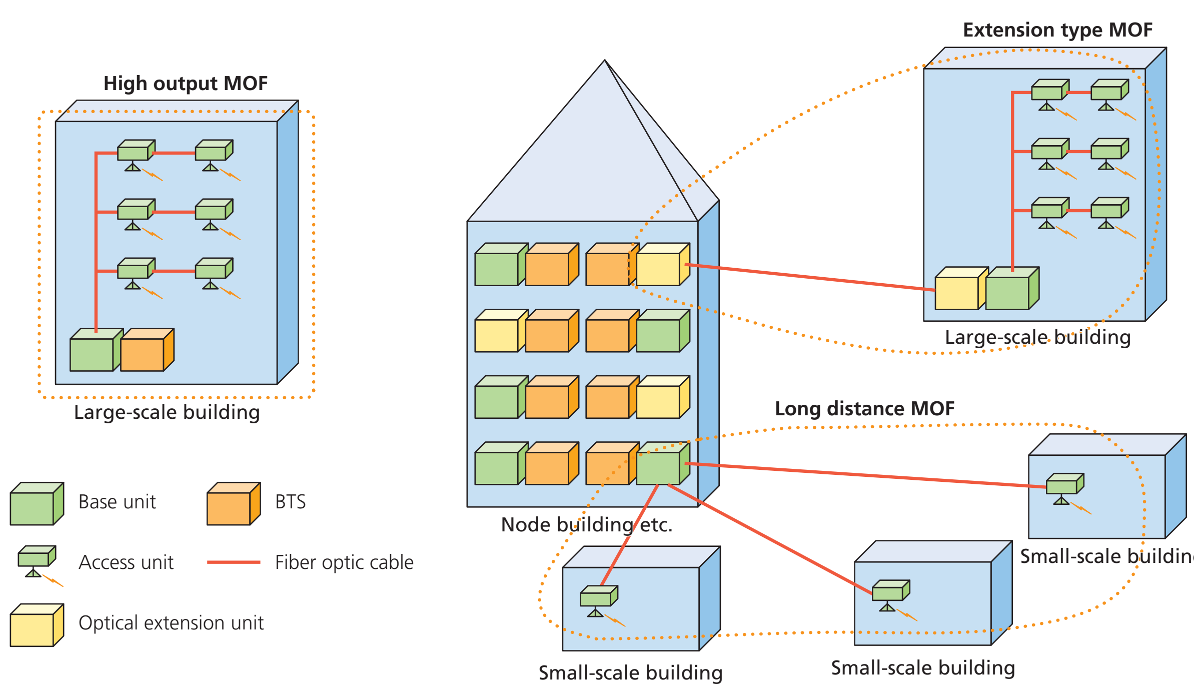

Figure 3 Usage image of each MOF

Table 2 Main specifications of MOF

	Downlink (base station→mobile terminal)	Uplink (mobile terminal→base station)
Transmission frequency band	810 – 818 MHz 1487 – 1491 MHz 2130 – 2150 MHz	940 – 948 MHz 1439 – 1443 MHz 1940 – 1960 MHz
Number of transmitted wavelengths	W-CDMA: 4 wavelengths PDC: 16 wavelengths (800 MHz band) + 8 wavelengths (1.5 GHz band)	
Line gain	W-CDMA: 25 dB PDC: 3 dB	0 dB
CNR	W-CDMA: 45 dB/4 MHz or more PDC: 60 dB/21 kHz or more	W-CDMA: 40 dB/4 MHz or more PDC: 60 dB/21 kHz or more
2 tone IM3	–45 dBc or less	–56 dBc or less
Fiber optic cable transmission distance	Up to 20 km (between optical extension units of long distance MOFs and extension type MOFs) Up to 2 km (between base unit and access unit of high output MOFs or extension type MOFs)	
Fiber optic cable type	1.3 μm zero-dispersion single mode fiber	
Power supply voltage	–57 to –40.5 V DC, 100 V ± 10% AC	

areas (e.g., in a business complex). Can be configured as a combination of high output MOF and optical extension unit. It is possible to integrate base station equipment with the MOF in a remote building.

The base unit and optical extension unit can be implemented in a 19" rack that houses Local Area Network (LAN) equipment etc., and both support 100 V AC, which means that power supply can easily be secured. Since access unit is frequently installed in narrow space such as on a ceiling, it was made compact and light-weight and employs a drip-proof structure etc. **Table 2** shows the specifications of MOF and **Photos 5** through **7** show example of each type of equipment.

The following explains the configuration and features of each type of equipment.

5.2 Area Coverage Expansion by High Output MOF

As a result of increasing the rated output of the final RF AMP for the downlink built in the access unit, the RF signal transmission output of the BTS was increased by a factor of 10 compared to the conventional equipment. Accordingly, the size of the area covered by a single antenna was approximately doubled, allowing a reduction of the number of access unit and antennae used as well as the initial implementation cost incurred in indoor area construction.

