

W-CDMA Mobile Terminal

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NTT DoCoMo, Inc. started its IMT-2000 mobile communication service last October. IMT-2000, which uses the W-CDMA system, is a global standard of 3rd generation mobile communication systems. Fujitsu was selected to be one of the developers of IMT-2000 together with NTT DoCoMo, Inc. in 1999 and since then has developed various commercial W-CDMA mobile terminals. We have pursued this development by drawing on our expertise in technologies such as radio, baseband signal processing, and hardware/firmware. One of the products of our development efforts, the FOMA F2611, is targeted for SOHO (Small Office Home Office) and was released in April. This paper introduces the FOMA F2611.

1. Introduction

One year has passed since NTT DoCoMo, Inc. first started its FOMA mobile multimedia communication service with IMT (International Mobile Telecommunication)-2000. At present, several kinds of mobile terminals are available. Fujitsu also released FOMA F2611 this April. This is the first terminal that supports 384 kb/s packet communication in the uplink and downlink, making it suitable for mobile multimedia communications. A major feature of this terminal is that it supports Internet services for multiple PCs, because it has a router in its main body.

Section 2 of this paper outlines the terminal, Section 3 outlines the common air interface, Section 4 describes the terminal's major functions, and Section 5 describes the terminal's performance.

2. Mobile terminal

The FOMA F2611 is based on the SOHO (Small Office Home Office) concept and supports 384 kb/s packet communication for the uplink and

downlink. It features a router and four 10base-T ports. By using a FOMA network, users can construct a simple LAN and connect to the Internet at a temporary office or outdoors without the need to lay cables. The terminal has a speech handset that is linked to the terminal by Bluetooth. The antenna for the Bluetooth link is inside the main body, and the handset will function up to several meters from the FOMA F2611 when there are no obstacles between them. The FOMA F2611 also has a 100 VAC power supply so it can be used in a fixed situation without batteries. **Figure 1** shows the FOMA F2611, and **Table 1** shows its main specifications.

Figure 2 shows the block diagram. The terminal includes an antenna, a duplexer, PA (power amplifier), a transmitter, a receiver, a frequency synthesizer, a baseband block, CPU block, and a router. Each part is described in Section 4.

The major communication functions are AMR (Adaptive Multi Rate) voice communication, high-speed packet communication, unrestricted digital data communication, and multi-access service.



Figure1
FOMA F2611.

Table 1
Terminal main specifications.

Item	F2611
Weight (body + handset + battery)	About 720 g
Size (W × D × H)	191 mm × 151 mm × 39.5 mm
Call time (handset)	About 120 min
Standby time (handset)	About 30 h
Battery	Lithium ion
Major functions	10BASE-T × 4, USB, router (IP protocol)

