**Special Article on Dual-band 800MHz/1.5GHz System**

# Mobile Terminals

*Koji Chiba, Isao Hirakodama, Toru Takahashi,*
*Naoki Naruse and Hisashi Yoshinaga*

*This article reviews the functions and the performance of a mobile terminal, based on the dual-band 800MHz/1.5GHz system launched by NTT DoCoMo in November 2001.*

## 1. Introduction

Since the commencement of mobile phone services based on the Personal Digital Cellular telecommunication system (PDC) [1] in March 1993, subscribers to NTT DoCoMo's mobile phone service has steadily increased to date. Because of the frequency saturation by increasing number of subscribers, NTT DoCoMo has been extending the frequency of the system including the terminals. **Figure 1** shows the number of subscribers to NTT DoCoMo's mobile phone service (including analogue phone service subscribers) and the measures taken by NTT DoCoMo to improve the frequency usage.

NTT DoCoMo launched its PDC service in the digital 800MHz band in March 1993 [2], followed by its PDC service in the 1.5GHz band in April 1994 [3]. It introduced a half-rate service to raise the efficiency of frequency usage in December 1995 [4], and changed analogue band into digital in October 1996 [5]. In the same period, NTT DoCoMo expanded the subscriber capacity extending the digital band. However, as subscribers continued to grow in number in subsequent years, it performed frequency extension in a new frequency band in November 1998 and June 2000 [6]. **Figure 2** shows the frequency allocation according to NTT DoCoMo's current PDC system. The extended frequency bands in Figure 1 marked ①-⑥ correspond to their counterparts marked ①-⑥ respectively in Figure 2.

As subscribers to NTT DoCoMo's PDC services continued to rise in number in the following years, the traffic overconcentration of traffic in the 800MHz band, especially in central Tokyo required an urgent solution. In order to solve this issue, NTT DoCoMo launched the dual-band 800MHz/1.5GHz system

