Orchestrating a brighter world NEC

White Paper

Massive MIMO for High-capacity Mobile Access

NEC Corporation

Executive Summary

Social solutions that employ high-grade ICT to resolve various social issues have been highlighted in recent years. The most effective way to realize a range of social solutions is to offer the ICT functions required by users and services on a common platform. NEC believes that next-generation 5G mobile systems can play a strong role in the provision of social solutions by integrating with these kinds of ICT platforms.

Offering high-speed data communication services and a variety of time-critical services on 5G mobile access networks requires faster throughput, greater capacity and lower latencies on end-to-end transmissions. NEC would like to introduce its latest research into massive MIMO technologies for low super high frequency (SHF) bands, designed to provide high speed next-generation mobile services and deliver significantly improved QoE to all users and applications.

Expanding bandwidth

Low SHF band and bands above 24 GHz were designated as the mobile spectrum bands for 5G broadband communication at World Radio communication Conference 2015 (WRC-15). Table-1 sets out the various characteristics of each band. 5G commercial services using low SHF bands are expected to start around 2020. The 3rd Generation Partnership Project (3GPP) is considering specifying license-assisted access (LAA) technologies that operate LTE using unlicensed bands, and the 5GHz unlicensed band could be one of the candidates. Low SHF bands, which can receive over-the-horizon communications, offer coverage areas ranging from hundreds of meters to several kilometers. With low SHF bands, being able to take advantage of fully mature RF chip technology helps reduce costs, and create highly energy efficient, smaller-sized massive-element antennas.

On the other hand, with bands above 24 GHz, the higher the frequency, the higher the distance decay and the lower the reflection and diffraction. This could potentially restrict coverage areas and diversity of usage. With these bands, it is important to resolve the outstanding issues of cost and power usage for RF chips, especially for mobile terminals.

Based on this comparison, low SHF bands would be the first choice for the deployment of 5G mobile systems. However, realizing 5G mobile systems using low SHF bands, requires a higher level of technology from a digital signal processing perspective, to accommodate more complex radio propagation characteristics. For those reasons, NEC is focusing on low SHF bands in its 5G research and development.

Table-1: Characteristics of higher frequency bands

	Low SHF band	**Above 24GHz bands**
Expected new bandwidth	Several 100MHz	Several GHz
Expected commercial release	Around 2020	Later than 2022
Service coverage	Several 100m – Several km	Several 10m
Propagation model	Mainly NLOS Many multi-path	Mainly LOS Few multi-path
Main purpose of Massive-element Antennas deployment	Improving spectrum efficiency with special reuse	Compensation of propagation loss with antenna gain

Reusing space

A massive-element antenna is made up of multiple antenna elements placed in an array or matrix formation. The antenna controls these elements to form beams, which can, for instance, transmit strong, highly focused radio waves to a specific user, with minimal interference to other users. This makes for much higher spectrum efficiency because it enables operators to use the same frequency resources at the same time for multiple users in different locations. This spatial reuse of frequency resources or the special beam multiplexing can also be applied to uplink transmission as well as downlink transmission. Figure-1 shows an example of a four-beam spatial multiplex, which offers four times the capacity of a regular cell. That capacity could be expanded even further by increasing the number of spatial multiplex beams. Basically, the more antenna elements, the more concentrated the beam, and the greater the number of possible spatial multiplex beams. For that reason, massive-element antennas can form more spatial multiplex beams than traditional multi-element antennas, and help expand cell capacity.

In addition, several massive-element antennas can be deployed on the same single site, increasing the number of spatial multiplex beams, and further expanding cell capacity without increasing the number of site locations.

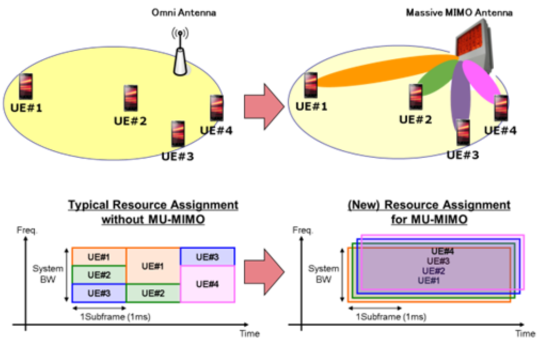

Figure-1: Intra-cell capacity enhancement on MU-MIMO with Massive-element Antenna

Low SHF bands Massive MIMO

As part of its drive to promote massive MIMO using low SHF bands, NEC has developed a prototype massive-element active antenna system (AAS). Figure-2 shows the exterior of the prototype massive-element AAS, and Table-2 lists its main specifications.

