Special Articles on HSDPA

HSDPA Terminal Development and Radio Transmission Performance

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Two new HSDPA compatible mobile terminals have been developed for the HSDPA service commenced in August 2006, one with new functions (music download, etc.) and designed for high-speed communications, and the other a card-type terminal model with corporate users in mind. This article outlines these terminals and describes the radio transmission throughput performance based on field experiments.

Technology Reports

1. Introduction

The FOMA service is subject to demands for greater capacity and communication at higher speed for such applications as the sending/receiving large-volume video movies, music download services, viewing of Websites for PC use, and connection to corporate LANs, and as such requires improved efficiency in radio usage and greater transmission speed. Under these circumstances, DoCoMo commenced a commercial High Speed Downlink Packet Access (HSDPA) service in August 2006 to reduce cost, increase speed, and reduce delays. This service made it possible to provide high-speed packet communications with a data download speed of up to 3.6 Mbit/s.

In conjunction with commencement of this service, a telephone-type mobile terminal (FOMA N902iX HIGH-SPEED, **Photo 1**) compatible with a music program download service (Music Channel), a service for downloading music contents,

Photo 1 N902iX HIGH-SPEED

Photo 2 M2501 HIGH-SPEED

and 5MB high-capacity i-motion, and a card-type mobile terminal for corporate use (FOMA M2501 HIGH-SPEED, **Photo 2**) compatible with HSDPA/3G roaming/Global System for Mobile communications (GSM)[*1] have been developed.

This article outlines the major points in the development of each of HSDPA mobile terminals, and describes the radio transmission throughput[*2] performance based on the field experiments.

2. HSDPA Mobile Terminal Categories and Maximum Throughput

The 3rd Generation Partnership Project (3GPP) classifies HSDPA mobile terminals into 12 categories according to data transmission capability. **Table 1** [1] shows the HSDPA mobile terminal categories. The maximum number of received codes is the number of multiplexed codes on the High Speed Physical Downlink Shared CHannel (HS-PDSCH) [2] that receives data, and minimum Transmission Time Interval (TTI) is the minimum time interval allocated to the mobile terminal for receiving data. An interval of 1 requires operation at a minimum TTI of 2 ms. The maximum buffer size for Hybrid Automatic Repeat reQuest (H-ARQ)[*3] is determined in consideration of signals received prior to resend and resent signals, and is the maximum number of bits in the receive buffer with demodulation [3]. 16 Quadrature Amplitude Modulation (16QAM)[*4] is an essential

Table 1 HSDPA mobile terminal categories

Category	Maximum number of received codes	Minimum TTI	Maximum number of received bits/TTI	Maximum H-ARQ buffer size	16QAM compatibility	Maximum throughput (Mbit/s)
Category 1	5	3	7,298	19,200	Compatible	1.2
Category 2	5	3	7,298	28,800	Compatible	1.2
Category 3	5	2	7,298	28,800	Compatible	1.8
Category 4	5	2	7,298	38,400	Compatible	1.8
Category 5	5	1	7,298	57,600	Compatible	3.6
Category 6	5	1	7,298	67,200	Compatible	3.6
Category 7	10	1	14,411	115,200	Compatible	7.2
Category 8	10	1	14,411	134,400	Compatible	7.2
Category 9	15	1	20,251	172,800	Compatible	10.2
Category 10	15	1	27,952	172,800	Compatible	14.0
Category 11	5	2	3,630	14,400	Not compatible	0.9
Category 12	5	1	3,630	28,800	Not compatible	1.8

*1 GSM: A Second-Generation mobile communication system used widely around the world, especially in Europe and Asia.

*2 Throughput: Effective amount of data transmitted without error per unit time.

*3 H-ARQ: Technology combining Automatic Repeat Requests (ARQ) and error correction codes to increase error correction capacity during repeats, and reduce the number of repeats. The retransmitted packet from BTS and the packet previously received are combined thus improving reception quality and providing higher efficiency in transmission.

requirement for Categories 1–10. The Maximum Throughput for Categories 6, 8, 10, and 12 is 3.6, 7.2, 14, and 1.8 Mbit/s, respectively.