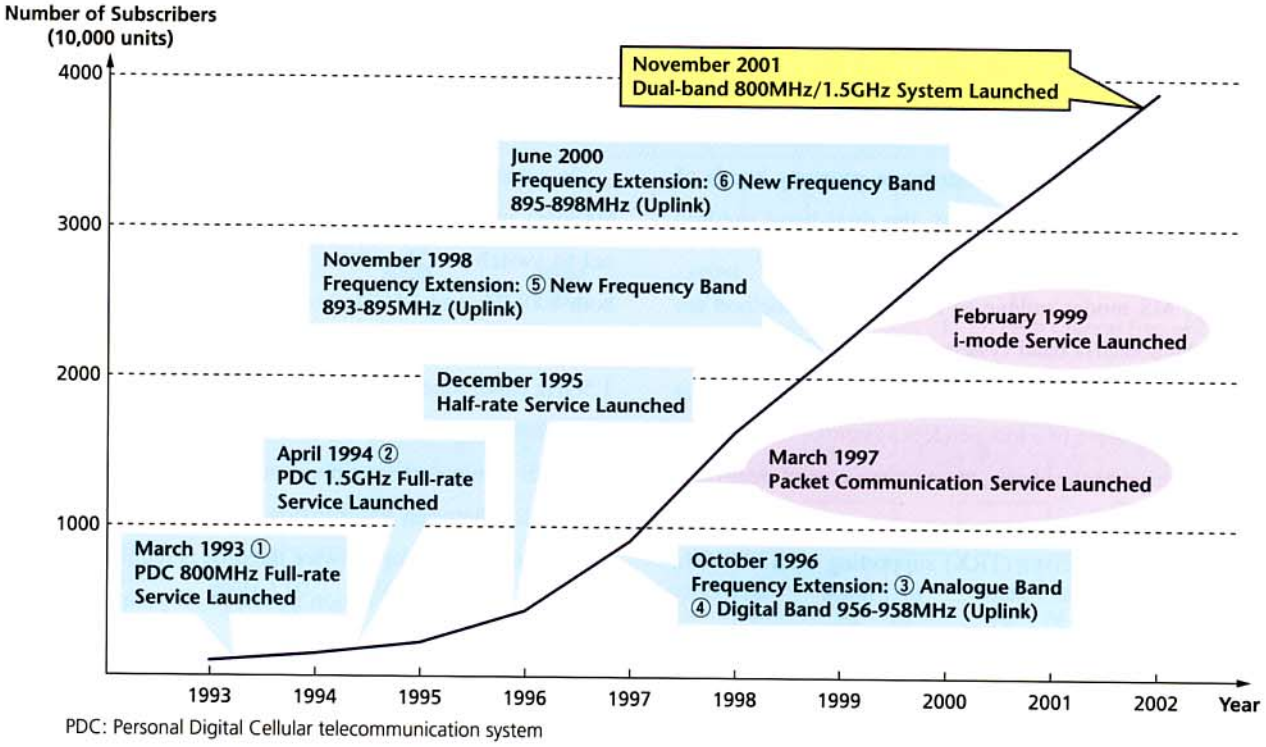



**Figure 1 Trends in the Number of NTT DoCoMo's Subscribers Nationwide and the History of Frequency Extension**

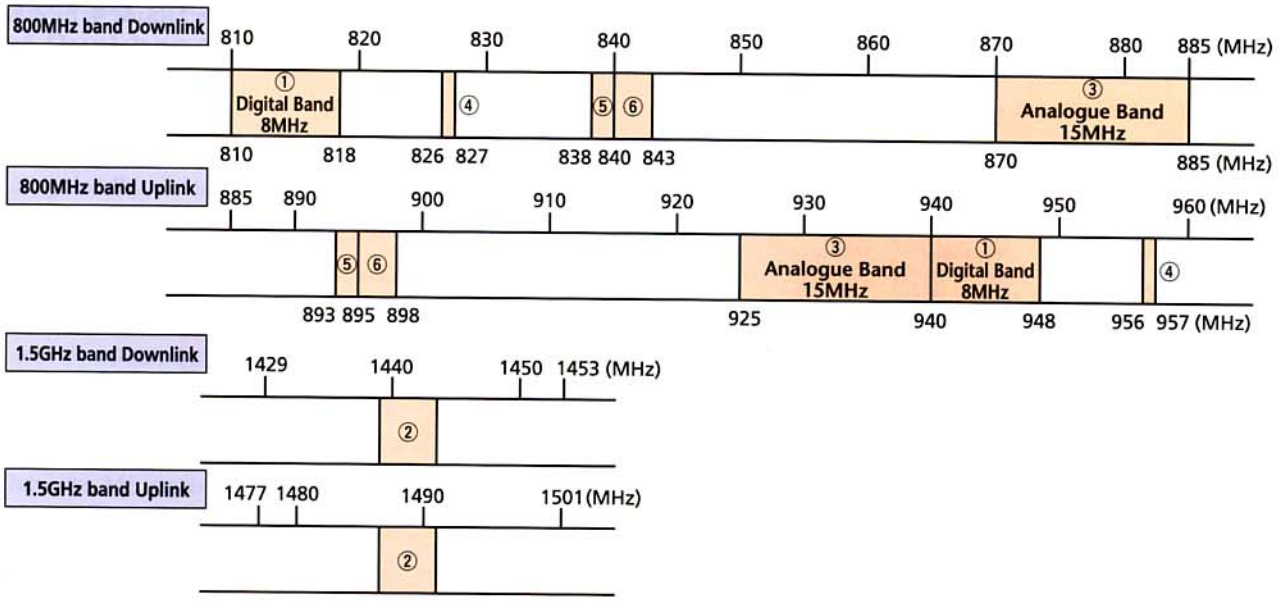



**Figure 2 NTT DoCoMo's PDC Frequency Allocation**

(hereinafter referred to as the "dual-band system") in November 2001.

According to the dual-band system, the mobile terminals, MSs, have the function to standby and communicate in both 800MHz and 1.5GHz bands. In a dual-band area, some MSs standing by in the 800MHz band shift to the 1.5GHz band referred to the information from the network. Also, MSs which originate and terminate calls and switch channels in one of these bands are assigned traffic channels in an alternative band. This makes it possible to disperse the 800MHz band traffic to the 1.5GHz band.

This article describes dual-band 800MHz/1.5GHz MS supporting the dual-band system ("dual-band MS").

## 2. Requirements of Dual-band MS

The dual-band 800MHz/1.5GHz method is different from

the existing frequency extension in the following two aspects.

Firstly, the MS must support a wider detuning frequency. So far, the frequency extension had been relatively close to the 800MHz band, and the solution was to standardize the interface system of MSs and broaden the hardware property bands of individual components. In contrast, the dual-band method requires the sharing of two completely different bands.

