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THE MOST RECENT APLLICATIONS OF MASSIVE MIMO TECHNOLOGY IN US PATENTS

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Abstract: Massive MIMO (Multiple Input Multiple Output) is a crucial technology for 5G and beyond. It greatly increases coverage, data rates, and spectral efficiency by using a large number of antennas at the base station. Massive MIMO more effectively exploits the spatial domain to improve the coverage, capacity and user throughput of mobile networks. This is achieved by harnessing multi–antenna technologies like beamforming, null forming and multiplexing. The results include a better user experience, higher network capacity, and an ability to support long–term traffic growth that would not be possible with conventional solutions using remote radio units. By utilizing spatial multiplexing and diversity, directing narrow beams towards users, and facilitating reliable communication even in difficult–to–reach areas, it accomplishes these benefits. The most recent uses of the massive MIMO system in US patents are described in this paper. Additionally, a brief description of the massive MIMO system is provided.
Keywords: US Patents, massive MIMO, structure and applications

INTRODUCTION

Because it can significantly increase the capacity and dependability of wireless systems, multiple–input multiple–output (MIMO) technology has been thoroughly studied and integrated into many wireless standards over the past 20 years.

Point–to–point MIMO links, in which two devices, each with multiple antennas, communicate directly, were the focus of initial research. However, more realistic multi–user MIMO (MU–MIMO) systems have become the focus of recent research. A base station (BS) with multiple antennas serves multiple single–antenna users concurrently in these systems, distributing the multiplexing gain among all users.

Multiple input multiple output (MIMO) systems use multiple antennas at both the transmitter and receiver along with software to coordinate signal paths and ultimately increase throughput. The resulting gains were a significant breakthrough, but the 5G era demands far more in terms of throughput and capacity.

By using comparatively cheap single–antenna devices, this method lessens the need for costly equipment on the user's end. Furthermore, in contrast to point–to–point MIMO systems, MU–MIMO systems have the advantage of multi–user diversity, which reduces the dependence of their performance on the propagation environment.

As a result, MU–MIMO is becoming more widely used globally and is a crucial part of communications standards like 802.11 (Wi–Fi), 802.16 (Wi MAX), and LTE. Base stations usually employ fewer than ten antennas in many MIMO implementations, which improves spectral efficiency but yields only modest gains.

The hardware component of Massive MIMO is a compact antenna array with a massive number of antenna elements and a large number of radio transmitter and receiver chains (more than eight transmitters and eight receivers). Along with baseband functionalities, these are tightly integrated in a unit capable of creating multiple steerable and shapeable beams. This is paired with software deploying sophisticated algorithms to maximize coverage, capacity and peak rates.

Large–scale antenna systems (LSAS) are also being developed to achieve significant performance improvements and simplify signal–processing requirements, as recent advances in wireless communication have led to the development of massive MIMO systems, or large–scale antenna systems (LSAS). Each BS in these systems has a much greater number of antennas, often 100 or more, than in traditional MIMO systems [1].

Massive MIMO more effectively exploits the spatial domain to improve the coverage, capacity and user throughput of mobile networks. This is achieved by harnessing multi–antenna technologies like beamforming, null forming and multiplexing. The results include a better user experience, higher network capacity, and an ability to support long–term traffic growth that would not be possible with conventional solutions using remote radio units.

Combinations of three fundamental multi–antenna techniques are harnessed in Massive MIMO to increase performance: beamforming, null forming and spatial multiplexing. These techniques can be applied to both downlink and uplink, and work either as main tools for achieving desired performance, or as further performance boosters.

MASSIVE MIMO STRUCTURE

Figure 1 shows a large MU–MIMO network with numerous antennas at the base station (BS) serving several users at once.

