High-density BDE | SRE | Small Cell Antenna

Technology Reports

Special Articles on PREMIUM 4G—Introduction of LTE-Advanced—

Radio Equipment and Antennas for Advanced C-RAN Architecture

*NTT DOCOMO began providing LTE-Advanced mobile communication services under the name PREMIUM 4G™ *1 in March 2015 as an evolved form of LTE. In this article, we overview newly developed high-density BDE, SRE, and antennas for constructing small cells, all with the aim of achieving and commercializing Advanced C-RAN architecture toward a full-scale rollout of LTE-Advanced.*

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1. Introduction

In March 2015, NTT DOCOMO launched "PREMIUM 4G" mobile communication services using LTE-Advanced, a communication system that achieves even higher transmission speeds and capacity than LTE. PREMIUM 4G applies Carrier Aggregation (CA)*2, a key technology of LTE-Advanced, to achieve a maximum downlink bit rate of 225 Mbps (reaching 262.5 Mbps in some areas) at the time of service launch, becoming the maximum transmission speed in Japan. The plan is to increase this bit rate to 300 Mbps within fiscal year 2015. To achieve PREMIUM 4G and support an effective rollout of LTE-Advanced, NTT DOCOMO has adopted Advanced Centralized Radio Access Network (Advanced C-RAN)*3 architecture [1].

As in the case of conventional C-RAN architecture, which was introduced for the rollouts of the W-CDMA [2] and LTE [3] mobile communication services, Advanced C-RAN consists of a Base-Band (BB)*4 unit having signal processing functions and Radio Equipment (RE)*5 having radio-signal transmitting/receiving functions. In this architecture, the BB unit connects to RE via optical fiber in a configuration where multiple RE units can be centrally controlled by a single BB unit. This "optical remote radio" configuration makes RE installation flexible and therefore speeds up the rollout of new services even in urban areas with limited installation space at the cell site. In addition, CA and mobile control through such centralized control enables advanced coordination between cells.

To effectively implement Advanced C-RAN architecture, NTT DOCOMO developed new high-density Base station Digital processing Equipment (BDE) as a BB unit, low power Small optical remote Radio Equipment (SRE) as RE for

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*1 **PREMIUM 4G™:** A trademark of NTT DOCOMO.

*2 **CA:** A technology that achieves high-speed communications through wider bandwidth while maintaining backward compatibility with existing LTE by performing simultaneous transmission and reception using multiple component carriers.

small cell*6 use, and base-station antennas likewise for small cells. An image of service area rollout by Advanced C-RAN architecture using the above equipment is shown in **Figure 1**. In this article, we provide an overview of high-density BDE, SRE, and base-station antennas for small cells.

2. High-density BDE

High-density BDE corresponds to the BB unit in an Advanced C-RAN optical-remote-radio configuration. It is capable of operating in LTE and LTE-Advanced simultaneously (**Photo 1**). This equipment has the features showed in **Table 1**.