As shown in Table 1, as the maximum number of received codes increases or as minimum TTI decreases, maximum throughput increases. In association with this increase, the maximum buffer size for H-ARQ increases, and since the signal processing function becomes more complex, higher capability is required of the mobile terminal. To ensure a balance between achievable throughput and the complexity of signal processing, DoCoMo commenced its service with Category 6, having a throughput of 3.6 Mbit/s. Compatibility of the mobile terminal with Category 6 requires such performance as the capability to demodulate up to five code-multiplexed signals, high-speed signal processing at a minimum TTI of 2 ms, and compatibility with 16QAM.

The following chapter outlines the N902iX HIGH-SPEED and M2501 HIGH-SPEED developed as HSDPA mobile terminals compatible with Category 6.

3. Overview of HSDPA Mobile Terminals

3.1 N902iX HIGH-SPEED

Table 2 shows the basic specifications. The N902iX HIGH-SPEED mobile terminal is based on the N902i, and shares, as much as possible, the component layout and chassis components. High-speed packet communication is facilitated by changing the communications CPU and addition of an HSDPA-compatible accelerator[*5]. A dedicated memory (3.75 Gbit) has been added for the storage of content downloaded from the Music Channel and music contents downloads. Power consumption has increased somewhat due to the addition of new hardware, but improvements made to the sleep function of the application CPU have resulted in a standby/talk time equal to or better than that of the N902i.

The major development points are as follows:

- Music Channel application
- Music player
- Compatible with i-motion (up to 5 MB)

Downloaded music contents, pieces of music stored on

Table 2 Basic specifications of N902iX HIGH-SPEED

	N902iX HIGH-SPEED	N902i (reference)
Radio frequency band	2 GHz/800 MHz	2 GHz/800 MHz
Send-receive frequency interval	190 MHz (when used at 2 GHz band) 45 MHz (when used at 800 MHz band)	190 MHz (when used at 2 GHz band) 45 MHz (when used at 800 MHz band)
Data transmission speed	Send Up to 384 kbit/s Receive Up to 3.6 Mbit/s	Send Up to 64 kbit/s Receive Up to 384 kbit/s
Mobile terminal capability with HSDPA	Category 6	—
Size	106×51×25 mm	106×51×25 mm
Weight	133 g	127 g
Continuous standby time	Approximately 520 hours (stationary) Approximately 390 hours (in transit)	Approximately 520 hours (stationary) Approximately 390 hours (in transit)
Continuous talk time (voice/videophone)	Approximately 150 minutes/100 minutes	Approximately 140 minutes/90 minutes
LCD	Main LCD 2.5 inch, 240×345 dots Sub LCD 1.0 inch, 120×90 dots	Main LCD 2.5 inch, 240×345 dots Sub LCD 1.0 inch, 120×90 dots
Main camera	2,000,000 pixels, Super CCD Honeycom	2,000,000 pixels, Super CCD Honeycom
Memory size for i-motion	5 MB (both streaming and downloading)	500 kB (downloading), 2 MB (streaming)
Memory size for music channel	25 MB	—
Encoding system for full music pieces	HE-AAC Enhanced aacPlus	—

Enhanced aacPlus: An audio compression and encoding scheme providing similar sound quality at a lower bit rate than HE-ACC.
HE-ACC: An audio compression and encoding scheme providing similar sound quality at approximately half the bit rate of MPEG-4 ACC. An enhanced MPEG-4 ACC specification.

*4 16QAM: A digital modulation method that allows transmission of 4 bits of information simultaneously by assigning one value to each of 16 different combinations of amplitude and phase.

*5 Accelerator: A peripheral or additional device used in improving such processing performance as CPU performance and screen display. In this article, it refers to an additional LSI used to improve processing speed of the communications CPU.

