Development of Prototype WiMAX Base Station

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WiMAX is the technology that enables high speed data communication while moveing an outdoor large area like a mobilephone. The authors have developed a WiMAX base station complied the International Standard IEEE16e-2005.
This base station have proprietary technologies, such as that for interference cancellation in uplink transmissions.
This paper reports on the brief description,equipment configuration, performance, and Field Evaluation of this WiMAX base station.

1. Introduction

Mobile WiMAX (Mobile Worldwide Interoperability for Microwave Access) is a mobile IP wireless solution developed based on a global standard technology. It is currently attracting attention for use in the area of next-generation mobile broadband communications where openness and low cost are required

As one of the world's leading companies in wired broadband communications technologies, Sumitomo El ectric Industries have committed itself to developing a WiMAX base station by utilizing its expertise in technologies associated with wired communications and wireless communications gained mainly through the development of personal handy-phone systems (PHS).

This paper gives the summary, system configuration and evaluation results of the new developed prototype WiMAX base station, and the results of field evaluation performed at Sumitomo Electric's Osaka Works.

2. Configuration and Specifications of Prototype Base Station

Figure 1 is the block diagram of the newly-developed WiMAX base station, and **Table 1** gives the specifications. The base station consists of a baseband block, an analog block, a global positioning system (GPS) receiver block, and a power supply block.

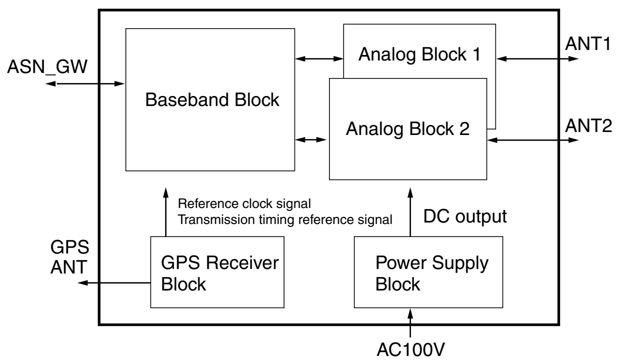

Fig. 1. Block diagram of prototype WiMAX base station

The baseband block receives IP data from upper network, processes signals and converts them to WiMAX-compliant signals, and sends these signals to the analog block. The baseband block and the analog block transmit and receive signals in the digital IQ format. The analog block converts IQ signals into intermediate-frequency (IF) vector signals by using a quadrature modulator, and converts IF signals into radio-frequency (RF) signals. Signals are then amplified to predetermined power levels by means of a power amplifier, and sent to the antenna. The analog block is made up of two sub-blocks: A direct-port sub-block and a diversity–port block. These sub-blocks support both the Matrix A and Matrix B multiple-input, multiple-output (MIMO) operations defined by the WiMAX Forum. Transmission power is 20 W (10 W × 2) at a maximum.

The power supply block generates DC power for individual blocks in the base station.

Table 1. Specifications of prototype WiMAX base station

Items	Specifications
RF Multiple Access Mode	OFDMA
Duplex Mode	TDD
Bandwidth	10MHz
Frequency Range	2550 to 2620 MHz
FFT Size	1024
MIMO	Matrix A/B
Number of Carriers	2
Transmission Power	Max. 20W (10W × 2)
Network I/F	100BASE-TX 1000BASE-T
Cooling Method	Natural air cooling
Power Supply Voltage	100V 50/60Hz
Power Consumption	Max. 250 W
Dimensions	500 × 400 × 300 (mm)
Weight	Less than 30 kg

The GPS receiver block receives GPS signals and generates reference clock signals and transmission timing reference signals within the base station and supplies these signals to the baseband block and the analog block.

3. Details of Individual Block in Base Station

3-1 Baseband block

Figure 2 is a block diagram of the baseband block. The baseband block consists of a network processor, a digital signal processor (DSP), a memory storage device, an Ethernet physical layer (Ether PHY) and a power supply.