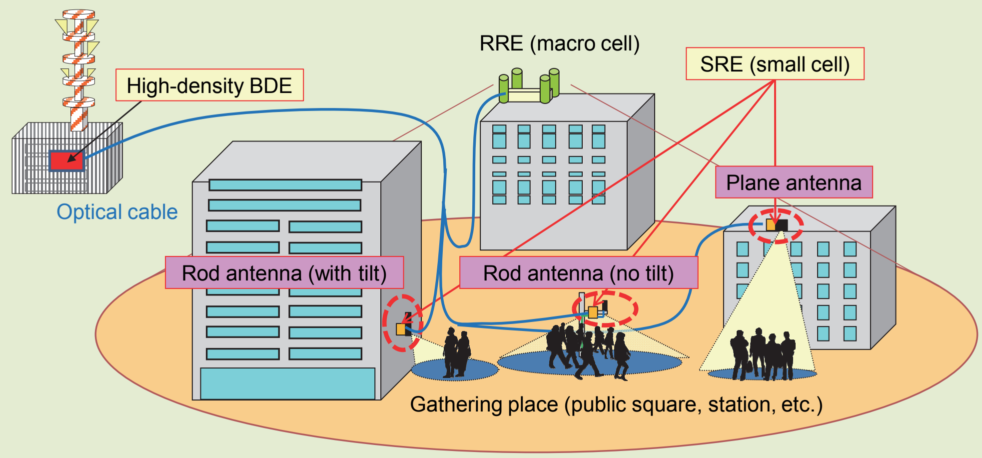

Figure 1 Service area rollout by Advanced C-RAN architecture

Photo 1 Appearance of high-density BDE

*3 **Advanced C-RAN:** Network architecture promoted by NTT DOCOMO using CA technology to enable cooperation between macro cells and small cells.

*4 **BB:** The circuits or functional blocks that perform digital signal processing.

*5 **RE:** Radio equipment that connects to BDE via CPRI.

*6 **Small cell:** Generic name for a cell covering a small area and having low transmission power relative to a macro cell.

2.1 Increase in Number of Accommodated Cells and Advanced Inter-cell Coordination

One unit of high-density BDE can accommodate a maximum of 48 optical fiber connections each over a Common Public Radio Interface (CPRI) link*7, which means a maximum of 48 cells or eight times that of existing BDE [4]. Centralized control of a large number of cells enables more flexible inter-cell coordination and cell combinations for CA. In addition, this equipment can connect to SRE for small cells as well as existing Remote RE (RRE)*8 used in macro cells, and thus realize CA with any combination of cells without restrictions on frequency bands or RE types.

To achieve higher peak speeds by CA in a stable manner, receive timing difference between Component Carriers (CCs)*9 in the mobile terminal must be kept to within a certain range for either macro cells or small cells [5]. The high-density BDE is equipped with a function for adjusting and synchronizing the transmission timing of all connected RE (RRE and SRE). This makes it possible to perform CA even between REs installed at different locations or REs having different optical cable lengths for connecting to the high-density BDE.

2.2 Greater Ease of Installation and Longer Optical Connections

High-density BDE makes the installation of equipment easier by significantly reducing the installation space and power needed per cell (installation space and power consumption approximately one-half and 40%, respectively, that of existing BDE). The optical-connection length between the BB unit and RE has also been extended by approximately 1.5 times that of existing equipment for more flexible area expansion and cell accommodation.

2.3 Future Extendibility

This high-density BDE also supports 3G and Time Division Duplex (TDD)*10 systems. Here, TDD support requires the synchronization of transmission timing among all adjacent RE units. High-density BDE supports GPS and Precision Time Protocol (PTP)*11 as time synchronization methods, and synchronization between high-density BDE units can be achieved through synchronization with GPS either directly or via a PTP network. This ability to synchronize via a PTP transmission path facilitates service expansion by TDD even in an environment in which GPS antennas—which are ordinarily used for TDD time synchronization—are difficult to install, such as underground complexes. In addition, high-density BDE supports TDD- Frequency Division Duplex (FDD)*12 CA [6] with existing FDD bands and 3CC-or-greater CA as further extensions of CA. It also supports extension to higher order Multiple Input Multiple Output (MIMO)*13 toward the realization of advanced designated base stations in the 3.5 GHz band [7].

Table 1 Basic specifications of high-density BDE

	High-density BDE	Existing BDE
Supported systems	LTE/LTE-Advanced	LTE
No. of CPRI links	Max. 48	Max. 6
Length of optical connection	Approx. 1.5 times existing BDE	—
Max. downlink speed (per cell)	225 Mbps (30 MHz bandwidth) - 3 Gbps (future support)	50 Mbps (20 MHz bandwidth)
Power consumption	125 W (per cell)	200 W (per cell)
Size	Approx. 1/2 existing BDE (per cell)	—

*7 **CPRI link:** Circuit between BDE and RE conforming to CPRI internal interface specifications for standard radio base stations. High-density BDE can operate a maximum of 48 CPRI links enabling a maximum of 48 RE connections.

