3.5-GHz Band TD-LTE CA

Technology Reports

Special Articles on Introducing the 3.5-GHz Band

NTT DOCOMO's Efforts Concerning Technical Developments for Introducing TD-LTE in 3.5-GHz Frequency Band

In December 2014, the MIC approved "Establishment Plan of Specified Base Stations for Introduction of Fourth-generation Mobile Communication Systems," and it thus became possible to utilize the 3.5-GHz frequency band in Japan. NTT DOCOMO has introduced TD-LTE using this band—combined with the existing FDD bands by means of CA—and communication services with a maximum data rate of 370 Mbps were launched to evolve our service called "PREMIUM 4G" in June 2016. This article describes international trends concerning the 3.5-GHz frequency band and efforts concerning NTT DOCOMO's technical developments to satisfy the technical requirements specified for domestic use.

Radio Access Network Development Department
Hiroyuki Atarashi
Hiromasa Umeda
Sadayuki Abeta

1. Introduction

On December 19th, 2014, the Ministry of Internal Affairs and Communications (MIC) approved "Establishment Plan of Specified Base Stations*1 for Introduction of Fourth-generation Mobile Communication Systems*2," and NTT DOCOMO was assigned 3.48 to 3.52 GHz in the 3.5-GHz frequency band [1]. In June 2016, NTT DOCOMO launched a service, called "PREMIUM 4G," utilizing this frequency band.

As for efforts concerning technical developments accomplished by NTT DOCOMO to utilize the 3.5-GHz frequency band up until now, this article explains our contributions to international standardization of frequencies by the International Telecommunication Union (ITU) and our contributions to formulation of LTE-Advanced*3-related specifications stipulated by the 3rd Generation Partnership Project (3GPP).

2. International Standardization of 3.5-GHz Frequency Band

1) Identification of 3.5-GHz Band by ITU

As mobile traffic continues to grow explosively, securing new frequencies

*1 **Specified base station:** A base station that uses a specified frequency stipulated by the Radio Law. A carrier, whose plan for establishing the station is accredited by the MIC, can apply for a license to exclusively use the specified frequency.

for mobile phones is becoming a serious problem. Moreover, if mobile-phone frequencies could be utilized in many countries around the world, benefits of lowering costs of equipment and implementing international roaming would be gained. At the World Radiocommunication Conference (WRC)*4 of the ITU, efforts are being continued to commonalize (i.e., identify) mobile-phone frequencies used in each country as much as possible under the name "International Mobile Telecommunication (IMT)."

As for utilization of the 3.5-GHz frequency band for mobile phones, this band was mentioned as a domestic candidate for frequency reallocation to satisfy medium-to-long-term frequency demand of mobile communication systems in "Restructuring Policy for Frequencies" publically announced by the MIC in October 2003. Through standardization activities of the ITU after that announcement, the 3.4 to 3.6 GHz frequency band was identified for IMT in 90 or so countries (including Japan) at the WRC held in 2007 (WRC-07). Moreover, at the WRC held in 2015 (WRC-15), although some countries planning to utilize (or were already using) this band for satellite-communications systems were in opposition, the number of countries in which this frequency band is identified for IMT was further increased; consequently, this frequency band was accepted as one of the additional mobile-phone frequency bands for universal common usage.

2) Contributions of NTT DOCOMO

To assist the above standardization activities by the MIC, NTT DOCOMO has been actively contributing to these activities at the ITU [2] [3]. In particular, as required for arguments at the WRC, as a member of the Japanese delegations, we took the initiative in regard to technical studies on future demand for mobile-phone frequencies and on frequency sharing between satellite-communications systems and IMT systems. Furthermore, in regard to standardization activities concerning the band plan*5 for the 3.5-GHz frequency band, which was developed at the 3GPP in accordance with the outcome at WRC-07, NTT DOCOMO actively participated in discussions and contributed to formulation of those standards until 2009 [4].

Since the 3.4 to 3.6 GHz frequency band was accepted for mobile-phone usage in many countries in the world, it is expected that utilization of that band for mobile phones will start in various countries (**Table 1**).

3. Technological Developments for Meeting Technical Requirements Concerning 3.5-GHz Band

To get our establishment plans for specified base stations approved by the MIC, a number of requirements concerning utilization of the 3.5-GHz band had to be satisfied [5]. Among those

Table 1 International trends concerning utilization of the 3.5-GHz band

Item		Contents
ITU		・The 3,400-3,600-MHz band is identified for IMT in all countries in Region 1 (122 countries in regions of Europe, Russia, the Middle East, and Africa). ・The 3,400-3,600-MHz band is identified for IMT in all countries in Region 2 (35 countries in the North and South Americas). ・Among the countries in Region 3 (36 countries in the Asia-Pacific region), the 3,400-3,500-MHz band is identified for IMT in 11 countries and the 3,500-3,600-MHz band is identified for IMT in 10 countries.
Trends in major countries	Europe	・Regarding the frequency band covering 3,400 to 3,800 MHz, utilization for mobile-broadband communication is assumed, and in some countries, frequencies have been allocated to operators.
	USA	・Regarding the frequency band covering 3,550 to 3,650 MHz, coexistence with existing systems is being considered, and opening up frequencies for usage by mobile-broadband services is being studied.
	China	・Regarding the frequency band covering 3,400 to 3,600 MHz, under the aim of introduction of mobile-phone systems, coexistence conditions are being studied.