5.3 Extension of Fiber Optic Cable Distance by Long Distance MOF

In order to address the increased transmission line loss caused by the longer distance of fiber optic cable used, the out-

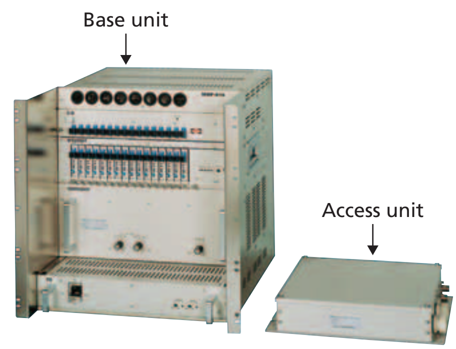

Photo 5 High output MOF (example)

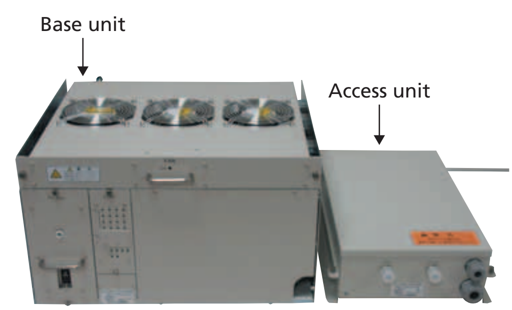

Photo 6 Long distance MOF (example)

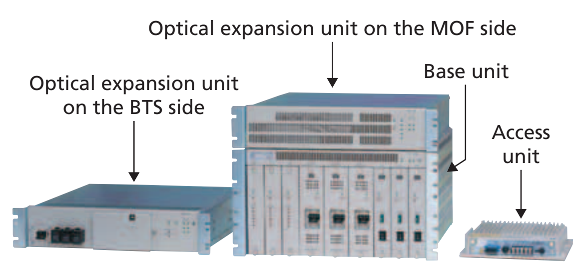

Photo 7 Expansion type MOF (Optical expansion unit + high output MOF) (example)

put of the laser diode used as the light source was increased and the fiber optic cable distance was extended to up to 20 km, which is approximately 10 times longer than with the conventional equipment. By extending the distance of the fiber optic cable, much of the base station equipment, including the BTS, can now be integrated and installed in a node building etc.; access unit and antennae are the only base station facilities that must be installed in the indoor area. As a result, the implementation cost is reduced by integrating and using base station facilities which were installed in multiple indoor areas in a decentralized manner so far. Moreover, now that the transmission line loss increase caused by the longer transmission line distance has become allowable, dark fiber, whose services are provided cheaply, can be used, leading to a dramatic reduction of running cost.

5.4 Reduction of Cores by WDM Technology of Extension Type MOF

In order to reduce costs for large-scale indoor areas where multiple antennae are utilized as well by integrating base station equipment, we have also developed optical extension units that allow connecting the BTS and base unit using fiber optic cable, rather than coaxial cable as before. The optical extension units are connected to BTS and base unit, respectively; a single fiber optic cable connects the two optical extension units. The Wavelength Division Multiplexing (WDM) technology is used for this transmission line; the line overlays monitor control signals on top of the RF signals of the up- and downlinks between a mobile terminal and base station. The number of transmission lines can thus be reduced to a fraction of several tens, compared to the case where separate transmission line must be prepared for each set of access unit, and the running cost is thus reduced.

6. Conclusion

This article explained a series of radio base stations equipments, which is developed in order to expand the FOMA services coverage areas quickly and economically. It discussed the implementation areas and features of each type of equipment. The BTSs introduced this time have been gradually implemented since 2002, in the order of a 4-carrier 6-sector BTS for urban areas first, then a 2-carrier 1-sector BTS for suburban areas, and finally a high output 1-carrier 1-sector BTS for rural areas; the lineup allows selection of equipment according to the traffic of the implemented area. Moreover, in order to expand indoor area coverage, low output 1-carrier 1-sector BTS, high output MOF, long distance MOF and extension type MOF equipment have been sequentially introduced since 2003, achieving reduction of facility construction costs and running costs for indoor areas. We intend to continue developing radio base stations-related equipments, aiming for further costs reductions, while supporting traffic demands and new services.

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ABBREVIATIONS

AC: Alternating Current
AMP: AMPlifier
ATM: Asynchronous Transfer Mode
BB: Base Band
BPF: Band Pass Filter
BTS: Base Transceiver Station
DC: Direct Current
DSP: Digital Signal Processor
DUP: DUPlexer
FLD-MT: File LoaDer Maintenance Tool
FOMA: Freedom Of Mobile multimedia Access
HWY-INT: HighWaY-INTerface
IMCS: Inbuilding Mobile Communication System
I-MTT: IMT-2000 Multiprotocol Turn up Test
LAN: Local Area Network
LNA: Low Noise Amplifier
LSI: Large Scale Integration circuit
MDE: Modulation and Demodulation Equipment
MOF: Multi-drop Optical Feeder
MTBF: Mean Time Between Failure
OA-RA: Open Air Receiver Amplifier
OA-RA-SC: Open Air Receiver Amplifier Supervisory Controller
PCMCIA: Personal Computer Memory Card International Association
PDC: Personal Digital Cellular
RF: Radio Frequency
RNC: Radio Network Controller
VP: Virtual Pass
W-CDMA: Wideband Code Division Multiple Access
WDM: Wavelength Division Multiplexing