Figure-2: AAS Proto type

Table 2: Massive-element Active Antenna (AAS) System Specifications

Carrier frequency	Low SHF band (Assume 5.2GHz)
Bandwidth	40MHz
Antenna structure	4(V)×8(H)×2(Pol.) 64 elements/1unit, 1-4 units/site
Maximum number of layers	16 layer (2layer/UE×8UE MU-MIMO)
UL/DL multiplex	TDD
Channel multiplex	OFDM, MU-MIMO spatial multiplex
Modulation scheme	QPSK/16QAM/64QAM

Figure-3 is a block diagram of the prototype massive MIMO containing the digital signal processing part and the massive-element AAS part. The digital signal processing part performs both the MIMO precoding process and beamforming control for each user in the frequency domain. This comprehensive digital process enables maximum utilization of available spatial freedom, as well as the most appropriate precoding and beam assignment for each mobile terminal. It is also possible to combine multi-paths with delay differences by using optimum precoding weights for each coherent frequency.

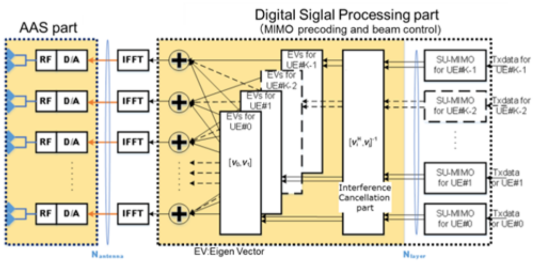

Figure-3: Block diagram of Massive MIMO

It is difficult to introduce the massive-element antennas (100 or more antenna elements) that are required for massive MIMO into traditional base stations, Attaching over 100 RF cables between each antenna element placed at half wavelength intervals and RF transceiver circuits (TRX) is unrealistic and would lead to significant losses through RF cables. Using an AAS that combines the antennas, and TRXs and D/A A/D converters into one unit would be an effective way to resolve these issues. In particular, implementing D/A A/D converters in the AAS part would make it easier to connect the AAS and digital signal processing part through one or several multicore fiber-optic cables.

In addition to the conventional rooftop locations, antennas for small cells are also expected to be installed in shopping malls, station forecourts, stations premises, stadiums and various other hot zones. That means the small cell antennas must be able to cover users distributed across a wide range of different areas surrounding the antenna site. To be effective, massive AAS/MIMO must be able to flexibly adapt to each individual small cell user's distribution environment, so we can offer the optimum antenna structure for any individual situation in terms of the number of vertical and horizontal antennal elements and the number of independent transceivers. NEC's AAS system can flexibly configure both the number of vertical and horizontal antenna elements by combining multiple AAS units (Figure-4).

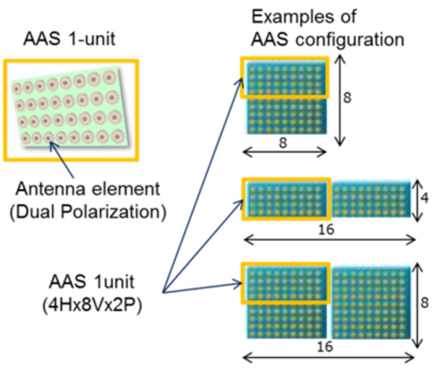

Figure-4: Examples of the AAS configuration

To create the right beam pattern using massive-element AAS, it is essential to calibrate the phase and amplitude of each antenna element, including TRXs. NEC's massive MIMO configuration with full digital processing of both the antenna beam control and MIMO precoding includes the calibration function in the digital signal processing part, and NEC's AAS solution applies the correction coefficient to both transmission and reception signals using full digital frequency domain calculation. NEC's AAS solution also realizes precise beamforming control. Figure-5 shows the antenna beam pattern of the massive-element AAS prototype.

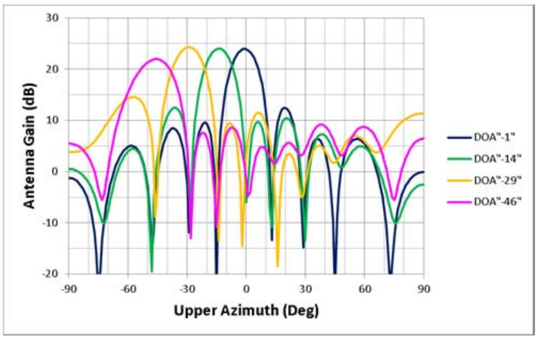

Figure-5: Measured AAS Beam Pattern

Abbreviations

ICT Information and Communication Technology
MIMO Multiple Input and Multiple Output
LAA Licensed-assisted access
SHF Super High Frequency
AAS Active Antenna System
TRX RF Transceiver and Receiver
RF Radio function
D/A Digital-Analog converting
A/D Analog-Digital converting
NLOS Non-Line of Sight
LOS Line of Sight
UE User Equipment
TDD Time Division Duplex
OFDM Orthogonal Frequency-Division Multiplexing
QPSK Quadrature Phase Shift Keying
QAM Quadrature Amplitude Modulation
UL/DL Uplink and Downlink

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