Technology Reports

Special Articles on Introducing the 3.5-GHz Band

Base-station Equipment with the Aim of Introducing 3.5-GHz band TD-LTE

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. In this article, upgrade of high-density BDE for TD-LTE (targeting introduction of 3.5-GHz band), newly developed SRE/RRE for 3.5-GHz band and FHM are overviewed.

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1. Introduction

As a more-evolved version of PREMIUM 4G, a communication service with a receiving rate up to 370 Mbps—achieved by combing newly introduced TD-LTE[*1] using the 3.5-GHz band and the existing Frequency Division Duplex (FDD)[*2] band by Carrier Aggregation (CA)[*3]—was launched in June 2016. The Network (NW) architecture for introducing TD-LTE using the 3.5-GHz band is shown in **Figure 1**.

PREMIUM 4G has been deployed with newly developed high-density Base-station Digital processing Equipment (BDE)[*4] supporting LTE-Advanced for FDD [1] by adopting Advanced Centralized Radio Access Network (C-RAN)[*5]. TD-LTE is newly supported by high-density BDE with software update.

Moreover, to handle the new frequency band (3.5 GHz), two types of new radio equipment, namely, low-power Small optical remote Radio Equipment (SRE)[*6] and Remote Radio Equipment (RRE)[*7], were developed. As for covering areas at which required wireless network capacity is low, to accommodate an even-greater amount of radio

*1 **TD-LTE:** A data-transmission scheme, specified in the LTE standard, which uses a single frequency alternating between uplink and downlink transmissions.

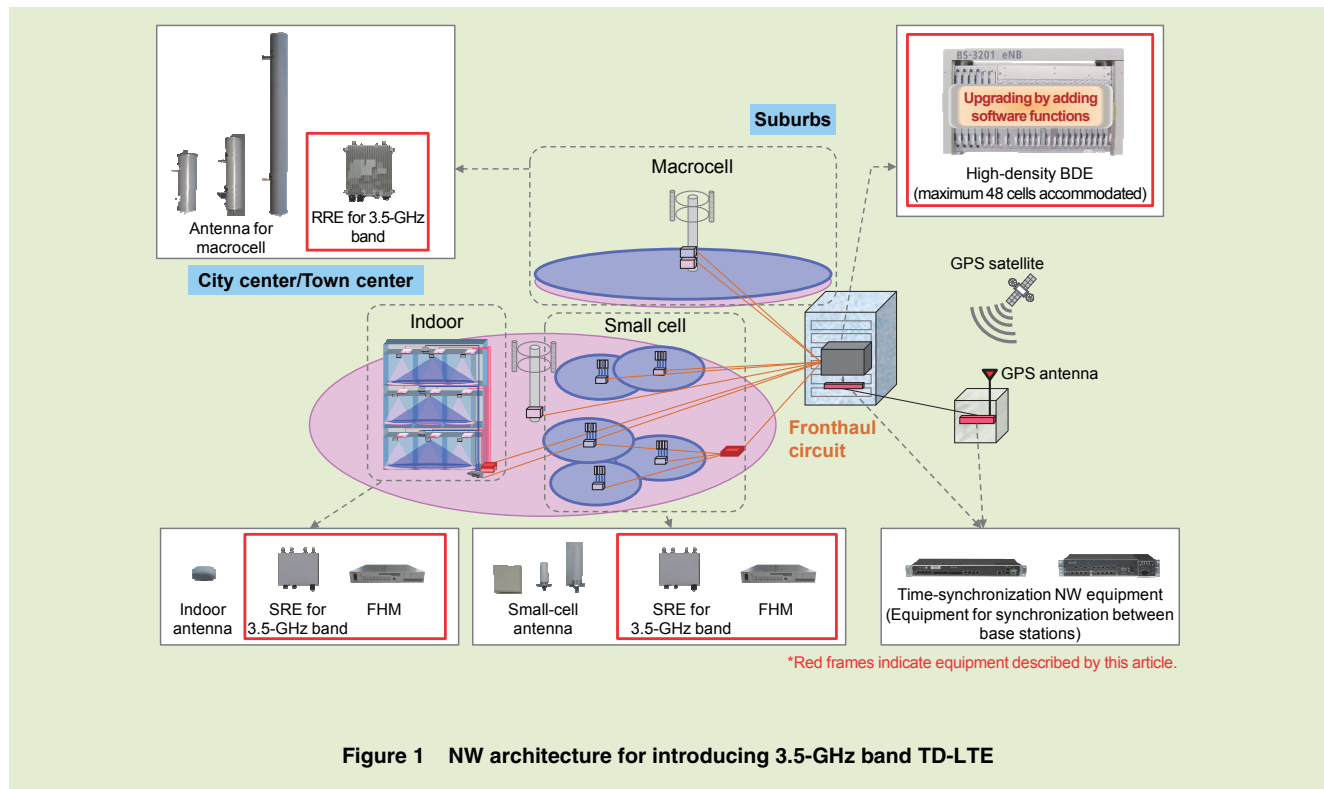*2 **FDD:** A scheme for transmitting signals using different carrier frequency bands for the uplink and downlink.