*2 **Fourth-generation Mobile Communication Systems:** Systems beyond the third-generation mobile communication system (IMT-2000), which are referred to as IMT-Advanced in ITU-R. The target data rates are 100 Mbps for high-mobility environments and 1 Gbps for static or low-mobility environments.

*3 **LTE-Advanced:** An enhanced radio-interface technology of LTE; its first version has been standardized as 3GPP Release 10.

*4 **WRC:** A conference that reviews, and if necessary, revises the ITU Radio Regulations, the international treaty governing the use of radio-frequency spectrum, and the orbits of geostationary and non-geostationary satellites. The conference normally is held once every three to four years, and is attended by administrations, ITU registered corporations and related organizations.

*5 **Band plan:** A plan for using a particular frequency band. It defines parameters such as frequency range and bandwidth of uplink and downlink transmissions.

requirements, the main ones related to technical matters are listed in **Table 2**.

1) Application of CA with FDD and TDD

As for the radio access technology, it is necessary to employ Time-Division Duplexing (TDD)*6 in LTE-Advanced (TD-LTE*7). Up until now, NTT DOCOMO has introduced LTE-Advanced for our PREMIUM 4G service by Carrier Aggregation (CA)*8 using the frequency bands with Frequency-Division Duplexing (FDD)*9. When TDD is introduced in LTE-Advanced for the 3.5 GHz band, application of CA is effective as well. In particular, if existing macro-cell*10 base stations using existing FDD bands and small-cell*11 base stations using the 3.5 GHz band were linked by means of CA through the advanced C-RAN*12 architecture proposed by NTT DOCOMO, in areas in which communication traffic is dense (such as around train stations and large-scale commercial facilities), it would be possible to provide stable communication at even higher data rates (**Figure 1**) [6]. To enable CA between FDD and TDD in LTE-Advanced, NTT DOCOMO actively participated in discussions at 3GPP and successfully incorporated the relevant CA functionalities into the 3GPP Release 12 specifications [7].

2) Other Technical Developments

As for deployment of base stations to utilize the 3.5 GHz band, it is essential to utilize macro-cell base stations, which can effectively satisfy requirements regarding population coverage. Furthermore, it is necessary to deploy base stations that can handle transmission by eight antennas (i.e., so-called "advanced specified base stations") in heavy traffic demand areas. Details of development of base-station equipment and related equipment as well as development of user terminals are explained in references [8] to [11] in this special article.

4. Conclusion

This article overviewed international trends concerning the 3.5 GHz band, which is now available in Japan for mobile-phone frequencies, and NTT DOCOMO's efforts up until now concerning technical developments for meeting the technical requirements concerning domestic utilization of this frequency band.

From now onwards, it will also be necessary to develop technologies for upgrading NTT DOCOMO's mobile-phone networks in terms of further increasing data rate and expanding network capacity. NTT DOCOMO will continue making great efforts concerning standardization and equipment development so that we can continue providing users with a comfortable environment for mobile communications.

References

[1] Ministry of Internal Affairs and Communications (MIC): "Approval of Establishment Plan of Specified Base Stations for Introduction of 4G Mobile Communication Systems," MIC Press Release, Dec. 2014. http://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/Releases/Telecommunications/

Table 2 Main technical requirements concerning utilization of the 3.5-GHz band

Item	Contents
Radio access technology	・LTE-Advanced (TDD)
Placement of specified base stations and opening time	・By the end of fourth year from the approval of the establishment plan, specified base stations should be deployed to cover more than 50% of the population within the jurisdiction of regional bureaus of telecommunications. ・By the end of second year from the approval of the establishment plan, operation of advanced specified base stations should be started in specified high traffic demand areas (such as downtown areas and transport terminals in which communications are particularly concentrated). ・In all administrative divisions of Japan, operation of specified base stations should be started.
Introduction of technology for assuring efficient utilization of frequencies	・Application of carrier-aggregation technology, adaptive modulation and coding, and other technologies for assuring efficient utilization of frequencies

*6 **TDD:** A bidirectional transmit/receive mode, which achieves bidirectional communication by allocating different time slots to uplink and downlink transmissions that use the same frequency.

*7 **TD-LTE:** A radio access technology specified in the 3GPP standard for LTE using the TDD mode (see *6).

*8 **CA:** A technology for increasing bandwidth and data rate while maintaining backward compatibility with LTE by simultaneously transmitting and receiving multiple LTE carriers.

*9 **FDD:** A bidirectional transmit/receive mode, which achieves bidirectional communication by using different frequencies for uplink and downlink transmissions.

*10 **Macro cell:** Cellular communication area with a cell radius of several hundred meters to several tens of kilometers mainly covering outdoors. Antennas are usually installed on towers or on roofs of buildings.

