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[Continued on the next page]

(54) Title: METHOD FOR CSI FEEDBACK IN RADIO COMMUNICATION SYSTEM, AND APPARATUS THEREFOR

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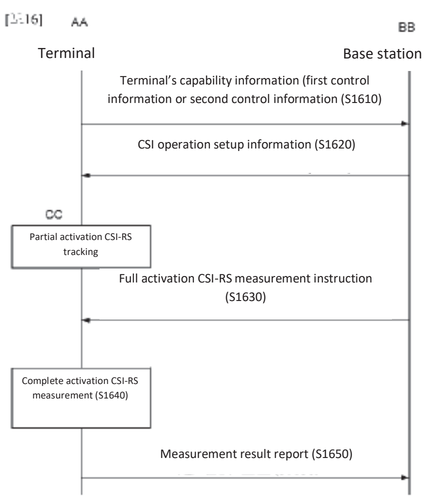

S1610 ... Terminal capability information (first control information and/or second control information)
S1620 ... CSI action-related configuration information
S1630 ... Command measurement of fully activated CSI-RS
S1640 ... Measure fully activated CSI-RS
S1650 ... Report result of measurement
AA ... Terminal
BB ... Base station
CC ... Track partially activated CSI-RS

(57) Abstract: A method for feeding back channel state information (CSI) in a wireless communication system, carried out by a terminal, according to the present specification comprises the steps of: transmitting, to a base station, capability information of the terminal for CSI-related action; receiving configuration information for the CSI-related action from the base station; tracking partially-activated CSI reference signal (RS); measuring fully-activated CSI-RS; and reporting the results of the measurement to the base station.

(57) Abstract: A method for feeding back channel state information (CSI) in a wireless communication system, carried out by a terminal, according to the present specification comprises the steps of: transmitting, to a base station, capability information of the terminal for CSI-related action; receiving configuration information for the CSI-related action from the base station; tracking partially-activated CSI reference signal (RS); measuring fully-activated CSI-RS; and reporting the results of the measurement to the base station.

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Disclosure:
- With the international investigation report (Article 21.(3) of the treaty)

Statement

Name of the invention: Method for CSI Feedback in Radio Communication System, and Apparatus Therefor

Technological field

[1] The present invention is about a radio communication system, and more specifically the present invention is about a method of feeding back CSI based on reference signals and a device to support this.

Background technology

[2] Mobile communication systems were originally developed to ensure user mobility while providing voice services. However, their scope has expanded beyond voice to include data services. Currently, due to the explosive increase in traffic, resource shortages have become a critical issue, and users are demanding higher-speed services. As a result, more advanced mobile communication systems are required.

[3] The requirements for next-generation mobile communication systems include accommodating explosive data traffic, significantly increasing per-user transmission rates, supporting a large number of connected devices, ensuring ultra-low end-to-end latency, and improving energy efficiency. To meet these demands, various technologies are being researched, including dual connectivity, massive MIMO (Multiple Input Multiple Output), in-band full duplex, NOMA (Non-Orthogonal Multiple Access), super wideband, and device networking.

Detailed description of the invention

Technical issues

[4] The purpose of the statement is to provide a method to transmit and receive capability information of the terminal (hereinafter “user equipment” or “UE”) related to the CSI operation.

[5] Another purpose of this statement is to provide a method to track partially activated CSI-RS and measure and report only fully activated CSI-RS in order to reduce delays in the CSI feedback process.

[6] Also, another purpose of the statement is to provide a method to initialize or renew windows related to CSI measurement.

[7] The technological issues that the present invention attempts to resolve are not restricted to those technological issues mentioned above, and other technological issues not mentioned here will be clearly understandable from the following information to those with ordinary level of knowledge in the field in which the present invention belongs.

Methods to resolve the issues

[8] The method to carry out CSI (channel state information) by UE in this statement includes the stage in which capability information of UE regarding operations related to the CSI is transmitted to the base station; the stage in which operation configuration information related to the CSI is received from the base station, wherein the operation configuration information related to the CSI includes at least one of operation index information related to partial activation CSI indicating operations related to the CSI that carries out partial activation and operation index information related to the full activation CSI which indicates operations related to the CSI that carries out full activation; the stage in which partial activation CSI-RS (reference signal) is tracked; the stage in

which full activation CSI-RS is measured; and the stage in which the measurement result is reported to the base station.

