Base Station | Active Antenna | Standardization

Technology Reports

Active Antenna for More Advanced and Economical Radio Base Stations — Connection with LTE Base Station and Evaluation of Service Area Quality by Field Experiment —

Active antennas that integrate radio transceiver functions in the antenna unit have been attracting attention as an approach to furthering the evolution of radio base stations. Compared to existing base stations, a base station using an active antenna can provide a higher-quality service area, reduce installation space, and improve power efficiency. This article describes the features of a base station using an active antenna, presents an overview and the results of a field experiment conducted by NTT DOCOMO, and outlines standardization trends at 3GPP.

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1. Introduction

Radio base stations continue to evolve to provide a better wireless communication environment to customers as mobile communication systems continue to evolve to meet the growing demand for mobile traffic. In recent years, attention has come to be focused on active antennas that integrate radio transceiver functions in the antenna unit as one approach to furthering the evolution of base stations. Standardization work for specifying radio characteristics of a base station using an active antenna is now in progress at the 3rd Generation Partnership Project (3GPP). A base station using an active antenna features a higher-quality service area, a smaller installation space, and improved power efficiency compared to existing base stations, and these features make active antennas a promising technology for the future.

At NTT DOCOMO, we have successfully connected an active antenna to a commercial LTE base station equipment via a standard interface and conducted for the first time in Japan a field experiment using an active-antenna base station [1] [2].

In this article, we describe the technical features of a base station using an active antenna, provide an overview of a field experiment conducted by NTT DOCOMO, and present experimental results. We also outline standardization trends at 3GPP.

2. Features of an Active-antenna Base Station

2.1 Basic Configuration of Base Station using an Active Antenna

The basic configuration and features of an active-antenna base station are shown in **Figure 1**. An active antenna consists of multiple antenna elements and corresponding compact radios as well as a controller for these radios. An

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antenna element acts as an outlet/inlet for radio waves and a compact radio performs transmit/receive signal processing such as digital-to-analog conversion, frequency conversion, and power amplification. The controller, meanwhile, performs digital control of excitation coefficients*1 given to each antenna element and combines/divides digital signals from/to each antenna element. In addition, a BaseBand Unit (BBU)*2 performs digital signal processing of transmit/receive information during communications with a mobile terminal and an optical fiber cable connects the active antenna to the BBU to transmit digital signals.

When changing the antenna beam tilt*3 to adjust the service area radius covered by the base station, a conventional base-station antenna generally uses an analog variable phase shifter, which is a device used to change the relative excitation phase difference*4 between antenna elements. An active antenna, on the other hand, enables the excitation coefficients of each antenna element to be separately controlled by equipping each antenna element with a compact radio. This means a much higher degree of freedom in controlling excitation coefficients compared to an analog variable phase shifter, and this, in turn, means that antenna directivity*5 can be controlled with more flexibility enabling the design of high-quality service areas. For example, referring again to Fig. 1, the tilt range can be expanded, different tilts can be set for the downlink transmission and uplink reception of radio signals at the base station, and tilts can be separately set for different Radio Access Technologies (RAT) such as LTE and W-CDMA, all without having to mount multiple analog variable phase shifters.

To obtain the desired antenna beam pattern, the amplitudes and phases of the antenna elements must be appropriately adjusted. Since an active antenna incorporates multiple radios, noise caused by the power amplification circuits of each radio generates time-varying excitation errors among antenna elements. An active antenna may therefore have a calibration function for correcting these excitation errors. This calibration helps