*8 **RRE:** eNB antenna equipment installed at some distance from an eNB using optical fiber or other means.

*9 **CCs:** Bundled carriers used for achieving CA.

*10 **TDD:** A bidirectional transmit/receive system. It achieves bidirectional communication by allocating different time slots to uplink and downlink transmissions that use the same frequency band.

*11 **PTP:** A protocol for achieving high-accuracy time synchronization among equipment connected to a network. In this protocol, equipment that delivers time information (Master Clock) synchronizes with GPS, so by having high-density BDE synchronize with the Master Clock, synchronization between high-density BDE units based on GPS time can be performed.

*12 **FDD:** A scheme for transmitting signals using different carrier frequencies and bands in the uplink and downlink.

*13 **MIMO:** Wireless communications technology for expanding transmission capacity by using multiple transmit/receive antennas.

3. SRE

SRE corresponds to compact, low-output, optical-RRE for small cells of the one-LTE-carrier, one-sector type using a dual-antenna system. It comes in two types: equipment supporting the 1.5 GHz band as a capacity band[*14] and equipment supporting the 1.7 GHz band (**Photo 2**).

Similar to existing RRE, SRE consists of a Transmitter and Receiver-INterFace (TRX-INF)[*15] functional component, Transmitter and Receiver (TRX)[*16] functional component, Transmission-Power Amplifier (T-PA)[*17], Low Noise Amplifier (LNA)[*18], and DUPlexer (DUP)[*19]. SRE features are summarized below (**Table 2**).

3.1 Compact, Light, and Low-power Configuration

SRE is smaller and lighter than existing RRE while consuming less power making it more advantageous for installation. Having a small cell radius and low output power, SRE is conducive to high-density arrangements and installation on low-rise buildings relative to RRE and can therefore be used to increase radio capacity. Furthermore, as the maximum transmit power of SRE is less than that of existing RRE, the degree of contribution of the TRX functional component to overall power consumption is relatively larger than that of the T-PA functional

RRH: Remote Radio Head

Photo 2 Appearance of SRE (left: macro cell RRE; right: SRE (3 models))

Table 2 Basic specifications of SRE

	1.5 GHz SRE	1.7 GHz SRE	(Reference) Existing 2 GHz RRE
Max. transmit power	2 W / 15 MHz / branch	2 W / 20 MHz / branch	20 W / 20 MHz / branch
No. of branches	2		2
Size	Under 3 ℓ		Under 13 ℓ
Equipment weight	Under 3 kg		Under 11.5 kg
Power consumption	Under 30 W		Under 220 W
Power supply	AC 100 V/200 V		DC −48 V

*14 **Capacity band:** A band used mainly for increasing radio capacity.

*15 **TRX-INF:** Functional component that converts IQ signals and maintenance and monitoring signals between BB and TRX to CPRI format for transmission along optical fiber.

*16 **TRX:** Functional component having a function for converting input BB transmit signals into RF transmit signals through orthogonal modulation and a function for performing A/D conversion on RF receive signals and converting result to BB receive signals.

*17 **T-PA:** Functional component that amplifies RF transmit signals from TRX to prescribed power levels.

*18 **LNA:** Device that performs initial amplification of signals received from an antenna. The noise level applied at amplification is low and resulting distortion is also low even for a weak received signal.

*19 **DUP:** Device that separates and multiplexes RF transmit signals and RF receive signals and connects to T-PA and LNA. Includes a function for filtering frequency components other than RF transmit components and RF receive components.

component. The TRX functional component includes a distortion compensation circuit for suppressing the distortion components generated during amplification by T-PA, so adopting simpler implementations applicable to SRE maximum transmit power for the distortion compensation circuit can reduce power consumption. Moreover, while existing RRE adopts a DC power supply, SRE adopts an AC power supply that can generally be provided by a commercial utility to simplify installation in an installation infrastructure different than the existing one. Reducing power consumption in SRE means less heat dissipation compared to existing equipment, so in addition to conventional vertical mounting (on a front or side surface), horizontal mounting can also be considered since heat will still be able to dissipate. These mounting options contribute to ease of installation.