Table 3 Basic specifications of M2501 HIGH-SPEED

	M2501 HIGH-SPEED	F2402 (reference)
Radio frequency band (W-CDMA)	2 GHz/800 MHz	2 GHz
Radio frequency band (GSM)	900 MHz, 1,800 MHz, 1,900 MHz	—
Send-receive frequency interval	190 MHz (when used at 2-GHz band) 45 MHz (when used at 800-MHz band)	190 MHz (when used at 2-GHz band) 45 MHz (when used at 800-MHz band)
Data transmission speed	Send Up to 384 kbit/s Receive Up to 3.6 Mbit/s	Send Up to 384 kbit/s Receive Up to 384 kbit/s
Mobile terminal capability with HSDPA	Category 6	—
Interface	PCMCIA Type II	PCMCIA Type II
Size	Approximately 54.0 mm×130.0 mm×18.0 mm	Approximately 54.0 mm×120.8 mm×12.4 mm
Weight	Approximately 70 g	Approximately 50 g
Compatible operating systems	Windows® XP Professional/Home Edition Windows2000 Professional	WindowsXP Professional/Home Edition Windows2000 Professional Windows98/98SE, WindowsMe
Power supply voltage	DC5.0V	DC5.0V

PCMCIA: Personal Computer Memory Card International Association. An entity established to regulate standards for IC cards connected to personal computers.
Windows®: A registered trademark or trademark of the Microsoft Corporation of the USA and other countries.

miniSD memory cards with the Secure Digital (SD)-Binding[*6] [4] function, and music created from commercial CDs using ripping software (SD-Audio) can be replayed seamlessly with the music player, and music functions are further strengthened to include the preparation of playlists and display of jackets and song lyrics. Moreover, enhancement of the range request[*7] function [5] allows reacquisition of content following failure or interruption during downloads from the Music Channel (25 MB) and music contents downloads (up to 5 MB), with i-motion downloads (up to 5 MB) also possible.

3.2 M2501 HIGH-SPEED

Table 3 shows the basic specifications. In addition to high-speed packet communication with HSDPA, the M2501 HIGH-SPEED is the first FOMA card-type mobile terminal compatible with international roaming, and since it is compatible with both Universal Mobile Telecommunications System (UMTS)[*8] and GSM/General Packet Radio Service (GPRS)[*9], it is usable in more than 132 countries. The internal antenna is multi-band compatible: 800 MHz and 2,100 MHz for HSDPA/UMTS, and 900 MHz, 1,800 MHz, and 1,900 MHz for GSM/GPRS, respectively. The utility software provided supports voice communication, a phonebook function, and communications status display, and various network service settings such as an answer-phone service are available to improve usability.

4. HSDPA Handover and Mobile Terminal Throughput Performance

4.1 HSDPA Handover

With HSDPA, Adaptive Modulation and Coding Scheme (AMCS) is adopted to adaptively change transmission data from the Base Transceiver Station (BTS) according to the received power condition, and technologies such as H-ARQ to retransmission and combining the packet data on the mobile terminal, and BTS scheduling to control the allocation of users are adopted to improve the efficiency of data transmission [6]. Since these technologies require constant one-to-one connection between the HSDPA mobile terminal and the BTS, Hard HandOver, in which the destination BTS is selected each time the cell changes, is essential in addition to Soft HandOver[*10] adopted by the conventional W-CDMA system.