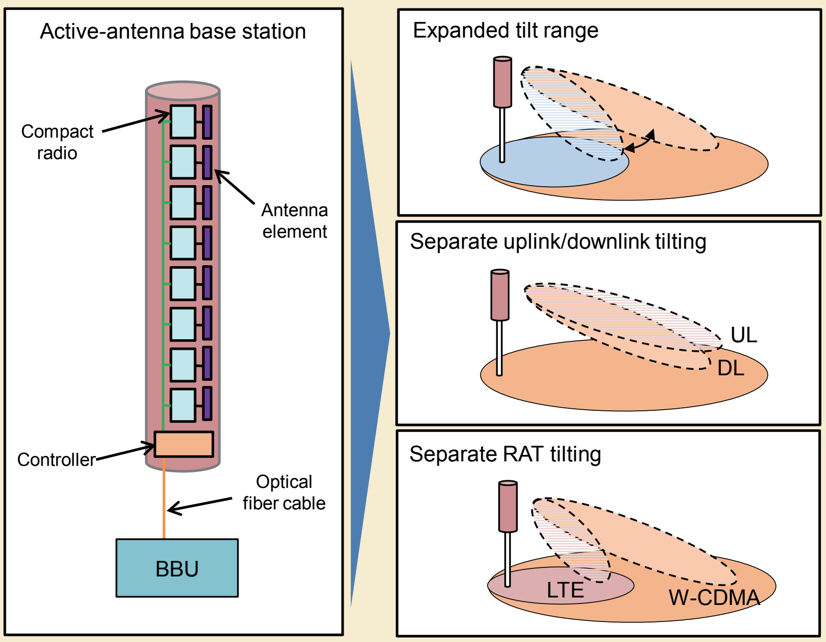


Figure 1 Configuration and features of active-antenna base station

*1 **Excitation coefficients:** Phase and amplitude information given to each antenna element.

*2 **BBU:** One component of base station equipment performing digital signal processing of transmit/receive information when communicating with a mobile terminal.

*3 **Tilt:** Inclination of antenna beam in the vertical plane. If the horizontal direction is designated as 0°, increasing or decreasing the tilt angle changes the communication area.

*4 **Excitation phase difference:** Phase difference between signals that antenna elements radiate or receive.

*5 **Antenna directivity:** The directional characteristics of the radiated or received strength of the antenna.

to achieve stable antenna directivity.

2.2 Advantages of Active Antennas in a Remote-type Base Station Configuration

One deployment configuration of a base station is the remote-installation type (optical-fiber-connected base station) consisting of a master station and multiple slave stations as shown in **Figure 2**. In a conventional base station of this type, a slave station consists of a Remote Radio Head (RRH)*6 performing transmit/receive signal processing and installed apart from the master station (BBU), and an antenna installed near the RRH. The BBU and RRH exchange digital signals through an optical fiber cable and an RRH and its associated antenna exchange radio signals through a Radio Frequency (RF)*7 coaxial cable. In contrast, since a base station using active antennas integrates the RRH function of conventional base stations in the antenna itself, the slave station can consist of one active antenna. In the case of an active antenna mounting multiple radios as shown in Fig. 1, the maximum transmit power required by a single radio is small, so each radio can generally be made small. This means that the total volume of the active antenna can likewise be made small. Furthermore, as there is no need for installing RRH, the entire base station size can be reduced compared to a conventional base station. This is advantageous for installing base stations at locations having limited space for installing equipment as in an urban area. Moreover, as an active antenna can be directly connected to the BBU via an optical fiber cable to transmit digital signals and as the excitation coefficients for each antenna element can be digitally controlled, electrical loss associated with RF coaxial cables and analog variable phase shifters in a conventional antenna configuration can be reduced thereby enhancing power efficiency. As a consequence, the service area covered by a single base station can be expanded and area quality improved while operating costs can be reduced through power savings.

3. Connection with BBU via a Standard Interface

NTT DOCOMO has conducted performance evaluations of an active-antenna base station using a prototype active antenna. To connect to the BBU using optical fiber cable, this active antenna supports a global standard interface based on the Open Radio equipment Interface (ORI) whose specifications are being established by the European Telecommunications Standards Institute (ETSI)*8. Referring to **Figure 3**, if the

