RoF | Indoor Coverage | Multiband

Technology Reports

Developing and Commercializing Multiband RoF Equipment and Indoor Antennas

NTT DOCOMO has begun providing MIMO-capable RoF equipment and indoor antennas developed to increase transmission speed and provide indoor coverage in small to medium-sized facilities. This RoF equipment is designed to cope with the recent traffic increases due to smartphone users, by simultaneously transmitting and receiving on multiple bands (1.5, 1.7 and 2 GHz). The equipment offers a quick and economical way to set up indoor coverage, and its multiband capabilities enable users to enjoy LTE services to their fullest.

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1. Introduction

Since 2000, NTT DOCOMO has been developing Radio over Fiber (RoF) equipment to transmit wireless signals via optical fiber for third-generation mobile telephone services (3G) in areas where received power is low such as in buildings or underground shopping malls. To apply LTE services, NTT DOCOMO developed 2 GHz band RoF equipment with Multiple Input Multiple Output (MIMO)*1 capabilities [1].

The number of users of NTT DOCOMO's LTE services, and demands for even faster communication speeds are increasing year by year. To increase the LTE transmission speed experienced by indoor users, it was necessary to expand occupied bandwidth. Therefore, NTT DOCOMO developed RoF equipment that operates on the 2, 1.5 and 1.7 GHz bands. The occupied bandwidth on the 1.5 and 1.7 GHz bands is 15 and 20 MHz respectively. This equipment enables indoor transmission speed up to 150 Mbps.

This article describes the multiband RoF equipment and the indoor antennas developed by NTT DOCOMO, and also describes results of actual commercial application.

2. Features

2.1 Equipment Overview

Figure 1 describes the system configuration. The equipment consists of a base unit, and hub and remote units. The equipment converts radio signals to digital signals, and adopts an optical transmission system for the digital signals. The systems supports 3G and LTE systems in the 1.5, 1.7 and 2 GHz bands, and enables transmit diversity*2 for 3G systems as well as MIMO transmission for LTE systems. This configuration enables installation of the base unit and base station MODEM device in one location, with the hub and remote units installed in serviced buildings. These buildings can be quite far away, making it possible to provide coverage with improved transmission speed in small to medium-sized areas with low installation costs.

(1) Base units monitor downlink radio power with a combiner, adjust levels, and convert downlink radio signals to Intermediate Frequency (IF)*3 bands. After that, a digital signal for each frequency band is converted by A/D convertor, and then the signals

*1 **MIMO**: Multiple Input Multiple Output. A wireless communication technique that utilizes multiple paths between multiple antennas at the transmitting and receiving ends to exploit spatial propagation properties, causing the capacity of wireless links to increase in proportion with the number of antennas.