Figure 1 NW architecture for introducing 3.5-GHz band TD-LTE

equipment by one high-density BDE unit, a FrontHaul Multiplexer (FHM)*8, for distributing fronthaul circuits*9 between BDE and radio equipment, was developed. In this article, upgrade of high-density BDE for TD-LTE (targeting introduction of 3.5-GHz band) development of SRE/RRE for handling the 3.5-GHz band and the one of FHM are overviewed.

2. Upgrade of High-density BDE for TD-LTE

Upgrade for TD-LTE (enabled by software update) consists of TD-LTE support of BaseBand (BB)*10 signal-processing units, higher data rate support for the fronthaul, and adding syn-

chronization function among base stations. Each of them is explained in detail in the following sections.

2.1 BBs with TD-LTE Support

For transmitted signals, BB functional unit performs error-correction coding, radio framing, data modulation, frequency-time transformations, Multiple Input Multiple Output (MIMO)*11 transmission, and for received signals, it performs time-frequency transformations, data demodulation, signal separation, error-correction coding, and so on [2]. Except for the signal processing of this functional unit, the ones of other function units are for higher-layer protocols (e.g. call processing) which are com-

mon for both FDD and Time Division Duplex (TDD) [3].

To support TDD, this functional unit was updated by software. By making it possible for each cell to switch either FDD or TDD, mixed operation of FDD cell(s) and TDD cell(s) on a single high-density BDE unit becomes possible. In this way, CA combining the FDD band and the TDD band is enabled.

2.2 Supporting High-speed Data Rate of the Fronthaul

As for the fronthaul for 3.5-GHz band, since it has wider bandwidth than conventional ones and we also upgrade MIMO for higher order (described later), data rate of the fronthaul was extended

to up to 9.8 Gbps from 2.4 Gbps (conventional). In this way, Radio Frequency (RF) signal up to four branches for 3.5-GHz band can be transmitted/received with a single fronthaul line.

2.3 Adding Synchronization Function between Base Stations

In the case of TDD, as shown in **Figure 2**, synchronization between base stations is necessary to avoid interference between uplinks and downlinks. Moreover, as there is no guard band[*12] between the bands allocated to operators, synchronization between base stations deployed by different operators is also necessary to prevent interfering each other by spurious emission[*13].
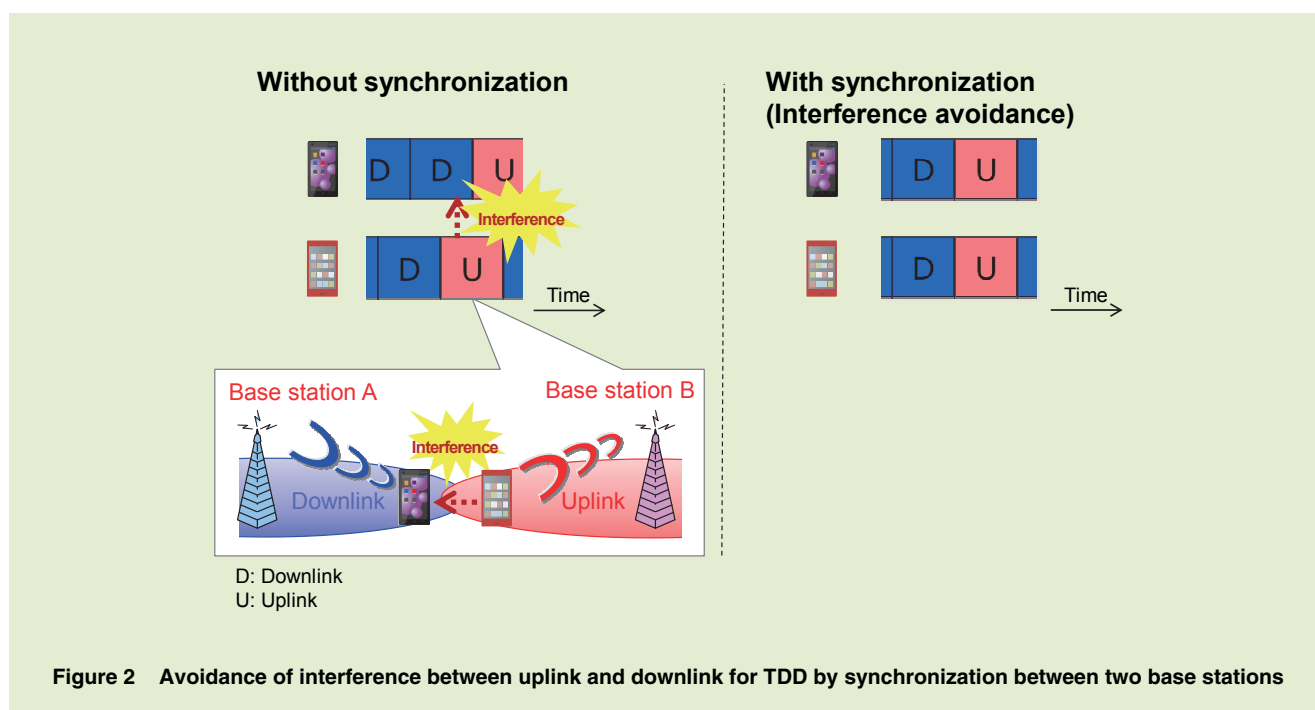
To achieve that, high-density BDE supports a GPS synchronization func-