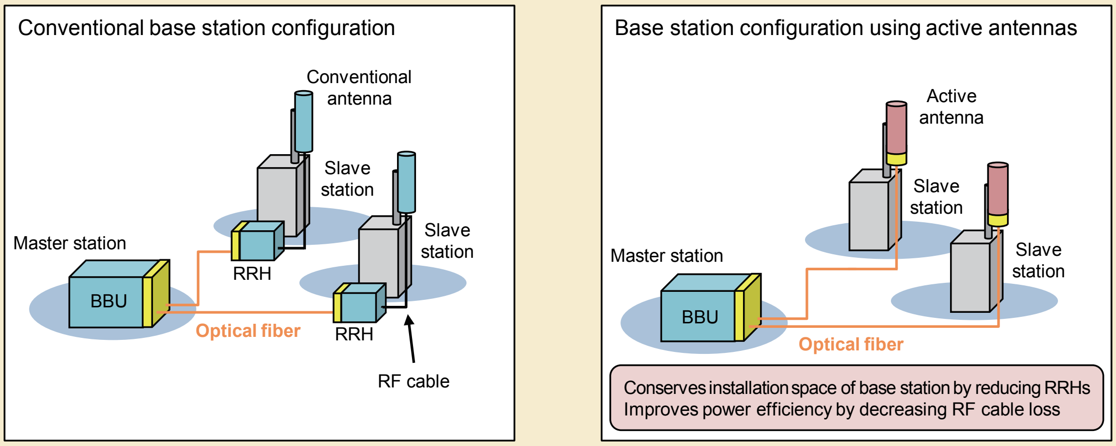


Figure 2 Conventional configuration and active-antenna configuration of a remote-type base station

*6 **RRH:** One component of base station equipment installed at a distance from the BBU using optical fiber or other means. It serves as radio equipment for transmitting/receiving radio signals.

*7 **RF:** The frequency range used in radio communications.

*8 **ETSI:** The standardization organization concerned with telecommunications technology in Europe.

active antenna that will be used to replace the slave station in a conventional remote-type base station has an equipment-specific interface, the BBU (master station) will also have to be replaced with equipment supporting that active antenna. However, if a standard interface is supported, compatibility can be achieved between the active antenna and a BBU from a different vendor making it unnecessary to replace the existing BBU and making it possible to inexpensively and quickly deploy active antennas. NTT DOCOMO has successfully connected a prototype active antenna to LTE base-station equipment used in its commercial network via an ORI-standard interface.

4. Field Experiment

4.1 Purpose of Experiment

At NTT DOCOMO, we conducted a field experiment using an experimental station consisting of LTE base-station equipment and a prototype active antenna. Our purpose here was to test the power-efficiency improvement effect achieved by a reduction in electrical loss, which is one of the key features of an active-antenna base station. Specifically, to clarify the amount of improvement achieved in comparison with a conventional base station, we also installed a conventional antenna (hereinafter referred to as "passive antenna" in contrast to "active antenna") designed so that basic antenna specifications such as antenna gain*9 and half-power beam width*10 were equal to those of the active antenna. We were then able to compare communications quality and service-area range in the downlink between the two types of antennas.