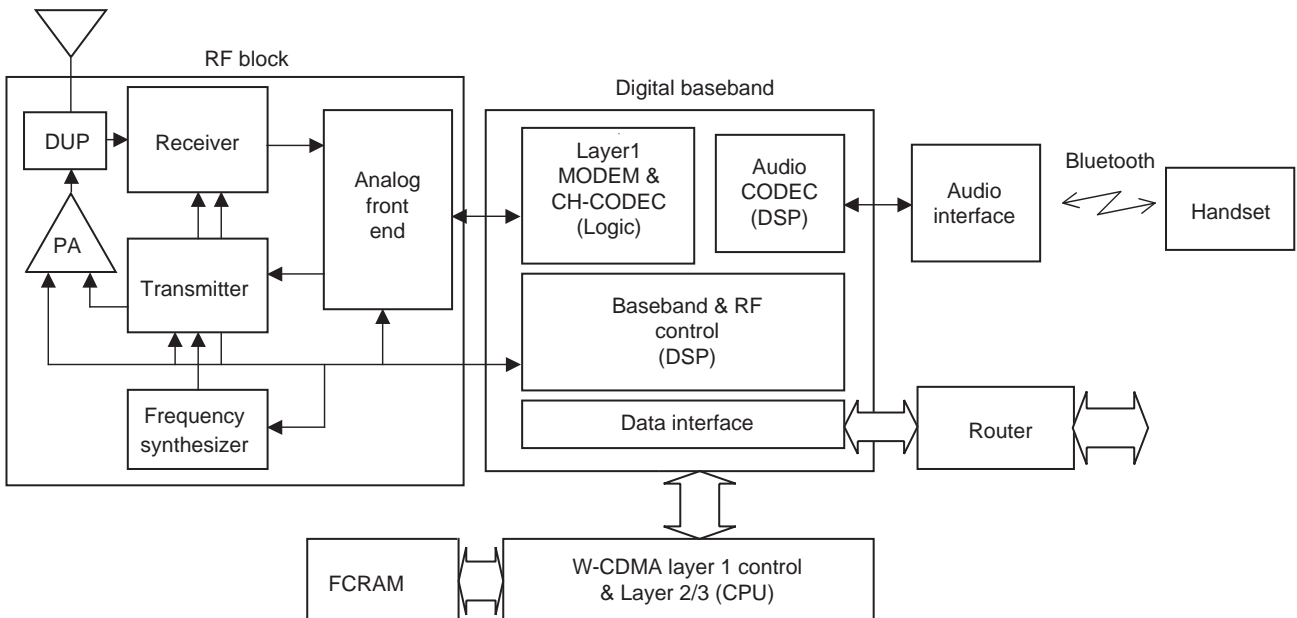


Figure 2
Block diagram.

Because AMR voice communication uses GSM-AMR coding/decoding, it has a high voice quality. The packet communication enables data transmission at up to 384 kb/s in the uplink and downlink and smooth Internet access. Unrestricted digital data communication can supply high-quality 64 kb/s data communication. The multi-access service can simultaneously supply multiple communication services. For example, an Internet service can be used even when the speech func-

tion is in use.

3. Common air interface

The FOMA F2611 common air interface is shown in **Table 2**. The frequency band is 1920 to 1980 MHz in the uplink and 2110 to 2170 MHz in the downlink. The bandwidth is 5 MHz, and the maximum information rate is 384 kb/s for the uplink and downlink.

Table 2
Common air interface.

Items		Specification
Frequency	Uplink	1920 to 1980 MHz
	Downlink	2110 to 2170 MHz
Spreading		Direct sequence
Chip rate		3.84 MHz
Symbol rate		15 to 960 ksp/s
Information rate		Up: Max 384 kb/s, Down: Max 384 kb/s
Bandwidth		5 MHz/carrier
Modulation	Information	Up: BPSK, Down: QPSK
	Spreading	Up: HPSK, Down: QPSK
Waveform shaping		Root Nyquist $\alpha = 0.22$
Transmission power	Speech	0.125 W
	Data	0.25 W

4. Functions

This section describes the main functions of the FOMA F2611.

4.1 Antenna and RF block

The antenna is a rotatable $\lambda/4$ monopole. The RF block consists of a duplexer, transmitter, receiver, and frequency synthesizer. The transmitter includes a GaAs FET power amplifier, a variable gain amplifier that can be controlled in 1 dB steps for TPC (Transmission Power Control), an up-converter, and a quadrature modulator. The TPC dynamic range is better than 70 dB. The receiver includes an LNA (Low Noise Amplifier), SAW (Surface Acoustic Wave) filter, down-converter, and quadrature detector. Wave shaping is done using the SAW filter. The image rejection filter is designed to minimize the group delay in order to maintain the performance. The receiver has an AGC (Automatic Gain Control) function that is controlled by a signal from the baseband block. The AGC dynamic range is 80 dB. The reference frequency synthesizer that supplies local signals to the transmitter and the receiver uses a 12.8 MHz TCXO (temperature compensated crystal oscillator). The TCXO is controlled to keep the frequency error within ± 0.1 ppm by AFC¹⁾ (Au-

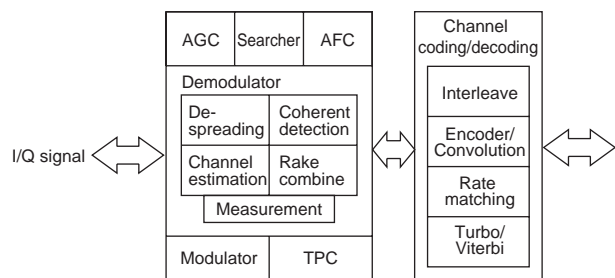


Figure 3
Baseband block.

tomatic Frequency Control) to synchronize with base stations. AFC is controlled by a signal from the baseband block.

4.2 Baseband block

The baseband block includes a modulator, searcher, demodulator, channel coding/decoding, AFC, AGC, TPC, and a measurement block. The baseband block is processed by hardware and firmware. Each part is optimized to obtain good performance, and a DSP is used to adapt to specification changes. **Figure 3** shows the block diagram.

