Mobile WiMAX Base Station Architecture and RF Technology

● Naoyuki Saitou ● Yoichi Endo ● Yasuhiro Shibuya

(Manuscript received February 26, 2008)

In March 2008, Fujitsu issued a press release about its commercial product of a Mobile WiMAX base station (BS) "BroadOne WX300", which is an all-in-one type of very small outdoor equipment, composed of a mobile IP network interface, IEEE 802.16e air interface and radio transceivers.
This base station has two transceivers in a cabinet and supports one 20 MHz or multiple 10 MHz channel bandwidths per transceiver by reconfiguring it with a software download. In addition, this platform is the same as an outdoor RF unit for the two-box separate type, which is an indoor baseband processing unit and the outdoor RF unit configuration.
In this paper, we introduce our achievements regarding this base station, which use highly efficient RF high-power amplifier technology, as a very small outdoor unit, and the base band technology for the benefit of efficient use of frequency.

1. Introduction

In Japan, the Ministry of Internal Affairs and Communications decided the frequency arrangement of 2.5 GHz license band in December 2007. Then, that ministry completed recognition and the license delivery of a telecommunications provider for a Mobile WiMAX[1)] system that depended on the IEEE 802.16e standard.[2)]

By 2010, it is expected that the business service of a Mobile WiMAX system will have rapidly developed in various places. The WiMAX system aims to be cost effective compared with 3GPP[3)] and 3GPP2[4)] systems.

Against this background, we have developed a base station (BS) that has high transmission power and low power consumption and is housed in a very small, outdoor unit.

Hereafter, these features and the approach of our development will be described in this paper.

2. BS architecture

Mobile WiMAX will start as a complementary service to the existing mobile network. Many BSs will be deployed, especially in urban areas, and they will need to have high power efficiency and be small in size. These characteristics will make it easy for telecommunication providers to install and maintain them. To satisfy these market requirements, a highly efficient amplifier with digital pre-distortion is used as a "BroadOne WX300" BS, which is an all-in-one type of very small outdoor equipment, composed of a mobile IP network interface, IEEE 802.16e air interface and radio transceivers.

The brief performance specifications of BroadOne WX300 are shown in **Table 1**.

2.1 RF band coverage

BroadOne WX300 has two types of RF frequency band coverage for Japanese domestic licensed and WiMAX Forum specified in the 2.5 GHz frequency band. The domestic band,

Table 1
Specifications of BroadOne WX300.

Feature	BS Performance Specification			Note
Wireless system	Mobile WiMAX System Profile Wave-2 certification ready			Band class Power class MAC/PHY
IP network	Mobile IP [IPv4, IPv6]			
Air interface	IEEE 802.16e WirelessMAN OFDMA			PHY feature
Channel BW	5.0 MHz	10.0 MHz	20.0 MHz	
FFT size	512	1024	2048	
Sampling factor	28/25	28/25	28/25	
Sampling clock	5.6 MHz	11.2 MHz	22.4 MHz	
CP ratio	1/32, 1/16, 1/8, 1/4			Normal: 1/8
Duplex	TDD			
Radio frame	5.0 ms			
TX power	10 W/Tx (At antenna port) × 2			
Frequency	2500-2690 MHz			
Sector	1 Sector/1 Base station (RRH)			
Multi-antenna technology	Downlink: STC/MIMO by 2 antenna per sector [Matrix-A, Matrix-B] Uplink: 2 antenna Rx-Diversity/MIMO Rx Detection			
Input power	DC-48 V, AC100/200 V			
Power consumption	Less than 200 W			
Physical size	Approx. 20 litters			
Weight	Approx. 20 kg			

called a wireless broadband access (WBA) frequency band, is part of the RF profile 3A defined on the WiMAX Forum system profile. In particular, the 3A profile covers the U.S., Canadian and European markets thanks to its wide band coverage that supports frequencies of 2500-2690 MHz. The following are the frequency allocations of the domestic WBA and the WiMAX Forum 3A profile band.