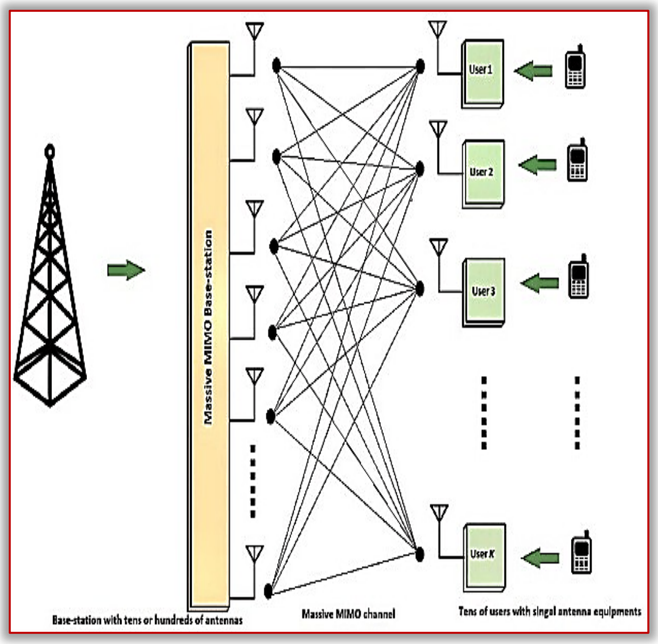

Figure 1. Massive MIMO Structure

Random matrix theory provides the theoretical underpinnings for the advantages of massive MIMO, implying that the effects of uncorrelated noise and small–scale fading decrease with the number of antennas [2]. This indicates that in a perfect massive MIMO system, the energy needed to send each bit drops toward zero, the number of users per cell becomes independent of cell size, and the quality of communication increases as the number of antennas increases. Furthermore, matched–filter (MF) pre–coding and detection are two basic linear signal processing methods that can be used in massive MIMO systems and are adequate for efficiently utilizing these performance improvements.

APPLICATIONS OF MASSIVE MIMO IN US PATENTS

A method, device, and system for determining an array antenna's total radiated power were provided by the patent in [3]. The array antenna's Rayleigh resolution in an angle space is determined, and a stepping grid spacing of sampling points is set in accordance with the Rayleigh resolution.

The sampling points are then determined in accordance with the stepping grid spacing, the equivalent isotropic radiated power (EIRP) is measured at the locations of the sampling points, and the TRP is calculated based on the EIRP. In addition to reducing measurement errors when compared to a traditional rest mode that uses an angle stepping grid with θgrid and φ grid of 15°, this also improves measurement efficiency by reducing the number of sampling points through a normalized wave vector space transformation.

The methods and devices for a user equipment (UE)–coordination set for a wireless network are described in [4].

A base station designates a group of UEs to create a UE–coordination set so that data meant for a target UE within the UE–coordination set can be transmitted and received jointly. One of the UEs in the UE–coordination set is chosen by the base station to serve as the coordinating UE for the UE–coordination set. The coordinating UE is then instructed to coordinate the joint transmission and reception of the data meant for the target UE by means of a request message.

A downlink signal is then sent by the base station to every UE in the UE–coordination set. The downlink signal is demodulated and sampled by each UE in the UE–coordination set. The samples are then sent to the coordinating UE, which aggregates and processes the samples to produce decoded data.

A node first receives a first information block in [5], which is used to indicate K1 reference signal resource groups, each of which contains at least one reference signal resource. Next, it measures a first reference signal resource group, which is one of the K1 reference signal resource groups. Finally, it transmits a first measurement result, which is obtained by using a measurement for the first reference signal resource group. The reference signal resource includes at least one SSB or CSI–RS resource, and the first reference signal resource group is identified from the K1 reference signal resource groups based on the location information of the first node. By introducing UAVs to lower the measurement overhead, the current application enhances the configuration and reporting method of measurements under a 5G NR system.

Techniques and equipment for adaptive phase–changing devices in multiple–input multiple–output transmissions are described in [6]. For multiple–input, multiple–output, or MIMO, transmissions, a base station chooses one or more adaptive phase–changing devices, or APDs, to employ in at least one communication path. Using at least one APD and one UE, the base station can carry out a channel characterization procedure for the minimum number of communication paths.