3.2 Optimization of Transmitting and Receiving Performance

There are also cases of operating small cells in the same frequency band in an area that overlaps a macro cell. In such a case, SRE transmit power can be increased to maintain each cell's required radius. Additionally, since the installation height of SRE antennas is lower than that of existing RRE, the propagation loss between a mobile terminal and the base station is less than that of macro equipment. Thus, while there may be times that SRE receives much interference from mobile terminals connected to the macro cell, SRE still satisfies the required receive dynamic range*20 enabling high-quality reception.

4. Base-station Antennas for Small Cells

Specifications for base-station antennas for use with small cells developed by NTT DOCOMO are overviewed in **Table 3**.

These antennas feature dual polarization*21 and can be shared among the 1.5 GHz and 1.7 GHz frequency bands. A separately developed compact duplexer is installed between the SRE and antenna to separate and combine signals of these frequency bands. The compact configuration of these antennas simplifies their installation.

When planning a service area by placing small cells next to each other, deterioration in signal quality due to interference between small cells is an issue of concern. To resolve this issue, downward tilting*22 in the vertical plane is effective to reduce the interference caused by that antenna's signals on adjacent cells while also to raise the receive level within the antenna's own cell. The end result is improved throughput [9]. The following summarizes the features of three types of antennas developed by NTT DOCOMO taking interference reduction and diverse installation environments into account.

1) Rod Antenna (Two Types)

Having an omnidirectional radiation pattern*23 in the horizontal plane, this type of antenna is installed on the wall or ceiling of a building to form a service area in its periphery. Two types of rod antennas have been developed: one with tilting for an interference-reduction effect and the other with no tilting for a compact configuration. The rod antenna with tilting consists of multiple vertically aligned antenna elements, the amplitude and phase of each of which is adjusted to produce an electrical tilt. The tilt angle, however, is predetermined.

2) Plane Antenna

This type of antenna has high gain*24 while having a unidirectional radiation pattern making it applicable to installation on high places like building roofs to form a service area in a spot-like manner. A plane antenna can be given a mechanical tilt with a metal fixture to reduce interference.

5. Conclusion

In this article, we overviewed high-density BDE, SRE, and base-station antennas for small cells all newly developed by NTT DOCOMO for implementing Advanced C-RAN. Looking to the future, we are committed to raising customer satisfaction even further by increasing transmission speeds and capacity in the radio network, such as

*20 **Dynamic range:** The range of input/output signal that can be processed without distortion.

*21 **Polarization:** Direction of electric-field vibration. Vibration of the electric field in the vertical plane relative to the ground is called vertical polarization and that in the horizontal plane is called horizontal polarization.

*22 **Tilting:** Inclination of an antenna's main beam direction in the vertical plane. There are mechanical tilt systems that physically tilt the antenna and electrical tilt systems that control the amplitude and phase of antenna array elements.

*23 **Radiation pattern:** Expresses the strength of radio waves radiated in different directions.

*24 **Gain:** Relative signal power in the direction of maximum radiation.

Table 3 Overview of base-station antenna specifications

Antenna type	Rod antenna with titling	Rod antenna with no tilting	Plane antenna	(Reference) Macro cell antenna [8]
Appearance				
Frequency band	1.5/1.7 GHz bands			0.7/0.8/1.5/1.7/2 GHz bands
Horizontal-plane directivity	Omnidirectional	Omnidirectional	Unidirectional	Unidirectional
Tilt type	Electrical tilt (no remote control support)	No tilt	Mechanical tilt (no remote control support)	Electrical tilt (remote control support)
Size (mm)	Under ϕ55×340	Under ϕ55×150	Under 200×200×60	Under ϕ200×2,700

through the development of 3.5 GHz, TDD-compatible equipment, and by improving the overall quality of communications.

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