4.2 Configuration of Experimental Station

The major specifications and equipment configuration of the experimental

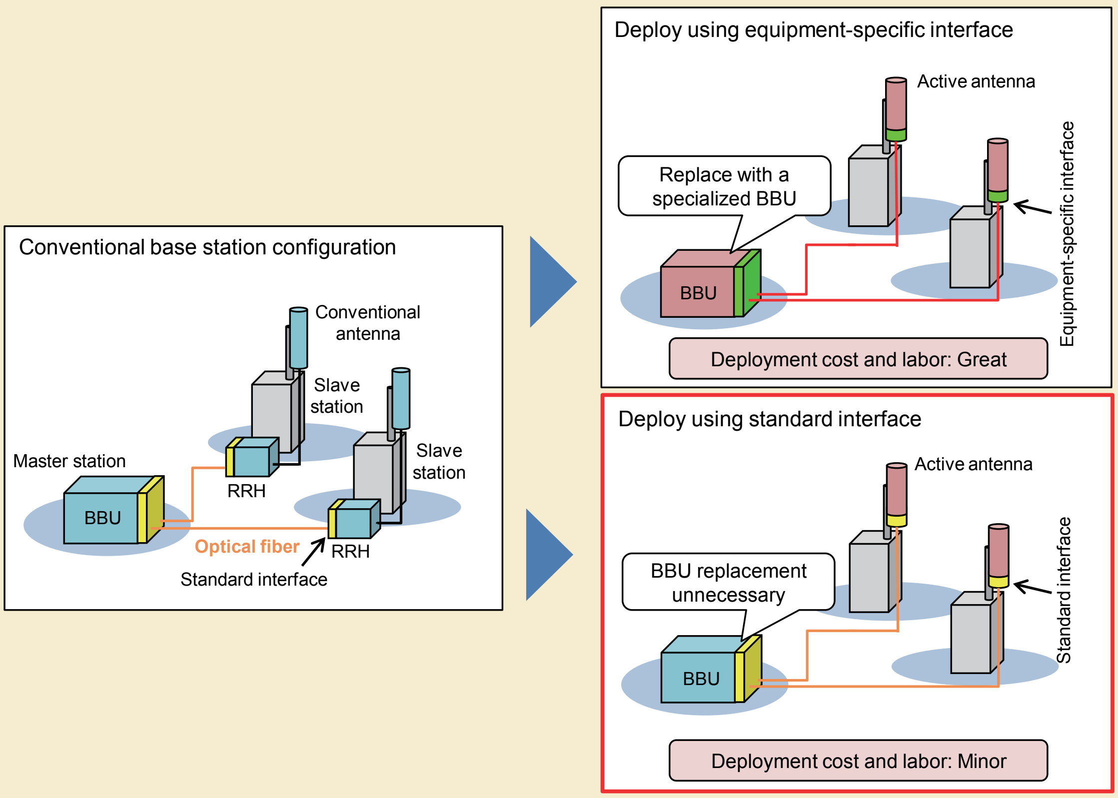


Figure 3 Efficient deployment of active antennas through a standard interface

*9 **Antenna gain:** Radiated power in the direction of maximum radiation usually expressed as the ratio of radiated power to that of an isotropic antenna.

*10 **Half-power beam width:** The angle at which radiated power of the antenna is half that in the direction of maximum radiation.

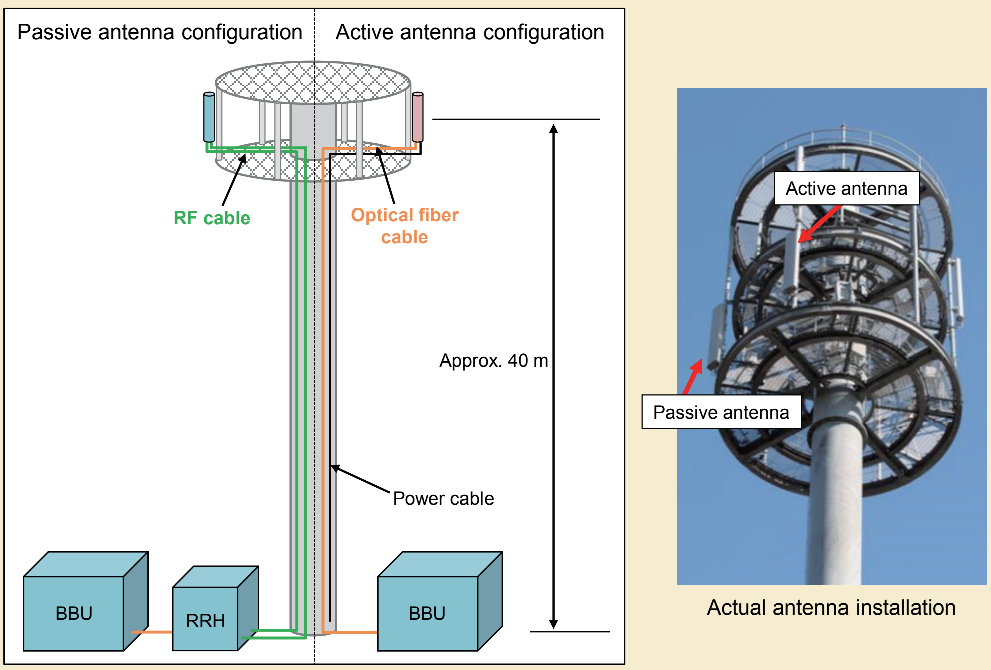
station are given in **Table 1** and **Figure 4**, respectively. The active antenna has an orthogonal polarization configuration[*11] made up of vertical and horizontal polarization and consists of eight antenna elements and eight corresponding compact radios for each polarization. The passive antenna, meanwhile, has the same configuration as the active antenna with respect to antenna elements, and it also mounts an analog variable phase shifter to control tilt angle. The RRH used in the passive-antenna configuration is installed at the foot of an antenna tower. Both antennas are installed at a height of approximately 40 m from the ground and are set to a tilt angle of 8°. The transmit power per polarization, which is the total output power of eight compact radios for the active antenna configuration and the output power of the RRH for the passive antenna configuration, was set to 10 W. The RAT used here was LTE, the radio frequency band was 800 MHz, and the bandwidth was 10 MHz.