The network processor contains a network interface block for connection with upper network, a medium access control (MAC) block for controlling WiMAX physical layer (WiMAX PHY), and an application block. The DSP, which serves as a WiMAX PHY, processes signals from the network processor, generates WiMAX-compliant signals, and transmits digital IQ signals to the analog block. The DSP incorporates Sumitomo Electric's proprietary technologies, such as that for interference cancellation in uplink transmissions, and these technologies differentiate the prototype base station from those developed by other companies.

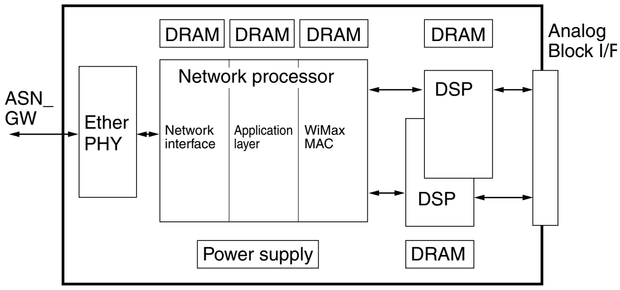

Fig. 2. Block diagram of baseband block

3-2 Analog block

Figure 3 is a block diagram of the analog block. Its major specifications are given in **Table 2**. The configuration and operation of the analog block is as follows: To support MIMO communications, the direct-port and diversity-port sub-blocks in the analog block respectively has a transmitter system and a receiver system. In the transmitter systems, digital IQ signals transmitted from the baseband block are converted into analog signals by means of a digital-to-analog converter, and then converted into IF signals by vector modulation in a quadrature modulator. The levels of the signals are adjusted by a variable attenuator, and converted into 2.6-GHz RF signals by an upconverter. These signals are amplified by the driver amplifier of the HPA block in the analog block to the level required to drive the power amplifier. They are then amplified to 10 W by the power amplifier, and are output via the transmitter/receiver switch.

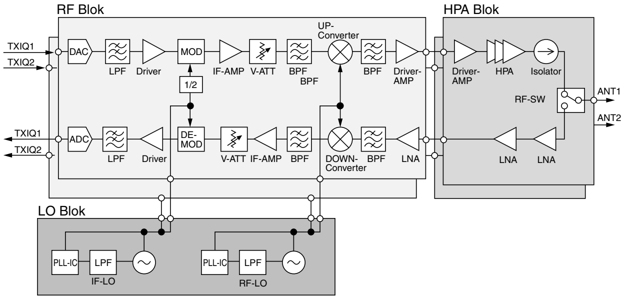

Fig. 3. Block diagram of analog block

Table 2. Specifications of analog block

Items	Specifications
Supply Voltage	RF Block : 5 V LO Block : 5 V PA Block : 28 V
Frequency Range	2550 MHz to 2620 MHz
Transmission Power	10W×2
Bandwidth	10MHz
Multiple Access Mode	TDD
Duplex Mode	OFDMA
Modulation Type	64QAM, 16QAM, QPSK
MIMO	Matrix A & Matrix B

To ensure that there is no interference with satellite communications, undesired radiated power in the 2,505-2,535 MHz band used by WiMAX base stations in Japan must be -42 dBm/MHz or less. To satisfy this requirement, the output end has a cavity bandpass filter (BPF). Thus undesired radiated power is suppressed before the output from the power amplifier is sent to the antenna.

The receiver systems operate as follows: Signals in the 2.6-GHz band received by the antenna are passed through the transmitter/receiver switch and amplified by a low noise amplifier (LNA). The prototype base station uses a single heterodyne system. The received signals pass through a BPF for image rejection and selection of system band and are converted into IF signals by a downconverter. The signals then pass through a channel-selection BPF, and the gain is adjusted by an attenuator and an IF amplifier. The signals are later converted into digital signals by an analog-to-digital converter, and then demodulated by the DSP in the baseband block.