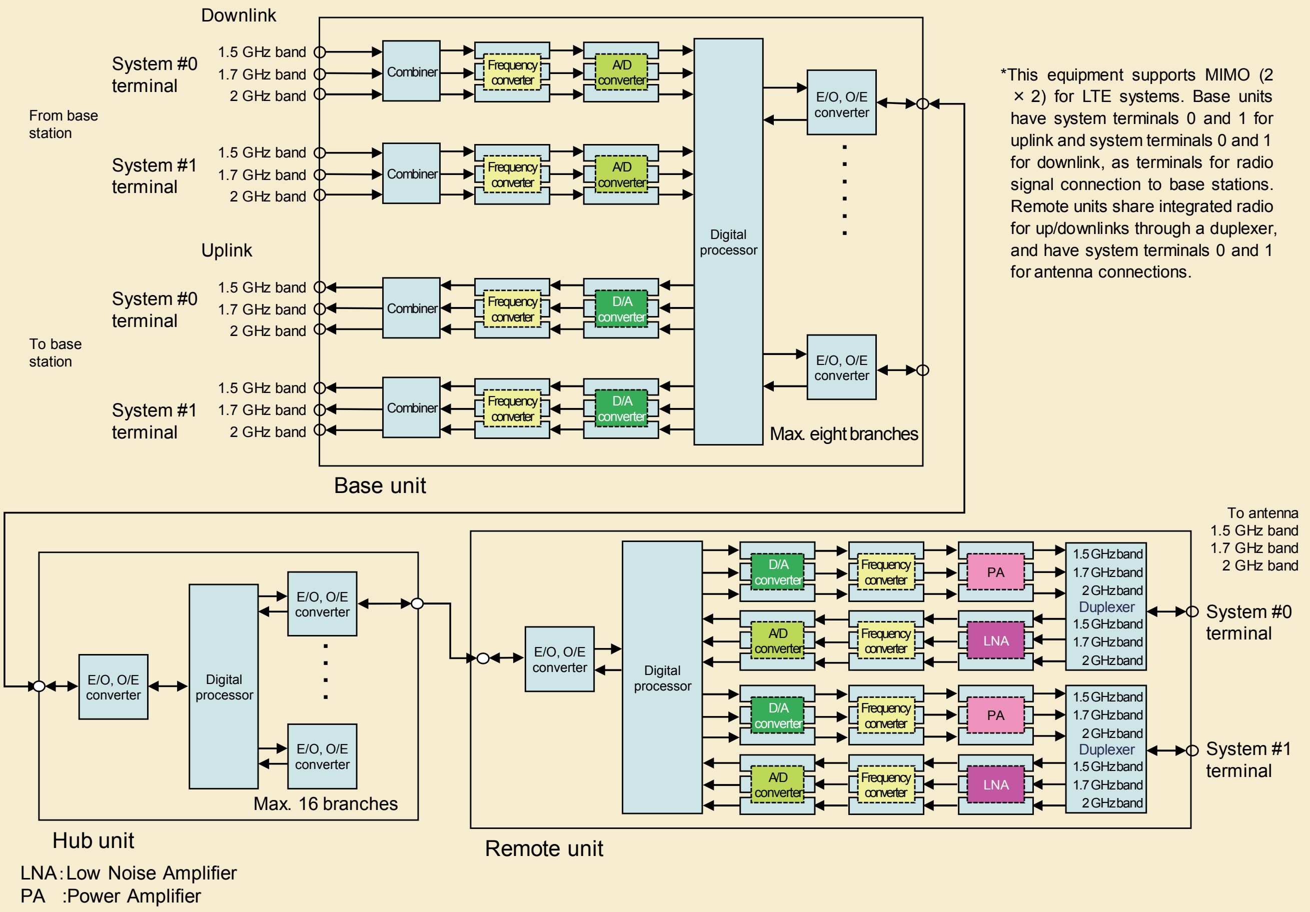


Figure 1 Multiband RoF system configuration

are combined as optical signals and transmitted. After optical signals from remote units are converted to digital signals, signals are distributed on each of the frequency bands, and then converted to uplink radio signals by D/A and frequency converters. This equipment can also be configured with only a small number of optical fibers by wavelength multiplexing optical uplink and downlink signals through E/O and O/E converters*4.

(2) Hub units convert optical signals from base units to electrical signals, and distribute them and transmit via optical fiber to the remote units with: E/O converter. The hub units also include functions that operate after they convert optical signals from remote units to electrical signals. Up to eight hub units can be connected to one base unit, and up to 16 remote units can be connected to each hub unit. Therefore, up to 128 remote units can be connected to each base unit.

(3) The remote units separate and convert the optical signals into digital signals for each frequency band. Radio signals are generated for the three frequency bands by D/A and frequency converters for each frequency band. After uplink radio signals are converted to the IF band by frequency converters, they are converted to digital signals by A/D converters, and then converted to optical signals by E/O, O/E converters and sent to the base unit via a hub unit.

Radio signals for the three frequency bands are combined in one terminal by a duplexer*5, and connected to multiband indoor antennas

*2 **Transmit diversity**: Technology which utilizes the differences in channel fluctuation between transmission antenna channels to obtain diversity gain.

*3 **IF**: Intermediate frequency.

*4 **E/O, O/E converter**: Converts electrical signals into optical signals and vice-versa.

*5 **Duplexer**: A device that consisting of a transmitter filter and receiver filter. It allows a single antenna to be used for both transmission and reception.

for the three bands developed with this RoF equipment. This enables multiband coverage to be installed efficiently using only one antenna.

In future, communicating via multiple frequency bands using only one mobile telephone will become possible due to LTE-Advanced[*6] Carrier Aggregation (CA)[*7], a technology that promises even greater transmission speeds in areas covered by RoF equipment.

2.2 Equipment Specifications

Equipment specifications are described in **Table 1**. Downlink signals use 5 MHz of bandwidth, with +10 dBm[*8] of output power/branch. The occupied bandwidth of the 1.5 GHz band is 15 MHz, with +14.8 dBm/branch. The 1.7 and 2 GHz bands use 20 MHz of occupied bandwidth, with output power at +16 dBm/branch. Radio transmission and reception are possible in the 1.5, 1.7 and 2 GHz bands. Output power deviation, Adjacent Channel Leakage power Ratio (ACLR)[*9], and spurious emissions[*10] conform to the technical specifications for both systems (3G, LTE) [2] [3]. **Figure 2** shows the output spectrum[*11] of the downlink signals for the three frequency bands in the remote units used with this equipment. Downlink signals for the three frequency bands are transmitted simultaneously from the output terminals of the remote units. Undesirable waveforms outside of the frequency bands used for transmitting signals are maintained at a low level.

