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Technology Reports

Special Articles on Introducing the 3.5-GHz Band

Base Station Antennas for 3.5-GHz 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. In this article, we overview new base-station antennas developed for small cells, indoor use, and macro cells to support this introduction of TD-LTE in the 3.5-GHz band.

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1. Introduction

To meet the technical requirements for using frequencies in the 3.5-GHz band allocated by the Ministry of Internal Affairs and Communications in December 2014 [1], NTT DOCOMO developed new base-station antennas for small cell*1, indoor, and macro cell use, as summarized below.

(1) Small cell base stations are being rolled out in outdoor areas with high volumes of traffic such as areas surrounding train stations to provide stable communications at higher speeds. To be effective, the formation of small cell service areas must consider the purpose of use and a variety of installation conditions (building walls, rooftops, etc.). For this reason, NTT DOCOMO developed three types of compact antennas for small-cell base stations.

(2) Use of the 3.5-GHz band is also vital in indoor areas such as large-scale commercial facilities to support ever-increasing volumes of traffic. To meet this indoor need, NTT DOCOMO developed a compact antenna for mounting on ceilings to form a service area on the floor of a building.

(3) The 3.5-GHz band will also be introduced in macro cell base stations to provide high-speed communications for more than just high-traffic areas such as

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*1 **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.

train station neighborhoods. To form a broad service area with a macro cell, NTT DOCOMO developed a base-station antenna with high antenna gain*2 for installation in existing building and steel-tower base stations.

In this article, we describe the features of these new base-station antennas developed by NTT DOCOMO to meet a variety of usage scenarios and installation conditions.

2. Antennas for Small Cells

Major specifications of antennas for small cells are listed in **Table 1**. Three types of antennas were developed taking into account diverse installation platforms such as building walls and roofs and interference with adjacent small cells. These antennas have vertical/horizontal polarization*3 in common, and compared with small-cell antennas supporting the 1.5 and 1.7 GHz bands [2], they are compact in size. The following summarizes the features of each of these antennas.

1) Rod Antenna (Two Types)

This is a rod-shaped antenna that is vertically installed to form a radiation pattern with no directivity*4 (omnidirectional radiation pattern) in the horizontal plane. It can be installed on a building wall or steel pillar to form a service area in its periphery. Two types of rod antennas have been developed: one with electrical tilting*5 that can reduce interference with adjacent small cells [3], and the other with no tilting for a compact configuration.

2) Plane Antenna

This is a box-shaped antenna having a planar radiating surface and unidirectional radiation pattern. Its high antenna gain makes it applicable to forming spot-like service areas from high locations such as building roofs. In addition to mechanical tilting to reduce interference between small cells, this antenna features a low sidelobe*6 design to further reduce interference.

3. Antenna for Indoor Use

Major specifications of the antenna for indoor use are listed in **Table 2**. When forming a new service area using the 3.5-GHz band, it must be kept in mind that antenna units supporting the 1.5/1.7/2-GHz bands have already been installed indoors [4]. Installation space is therefore limited, which means that replacing existing antenna units is desirable. This newly developed antenna

Table 1 Major specifications of antennas for small cells

Antenna type	Rod antenna with tilting	Rod antenna with no tilting	Plane antenna
Appearance			
Supported frequencies	3.5-GHz band		
No. of branches	2		
Horizontal directivity	Omnidirectional		Unidirectional
Tilt support	Electrical tilting (remote control not supported)	No tilting	Mechanical tilting
Size (mm)	Under ϕ 49 × 240	Under ϕ 49 × 140	Under 150 × 150 × 60

*2 **Antenna gain:** Relative signal power in the direction of maximum radiation (main beam).

*3 **Polarization:** Direction of electric-field oscillation. Oscillation 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.

*4 **Directivity:** The property of an antenna in which signal intensity differs according to direction. An omnidirectional antenna radiates signals with the same intensity in all directions and a unidirectional antenna radiates strong signals in only one direction.

unit therefore supports the 1.5-, 1.7-, 2-, and 3.5-GHz bands in one unit with support of the 3.5-GHz band achieved through Multiple Input Multiple Output (MIMO) operation using four antenna elements. The antenna unit has the same size as existing antenna units supporting the 1.5/1.7/2-GHz bands making antenna unit replacement simple. The 3.5-GHz band can therefore be introduced without changing the overall look of indoor facilities.

The polarization configuration of the four antenna elements used for the 3.5-GHz band was studied by comparing a "vertically polarized element × 4" configuration with a "vertically polarized element × 2 and horizontally polarized element × 2" configuration. Since the size of the newly developed antenna unit is the same as existing ones, sufficient spacing between antenna elements cannot be secured, and as a result, the configuration having only vertically polarized elements exhibits high antenna correlation*7 compared with the configuration having both vertically and horizontally polarized elements. This high antenna correlation causes throughput*8 to drop. For this reason, we adopted the latter configuration providing higher throughput (low antenna correlation).

Table 2 Major specifications of antenna for indoor use

Appearance	
Supported frequencies	1.5/1.7/2/3.5-GHz bands
No. of branches	1.5/1.7/2-GHz bands: 2 3.5-GHz band: 4
Size (mm)	150 × 150 × 40

4. Antennas for Macro Cells

Major specifications of antennas for macro cells are listed in **Table 3**. Three types of antennas were developed here

Table 3 Major specifications of antennas for macro cells

Antenna type	Gain-oriented	Installation-oriented	
Appearance			
No. of sectors	3	3	6
Supported frequencies	3.5-GHz band		
No. of branches	2		
Tilt support	Electrical tilting (remote control supported)		
Size (mm)	Under ϕ 125 × 1,400	Under ϕ 125 × 600	Under ϕ 155 × 500

*5 **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 to tilt the main beam.

*6 **Sidelobe:** A weak signal radiated outside the direction of maximum radiation (main lobe). A sidelobe is generally radiated in an undesired direction and must therefore be suppressed.

*7 **Correlation:** An index expressing similarity between different signals. Expressed as a complex number, its absolute value ranges from 0 to 1. Similarity is higher for a value closer to 1, in which case signal separation at the receiver is difficult resulting in a drop in throughput.

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

according to the service area to be formed: two types (gain-oriented and installation-oriented) for use with three sectors and one type (installation-oriented) for use with six sectors. To install and operate these antennas together with other base-station antennas supporting the 700- and 800-MHz bands, 1.5-, 1.7- and 2-GHz bands, etc., it may be difficult to secure space for setting up a new steel pillar for an antenna supporting the 3.5-GHz band on a building roof or elsewhere in an urban area. Accordingly, to make it easy to install a new antenna on the same steel pillar mounting existing antennas, we also developed an installation-oriented type of antenna with roughly half the volume of the gain-oriented type. In these antennas for macro cells, remote control signals can be used to drive internal phase shifter*9 devices and control tilting. We adopted the global standard specified by the Antenna Interface Standards Group (AISG)*10 as the interface here for remote control of the tilt angle.

5. Conclusion

This article described the features of new base-station antennas developed for small cell, indoor, and macro cell use to support the newly available 3.5-GHz band. Base-station antennas are important facilities closely tied to area formation in a cellular system. Going forward, NTT DOCOMO is committed to developing advanced antennas to provide users with an even better network experience including enhanced radio capacities and faster communication speeds.

References

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*9 **Phase shifter:** A circuit that can change the phase going to each antenna element.

*10 **AISG:** An interface standards group formulating standards for remote control and monitoring of antenna tilt angle. AISG standards have been adopted as 3GPP technical specifications.