[9] Also, the stage in which full activation CSI-RS is measured in the statement includes the stage in which the first message that addresses activation of the measurement regarding the full activation CSI-RS is received from the base station; and the stage in which the full activation CSI-RS activated by the first message is measured.

[10] Also, the operation related to CSI in the statement is related to at least one of CSI-RS, CSI-IM (interference management), and CSI process.

[11] Also, in the statement the user equipment's capability information includes the first control information that indicates the maximum number of the operations related to the CSI that can be fully activated and the second control information that indicates the maximum number of operations related to the CSI that can be partially activated.

[12] Also, in the statement the stage in which the partial activation CSI-RS is tracked includes the stage in which alignment is set in terms of time and/or frequency regarding the partial activation CSI-RS.

[13] Also, in the statement the tracking is carried out by applying specific RS (reference signal) and quasi colocation (QCL) assumptions included in the operation setup information related to the CSI.

[14] Also, in the statement the full activation CSI-RS is selected at the partial activation CSI-RS.

[15] Also, in the statement the first message is an MAC (media access control) CE (control element) or DCI (downlink control information).

[16] Also, the statement further includes the stage in which the third control information related to the CSI-RS measurement window is received from the base station, and the CSI-RS measurement stage, if the first message is received, includes the stage in which the CSI-RS measurement window is initialized or renewed; the stage in which CSI-RS measurement is carried out repeatedly from the point at which the CSI-RS measurement window is initialized or renewed to a specific section; and the stage in which the measurement results are averaged.

[17] Also, in the statement if the CSI feedback is periodic CSI feedback, the point in time at which the CSI-RS measurement window is initialized or renewed is at the point in time of a specific reference resource related to the RI (rank indicator) that occurs for the first time after the specific section.

[18] Also, in the statement the first message is received from the based station for each CSI process.

[19] Also, in the statement the first message is beam-change indicator (BCI) signaling that notifies changes in the matrix related to beamforming.

[20] Also, in the statement the user equipment that feeds back CSI (channel state information) in radio communication systems includes at least one of a RF (radio frequency) unit that transmits and receives wireless signals; and a processor that controls the RF unit, transmits the user equipment's capability information regarding the operation related to the CSI to the base station; and receives the operation configuration information related to the CSI from the base station, wherein the operation configuration information related to the CSI includes at least either of the index information related to the partial activation CSI that indicates the operation related to the CSI that carries out partial activation or operation index information related to full activation CSI that indicates operations related to the CSI that carries out full activation; measures full activation CSI-RS; and controls so that the measurements are reported to the base station.

Effects of the invention

[21] In the statement, information related to the CSI configuration is transmitted to the user equipment at the MAC level or PHY level, so that delays are reduced in the CSI feedback process.

[22] Also, in the statement the window related to the CSI measurement is initialized or renewed at the point in time at which CSI measurement activation is ordered or at the point in time of CSI configuration change notification,

thereby ensuring that unnecessary past environment is not reflected on the CSI measurement to ensure that more accurate CSI feedback will be carried out.

[23] The effects that can be obtained from the present invention are not restricted those effects mentioned previously, and other effects not mentioned will be clearly understood by those with ordinary level of knowledge in the technological field in which the present invention belongs based on the following information.

Brief descriptions of the drawings

[24] In order to assist with understanding of the present invention, the attached drawings, which are included as part of the detailed description section, will provide embodiments of the present invention, and will describe technological features of the present invention along with the detailed description section.

[25] Figure 1 illustrates a radio frame structure in a radio communication system on which the present invention could be applied.

[26] Figure 2 is a drawing that illustrates a resource grid for a downlink slot of a radio communication system to which the present invention could be applied.

[27] Figure 3 illustrates a downlink sub-frame in a radio communication system to which the present invention could be applied.

[28] Figure 4 illustrates the structure of an upward link sub-frame in a radio communication system to which the present invention could be applied.