Domestic WBA frequency in 2.5 GHz band (part of Band Class "3A"): 2535-2630 MHz

WiMAX Forum 3A profile frequency: 2500-2690 MHz

The frequency coverage of the BS is also shown in **Figure 1**.

2.2 Carrier allocation

BroadOne WX300 supports 5 MHz, 10 MHz and 20 MHz channel bandwidth. Moreover, it can operate two carriers per transceiver when operating on the 10 MHz channel bandwidth. When operating on a 20 MHz channel bandwidth, one carrier can be operated. In the case of the 5 MHz channel bandwidth, only a single carrier can be operated, though two carriers can be used when operating on the 10 MHz channel bandwidth. The following are the operable channel bandwidths and carriers of BroadOne WX300.

Carrier allocation:

5 MHz × 1carrier,

10 MHz × 1carrier, 10 MHz × 2carriers,

20 MHz × 1carrier

2.3 Antenna and sector configuration

BroadOne WX300 has full BS functions or an RF transceiver function in a housing. Therefore, a BS covers one sector or one omni cell. To make three or more sectors have a cell configured for four or six sectors, it is necessary

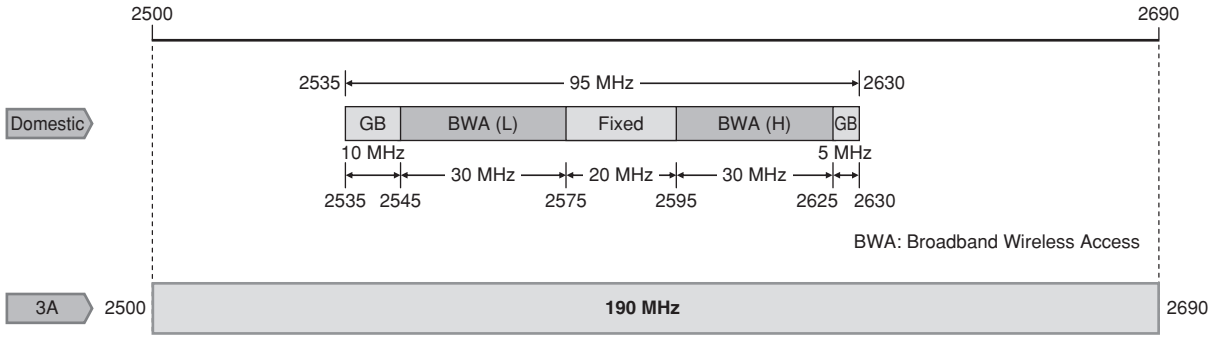

Figure 1
Frequency allocation and coverage of BroadOne WX300 (2.5 GHz Band).

to have the same number of BSs as sectors. In other words, there is no difference between an omni-sector configuration and a multi-sector configuration for the BS equipment. Just the number of BSs is different.

2.4 Equipment type

BroadOne WX 300 is an all-in-one type of outdoor type equipment. In addition to the all-in-one type equipment, a two-box separate type of indoor equipment and an outdoor type will be available with common product architecture. The two-box type of BS will comply with the IEEE 802.16e WiMAX air interface specification in the 2.5 GHz frequency band. It will also be composed of two transceivers in a BS to act as a transmitter and receiver for multiple-input multiple-output (MIMO), and there will be two antenna ports on the BS so that each antenna port is connected to a separate transceiver.

2.4.1 All-in-one Type of Outdoor Equipment

BroadOne WX300 is a one-box type of WiMAX BS which has all the necessary functions and sits in a housing for a Mobile WiMAX BS. Its functions include an Ethernet interface, IEEE 802.16e air interface processing, 2.5 GHz RF high power transmitters, high sensitivity receivers, and a Global Positioning System (GPS) receiver. Moreover, the BS is housed in a waterproof outdoor shell which means it can be installed outdoors. The BS is composed of two transceivers, namely two transmitters and receivers for MIMO. These two transceivers each have an antenna port.