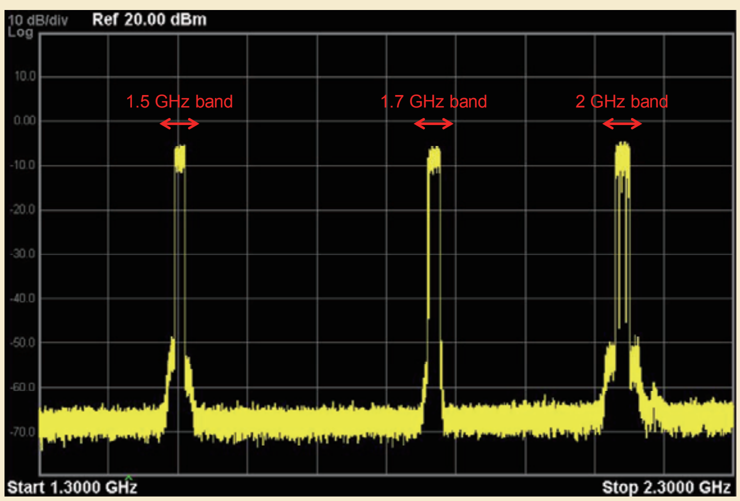
The maximum optical fiber distance between base and hub units is 20 km, while the maximum optical fiber distance between hub and remote units is 4 km.

The equipment can be seen in

Table 1 Equipment specifications

Item	Downlink	Uplink
Radio frequencies	1.5 GHz band: 1,495.9 – 1,510.9 MHz 1.7 GHz band: 1,859.9 – 1,879.9 MHz 2 GHz band: 2,130 – 2,150 MHz	1.5 GHz band: 1,447.9 – 1,462.9 MHz 1.7 GHz band: 1,764.9 – 1,784.9 MHz 2 GHz band: 1,940 – 1,960 MHz
Input power	-9 dBm/5 MHz/branch	-20 dBm/branch
Output power	1.5 GHz band: +14.8 dBm/branch 1.7 GHz band: +16 dBm/branch 2 GHz band: +16 dBm/branch	-20 dBm/branch
Output power deviation	Within ±1.0 dB	Within ±2.0 dB
Adjacent channel leakage power ratio (ACLR)	-45.8 dBc or lower	
Noise figure		26.3 dB or lower (with one remote unit) 47.4 dB or lower (with 128 remote units)
No. of hub units	Max. eight units	
No. of remote units	Hub unit – remote unit: Max 16 remote units, total units: Max. 128 remote units	
Power Supply	Base unit: -48V Hub unit: -48V or AC100V Remote unit: DC -163.8 to -110V or AC100V	
Optical transmission distance	Base unit – hub unit: Max 20 km, hub unit – remote unit: Max. 4 km	

dBc (decibels relative to the carrier): Level relative to the carrier signal.



Horizontal axis: Frequency: Center frequency 1.8 GHz, 100 MHz/div
Vertical access: Power, 10 dB/div

Figure 2 Output spectrum for downlinks for the three frequency bands (1.5 GHz band: LTE 15 MHz, 1.7 GHz band: LTE 20 MHz, 2 GHz band: 3G 5 MHz four waves)

*6 **LTE-Advanced**: Name of IMT-Advanced in 3GPP. IMT-Advanced is the successor to the IMT-2000 third-generation mobile communications system.

*7 **CA**: Technology to simultaneously transmit and receive signals from 1 user using multiple carrier waves to enable wider bandwidths while maintaining back compatibility with existing LTE, and achieve faster transmission speed.

*8 **dBm**: decibel-milliwatt. Power value [mW] expressed as 10log (P). The value relative to a 1mW standard (1mW=0 dBm).

*9 **ACLR**: In modulated signal transmission, the ratio between the transmitted signal band power and undesired power generated in the adjacent channels.

*10 **Spurious emission**: An undesired signal that appears out of band when a signal is transmitted.

Photo 1. Base units have a volume of 18ℓ or less, and weigh 8 kg or less. Hub units have a volume of 6ℓ or less, and weigh 5 kg or less. Remote units have a volume of 14ℓ or less, and weigh 9 kg or less.