Table 3 shows the performance of the prototype analog block. The results shown in the table satisfy the standard values specified by the standardization organizations (the Association of Radio Industries and Businesses of Japan and the WiMAX Forum).

3-3 Casing

The casing employs an all-in-one structure for easy installation and maintenance. The power amplifier and power supply module are mounted directly on radiation fins. The fins exchange heat directly with the air, enabling natural air cooling that does not require an air-cooling fan.

Table 3. RF characteristics in analog block

Items	Standard Values	Results
Relative Constellation Error	less than -18 dB QPSK-3/4 less than -24 dB 16QAM-3/4 less than -30d B 64QAM-5/6	-36 dB or more QPSK-3/4, 16QAM-3/4, 64QAM-5/6
Spectrum Mask	offset frequency: 15 MHz to 25 MHz, less than -22 dBm/MHz	-30.6 dBm/MHz
Adjacent Channel Leakage Power	less than3 dBm/9.5 MHz	-4.3 dBm
Transmission Power Range	10 dB or more	15.5 dB
Rx Maximum Input Level	-45 dBm (capable of decoding) -10 dBm (not damaged)	-45 dBm or more -10 dBm or more

4. Evaluation

The prototype WiMAX base station was evaluated for communication with mobile stations manufactured by other companies. After the basic performance and connection with other companies' mobile stations and access service network gateway (ASN-GW) equipments were tested in the laboratory, the base station underwent field tests in Sumitomo Electric's Osaka Works and on nearby public roads upon acquiring an experimental radio station license. In the field evaluation, the WiMAX base station and a base-station antenna (**Photo 1**) were set up on the top of one of the buildings in the premises of the Osaka Works. A mobile station manufactured by another company was placed in a radio wave measuring vehicle along with test equipment, and antennas for the mobile station were installed on top of the vehicle. The WiMAX base station and antenna were installed in the same manner on top of each of two other buildings within the Osaka Works' premises. The radio wave measuring vehicle was driven around to test handover between the base station and the mobile station.

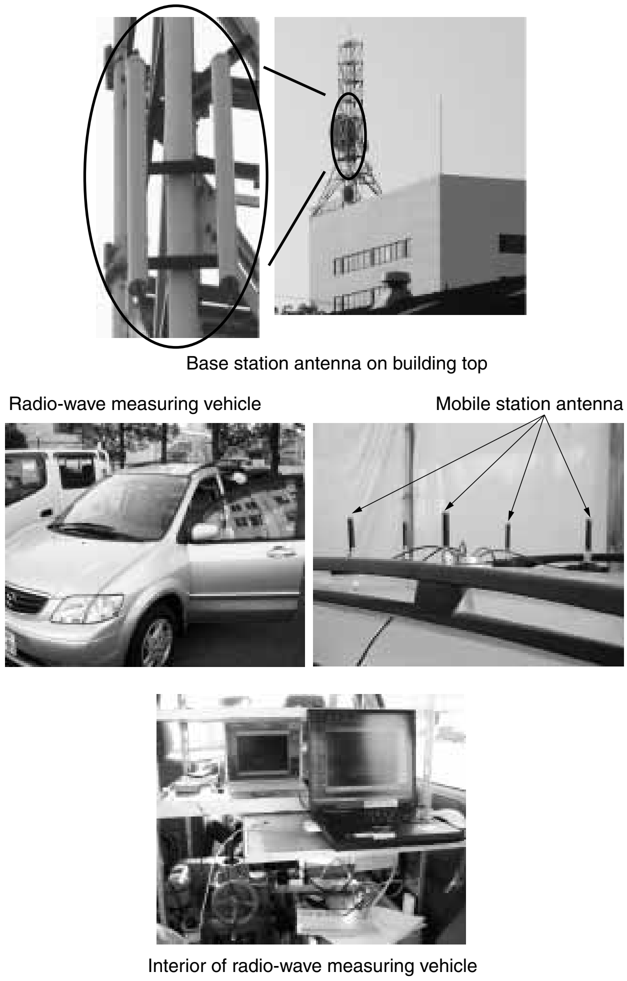

Photo 1. Radio-wave measuring vehicle (appearance and interior) and mobile station antenna