tion (for synchronizing with GPS) and a Precision Time Protocol (PTP) synchronization function [4] (by which high-density BDE synchronizes to a server synchronized with GPS by the PTP). Thus, the transmission timing of the radio frame at the antenna connectors of remote radio equipment connected to high-density BDE synchronizes with Coordinated Universal Time (UTC) obtained from GPS or PTP. As for transmission timing synchronization accuracy, less than ± 1.5 μs was attained. In this way, high-density BDE meets the synchronization accuracy requirement between base stations, less than 3 μs specified by 3rd Generation Partnership Project (3GPP), and can prevent interference between our base stations and the one between our base stations and

other operators' base stations.

3. Optical Remote Radio Equipment for 3.5-GHz band

Since the requirements for radio equipment differ in the cases of small cells and macrocells, SRE and RRE for 3.5-GHz band were developed with different specifications optimized to each scenario (SRE for small cells and RRE for macrocells). SRE and RRE mainly consists of a Transmitter and Receiver INterFace (TRX-INF)[*14], a Transmission-Power Amplifier (T-PA)[*15], a Low-Noise Amplifier (LNA)[*16], a Switch[*17] or CIRculator (CIR)[*18], and a Band-Pass Filter (BPF)[*19]. The main point of difference is that in the case of FDD, a DUPlexer (DUP)[*20] is used, but in the

Figure 2   Avoidance of interference between uplink and downlink for TDD by synchronization between two base stations

case of TDD, a Switch/CIR and BPF are used. The basic specifications of SRE and RRE are listed in **Table 1**, and their external appearances are shown in **Figure 3**. The main features of SRE and RRE are described in the following sections.

3.1 SRE

In places where a large number of people gather (such as city and town centers), it is suitable to cover the area by small cells to increase capacity. In comparison with macrocells, small cells have the advantage that they effectively utilize MIMO technology. Thus, the number of branches per SRE is four to achieve higher data rate by MIMO technology with one SRE. Moreover, by suppressing maximum output power per SRE as 3.84 W to optimize operating small cells, the size of the SRE could be kept below 4 ℓ.

3.2 RRE

To cover the suburbs area effectively, macrocell is suitable. In consideration that the maximum cell radius of a macrocell is about 2 km, maximum output power is specified as 19 W per 20 MHz per branch[21]. In consideration of installability of RRE and antennas for macrocells, the number of branches per RRE is two. And to achieve four-branch operation, cascade connection of two RREs can be handled (see **Figure 4**).