3. Multiband Indoor Antennas

To provide indoor services in the 1.5 and 1.7 GHz band in addition to the 2 GHz band, it was necessary to develop an indoor antenna to emit radio waves at these frequencies. However, producing a singleband antenna for each frequency could make it impossible to install the units in certain locations due to space and appearance considerations. To solve this issue, we developed a multiband dual polarized antenna that supports two MIMO branches in a single radome, and also supports the three bands used with this system (1.5, 1.7 and 2 GHz). This antenna is similar in size to the conventional 2 GHz indoor antenna, as shown in **Figure 3**.

In general, to maintain performance, antennas must be bigger as frequency becomes lower. The internal structure of an antenna is also complicated by multi-

(a) Base unit (b) Hub unit (c) Remote unit

Photo 1 Equipment appearance

	Multiband indoor antenna	Conventional indoor antenna
Appearance		
Supported frequencies	1.5/1.7/2 GHz bands	2 GHz band
Size	150 × 150 × 40 mm	130 × 130 × 40 mm
Weight	Approx. 320 g	Approx. 230 g
MIMO support	Supported (two antennas)	Supported (two antennas)
CA support	Supported	Not supported

Figure 3 Indoor antenna specifications

*11 **Output spectrum**: This depicts the relationship between frequency (on the horizontal axis) and power (on the vertical axis) at the output port.

band design, and considerations must be given to how waveform characteristics are affected. This antenna adopts miniaturization methods such as capacity loaded monopole [4], and has been made possible by independent parameter design. As a result, its waveform characteristics and size are similar to the existing 2 GHz indoor antennas.

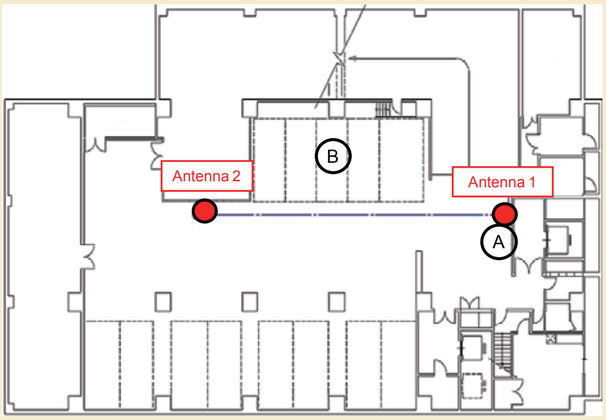
Thus, by simply replacing conventional antennas already installed in coverage areas with this new antenna, it's possible to improve the quality and speed of communications with almost no need for additional installation space or changes to the coverage area.

Moreover, because the installation position and method are the same as the conventional antenna, installation works can be performed with ease. **Photo 2** shows an image of the antenna installations. Because this antenna is designed to support CA with LTE-Advanced systems, it will also be possible to further increase transmission speeds in future without replacing antennas.

4. Throughput using This Equipment

An overview of the area and LTE throughput*12 results associated with using this equipment and indoor antenna in a weak radio area are shown in **Figure 4** and **Table 2**. This area was serviced with the 1.5 and 2 GHz frequency bands. The maximum logical downlink throughput was 112.5 Mbps in the 1.5 GHz band (LTE bandwidth 15 MHz), and 75 Mbps in the 2 GHz band (LTE bandwidth 10 MHz), whereas the actual maximum throughput was 98.9, and 53.5 Mbps respectively.

Photo 2 Indoor antenna installed in hallway



■Test environment
·B1 basement car park
·LTE 2 GHz band: 10 MHz
·LTE 1.5 GHz band: 15 MHz
·Remote units/number of antennas: 2

Figure 4 Test point scheme

Table 2 LTE throughput test results

	1.5 GHz band	2 GHz band
DL at Point A (Mbps)	98.9	53.5
DL at Point B (Mbps)	95.7	48.2

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

5. Conclusion

We developed multiband (1.5, 1.7 and 2 GHz bands) RoF equipment and a multiband indoor antenna to service weak radio areas in buildings and improve transmission speeds. Compared to the theoretical value, throughput was 88% for the 1.5 GHz band and 71% of the 2 GHz band. This confirms that the system is capable of large-capacity traffic in commercial settings.

We intend to further miniaturize the remote units and make them lighter, and study expansion of supported frequency bands.

References

[1] Y. Ito et al.: "RoF Equipment Developed for Coverage in Small Areas where Received Power is Low," NTT DOCOMO Technical Journal, Vol. 15, No. 2, pp. 49–55, Oct. 2013.

[2] TELEC T–112: "Characteristics test method for DS-CDMA/T-HCDMA mobile radio communication base stations, etc" (In Japanese).

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[4] W. Shen, H. Arai, J. Huiling and K. Cho: "Low-profile cross-polarized MIMO antenna for indoor base stations" IEICE, Vol. J96–B, No.6, pp. 641–647, Jun. 2013 (In Japanese).