Table 1 Major specifications of experimental station

Communications system	LTE
Radio frequency band	800 MHz
Bandwidth	10 MHz
Total transmit power per polarization	10 W
Antenna height	Approx. 40 m
Tilt angle	8°

4.3 Measurement Environment

This field experiment was conducted in a suburb of Chiba City in Chiba Prefecture, Japan. The area surrounding the experimental station was a relatively open environment with few tall buildings. As shown in **Figure 5**, measurements were performed along measurement courses within a short-range area and long-range area at a distance of 200–700 m and 1–3 km, respectively,



Configuration of experimental station

Actual antenna installation

Figure 4 Equipment configuration of experimental station

***11 Orthogonal polarization configuration:** An antenna configuration that can perform transmitting and receiving equivalent to two antennas from a single antenna enclosure by using orthogonal polarization in the vertical/horizontal or ±45° directions.

from the base station. The short-range area was roughly within the range of the main beam's half-power beam width (vertical and horizontal planes). In this area, we evaluated the Reference Signal Received Power (RSRP)*12 and user throughput*13 in the downlink. In the long-range area, we evaluated the range in which communications could be performed.

4.4 Results of Experiment

(1) Short-range area

Measurement results for RSRP and user throughput in the short-range area are shown in **Figure 6**. Measurement values were obtained by taking the average of values measured within a 10-meter-square cell, and these graphs show median values of measurement results obtained within the area. These results show that the median values for RSRP and user throughput improved by approximately 4 dB and 10%, respectively, when using the active-antenna configuration compared with the passive-antenna configuration. In short, for a comparison made within the same area, these results demonstrate that an active-antenna configuration can improve communications quality compared to a passive-antenna configuration.

(2) Long-range area

For the long-range area, the active-antenna configuration and the passive-antenna configuration were compared in terms of the range within which communications could actually be performed. It was found that the range of communications when using a passive-antenna configuration was no greater than 2.5 km from the base station along a straight line and that when using an active-antenna configuration was at least 3 km. These results show that the active-antenna configuration can expand the cell radius covered by a single base station by 1.2 times or more compared with the passive-antenna configuration.