Table 1   Basic specification of SRE and RRE for 3.5-GHz band

Item	3.5-GHz band	
	SRE	RRE
Maximum transmission power	0.48 W/20 MHz/branch	19 W/20 MHz/branch
Number of branches	4	2
Size	Less than or equal to 4 ℓ	Less than or equal to 9 ℓ
Equipment weight	Less than or equal to 4.5 kg	Less than or equal to 12 kg
Power consumption	Less than or equal to 100 W	Less than or equal to 380 W
Power source	AC 100 V/200 V	DC − 48 V
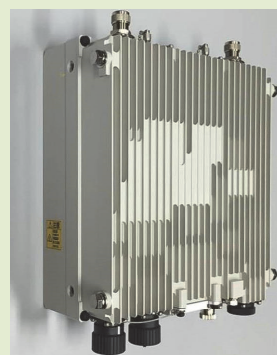
(a) SRE   (b) RRE

Figure 3   External appearance of SRE and RRE compatible with 3.5-GHz band

*17 **Switch:** A circuit for switching (on a time basis) transmitting and receiving circuits connected by RF connectors.
*18 **CIR:** A circuit (with more than three terminals) for outputting the signals input from one terminal to the next terminal only.
*19 **BPF:** A filter passing only a specific frequency band.

*20 **DUP:** A device consisting of a transmitter filter and a receiver filter. It allows a single antenna transmission and reception.

*21 **Branch:** In this article, an antenna and an RF transceiver.

4. FHM

A FHM has a function for distributing and combining a maximum of 16 RF signals on the fronthaul. The external appearance of a FHM is shown in **Figure 5**. By using a FHM, it is possible to operate multiple radio equipment connected to a high-density BDE as one cell (see **Figure 6**).

In this way, a greater number of radio equipment connected to a single high-density BDE can be deployed for the area where the need for wireless network capacity is low. Moreover, all remote radio equipment connected to a FHM transmit and receive RF signals as the same cell. Accordingly, it is possible to reduce the interference between remote radio equipment and suppression

of frequent handover[*22] when a mobile terminal moves between remote radio equipment. Still, as well as being connected to radio equipment for 3.5-GHz band, a FHM can be connected to radio equipment for the existing frequency band.

5. Conclusion

In this article, upgrade of high-density

Antenna for macrocells

BS-3201 eNB

CPRI maximum transmission rate: 9.8 Gbps

Cascade connection

High-density BDE

RRE for 3.5-GHz band

CPRI: Specification for internal interfaces for base stations standardized for fronthaul between RE and BDE
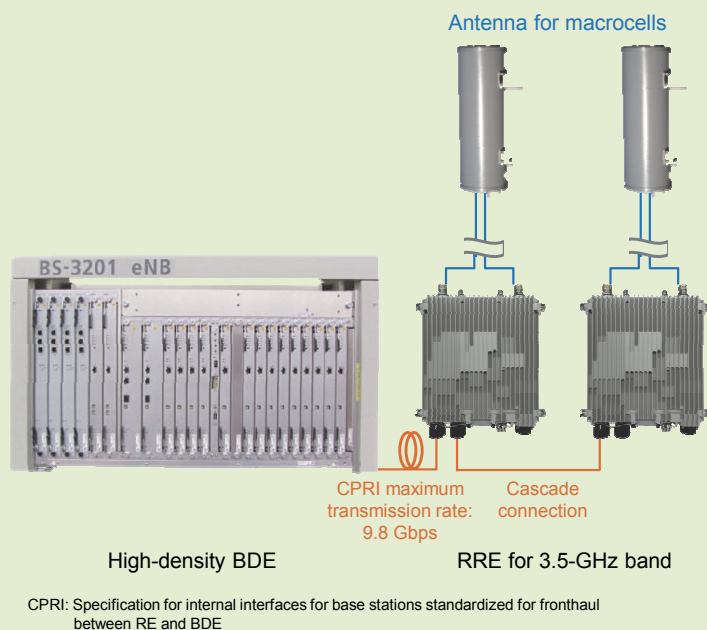
Figure 4   Cascade configuration for handling four branches

Figure 5   External appearance of FHM

Without FHM: Each radio unit accommodatable as one cell

Cell 4
Cell 3
Cell 2
Cell 1

BS-3201 eNB

High-density BDE
(maximum of 48 cells
accommodated)

Cell 8
Cell 7
Cell 6
Cell 5

With FHM: Multiple radio units accommodatable as one cell

Cell 1
Cell 1
Cell 1
Cell 1

FHM

BS-3201 eNB

High-density BDE
(maximum of 48 cells
accommodated)