1) Modulator

The modulator outputs a modulated signal to the RF block. It is composed of the HPSK (Hybrid PSK) modulator, a spreading block, BTF (Binary Transversal Filter), and other components. The BTF is optimized to realize good transmission performance and minimize the hardware scale.

2) Searcher

The searcher is a function for synchronizing with a base station. It is composed of a cell searcher²⁾ and a path searcher. The cell searcher has the functions for initial acquisition of a spreading code and observation of the neighborhood base stations using PCCPCH (Primary Common Control Physical Channel)/SCH (Synchronization Channel). The hardware scale has been greatly reduced by using the memory store method.³⁾ The path searcher detects the delay profile and path timing to maintain synchronization with a base

station using CPICH (Common Pilot Channel) and assigns the detected path timing to each finger of the de-spreading block. It can operate in fast acquisition mode or in steady mode, and its processing is performed by hardware and firmware.

3) Demodulator

The demodulator⁴⁾ is composed of a de-spreader, a channel estimator, a coherent detector, a RAKE combiner, and a level measurement block. Its processing is performed by hardware and firmware and controlled by the DSP. Time division processing is used to reduce the hardware scale.

The received signal is de-spreaded at the timing detected by the path searcher. The channel estimation block generates a reference signal for coherent detection. The demodulator can use the CPICH and pilot symbols, and it has an averaging function to improve the SNR (Signal to Noise Ratio). The de-spreaded signal is coherently detected by the reference signal. After each coherent detected signal is combined in the RAKE combine block, the demodulated signal is output for channel coding/decoding. The measurement block performs SIR (Signal to Interference Ratio) measurement, RSCP (Received Signal Carrier Power) measurement of the DPCH and CPICH, and RSSI (Received Signal Strength Indicator) measurement. The processing for these measurements is done by firmware.

Also, since there is a degradation of performance by multipath interference in the W-CDMA system, a multipath interference reduction method⁵⁾ has been investigated to improve the receiver performance. A channel estimation improvement⁶⁾ method has also been investigated.

4) RF controller (AFC, AGC, TPC, APC)

The RF controller is composed of the AGC, AFC, TPC and APC (Automatic Power Control) blocks. Because the AGC has an initial acquisition mode and a stable mode, it realizes fast acquisition and good stability. The AFC has a fast acquisition mode and steady mode to keep the frequency error to within ± 0.1 ppm. The frequency

error is detected by a hardware frequency discriminator, and the other functions are provided by the DSP. The TPC minimizes the process delay. The step width of transmission power is accurately set to 1 dB by the APC and the use of a correction table.

5) Channel coder/decoder

The Channel Coder/Decoder performs service multiplexing and error correction/detection. The service multiplexer consists of a rate matcher, which assigns different quality services to the same physical channel according to a repetition or a puncture, and a transport channel multiplier, which multiplies services. Error correction is done by a CRC detector, Viterbi decoder, Turbo decoder, and interleaver. The Turbo decoder adopts the Sub-log-Map method, and the memory scale is reduced by 40% by using the Stepping Stone method.^{7),8)}

4.3 Controller

The controller has a Micro Control Unit main processor, which contains program modules for Layer 3 functions such as Radio Resource Management, Radio Resource Control, and Mobility Management as well as Layer 2 functions of MAC (Media Access Control), RLC (Radio Link Control), and hardware drivers as a Layer 1 controller. As a Layer 1 hardware driver, the controller provides Layer 1 services to the upper stratum, for example, hand over control, error correction/detection control, and spreading/de-spreading control with outer/inner transmission power control. To control the outer loop transmission power, the controller implements an efficient target SIR management algorithm in cooperation with firmware in the DSP, which controls the target SIR. This method reduces the transmission power to the minimum needed for the required transmission quality and transmission data rates.⁹⁾

For the external interface, the controller has USB revision 1.1 and four 10BASE-T ports. Moreover, the FOMA F2611 handset is linked to the main body by Bluetooth.

4.4 Router

The FOMA F2611's router function makes it suitable for use in various business applications. The routing protocol is for IP (RIP, RIP2, static). The WAN protocol is PPP. A DHCP server and proxy DNS function are supported. Also, the router has security functions such as PAP/CHAP authentication, password management, and an IP filter. Up to four PCs can be directly connected to the FOMA F2611 since it has four LAN ports.