*11 **Small cell:** A general term for cells that transmit with power that is low compared to that of a macro-cell transmitting at higher power.

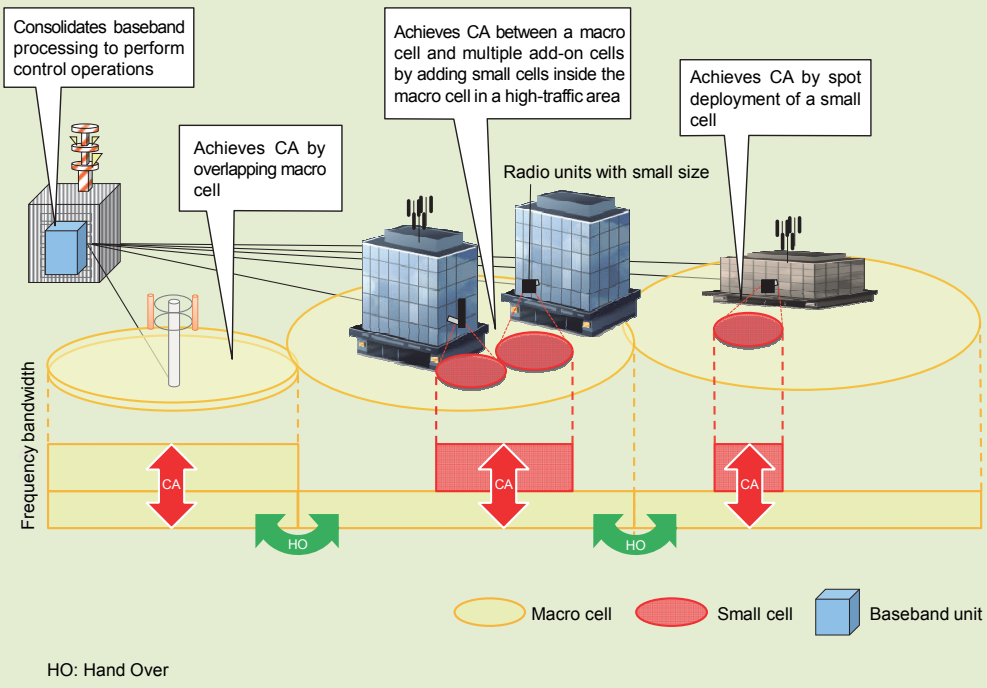

Figure 1 CA by advanced C-RAN architecture

141219_01.html

[2] H. Yoshino et al.: "The Future Development of IMT-2000 and Systems Beyond (IMT-Advanced) - Report from ITU-R World Radiocommunication Conference 2007 (WRC-07) -," NTT DOCOMO Technical Journal, Vol.10, No.1, pp.73-79, Jun. 2008.

[3] H. Atarashi et al.: "2015 ITU World Radiocommunication Conference (WRC-15) Report - Standardization of Mobile Phone Spectrum -," NTT DOCOMO Technical Journal, Vol.18, No.1, pp.66-74, Jul. 2016.

[4] 3GPP TR 37.801 V10.0.0: "UMTS-LTE 3500 MHz Work Item Technical Report," Oct. 2011.

[5] MIC: "Results of Appeal for Opinions on Assignment of Frequencies for Introduction of Fourth-generation Mobile Communication Systems and Report from the Radio Regulatory Council," MIC Press Release, Sep. 2014. http://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/Releases/Telecommunications/140910_04.html

[6] S. Abeta et al.: "LTE-Advanced as Further Evolution of LTE for Smart Life," NTT DOCOMO Technical Journal, Vol.17, No.2, pp.4-9, Oct. 2015.

[7] T. Uchino et al.: "Carrier-aggregation Upgrading and Dual Connectivity Technology for Creating Even Higher Speed and Capacity," NTT DOCOMO Technical Journal, Vol.23, No.2, pp.35-45, Jul. 2015.

[8] M. Fujii et al.: "Base-station Equipment with the Aim of introducing 3.5-GHz band TD-LTE," NTT DOCOMO Technical Journal, Vol.18, No.2, pp.8-13, Oct. 2016.

[9] S. Yokote et al.: "High-precision Clock-time-synchronization Network Equipment for Introduction of 3.5-GHz band TD-LTE," NTT DOCOMO Technical Journal, Vol.18, No.2, pp.18-26, Oct. 2016.

[10] T. Yoshihara et al.: "Base-station Antennas for 3.5-GHz band," NTT DOCOMO Technical Journal, Vol.18, No.2, pp.14-17, Oct. 2016.

[11] R. Osawa et al.: "Router-type Mobile Terminal for TD-LTE in 3.5-GHz band," NTT DOCOMO Technical Journal, Vol.18, No.2, pp.27-31, Oct. 2016.

*12 **Advanced C-RAN:** A new centralized radio-access network (C-RAN) architecture proposed by NTT DOCOMO. Being controlled by the same base station, a radio access network makes a linkage between a macro cell (which covers a wide area) and a small cell (which covers a local area) by applying CA.