The hardware block diagram of the BroadOne WX300 all-in-one type of BS is shown in **Figure 2**.

For downlinking, the Ethernet connection from an ASN-GW side is connected to the L2 interface, and the incoming packets are input to the base band processing section in the outdoor BS. Then, the user traffic is mapped into the radio frame regarding the IEEE 802.16e air interface specifications. The mapped signal then transports to the Digital Pre-distortion and RF section. The signal is modulated and up-converted to an RF signal. The Digital Pre-Distorter and RF section also has an RF high-power amplifier, and the signal is amplified so that it has sufficient RF output power. The BS can be output for a maximum of 10 W per transceiver. The amplified RF signal is shaped and any undesired spurious signals are cut out by the Front End unit. To ensure downlink diversity, the necessary coding is processed in the base band section on the baseband processing portion, and each signal passes into the two separate RF sections.

For uplinking signals, the received signals are sent to the Front End and any undesired band noise is cut down by the filter in the Front

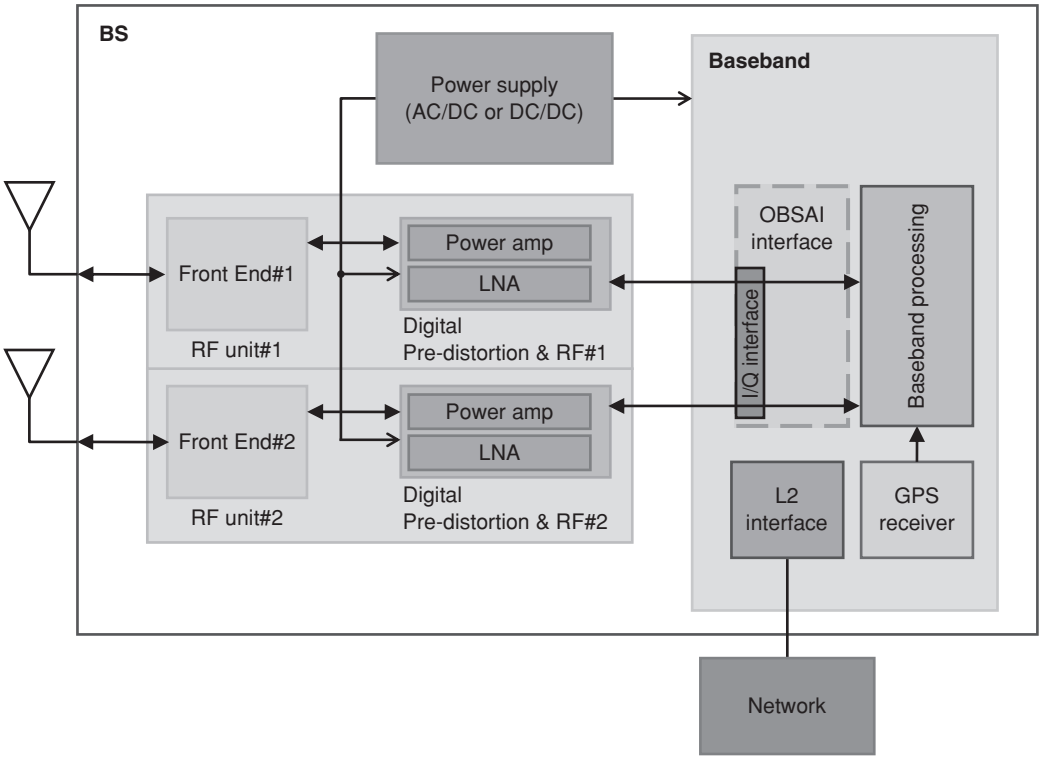

Figure 2
Hardware block diagram of BroadOne WX300.