5. 3GPP RAN4 Standardization Trends

The 3GPP Radio Access Network working group 4 (RAN4) is in charge of standardizing RF aspects of Universal Terrestrial Radio Access Network (UTRAN)*14 and Evolved UTRAN (E-UTRAN)*15 in 3GPP. Thus, specifications related to radio characteristics of a base station using the active antenna, which is called Active Antenna System (AAS) in 3GPP, also fall within the scope of this group and Study Item (SI)*16 discussions on those specifica-

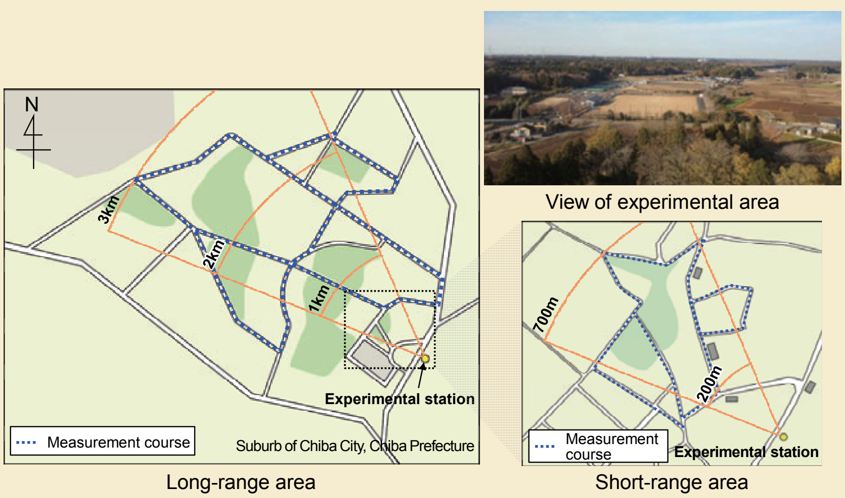


Figure 5 Experimental area

*12 **RSRP:** The received power of a signal measured by a mobile terminal in LTE. Used as an indicator of the receiver sensitivity of a mobile terminal.

*13 **Throughput:** The amount of data transferred through a system without error per unit time.

*14 **UTRAN:** A 3GPP radio access network using the W-CDMA system.

*15 **E-UTRAN:** A 3GPP radio access network using the LTE system.

*16 **SI:** The work of studying an issue in the creation of specifications.

tions began in September 2011. These discussions, which were completed in March 2013, examined differences in transmit/receive signals between existing base stations and AAS. At present, discussions on specifying AAS radio characteristics and measurement methods continue as a Work Item (WI)*17 that began in March 2013. The plan is to complete these WI discussions in early 2015.

5.1 SI Discussions

In the SI, the structure of AAS was first discussed as a basis for future discussions. As shown in **Figure 7**, a consensus was reached on defining the AAS structure as one consisting of a Transceiver Unit Array*18 with K Transceiver Unit(s)*19, an Antenna Array*20 with L antenna element(s), and a Radio Distribution Network (RDN)*21 that divides/combines the signals from Transceiver Unit Array to the Antenna Array and vice versa in a K:L format.

Next, discussions were held on unwanted emissions from the transmitters. The effects of unwanted emissions in AAS were evaluated by simulation, and it was found that AAS causes the same radio quality degradation as existing base stations if the Adjacent Channel Leakage Ratio (ACLR)*22 were specified as 45 dB per transmitter (which is the same value as the requirement for existing base stations). On the receiver side, in-band blocking*23 was also discussed and it was found that the level of interference from other base stations to the AAS would be the same as that from other base stations to existing base stations. Details on the consensus reached in these discussions can be found in a 3GPP Technical Report [3].

5.2 WI discussions

Adding to the SI discussions, simulations on unwanted emissions from the transmitters were performed for a variety of scenarios envisioned for actual propagation environments, and it was agreed that the ACLR requirement for AAS is to be specified as 45 dB.

The requirements for existing base stations are specified at the "antenna connector," which connects the antenna and the radio equipment. An AAS, however, enables antenna directivity and effective radiation gain to be dynamically varied by integrating the antenna and