The base station sets up at least one APD to enable single user–MIMO communication with a UE or multiple user–MIMO communication with multiple UEs based on the outcomes of the channel characterization process. By doing this, the base station can use APDs to implement MIMO transmissions, which can increase a wireless network's spectral efficiency by communicating with at least one UE using the same time and frequency resources.

Methods and apparatus in a fifth–generation wireless communications network, including an example method in a wireless device, are described in [7]. These include:

- establishing a reporting quality threshold for a channel state information (CSI) parameter;
- measuring each of a plurality of beams from a first predetermined set of beams for evaluation;
- comparing the measurement for each of the plurality of beams to the reporting quality threshold;
- stopping the measurement and evaluation process when it is determined that the reporting quality threshold is met for one of the beams, so that one or more beams in the first predetermined set of beams are not measured and evaluated; and
- reporting, to the wireless communications network, CSI for one of the beams.

Implementations of an antenna structure are provided in [8]. The antenna structure in one implementation consists of a first stacked radiating structure with multiple radiators at each stack level, a second stacked radiating structure with multiple radiators at each stack level, and a feeding network that provides a signal to the radiators. The feeding network consists of a first branch that feeds a first radiator of each of the first and second stacked radiating structures, and a second branch that feeds a second radiator of each of the first and second stacked radiating structures.

A wireless communications method and device in a node are provided by the patent in [9]. A node first receives a first signaling in a first time–frequency resource set, and both the first signaling and the first reference signal resource are QCL. Next, it receives a MAC–layer control unit, which is used to indicate a second reference signal resource. Finally, it receives a second signaling in a second time–frequency resource set, and a second signal in a third time–frequency resource set.

The first reference signal resource is linked to a first PCI, and the second reference signal resource is linked to a second PCI. Finally, the second signaling is used to indicate the third time–frequency resource set, and the second reference signal resource is QCL. To maximize system performance, the application enhances the device and procedure for updating TCI state under M–TRP.

The device, method, device, and computer–readable storage media of the beamforming scheme in higher rank transmission for massive multiple input multiple output systems are examples of the current disclosure in [10].

The process entails identifying a target beam to carry a reference signal transmission from the base station to the user equipment, figuring out a target arrangement of the multiple ports formed at the base station's antenna array, and sending various parts of the target beam to the user equipment via a number of ports in accordance with the target arrangement. Thus, a novel beam forming technique is suggested for multi–port communication systems when Massive–MIMO selects higher rank transmission. To adhere to the QCL principles, the gNB would only choose the best beam with distinct halves in the same polarization.

In [11], a terminal device receives M pieces of sub–data from the first downlink channel, each of which represents a single data space in M data spaces. Based on a first dictionary corresponding to an i.sup.th data space, the terminal device determines the first information corresponding to the i.sup.th piece of first downlink channel sub–data for an i.sup.th piece of first downlink channel sub–data in the M pieces of first downlink channel sub–data.

A total of M pieces of first information are determined. To indicate the M pieces of first information, the terminal device transmits the first indication information. Information about the channel environment can be represented by various data spaces.

In order for an access network device to ascertain a correspondence between the first information and environment information, the terminal device feeds back first information corresponding to various data spaces. The accuracy of the initial data that the terminal device feeds back has increased.

At least one RE of a network node uses method 1400 in [12], which entails estimating the channel quality, calculating at least one BFW, and reducing the port in relation to input data and/or an input signal. Measurement data related to port reduction, at least one BFW computation, and channel quality estimation are sent from the RE to a REC.

In [13], a method for synchronized selection of user equipment's (UEs) for both downlink (DL) Multi–User Multiple Input Multiple Output (MU–MIMO) operation and uplink (UL) MU–MIMO operation is presented. This method entails applying a common set of selection criteria for selecting a common pool of UE candidates for both DL and UL MU–MIMO operations. If the Stage–1 selection process using the common set of selection criteria is unable to find UE candidates for a list of available slots in the UE candidates list, the Stage–2 selection process is initiated, which entails:

- applying a first set of Stage–2 selection criteria to select DL–only traffic UEs as Stage–2 candidates for the UE candidates list, and
- applying a second set of Stage–2 selection criteria to select UL–only traffic UEs as Stage–2 candidates for the UE candidates list.