[29] Figure 5 is a configuration drawing of a general massive multiple input multiple output (MIMO) communication system.

[30] Figure 6 is a drawing that illustrates a reception antenna channel from multiple transfer antennas.

[31] Figure 7 illustrates an example of a component carrier combination in a radio communication system to which the present invention could be applied.

[32] Figure 8 is a drawing to explain a random access process based on competition in a radio communication system to which the present invention could be applied.

[33] Figure 9 illustrates a reference signal pattern mapped to a downlink resource block pair in a radio communication system to which the present invention could be applied.

[34] Figure 10 is a drawing illustrating the CSI-RS configuration in a radio communication system to which the present invention could be applied.

[35] Figure 11 illustrates a system equipped with multiple transfer/reception antennas wherein the base station or user equipment could form a 3D (3-dimension) beam based on AAS in a radio communication system to which the present invention could be applied.

[36] Figure 12 illustrates an RSRP for each antenna port of the RRM-RS in accordance with an embodiment of the present invention.

[37] Figure 13 illustrates an RRM-RS antenna port grouping level in accordance with an embodiment of the present invention.

[38] Figure 14 is a drawing that illustrates an antenna port and an antenna port group of RRM-RS arrayed in two-dimensional index in accordance with an embodiment of the present invention.

[39] Figure 15 to Figure 17 are drawings that illustrate examples of the CSI measurement and reporting method proposed by the present statement.

[40] Figure 18 illustrates a block configuration drawing of the wireless communication device in accordance with an embodiment of the present invention.

Formats to embody the present invention

[41] Below, a preferred embodiment format in accordance with the present invention will be described in detail by referring to the attached drawings. The detailed description to be presented below with the attached drawings is to describe an illustrative embodiment of the present invention, and it is not the only embodiment format of the present invention. The detailed description below includes specific details in order to provide complete understanding of the present invention. However, those in the industry understand that the present invention could be embodied without such specific details.

[42] In some cases, publicly known structure and devices were omitted, or illustrations could be provided in block diagrams in order to avoid situations in which the concept of the present invention could become unclear.

[43] In the statement, the term base station refers to a terminal node of a network that directly communicates with UE. In the statement, specific operations that are described as being carried out by the base station could be carried out by the upper node of the base station under certain circumstances. Namely, it is self-evident that various operations carried out by a network composed of multiple network nodes including the base station in order to communicate with UE could be carried out by other network nodes. The term "base station (BS)" could be replaced by such terms as fixed station, Node B, eNB (evolved-NodeB), BTS (base transceiver system), access point (AP), and so on. Also, a user equipment could be fixed or mobile, and this term could be replaced by such terms as UE (user equipment), MS (mobile station), UT (user terminal), MSS (mobile subscriber station), SS (subscriber station), AMS (advanced mobile station), WT (wireless terminal), MTC (machine-type communication) device, M2M (machine-to-machine) device, D2D (device-to-device) device, and so on.

[44] From herein, the term downlink (DL) refers to communication from the base station to a user equipment, and the term uplink refers to communication from a user equipment to the base station. In a downlink, a transmitter could be part of the base station, and a receiver could be part of a user equipment. In an uplink, a transmitter could be part of a user equipment, or a receiver could be part of the base station.

[45] Specific terms used in the descriptions below are provided in order to help the reader to understand the present invention better, and these terms could be changed to other terms without deviating from the technological philosophy of the present invention.

[46] The following technology could be applied to various wireless connection systems such as CDMA (code division multiple access), FDMA (frequency division multiple access), TDMA (time division multiple access), OFDMA (orthogonal frequency division multiple access), SC-FDMA (single carrier frequency division multiple access), NOMA (non-orthogonal multiple access), and so on. CDMA could be embodied with such radio technologies as UTRA (universal terrestrial radio access) and CDMA2000. TDMA could be embodied with such wireless technologies as GSM (global system for mobile communications)/GPRS (general packet radio service)/EDGE (enhanced data rates for GSM evolution). OFDMA could be embodied with such wireless technologies as IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802-20, E-UTRA (evolved UTRA), and so on. UTRA is part of UMTS (universal mobile telecommunications system). 3GPP (3rd generation partnership project) LTE (long term evolution) is part of E-UMTS (evolved UMTS) that uses E-UTRA, which uses OFDMA in the downlink and SC-FDMA in the uplink. LTE-A (advanced) is an enhancement of 3GPP LTE.