End. Then the signals are input to the low-noise amplifier (LNA) and down-converted to an intermediate frequency (IF). The IF signals are demodulated in the digital pre-distorter and RF section and input to the baseband processing section. In the Baseband processing section, the signals are decoded and de-mapped from an IEEE 802.16e radio frame to an Ethernet frame, then output to an ASN-GW via the L2 interface.

2.4.2 Two-box separate type of equipment

The two-box separate type of equipment is composed of a BS from a base band processing unit and an RF transceiver. The base band processing unit is indoor implementation equipment based on a standard advancedTCA[6] shelf mount card installation. The indoor equipment is mainly composed of an Ethernet interface to enable ASN-GW connection, most of the IEEE 802.16e air interface processing and to allow the BS to be controlled and maintained. A GPS receiver is also included in the indoor unit. RF transceiver functions such as 2.5 GHz high-power transmitters and highly sensitive receivers are installed in a separate outdoor housing. The outdoor RF head has two transceivers for MIMO, and there are two antenna ports on the RF head as well. They are connected so that the advancedTCA shelf based indoor equipment and the outdoor RF head by OBSAI[7] which is an open standard based on an optical interface.

2.5 L2 interface

The L2 interface is the interface between the BS and an ASN-GW. The L2 Interface has one optical and four electrical Ethernet ports, and Layer 2 switching functions between these Ethernet ports. The optical port supports 100BASE-FX with TS-1000[8] protocol which is a specification of 100 Mb/s single-fiber bi-directional interface by WDM in Telecommunication Technology Committee (TTC) for domestic

use. For other regions, 1000BASE-SX is used on the optical interface. In the four metal Ethernet interface, 100BASE-TX is used for all regions. These 100BASE-TX Ethernet ports are used to connect BSs in the case of three-sector configuration. Therefore, the L2 Interface is accommodated in the one-box type of BS, but not in the two-box type. A network interface is connected to the Ethernet port of the L2 Interface on the first sector BS, and then network traffic is distributed to the second and third sector BSs via the first sector BS using a star type of connection in the three-sector configuration.

2.6 GPS receiver

The GPS Receiver synchronizes to the GPS time base and extracts a highly stable equipment clock from the received GPS signal. Mobile WiMAX specification requires very high stability and little time deviation from the WiMAX BS clock to realize hand over and MBS service. BroadOne WX300 has a GPS receiver in each BS to synchronize its equipment clock to GPS time.

2.7 Power supply

BroadOne WX300 supports two types of power supply voltage. The supported primary power supply voltage is AC100/200 V and DC−48 V. The following is the primary input coverage of the power supply for each type of power supply.

AC100/200 V: AC100 V to 230 V

DC−48 V: DC−58 V to −38 V

The front view of BroadOne WX300 is shown in **Figure 3**, and the bottom view is shown in **Figure 4**.

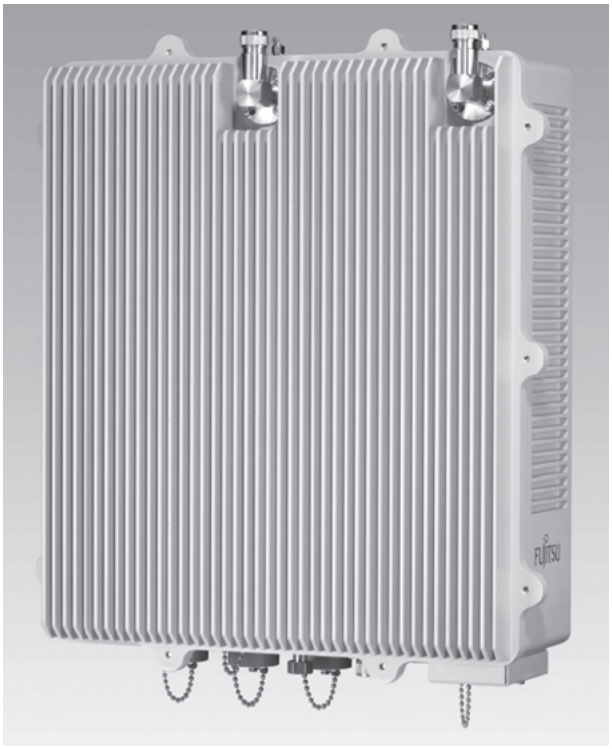

Figure 3
Front view of BroadOne WX300.