4-1 Evaluation results for basic performance

For basic performance testing, the throughput of the prototype WiMAX base station was evaluated. An evaluation was carried out with the prototype WiMAX base station and a mobile station connected to each other via a coaxial cable. In the evaluation, MIMO that uses multiple antennas for data transmission was applied. The WiMAX Forum standards define two types of MIMO operation: Matrix A and Matrix B. **Figure 4** outlines MIMO operation. In Matrix A, multiple antennas transmit identical data, thus improving radio communication quality. In Matrix B, multiple antennas each transmit different data, which improves data transmission throughput.

The evaluation was performed for each modulation matrix, and theoretical values and measured values were compared. Theoretical values were determined based on the WiMAX orthogonal frequency division multiple access (OFDMA) frame structure, frame transmission intervals, and modulation levels. **Figure 5** shows the results for the evaluation of MIMO Matrix B throughput. Throughput was measured using 1,470-byte user datagram protocol (UDP) packets. The results confirmed that the actual throughput values were close to the theoretical values.

4-2 Connection tests with other companies' mobile stations

Before a WiMAX base station can be approved by the WiMAX Forum, it must be tested for connection with the mobile stations of the three designated manufacturers (Manufacturer A, Manufacturer B and Manufacturer C).

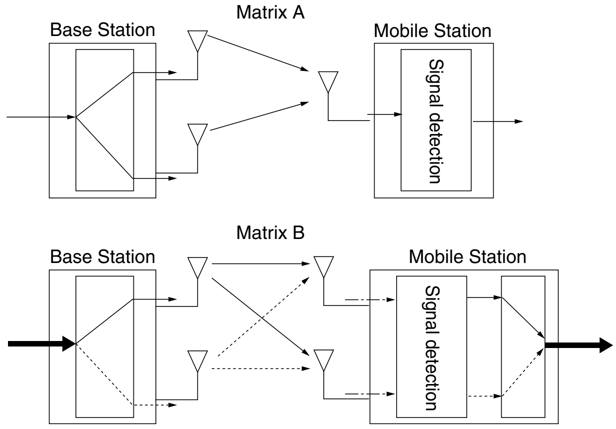

Fig. 4. Outline of MIMO operation

The test results indicated that IP connection was successful for the mobile stations of all three manufacturers, thus confirming the basic interconnection performance between the prototype WiMAX base station and mobile stations. It was tested whether or not the prototype base station supports special modes (such as Idle mode and Sleep mode), and the user authentication of Manufacturer A's mobile station.

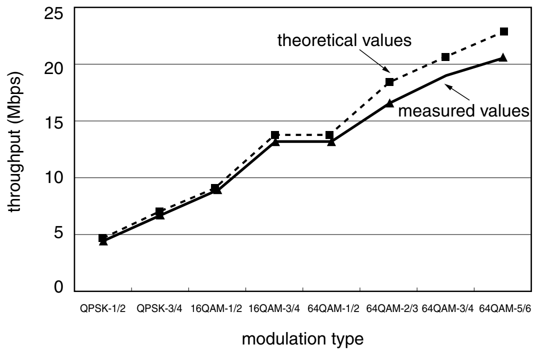

Fig. 5. Fundamental performance evaluation result

4-3 Connection tests with access service network (ASN) gateways

As shown in **Fig. 6**, a WiMAX base station is connected with the core network and with another WiMAX base stations through an access service network (ASN) gateway. An ASN gateway has many functions, such as control over the WiMAX mobile station connection, service quality control, mediation of authentication, and relaying and buffering of user data.