[47] Embodiments of the present invention could be supported by standard documents presented by at least one of IEEE 802, 3GPP, and 3GPP2. Namely, among the embodiments of the present invention, those stages or parts that are not described in order to clearly disclose the technological ideas of the present invention could be supported by these documents. Also, all terminologies presented in this document could be explained by these standard documents.

[48] Although the focus of the description will be on 3GPP LTE/LTE-A for clarity purposes, the technical features of the present invention are not restricted by this.

[49]

[50] <u>General radio communication systems to which the present invention could be applied</u>

[51] Figure 1 illustrates the structure of a radio frame in a radio communication system to which the present invention could be applied.

[52] Under 3GPP LTE/LTE-A, the type 1 radio frame that could be applied to FDD (frequency division duplex) and the type 2 radio frame structure that could be applied to TDD (time division duplex) are supported.

[53] In Figure 1, the size of the time domain of the radio frame is expressed as a multiple of the time unit of T_s=1/(15,000*2,048). Downlink and uplink transmission are made up of radio frames with a period of T_f=307200*T_s=10ms.

[54] Figure 1 (a) illustrates the structure of a type 1 radio frame. Type 1 radio frames could be applied to both full duplex and half duplex FDDs.

[55] A radio frame is composed of 10 sub-frames. A single radio frame is composed of 20 slots with a length of T-slot=15360*T_s=0.5m, and each slot is assigned an index from 0 to 19. A single sub-frame is composed of 2 consecutive slots in the time domain, and sub-frame i is composed of slot 2i and slot 2i+1. The amount of time it takes to transmit a single sub-frame is referred to as TTI (transmission time interval). For example, the length of a single sub-frame could be 1ms, and the length of a slot could be 0.5ms.

[56] In the FDD, uplink transfer and downlink transfer are classified in the frequency domain. Whereas there is no limitation with full duplex FDD, with half duplex FDD operation the user equipment is not able to transmit and receive signals at simultaneously.

[57] A single slot includes multiple OFDM (orthogonal frequency division multiplexing) symbols, and includes multiple resource blocks (RB) in the frequency domain. Since the 3GPP LTE uses the OFDMA in the downlink, the OFDM symbol's purpose is to express a single symbol period. The OFDM symbol could be considered as a single SC-FDMA symbol or symbol period. A resource block is a resource allocation unit, and a single slot includes multiple consecutive subcarriers.

[58] Figure 1 (b) illustrates a type 2 frame structure.

[59] A type 2 radio frame is composed of 2 half frames with a length of 153,600*T_s=5ms for each half frame. Each half frame is composed of 5 sub-frames with a length of 30,720*T_s=1ms.

[60] In a TDD system's type 2 frame structure, the uplink-downlink configuration allocates (reserves) uplinks and downlinks for all sub-frames.

[61] Table 1 illustrates an uplink-downlink configuration.

[62] [Table 1]

Uplink-Downlink configuration	Downlink-to-Uplink Switch-point periodicity	Subframe number									
		0	1	2	3	4	5	6	7	8	9
0	5ms	D	S	U	U	U	D	S	U	U	U
1	5ms	D	S	U	U	D	D	S	U	U	D
2	5ms	D	S	U	D	D	D	S	U	D	D
3	10ms	D	S	U	U	U	D	D	D	D	D
4	10ms	D	S	U	U	D	D	D	D	D	D
5	10ms	D	S	U	D	D	D	D	D	D	D
6	5ms	D	S	U	U	U	D	S	U	U	D

[63] When we refer to Table 1, we can see that for each sub-frame of the radio frame "D" indicates a sub-frame for downlink transmission, "U" indicates a sub-frame for uplink transmission, and "S" indicates a special sub-frame composed of three types of field, which are DwPTS (downlink pilot time slot), guard period (GP), and UpPTS (uplink pilot time slot).