Secondly, MS modes unique to the dual-band method are required, as the 800MHz band system and the 1.5GHz band system are independent of each other and dual-band operation is necessary between those two independent systems.

In consideration of the above, the requirements of dual-band MS are as follows.

(1) Transmitter and Receiver (TRX) supporting both 800MHz and 1.5GHz bands

Among the devices constituting MS supporting the dual-band system, NTT DoCoMo had to newly develop the new antenna, transmitter, receiver and synthesizer. **Figure 3** shows an example of the devices configuration constituting dual-band MS.

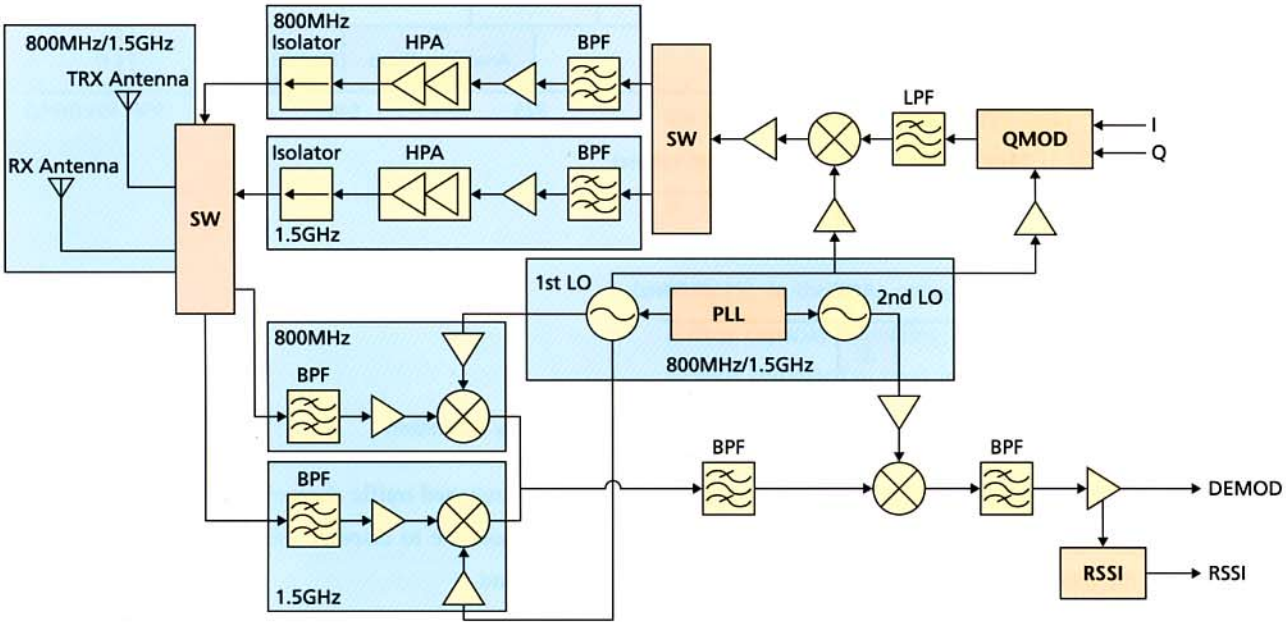
As the antenna, the amplifier, the filter and other individual components must have broadband properties to satisfy the required configuration, heavier costs had been expected associated with the development of new parts and components. Therefore, NTT DoCoMo adapted the radio frequency (RF) for both 800MHz and 1.5GHz bands, and minimized MS in terms of both weight and size by sharing the interface system and the synthesizer.

(2) Fast Frequency Switching

In a dual-band area, the dual-band MS selects zones in both 800MHz and 1.5GHz bands as the zone to shift to and the channel to switch to. Therefore, the dual-band MS must monitor both 800MHz and 1.5GHz bands as periphery zones, which can be up to 20 waves in the 800MHz band and 20 waves in the 1.5GHz band, totaling 40 waves, which is double the number of the existing 800MHz band MS. Whereas the existing 800MHz band MS monitors the periphery zone with respect to each wave in idle slots between transmission slots and reception slots during communication, up to twice the time is required to complete the detection of the reception power in all periphery zones. As the longer monitoring time reduces the success rate of handover, NTT DoCoMo improved the synthesizer as follows.