FHM

Cell 2
Cell 2
Cell 2
Cell 2

Maximum of 16

: Radio units

Figure 6   Accommodating radio units with a high-density BDE via a FHM
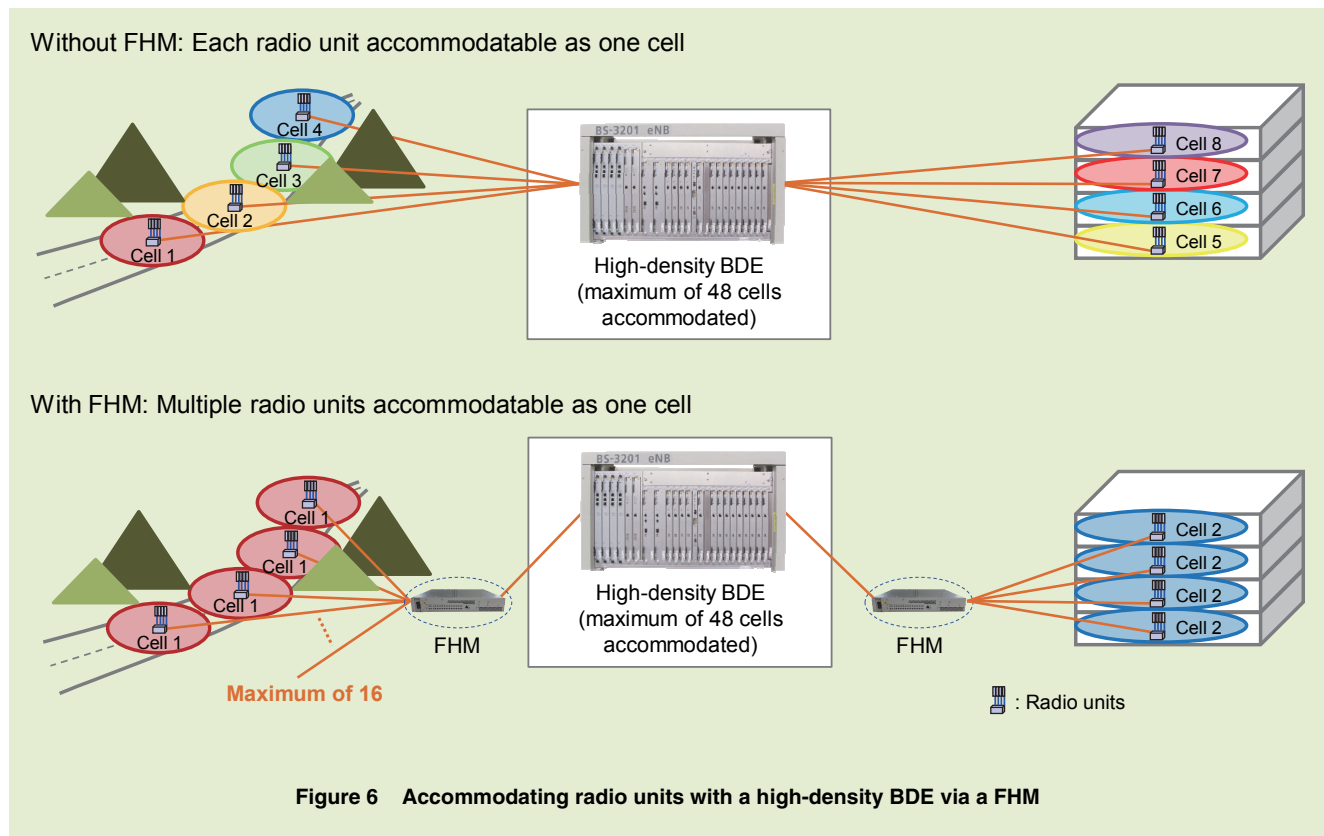
BDE for TD-LTE (targeting introduction of 3.5-GHz band), newly developed SRE/RRE for 3.5-GHz band and FHM are overviewed. From now onwards, by MIMO enhancement, further higher-order modulation, and expanding the number of frequency bands simultaneously operating CA and so on, we will continue development aimed at further enhancing our PREMIUM 4G service.

REFERENCES

[1] T. Yoshihara et al.: "Radio Equipment and Antennas for Advanced C-RAN Architecture," NTT DOCOMO Technical Journal, Vol.17, No.2, pp.19-24, Oct. 2015.

[2] Y. Shimadzu et al.: "RRE Shared between W-CDMA and LTE systems," NTT DOCOMO Technical Journal, Vol.12, No.1, pp.29-33, Jun. 2010.

[3] T. Uchino et al.: "Carrier Aggregation Enhancement and Dual Connectivity Promising Higher Throughput and Capacity," NTT DOCOMO Technical Journal, Vol.17, No.2, pp.36-46, Oct. 2015.

[4] 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.