[64] DwPTS is used for initial cell searching, alignment, or channel estimation at the user equipment. UpPTS is used by the base station to estimate channels and set the uplink transmission alignment of a user equipment. GP is the period where interferences that occur in the uplink due to multiple route delays of downlink signals between the uplink and the downlink are eliminated.

[65] Each sub-frame i is composed of slot 2i and slot 2i+1, each with a length of T_slot= 15360*T_s=0.5ms.

[66] Uplink-downlink configurations could be classified into 7 types, and each configuration is different in terms of the location and/or number of downlink sub-frames, special sub-frames, and uplink sub-frames.

[67] The point in time at which the downlink changes to the uplink and the point in time at which the uplink transitions to the downlink are referred to as switching points. The switch-point periodicity at the switching point refers to the periodicity at which the uplink sub-frames and the downlink sub-frames switch periodically, and both 5ms and 10ms are supported. If the periodicity involves only the 5ms downlink-uplink switching point, the special sub-frame (S) exists at each half-frame, and if the periodicity involves 5ms downlink-uplink switching point periodicity, only the first half-frame exists.

[68] For all configurations, the zero and 5th sub-frames and the DwPTS are exclusively downlink transmission periods. The sub-frame that immediately follows the UpPTS and sub-frames are always exclusively uplink transmission periods.

[69] Such an uplink-downlink configuration is system information that both the base station and the user equipment know about. The base station transmits only the index of the configuration information whenever the uplink-downlink configuration information changes, thereby being able to inform the user equipment of the change in the radio frame's uplink-downlink allocation state. Also, the configuration information is a type of downlink control information, which could be transmitted through the PDCCH (physical downlink control channel) just like other types of scheduling information, and it could be transmitted to all UE within a given cell through a broadcast channel as broadcast information.

[70] Table 2 indicates the configuration of the special sub-frame (length of DwPTS/GP/UpPTS).

[71] [Table 2]

<table>
<tr><th rowspan="3">Special subframe configuration</th><th colspan="3">Normal cyclic prefix in downlink</th><th colspan="3">Extended cyclic prefix in downlink</th></tr>
<tr><th rowspan="2">DwPTS</th><th colspan="2">UpPTS</th><th rowspan="2">DwPTS</th><th colspan="2">UpPTS</th></tr>
<tr><th>Normal cyclic prefix in uplink</th><th>Extended cyclic prefix in uplink</th><th>Normal cyclic prefix in uplink</th><th>Extended cyclic prefix in uplink</th></tr>
<tr><td>0</td><td>$6592 \cdot T_s$</td><td rowspan="5">$2192 \cdot T_s$</td><td rowspan="5">$2560 \cdot T_s$</td><td>$7680 \cdot T_s$</td><td rowspan="4">$2192 \cdot T_s$</td><td rowspan="4">$2560 \cdot T_s$</td></tr>
<tr><td>1</td><td>$19760 \cdot T_s$</td><td>$20480 \cdot T_s$</td></tr>
<tr><td>2</td><td>$21952 \cdot T_s$</td><td>$23040 \cdot T_s$</td></tr>
<tr><td>3</td><td>$24144 \cdot T_s$</td><td>$25600 \cdot T_s$</td></tr>
<tr><td>4</td><td>$26336 \cdot T_s$</td><td>$7680 \cdot T_s$</td><td rowspan="3">$4384 \cdot T_s$</td><td rowspan="3">$5120 \cdot T_s$</td></tr>
<tr><td>5</td><td>$6592 \cdot T_s$</td><td rowspan="4">$4384 \cdot T_s$</td><td rowspan="4">$5120 \cdot T_s$</td><td>$20480 \cdot T_s$</td></tr>
<tr><td>6</td><td>$19760 \cdot T_s$</td><td>$23040 \cdot T_s$</td></tr>
<tr><td>7</td><td>$21952 \cdot T_s$</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>8</td><td>$24144 \cdot T_s$</td><td>-</td><td>-</td><td>-</td></tr>
</table>

[72] The structure of the radio frame in accordance with the example of Figure 1 is only an example, and the number of sub-carrier waves, the number of slots included in a sub-frame, and the number of OFDM symbols included in a slot could be changed in various ways.