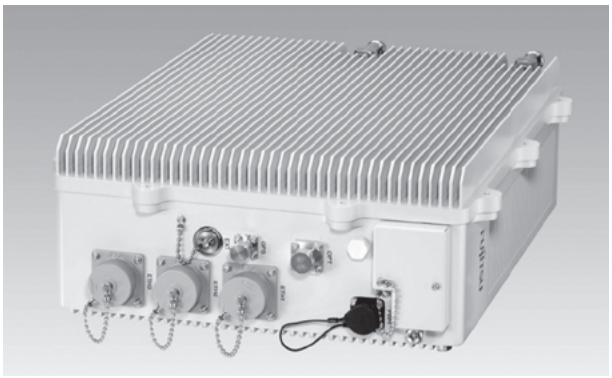

Figure 4
Bottom view of BroadOne WX300.

3. Baseband technology and features

Baseband processing has flexible software-defined radio (SDR) technology.

There are some typical features of the radio interface function for Mobile WiMAX as shown below.

We improve the efficiency of frequency use by synchronizing these functions. Then, the user throughput and system throughput can be improved by optimizing these features.

- Fractional Frequency Reuse (FFR) for downlink and uplink
- Adaptive Modulation and Coding Scheme (MCS) selection for downlink and uplink

- Adaptive space-time coding (STC)/MIMO switching for downlink
- Adaptive Collaborative Spatial Multiplexing (CSM) switching for uplink
- Uplink power control and sub-channelization
- Dynamic MAP allocation for downlink and uplink
- QoS packet scheduler

An outline of these functions is explained as follows.

This FFR function is the setting of two areas where the efficiency of frequency use is different, and they are switched by timesharing. (The reuse factor is 1.0 or 0.33.) The allocation of the accessed frequency domain is controlled according to the radio propagation environment of each user.

This adaptive STC/MIMO switching on the downlink is the selection of user's data throughput ratio. It depends on the radio propagation environment of each user in the FFR allocation.

This adaptive CSM switching on the uplink is the control of multi-user MIMO by two users for efficiency of frequency use. Of course, when the radio propagation quality of each user is low, it does not select CSM. In that case, those users' signals are received by two antennas for maximum ratio combining (MRC).

Next, the advantages of the system construction are shown below.

Looking at the processing performance of this SDR, there is a 20 MHz channel bandwidth, two transmitting antenna and two receiving antenna. Then we can support dual MAC/PHY and dynamic link adaptation for multiple channels services with 10 MHz channel bandwidth per channel. In the future, we will support IEEE 802.16m[2)] features through a software upgrade.

4. RF technologies and features

To minimize the dimensions of the BS, GaN-HEMT and digital pre-distortion technology are applied to obtain highly efficient performance of the RF unit for the transmitter's high-power amplifier. Moreover, the analog and digital circuits of the transmitter and receiver are integrated into one printed circuit board (PCB).

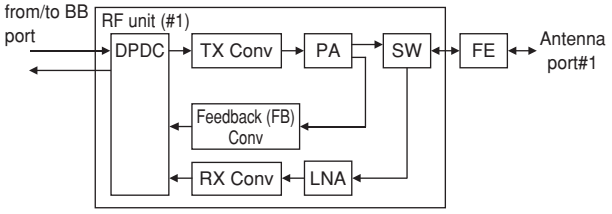

Figure 5
RF unit configurations.

In the following section, the highly efficient amplifier and BS miniaturization techniques are introduced.