The dual-band MS measures two waves in total, one wave each with respect to the periphery zone in the 800MHz band and the 1.5GHz band in the idle slots between the transmission slots and the reception slots as shown in **Figure 4**, by doubling the frequency switching performance of the Phase Lock Loop (PLL) from the existing level.

This enables the dual-band MS to ensure zone shifting and




BPF: Band Pass Filter
DEMOD: DEMODulation
HPA: High Power Amplifier
LO: Local Oscillator
PLL: Phase Lock Loop
QMOD: QPSK MODulation
RSSI: Receive Signal Strength Indication
RX: Receiver
SW: SWitch
TRX: Transmitter and Receiver

**Figure 3 Block Diagram of Radio Unit for Dual-Band MS**

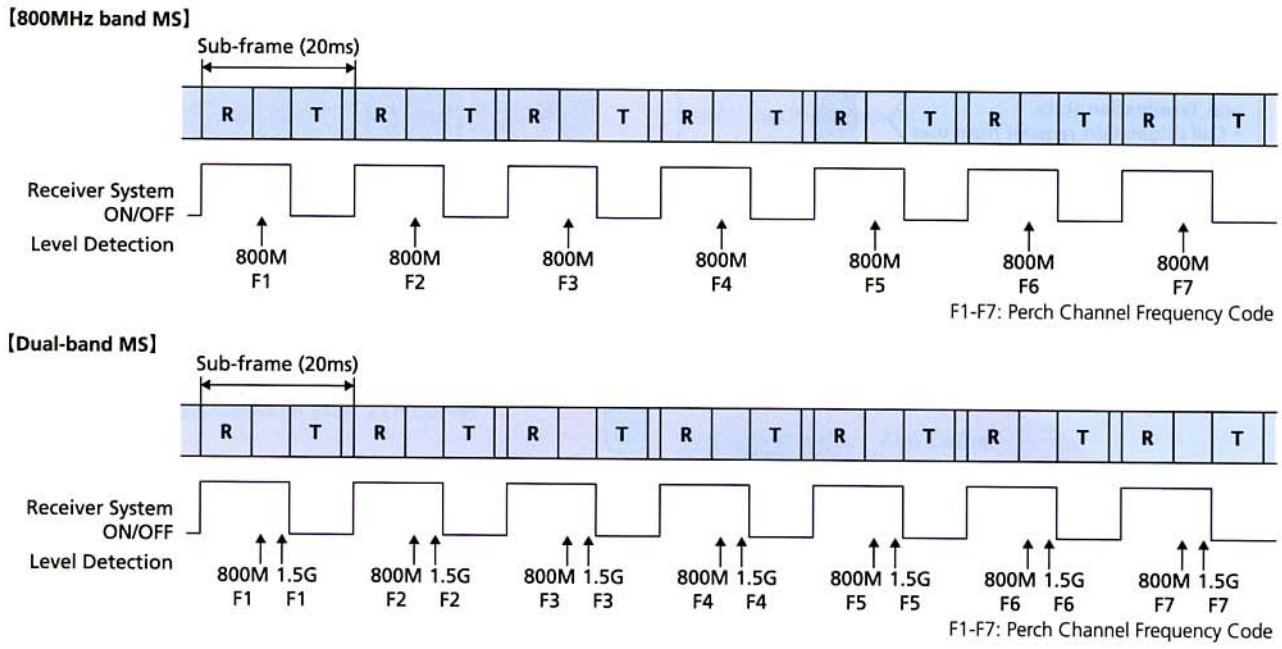



**Figure 4 Supervision and Control of Periphery Zones**

handover states equivalent to the existing 800MHz band MS.

## 3. Standby and Communication States of Dual-band MS

(1) Standby State

This section explains the standby state of dual-band MS.

During standby, information on the visited area is given to the MS by broadcast information, identifies as to whether the area is a dual-band area or not. In a non dual-band area, the MS always stands by in the 800MHz band. In a dual-band area, the MS stands by in either the 800MHz band or the 1.5GHz band, and monitors the periphery zone notified by broadcast information (in the 800MHz band and the 1.5GHz band).

When the MS enters into a dual-band area from a non dual-band area, it executes the band-assignment process and decides the band where it will stand by in the dual-band area (**Figure 5**). In the band-assignment process, the MS compares the band-shifting probability notified by broadcast information and the random number generated inside the MS to decide the band in which it is going to stand by. The MS memorizes the band in which it is going to stand by decided at that time as the home band, and preferentially stands by in the home band thereafter until it leaves the dual-band area (**Figure 6**).