The HSDPA handover procedure is as follows:

1) The quality level of the Common PIlot CHannel (CPICH) sent at fixed power from a cell in the vicinity is measured by the mobile terminal.
2) If a CPICH has a quality level exceeding a fixed threshold (reported by the network as a parameter) in relation to the handover source cell CPICH quality level, the relevant cell

*6 SD-Binding: Technology for embedding conditions for extracting the encoding key (FOMA card (UIM) and mobile terminal model information) when encoding and storing downloaded content in SD memory. Only used when decoding is compatible with encoding conditions.
*7 Range Request: A method of part-acquisition on HTTP. Used when a download is resumed after being interrupted, or when part of a file is acquired.
*8 UMTS: The Third-Generation European mobile communications system. Either the W-CDMA adopted by DoCoMo or the TD-CDMA unique to Europe. This card-type terminal adopts the W-CDMA system.
*9 GPRS: A packet-switching service available on GSM network.

is reported to the Radio Network Controller (RNC)[*11]. (If multiple cells exceed the threshold value, the cell with the highest quality level is reported.)

3) The RNC sets up the handover destination cell based on the report sent from the mobile terminal, and issues a handover notification to the mobile terminal.
4) The mobile terminal receiving the handover notification disconnects from the handover source cell and connects to the handover destination cell.

In accordance with the procedure above, the HSDPA mobile terminal selects and reports on cells having a satisfactory reception level, and repeats handover in accordance with instructions issued from the RNC to move between cells.

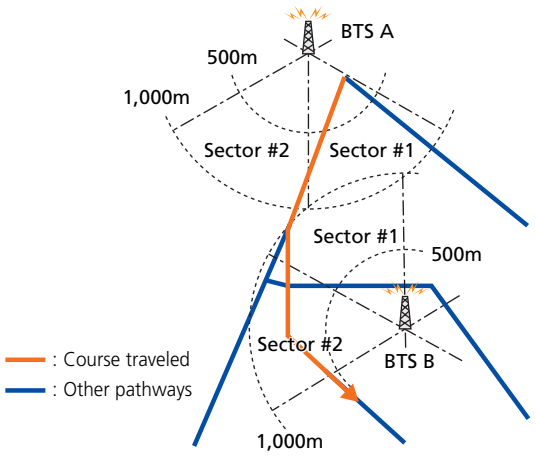

Figure 1 Course between BTS A and B

4.2 HSDPA Mobile Terminal Throughput Performance

HSDPA mobile terminal throughput performance when moving from BTS to BTS have been measured in an actual field environment. A 2.5-km course between BTS A and B was traveled at a speed of 30 to 40 km/h (**Figure 1**). **Figure 2** shows the throughput performance over time for the N902iX HIGH-SPEED and the conventional W-CDMA terminal. The mobile terminals were connected to a PC, and after accessing a content server, a large file was downloaded using File Transfer Protocol (FTP)[*12], and the Transmission Control Protocol (TCP) layer throughput averaged over 4 seconds measured. The blue, yellow, red, and green lines in the graph respectively indicate throughput when connected to BTS A sectors #1 and #2, and BTS B sectors #1 and #2, while the purple dashed line indicates throughput for the conventional W-CDMA terminal. **Figure 3** shows the