5. Performance

This section looks at the performance of the FOMA F2611. The transmitter and receiver performances were measured according to the 3GPP TS34.121¹⁰ test procedure. This section also gives the results of a field trial.

5.1 Transmission spectrum

The 384 kb/s transmission spectrum (ACLR performance) is shown in **Figure 4**. This high

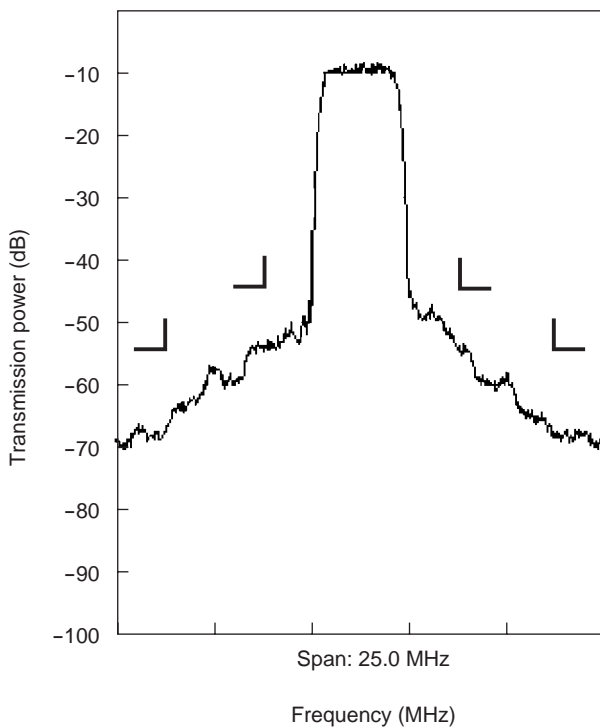


Figure 4
Transmission spectrum.

level of performance was obtained by optimizing the modulator structure and the transmitter. The margin is more than 10 dB, and the center frequency is 1922.6 MHz.

5.2 Receiver performance

Figure 5 shows the BLER (Block Error Rate) performance of the DPCH. The moving speed was 120 km/h, the power ratio of the received signal to the interference signal was 6 dB, the multipath number was 4, and the data rate was 384 kb/s. The vertical axis shows the BLER, and the horizontal axis shows the DPCH/I_{or}, where I_{or} is the total power of all physical channels. The good performance shown in this figure was obtained by optimizing the number of RAKE fingers and the channel-estimation averaging period. The margin is more than 1 dB.

5.3 Field test

We conducted a field test to determine how well the mobile terminal is controlled and determine the receiver performance in a practical

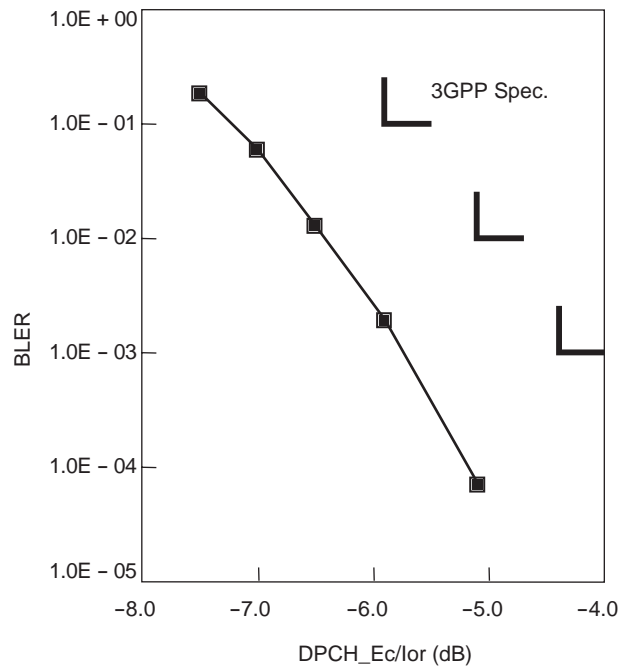


Figure 5
BLER performance.

environment. The test was conducted in a city with many buildings, and the mobile terminal was positioned where it could simultaneously receive radio signals from multiple base stations so we could test for high-quality soft handover. We set the packet communication rate to 384 kb/s and controlled the terminal with TPC to keep the BLER to within 5%. **Figure 6** shows the result of the test. The base station number shows the soft handover status, and the SIR and received power show the propagation environment. The BLER corresponding to the propagation environment is shown at the bottom. The vertical axis is in dB for the SIR and dBm for the received power. The horizontal axis is in seconds. This figure shows how the SIR and BLER change with the propagation environment. The BLER of the FOMA F2611 is steady, even when it is moving, so it is suitable for use as a terminal for SOHO.