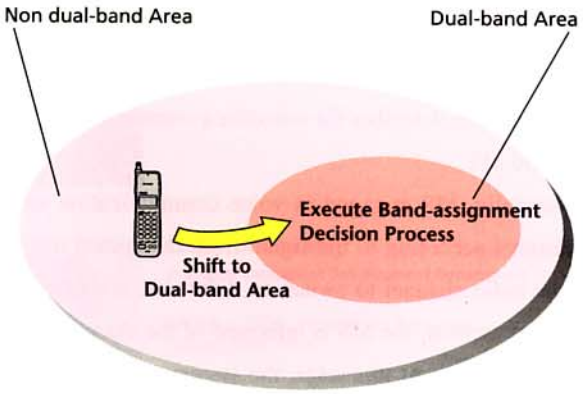
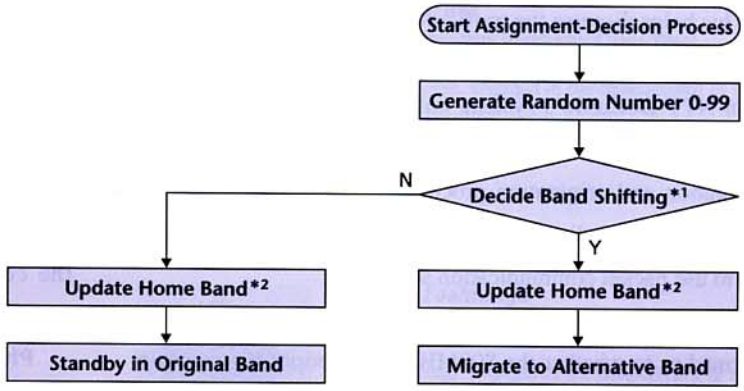
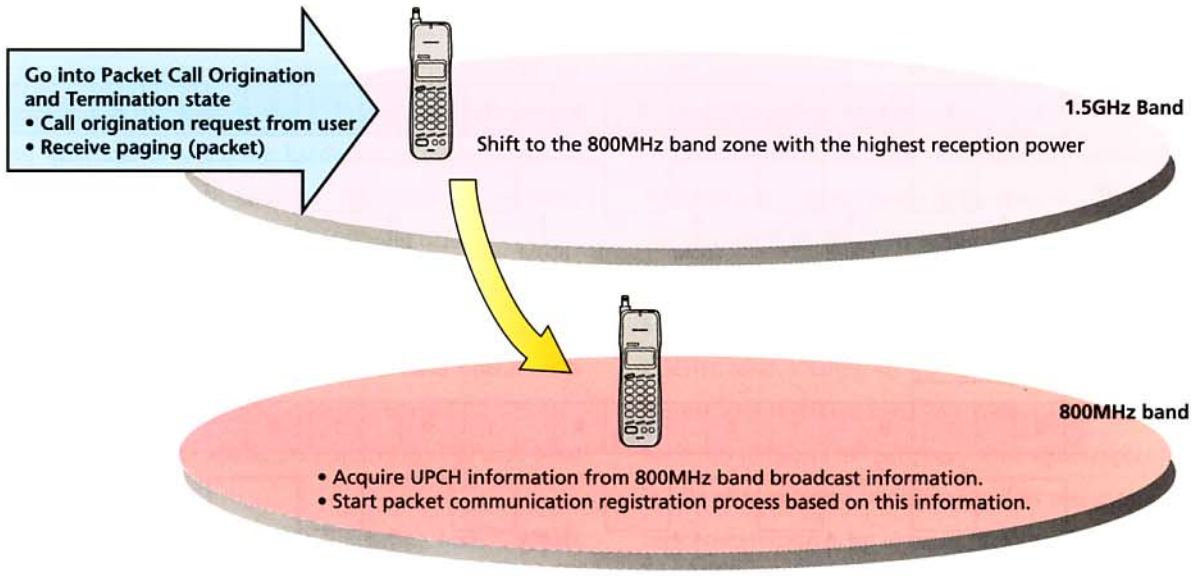



**Figure 5 Area Configuration**




*1: Check whether [Random number 0-99] < [Band shifting probability]
* Information element in broadcast information [Band shifting probability]: 0-100
*2: Update [Home band] to the band decided in the "decide band shifting" step in *1.