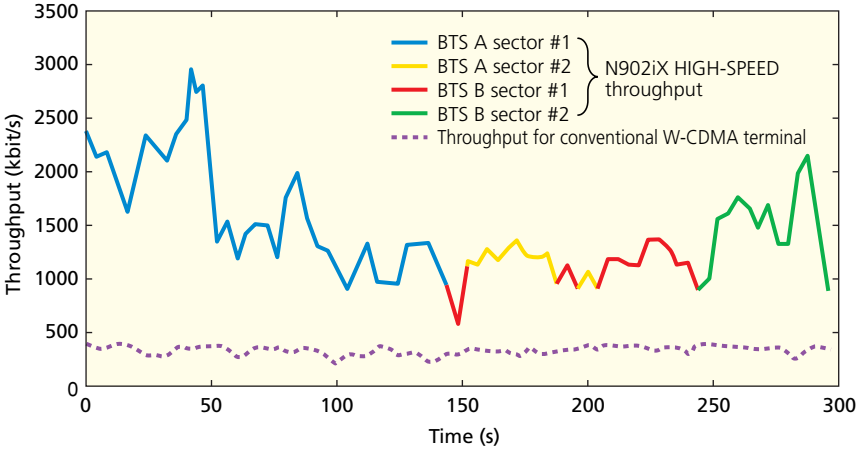

Figure 2 Changes in throughput performance over time

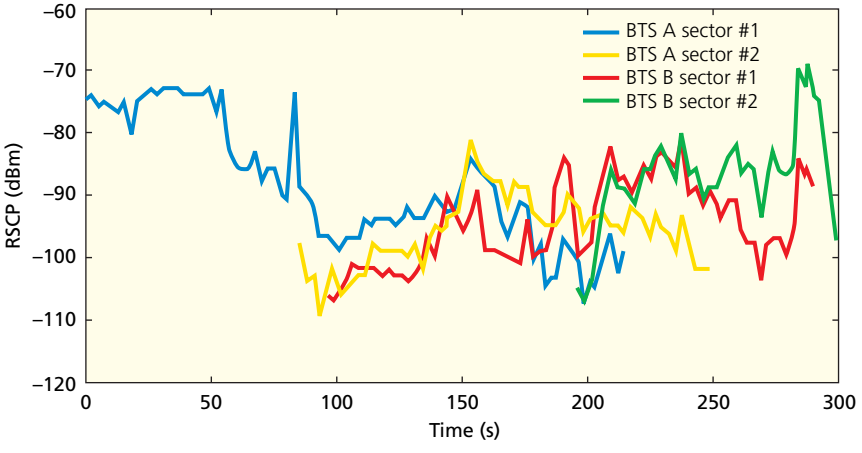

Figure 3 Changes in RSCP characteristics over time

*10 Soft HandOver: Receiving, selecting, and synthesizing of signals from multiple base stations connected simultaneously to ensure the switching of cells without interrupting communication.
*11 RNC: A device defined by the 3GPP for performing radio circuit control and mobility control in the FOMA networks.
*12 FTP: A protocol commonly used for file transfer on TCP/IP networks such as the Internet and intranets.

changes in Received Signal Code Power (RSCP)[*13] over time for sectors #1 and #2 of BTS A and B.

In the first stage (0–50 seconds) of the measurement course, that is, under line-of-sight propagation conditions for BTS A sector #1, the characteristics were satisfactory (1.5–2.9 Mbit/s). However, as the mobile terminal was moved, the signal power (or interference waveforms) from other cells increased and throughput deteriorated (50–140 seconds). The received signal level for BTS B sector #1 exceeded that of BTS A sector #1 at approximately 140 seconds, and while throughput temporarily spiked downwards, transition of the destination BTS improved the received signal level. After 150 seconds as well, Hard HandOver (in which the destination BTS is switched in response to the received level from the BTS) was repeated, and movement continued with varying throughput according to the radio environment. Since the transmission power of the conventional W-CDMA terminal is controlled to maintain a constant level of received signal quality, throughput remained constant irrespective of the received signal level from the BTS. Average throughput obtained with the N902iX HIGH-SPEED as used on this course was 1.4Mbit/s, an improvement by a factor of approximately 3.8 times compared with the conventional W-CDMA terminal.

5. Conclusion

This article outlined and described the characteristics of the N902iX HIGH-SPEED and M2501 HIGH-SPEED developed as mobile terminals for HSDPA service commenced in August 2006, as well as describing the details of HSDPA handover, and clarifying the throughput performance at handover based on the field experiment using the N902iX HIGH-SPEED. Based on the figures for average throughput obtained by the testing station on a test course, the N902iX HIGH-SPEED was found to improve throughput by a factor of approximately 3.8 times compared with the conventional W-CDMA terminal. Compatibility with higher HSDPA categories for greater speed, the introduction of High Speed Uplink Packet Access (HSUPA) which is characterized by higher uplink speed are now being investigated.

REFERENCES

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*13 RSCP: The received power measured at a mobile terminal. An index of signal sensitivity at the mobile terminal.