[73] Figure 2 is a drawing that illustrates a resource grid for a downlink slot in a radio communication system to which the present invention could be applied.

[74] When we refer to Figure 2, we can see that a downlink slot includes multiple OFDM symbols in the time domain. Here, it is illustrated that a single downlink slot includes 7 OFDM symbols, and that a single resource block includes 12 sub-carrier waves in the frequency domain, but possible configurations are not restricted to this configuration.

[75] In the resource grid each element is referred to as resource element, and a single resource block (RB) includes 12 x 7 resource elements. The number of resource blocks included in a downlink slot, which is N^DL, belongs to the downlink transmission bandwidth.

[76] The structure of an uplink slot could be identical to that of a downlink slot.

[77] Figure 3 illustrates a downlink sub-frame structure in a radio communication system to which the present invention could be applied.

[78] When we refer to Figure 3, we can see that up to 3 OFDM symbols in front of the first slot in the sub-frame constitute the control region to which control channels are allocated, and the remaining OFDM symbols constitute the data region where the PDSCH (physical downlink shared channel is allocated. Examples of downlink control channels used at 3GPP LTE include PCFICH (physical control format indicator channel), PDCCH (physical downlink control channel), PHICH (physical hybrid-ARQ indicator channel), and so on.

[79] The PCFICH is transmitted from the first OFDM symbol of a sub-frame, and information regarding the number of OFDM symbols used in order to transmit control channels within the sub-frame (namely, the size of the control region) is carried. PHICH is a response channel regarding the uplink, and it carries ACK (acknowledgement)/NACK (not-acknowledgement) signals regarding the HARQ (hybrid automatic repeat request). The control information transmitted through the PDCCH is referred to as downlink control information (DCI). Downlink control information includes uplink resource allocation information, downlink resource allocation, or uplink transmission (Tx) power control commands for a given user equipment group.

[80] The PDCCH could carry DL-SCH (downlink shared channel)'s resource allocation and transmission format (this is referred to as a downlink grant), UL-SCH (uplink shared channel)'s resource allocation information (this is referred to as uplink grant), PCH (paging channel)'s paging information, system information at the DL-SCH, resource allocation for upper layer control messages such as random access responses transmitted from the PDSCH, a group of transmission power control commands for individual UE in a given user equipment group, VoIP (voice over IP) activation, and so on. Multiple PDCCHs could be transmitted within the control domain, and the user equipment could monitor multiple PDCCHs. The PDCCH is composed of a single or multiple groups of consecutive CCEs (control channel elements). The CCE is a logical allocation unit used in order to provide the coding rate in accordance with the radio channel's state. The CCE corresponds to multiple resource element groups. The number of PDCCH bits that could be used for formatting and using the PDCCH is determined based on the number of CCEs and based on the coding rate provided to the CCEs.

[81] The base station determines the PDCCH format in accordance with the DCI, and attaches the CRC (cyclic redundancy check) to the control information. A unique identifier (this is referred to as RNTI (radio network temporary identifier) is masked in accordance with the owner or usage of the PDCCH. A unique user equipment identifier, for example C-RNTI (cell-RNTI) could be masked on the CRC in the case of the PDCCH for a specific user equipment. Also, a paging command identifier, for example P-RNTI (paging-RNTI), could be masked on the CRC in the case of the PDCCH for paging messages. If the PDCCH is for system information, more specifically for a system information block (SIB), a system information identifier could be masked on the CRC. The RA-RNTI (random access-RNTI) could be masked on the CRC in order to command random access response, which is the response to the random access preamble transmission of the user equipment.

[82] The EPDCCH (enhanced PDCCH) carries user equipment-specific (UE-specific) signaling.

The EPDCCH is located at the physical resource block (PRB) set up for a specific user equipment. In other words, as described previously, the PDCCH could be transmitted from up to 3 OFDM symbols in front of the first slot, but the EPDCCH could be transmitted to resource domains besides the PDCCH. The point at which the EPDCCH starts within a sub-frame (namely, a symbol) could be set up in the user equipment through the higher level signaling (e.g., RRC signaling, etc.).