An ASN gateway plays an important role in the handover function, in which a WiMAX mobile station switches its wireless connection from one WiMAX base station to another adjacent WiMAX station while retaining IP communications.

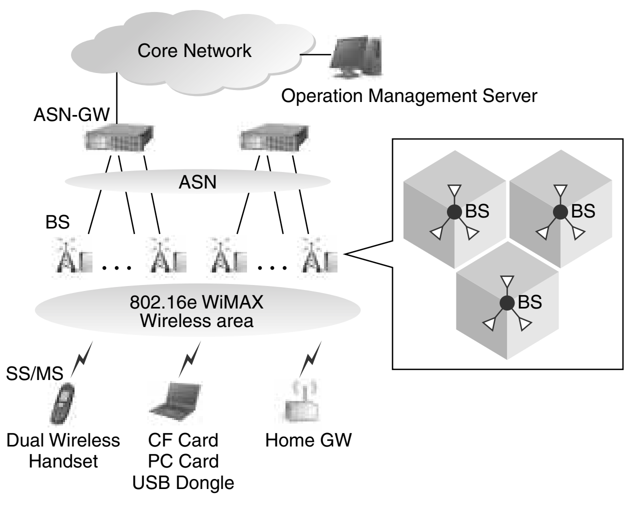

Fig. 6. WiMAX system configuration

In developing the prototype WiMAX base station, an ASN gateway that interfaces with the station was essential. However, at the start of development, no commercial or experimental ASN gateways were available. The authors therefore developed a simple ASN gateway by themselves.

At the time the prototype WiMAX base station was being developed, the development of specifications for interface between WiMAX base stations and ASN gateways was underway at the WiMAX Forum, but many parts of the specifications were yet to be determined. The authors therefore established provisional specifications for ASN gateways. Each time a part of the specifications was determined by the WiMAX Forum, the authors incorporated it into provisional specifications, to keep their specifications up to date with the WiMAX Forum specifications.

As the next step in the development of a simple ASN gateway, an interoperability testing (IOT) was performed with an ASN gateway manufactured by Manufacturer D, which is a major core network equipment manufacturer.

Although Manufacturer D's ASN gateway was in compliance with the WiMAX Forum's interface specifications, its specifications were somewhat different from those required by the authors due to differences in interpretation of the WiMAX Forum specifications and in the functions provided.

Therefore, the authors established common specifications with Manufacturer D before performing IOT. The common specifications were incorporated into the prototype base station and Manufacturer D's ASN gateway. As a result, no major changes were required during the IOT and the test was completed with minimum man-hours.

4-4 Field Evaluation

Field Evaluation (outdoor tests) were conducted to assess the handover function and adaptive modulation control function of the prototype WiMAX base station.

1) Handover function test

During a handover, a moving mobile station communicating with a base station switches from a base station transmitting low-intensity radio signals to another adjacent base station that can transmit higher-intensity radio signals while retaining communications. WiMAX uses two handover methods: One is "controlled" handover, and the other is "uncontrolled" handover. Controlled handover is a method that prevents any packet loss from occurring during switching from one base station to another base station. The ASN gateway buffers the downlink (from the ASN gateway to the mobile station) data packets to prevent any packet loss. Uncontrolled handover does not have a mechanism to prevent data packet losses. It is characterized by a simpler handover process between base station and mobile station than with controlled handover. The controlled handover function was tested in the field evaluation. **Figure 7** shows the controlled handover sequence.

To evaluate the handover performance, two base stations were installed in the premises of Sumitomo Electric's Osaka Works, and synchronization between base stations was maintained by using GPS signals. In the handover test, a car equipped with a mobile station traveled back and forth between the two base stations while transmitting streaming video. At first, multiple packets were lost. After improving buffering control between the ASN gateway and the prototype WiMAX base stations, handover operations were successfully performed without losing any data in continuous video streaming.