**Figure 6 Band-assignment Process**




UPCH: User Packet CHannel

**Figure 7 Packet Call Origination and Termination State**

This disperses the traffic over the control channel in the dual-band area.

(2) Voice/Data Communication State

This section describes the voice/data communication state of dual-band MS.

Normally, MS engaged in voice communication switches the channel according to the signal from the system that specifies the radio channel to switch to. Likewise, according to the dual-band method, the MS is informed of the channel to switch to by the system. At this stage, the system may inform the MS of a channel in an alternative band, in which case the MS can continue communicating by switching to a channel in the alternative band according to the system's instructions.

This helps disperse the traffic over traffic channels.

(3) Packet Communication State

In NTT DoCoMo's system, only the 800MHz band system provides packet communication services. Thus, the packet call termination and origination processes shown in **Figure 7** are used for MSs standing by in the 1.5GHz band in a dual-band area to use packet communication services.

In the 1.5GHz band zone in a dual-band area, the MS is informed as to whether the 800MHz band periphery zones support packet communication services by means of broadcast information. When the MS receives a packet call origination request from the user or paging (packet) from the system, it goes into packet call origination and termination state and shifts to the 800MHz band periphery zone that supports packet communication services with the highest reception power according to the results of monitoring periphery zones in standby state. The MS selects the channel where it stands by at the destination 800MHz band zone and receives the broadcast information, and at this point, acquires information of the User Packet CHannel (UPCH) information of that zone. The MS moves onto the packet communication registration process and starts packet communication based on this information.

This enables the dual-band MS to use packet communication services when standing by in the 1.5GHz band, as same as in the case of standby in the 800MHz band.

## 4. Development of Dual-band MSs

NTT DoCoMo started working on the development of dual-band MSs in 1994. It has solved development issues on both hardware and software fronts, including the development of the radio unit that supports both 800MHz and 1.5GHz bands, the development of PLL to enable faster frequency switching, and the control sequence for shifting to and fro between the 800MHz band system and the 1.5GHz band system.

**Photo 1** shows dual-band MSs named the "211i Series," sold as of April 2002. NTT DoCoMo managed to make the 211i Series more or less the same as the 800MHz band MSs "210i Series" in terms of weight and size.

**Photo 1 Dual-band MSs: 211i Series**

GLOSSARY

BPF: Band Pass Filter
DEMOD: DEMODulation
HPA: High Power Amplifier
LO: Local Oscillator
PDC: Personal Digital Cellular telecommunication system
PLL: Phase Lock Loop
QMOD: QPSK MODulation
RSSI: Receive Signal Strength Indication
RX: Receiver
SW: SWitch
TRX: Transmitter and Receiver
UPCH: User Packet CHannel

## 5. Conclusion

This article described the overview of MSs supporting the dual-band 800MHz/1.5GHz service launched by NTT DoCoMo in November 2001. In order to cope with the rapid increase in the number of subscribers since the launch of the PDC service, NTT DoCoMo has been improving its capacity to accommodate more subscribers by raising the efficiency of frequency usage and by frequency extension. The introduction of the dual-band system is expected to have a substantial effect on dispersing traffic in central Tokyo and other regions suffering from frequency saturation.

REFERENCES

[1] Personal Digital Cellular Telecommunication System RCR STD-27I Edition
[2] Murota, et. al: "Digital Mobile Communication System: Mobile Stations" NTT DoCoMo Technical Journal, Vol.1, No.1, pp.43-46, Jul. 1993.
[3] Chiba et. al: "1.5GHz Digital Mobile Communication System: Digital 1.5GHz-band Mobile Stations" NTT DoCoMo Technical Journal, Vol.2, No.2, pp.13-15, Jul. 1994.
[4] Chiba et. al: "Special Article on Half-rate Digital Mobile Communications: Mobile Stations" NTT DoCoMo Technical Journal, Vol.3, No.3, pp.19-21, Oct. 1995.
[5] Chiba et. al: "Special Article on PDC Frequency Extension –Digitization of Analogue Bands— Mobile Stations" NTT DoCoMo Technical Journal, Vol.4, No.4, pp.16-19, Jan. 1997.
[6] Watanabe, et. al: "Overview of New PDC Base Station Equipment and Terminals supporting Frequency Extension" NTT DoCoMo Technical Journal, Vol.7, No.1, pp.28-35, Apr. 1999.