[83] The EPDCCH could carry transfer formats related to the DL-SCH, resource allocation and HARQ information, transfer formats related to the UL-SCH, resource allocation and HARQ information, resource allocation information related to the SL-SCH (side-link shared channel) and the PSCCH (physical side-link control channel), and so on. Multiple EPDCCHs could be supported, and the monitor could monitor a set of EPCCHs.

[84] The EPDCCH could be transmitted by using one or more consecutive enhanced CCEs (ECCE: enhanced CCE), and the number of ECCEs per a single EPDCCH could be determined for each EPDCCH format.

[85] Each ECCE could be composed of multiple resource element groups (EREG). EREGs are used for defining mapping at the RE of the ECCE. There are 16 EREGs for each PRB pair. Within each PRB pair, numbers from 0 to 15 are assigned to all REs in the order in which frequency increases and then in the order in which time increases, except for the RE, which carries the DMRS.

[86] A user equipment can monitor multiple EPDCCHs. For example, one or two EPDCCH sets could be set up within a single PRB pair for which a monitor monitors EPDCCH transfer.

[87] By combining different numbers of ECCEs, it is possible to achieve different coding rates for the EPCCH. Localized transmission or distributed transmission could be used for the EPCCH, and the ECCE mapping in the RE within the PRB could change accordingly.

[88] Figure 4 illustrates the structure of an uplink sub-frame in a radio communication system to which the present invention could be applied.

[89] When we refer to Figure 4, we can see that the uplink sub-frame could be divided into the control domain and the data domain in the frequency domain. In the control domain, the PUCCH (physical uplink control channel) that carries uplink control information is assigned. The data domain is assigned with the PUSCH (physical uplink shared channel) that carries user data. In order to maintain the single carrier wave characteristic, a given user equipment does not transmit the PUCCH and the PUSCH simultaneously.

[90] The PUCCH for a single user equipment is assigned with a pair of resource blocks (RB) within the sub-frame. Each of the RB's belonging to the RB pair takes a different sub-carrier wave. This is referred to as frequency hopping at the slot boundary by the RB pair assigned to PUCCH.

[91]

[92] <u>MIMO (multi-input multi-output)</u>

[93] The MIMO technology uses multiple transmission (Tx) antennas and multiple reception (Rx) antennas instead of using a single transmission antenna and a single reception antenna, which has been the general situation up to now. In other words, the MIMO technology uses multiple input multiple output antennas at the transmission end or receiving end of radio communication systems in order to attempt to increase capacity or improve performance. Here, “MIMO” will be referred to as “multiple input multiple output antenna.”

[94] More specifically, the multiple input multiple output antenna technology does not rely on a single antenna route to receive total messages, but rather completes the data by collecting multiple data pieces received through multiple antennas. In conclusion, the multiple input multiple output antenna technology can increase the data transmission rate within a specific system range, and is able to increase the system range through a specific data transmission rate.

[95] Due to the fact that the next-generation mobile communication requires much higher data transmission rate compared to the current mobile communication, it is expected that efficient multiple input multiple output antenna technology will be necessary. In this kind of situation, the MIMO communication technology is a next-

generation mobile communication technology that could be widely applied to mobile communication UE, repeaters, and so on, and the technology is considered as potential technology to overcome transmission volume limitations of other mobile communication systems faced with the increase in data communications, and so on.

[96] On the other hand, among various technologies to improve transmission efficiency being researched today, the multiple input multiple output antenna (MIMO) technology is the technology considered to have the best chance of substantially increasing communication volume and transmission and reception performance without additional frequency allocations or power increases.

[97] Figure 5 is a configuration drawing of a general multiple input output antenna (MIMO) communication system.

[98] When we refer to Figure 5, we can see that if the number of transmission antennas is increased to N_T and the number of reception antennas is increased to N_R simultaneously, the theoretical channel transmission capacity increases in proportion to the number of antennas, unlike in the case in which multiple antennas are used only with transmitters or receptors, so that it is possible to improve the transmission rate, and to substantially increase frequency efficiency.