2) Adaptive modulation test

Adaptive modulation is a technique for dynamically switching the method of modulation to the appropriate one according to the conditions in the propagation path of radio waves. Generally, the greater the number of modulation multi-values (the number of bits that can be carried by one carrier wave), the greater the data volume that can be transmitted. But when reception is at a low level, the accuracy of demodulation also becomes low, resulting into lost packets. The basic idea is that when the quality of radio wave propagation path is low, the number of modulation multi-values is decreased to reduce the percentage of lost packets in data communications, and when the quality is high, the number of modulation multi-values is increased to improve throughput.

The prototype WiMAX base station selects an appropriate modulation method based on the quality of radio wave propagation path detected by the mobile station and fed back to the base station. In the field tests conducted by the authors to assess the performance and validity of the adaptive modulation function in the prototype WiMAX base station, measurers drove around in a car equipped with a mobile station, and collected quality indicators for radio wave communications that indicate the quality of radio wave propagation path, and also collected data on the rate of traffic received by the mobile station. The collected test data shown in **Fig. 8** confirms that by dynamically switching modulation methods according to radio wave quality, communication speeds could be improved and the stability of communication quality could be achieved.

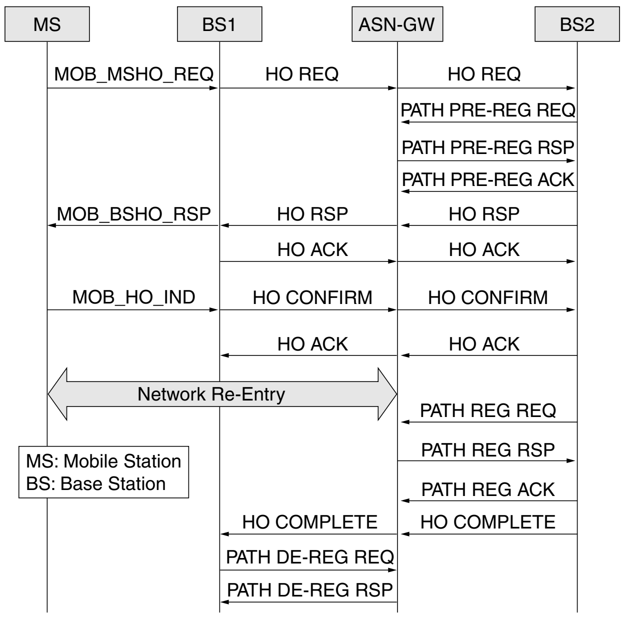

Fig. 7. Controlled handover sequence

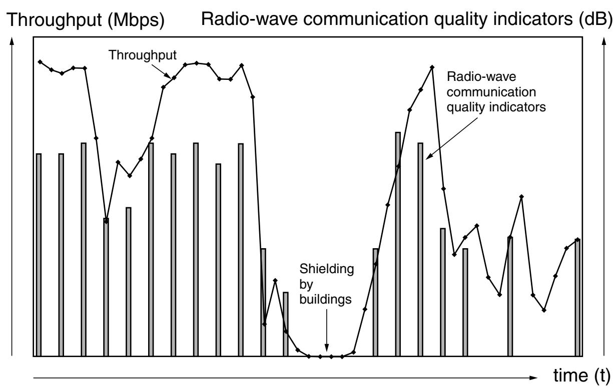

Fig. 8. Adaptive modulation measurement

5. Conclusions

This paper gives an outline, system configuration and evaluation results for the prototype WiMAX base station the authors had developed, along with the results of the field evaluation performed at Sumitomo Electric's Osaka Works. The test results confirmed that the prototype base station is capable of being practically used. In future, surveys will be performed on market trends in Japanese and international markets in order to further promote the development of WiMAX base station products that will satisfy market needs.

References

(1) IEEE Standard 802.16e-2005

(2) IEEE Standard 802.16d-2004

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