4.1 RF unit configuration

BS has two RF units, and each RF unit is composed of a transmitter and a receiver (1T1R). The RF unit has the some functional blocks, such as DPDC, TX conv, PA, RF SW, FE, and RX conv. **Figure 5** shows the RF unit configuration.

- DPDC: Digital pre-distortion circuit

The DPDC section consists of three components, an Interface to Baseband (BB) part, a pre-distortion processor and a modulator/demodulator.

- TX Conv:

The TX Conv converts the modulated signal into an RF transmission signal.

- Feedback (FB) Conv:

The Feedback Conv converts the transmission distortion signal into an IF signal.

- FE:

The FE unit consists of an RF band pass filter (BPF)

- SW:

The SW switches rapidly between the transmission signal and the received signal.

- LNA:

The LNA amplifies the received signal from the RF antenna port.

- RX Conv:

The RX Conv converts the received RF signal into an IF via LNA.

The RF unit supports operations from 5 MHz up to 20 MHz channel bandwidth with the same hardware. The profile can be changed by merely downloading software. The RF high-power amplifier reaches 30% power efficiency by optimizing the highly effective amplifier design and using the digital pre-distortion technique developed by Fujitsu.

4.2 Achievement of highly efficient amplifier

4.2.1 Highly efficient amplifier

To improve the efficiency of the amplifier, the GaN-HEMT[note 1)] device is more functional than the LD-MOS FET[note 2)] that has been used so far, and it is has been commercialized in recent years. The GaN-HEMT device has the following features.

1) High voltage tolerance.
2) High electric power density.
3) High current density.
4) High switching speed.
5) Low resistance.

The GaN-HEMT is expected to be a device for the amplifiers of next-generation mobile communication BSs, because the drain efficiency of GaN-HEMT will be about 10% higher than that of LD-MOS FET.

A highly efficient amplifier has been developed by using GaN-HEMT and optimizing the design of the amplifier circuits.

4.2.2 Adoption of digital pre-distortion

We adopt the Digital Pre-distortion technology[5)] that has been developed with the current 3G system. In Mobile WiMAX, TDD operation is needed, and we have optimized the Digital Pre-distortion parameter matched to burst transmission operation. **Figure 6** shows the transmission spectrum when the burst signal is transmitted (before and after pre-distortion).

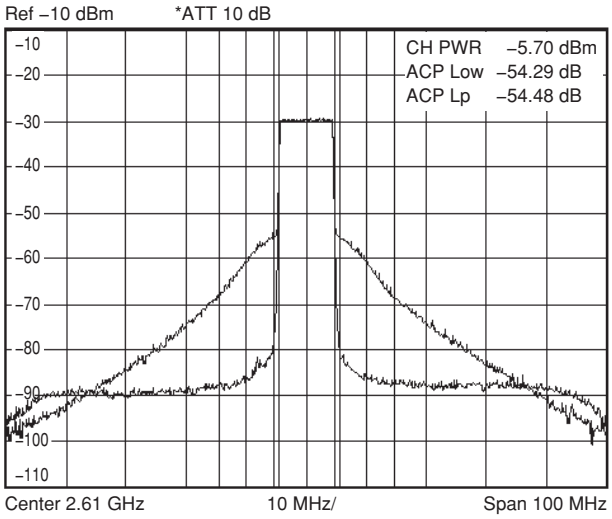

Figure 6
Transmission spectrum.

4.3 Miniaturization of RF unit

To minimize the dimensions of the RF unit, all functional blocks of the RF unit, shown in Figure 5, are integrated in one PCB.

So far, we have realized an RF analog circuit and a high-speed digital circuit with an individual substrate. To integrate circuits on one substrate, we needed to overcome the difference of impedance on the circuit and the interference between the circuits. We have achieved one substrate by optimizing the impedance on the substrate and considering shield measures for the interference between the circuits. As a result, the PCB, the connector and the cable for a connection between function blocks, are about two-thirds the size of those used in the past. **Figure 7** shows the extent to which we have miniaturized the RF unit.