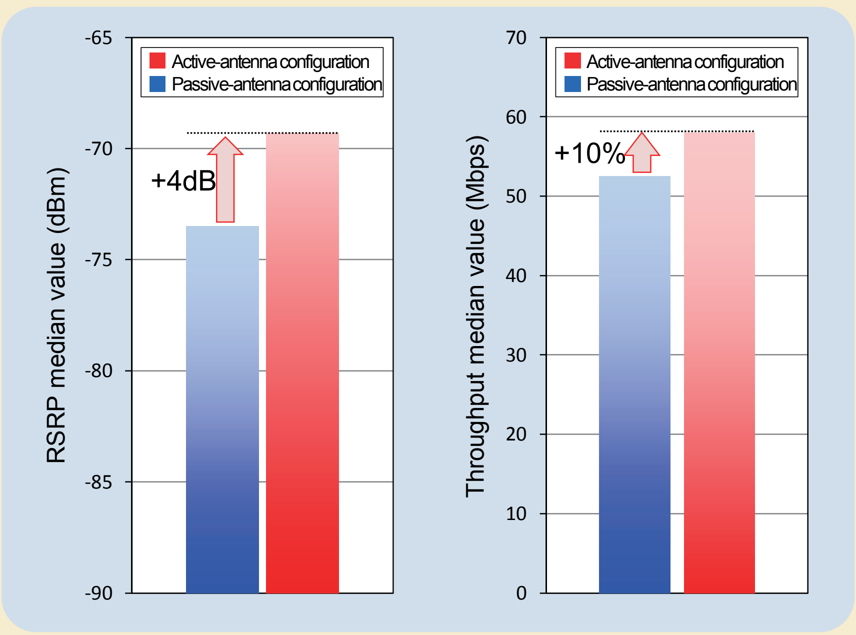


Figure 6 Comparison of communications quality in the downlink (Short-range area)

*17 **WI:** The work of prescribing specifications.
*18 **Transceiver Unit Array:** An array of radios.
*19 **Transceiver Unit:** Equipment that integrates a transmitter and receiver. A radio.
*20 **Antenna Array:** An array of antenna elements.
*21 **RDN:** A logical node situated between and interconnecting the Transceiver Unit Array and Antenna Array.
*22 **ACLR:** Ratio of the wanted signal power to the unwanted emission power in an adjacent channel.
*23 **In-band blocking:** Receiver ability to receive a wanted signal in the presence of an unwanted interferer within the receive bandwidth.

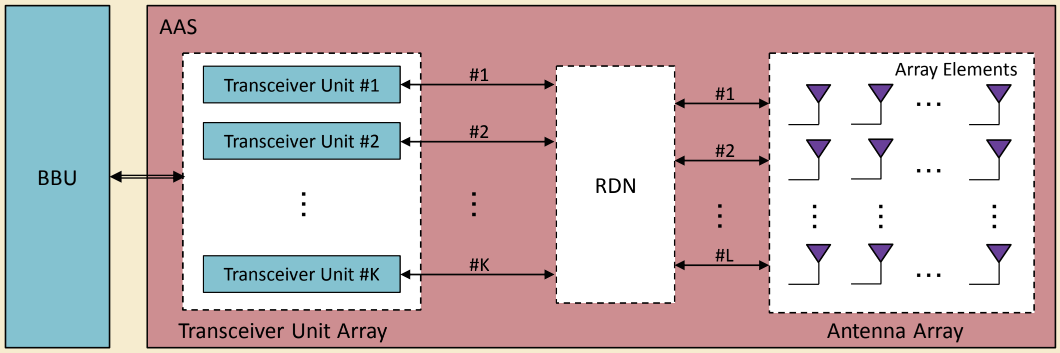


Figure 7　AAS structure agreed upon in RAN4

radio equipment. Discussions are therefore being held on the need for specifying Over The Air (OTA) characteristics such as radiated transmit power requirements and OTA sensitivity requirements in addition to the requirements specified at the antenna connector. Details on the consensus reached up to November 2014 can be found in a 3GPP Technical Report [4].

6. Conclusion

This article described the technical features of an active antenna for furthering the evolution of base stations by integrating radio transceiver functions in the antenna unit. It also presented an overview and results of a field experiment conducted by NTT DOCOMO and outlined standardization trends at 3GPP.

Going forward, we will continue our studies towards introducing an active-antenna base station into commercial networks to further improve the overall quality of mobile communications.

References

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