Many elements of the current disclosure are generally related to wireless communication in [14]. According to certain aspects, a user equipment (UE) may be given configuration information that sets up resources related to an on–demand synchronization signal block (SSB). This information may occur twice, once during a cell's DTX inactive time and once during a cell's DTX active time. Whether the UE is allowed to request the on–demand SSB to be transmitted during the cell DTX inactive time may be indicated to the UE. Based at least partially on the indication, the UE can either transmit a request for the first instance of the on–demand SSB to be transmitted on the first occasion or choose not to transmit the request. Many other facets are explained.

A method and device for choosing a beam used in communication in a massive–MIMO beamforming environment is described in [15]. This includes a base station with a communication unit that can form multiple beams and communicate with a terminal apparatus, as well as a control unit that can send the first identification information of a group that communicates with the terminal apparatus to the terminal apparatus. The first identification information is distributed to groups, each of which includes multiple beams to be formed.

A technique for lowering the transmission's peak–to–average power ratio (PA–PR) using multiple–input multiple–output (MIMO) from a transmitter is revealed in [16]. The process consists of defining a rank–extended MIMO transmission towards one or more intended receivers and one or more virtual receivers (where the one or more virtual receivers reside in a null space of a MIMO channel between the transmitter and the one or more intended receivers), creating a rank–extended MIMO signal for the rank–extended MIMO transmission (where the rank–extended MIMO signal consists of an intended receiver signal portion and a virtual receiver signal portion), figuring out a clipping signal for the rank–extended MIMO signal, and combining the rank–extended MIMO signal with a projection of the clipping signal onto the null space of the MIMO channel to create a PAPR reduced MIMO signal.

The technique also includes sending the PAPR reduced MIMO signal over the MIMO channel in certain implementations. Additionally disclosed are the corresponding computer program product, apparatus, user device, control node, radio access node, and system.

In [17], the application offers an uplink pre–coding indication method that includes:

- sending first indication information and third indication information when a terminal device's uplink transmission layer count is less than or equal to X; or
- sending first indication information, second indication information, and third indication information when a terminal device's uplink transmission layer count is greater than X.

In the former case, the first indication information shows the index of a first code word in a first codebook and the number of uplink transmission layers of the first code word.

The second indication information shows the index of a second code word in the first codebook and the number of uplink transmission layers of the second code word.

The third indication information shows that a terminal device's uplink transmission layer count is greater than X, and the second code word and the first code word have the same coherent capability.

SUMMARY AND CONCLUSION

The 5G era has brought more deployments, booming data traffic and subscriber growth. Networks require new levels of spectral efficiency to meet the user and capacity demands now required. Mid–band is the sweet spot between coverage and capacity: Massive MIMO technology offers communications service providers the larger bandwidth of the mid–band to deliver powerful 5G experiences in a cost and energy efficient way.

Massive MIMO is a wireless technology that uses a very large number of antennas at a base station to significantly improve performance in 5G networks. It enhances spectral efficiency, data rates, and coverage by using techniques like spatial multiplexing to send multiple data streams simultaneously and beamforming to focus signals directly towards users. This is an advancement over traditional MIMO, which uses a much smaller number of antennas.

Massive MIMO evolves from traditional MIMO technology, which uses a smaller number of antennas at both the transmitter and receiver. Massive MIMO scales this by deploying dozens or even hundreds of antennas at the base station to create multiple, simultaneous data streams. Massive MIMO dramatically expands upon the scale and capabilities of MIMO, and has been an intrinsic component of networks since the start of 5G. Build out began in dense urban areas where initial demand was highest, before continuing in areas with lower population density. There is now a significant uptake globally.

Adding a large array of antennas to a base station (BS) is the fundamental concept behind massive MIMO, which has the potential to significantly improve energy and spectral efficiency. In this way, massive MIMO can support more users and provide faster data rates with lower power consumption, making it a promising technology for applications in future wireless networks. Therefore, this paper gave a brief explanation of how massive MIMO is used in US patents.

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