5. Conclusion

We have developed this High-power Macro BS as an all-in-one configuration in a very small outdoor unit. GaN-HEMT and Digital

note 1) Gallium Nitride-High Electron Mobility Transistor.
note 2) Laterally Diffused Metal-Oxide-Semiconductor.

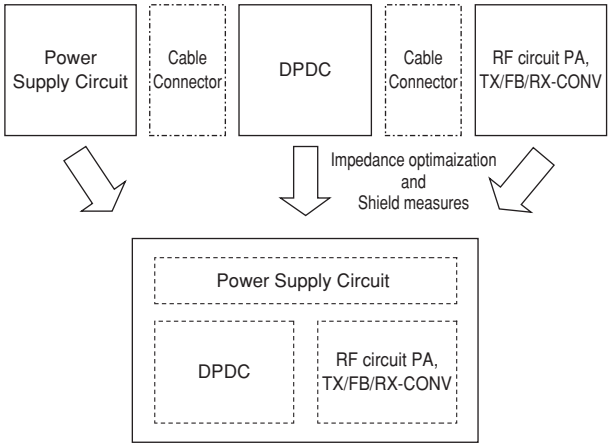

Figure 7
RF unit miniaturization.

Pre-distortion technologies are applied to obtain highly efficient performance of the RF unit for the transmitter's high-power amplifier. We minimized the power consumption and dimensions of the BS.

The power consumption is less than 200 W. The physical volume is approx 20 liters and the weight is approx 20 kg. The Radio Frequency band of 2.3 GHz or 3.5 GHz could provide the same technologies.

This outdoor unit has a common platform and architecture for system configuration flexibility. We have developed it for the global market, while continuing to further improve it as part of the BroadOne WX series.

References

1) WiMAX Forum.
http://www.wimaxforum.org/
2) IEEE Standards Association.
http://standards.ieee.org/
3) 3GPP.
http://www.3gpp.org/
4) 3GPP2.
http://www.3gpp2.org/
5) T. Kubo et al.: A highly efficient adaptive digital predistortion amplifier for IMT-2000 base stations. Proc. of IEEE Vehicular Technology Conf., Jeju, South Korea, 2003, p.2206-2210.
6) Open Modular Computing Specifications: AdvancedTCA.
http://www.picmg.org/v2internal/newinitiative.htm
7) OPEN BASE STATION ARCHITECTURE INITIATIVE (OBSAI).
http://www.obsai.org/
8) TS-1000: TS-1000 Optical Subscriber Line Interface — 100 Mbit/s Single-fiber Bi-directional Interface by WDM — (English Edition) version 2.

Naoyuki Saitou
Fujitsu Laboratories Ltd.
Mr. Saitou received the B.E. degree in Electrical Engineering from Nihon University, Fukushima, Japan in 1993. He then joined Fujitsu Ltd., Japan, where he was engaged in development of Modulation and Demodulation units for digital microwave wireless communication systems. After that, in 2001 he moved to Fujitsu Laboratories Ltd. He has been engaged in development of the NodeB baseband processing for W-CDMA system on 3GPP.

E-mail: saitou.naoyuki@jp.fujitsu.com

Yoichi Endo
Fujitsu Ltd.
Mr. Endo graduated from Gifu National College of Technology, Gifu, Japan in 1987. He joined Fujitsu Ltd., in 1987, and was engaged in development of an SDH Microwave Radio System. Now, he is engaged in development of an RF subsystem of the mobile wireless base station.

E-mail: endo.yoichi@jp.fujitsu.com

Yasuhiro Shibuya
Fujitsu Ltd.
Mr. Shibuya graduated from Sendai National College of Technology, Sendai, Japan in 1990. He joined Fujitsu Ltd., in 1990, and was engaged in development of the FRX series SDH Microwave Radio System. Now, he is engaged in development of the radio frequency unit of the mobile wireless base station.

E-mail: shibuya.yasu@jp.fujitsu.com