6. Conclusion

The FOMA F2611 is new-concept mobile terminal suitable for the needs of a multimedia mobile communication system. It makes it possible to quickly and easily construct an Internet-ready LAN that links up to four PCs without the need to lay any cables. Fujitsu is continuously improving its technology to provide mobile terminals that satisfy its customers' needs.

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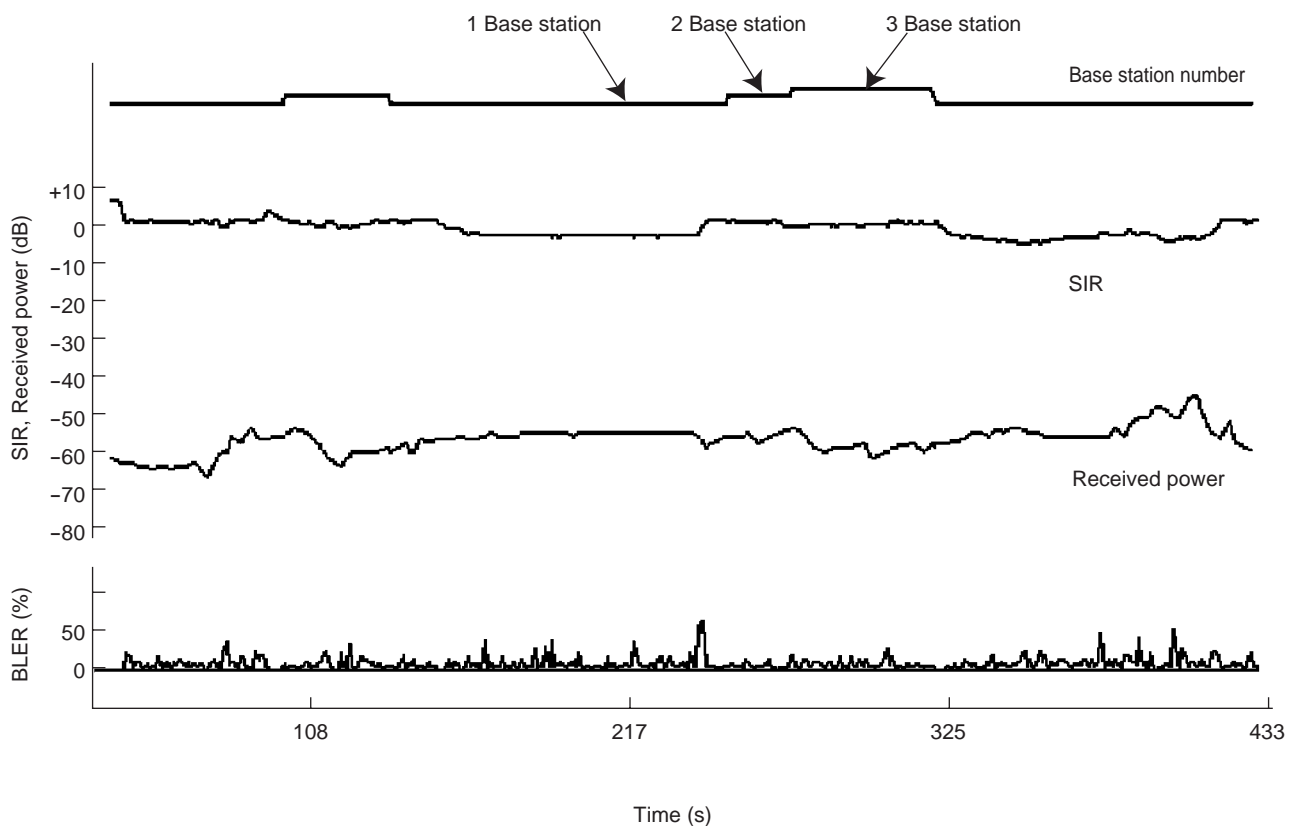


Figure 6
Field test.

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