In this case, the transmission rate in accordance with the increase in the channel transmission capacity could theoretically increase to the extent of the maximum transmission rate (R_o) times the increase in the rate (R_i) in the event that a single antenna is used.

[99] [Equation 1]

$$R_i = \min\left(N_T, N_R\right)$$

[100] Namely, with a MIMO communication system that uses 4 transmission antennas and 4 reception antennas, it is theoretically possible to achieve 4 times the transmission rate compared to single antenna systems.

[101] This multiple input multiple output antenna technology could be classified into the spatial diversity method wherein transmission reliability is enhanced using symbols that passed through diverse channel routes and the spatial multiplexing method wherein the transmission rate is improved by simultaneously transmitting multiple data symbols using multiple transmission antennas. Also, there are many research activities on how to appropriately take advantage of strong points of each method by appropriately combining these two methods.

[102] Let’s examine each method in more detail next.

[103] First, the spatial diversity method is further classified into the space-time block code system method and the space-time trellis code system method to use both diversity advantage and coding advantage simultaneously. Generally, the trellis code method is superior in terms of improving the bit error rate and in terms of degree of freedom of code generation whereas the space-time block code method is superior in terms of computational complexity. Spatial diversity gain equals the number of transmission antennas (N_T) times the number of reception antennas (N_R), which is (N_T x N_R).

[104] Second, the spatial multiplexing method is the method whereby different data columns are transmitted with different transmission antennas, and interferences occur between data transmitted simultaneously from the transmitters. The receiver receives data after removing these interferences using an appropriate signal processing method. Noise elimination methods used could include the MLD (maximum likelihood detection) receiver, the ZF (zero-forcing) receiver, the MMSE (minimum mean square error) receiver, the D-blast (diagonal-Bell Laboratories layered space-time), V-BLAST (vertical-Bell laboratories layered space-time), and so on, and in the case in which the channel information can be obtained by the transmission end, such methods as the SVD (singular value decomposition) method could be used.

[105] Third, the method that aggregates the spatial diversity method and the spatial multiplexing method could be used. If only spatial diversity gain is obtained, the performance improvement gain in accordance with the increase in the diversity order becomes gradually saturated, and if only spatial multiplexing gain is obtained transmission reliability decreases in radio channels. In order to resolve this problem, methods to obtain both

advantages have been researched, and there is the double space time block code (double-STTD), space-time BICM (STBICM) method, and so on.

[106] We could mathematically model communication methods regarding multiple input multiple output systems described previously in order to describe these methods in more detail.

[107] First, as illustrated by Figure 5, let's assume that there are N_T transmission antennas and N_R reception antennas.

[108] First, when we examine transmission signals, if there are N_T transmission antennas as described here, the maximum amount of information that could be transmitted is N_T, and this could be expressed with the following vectors.

[109] [Equation 2]

$$\mathbf{s} = \left[s_1, s_2, \cdots, s_{N_T}\right]^T$$

[110] Also, we could differentiate transmission power for each of the transmission information pieces s_1, s_2, …, s_N_T, and if we assume that each transmission power is indicated as P_1, P_2, …, P_N_T, the transmission information for which transmission power has been adjusted could be expressed with the following vectors.

[111] [Equation 3]

$$\hat{\mathbf{s}} = \left[\hat{s}_1, \hat{s}_2, \cdots, \hat{s}_{N_T}\right]^T = \left[P_1 s_1, P_2 s_2, \cdots, P_{N_T} s_{N_T}\right]^T$$

[112] Also, the transmission information for which the transmission power of equation 3 has been adjusted could be expressed as follows with the diagonal matrix P of the transmission power.

[113] [Equation 4]

$$\hat{\mathbf{s}} = \begin{bmatrix} P_1 & & & 0 \\ & P_2 & & \\ & & \ddots & \\ 0 & & & P_{N_T} \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \\ \vdots \\ s_{N_T} \end{bmatrix} = \mathbf{Ps}$$

[114] Also, the information vector for which the transmission power of equation 4 has been adjusted is multiplied by the weight matrix W afterwards to make up N_T transmission signals that are actually transmitted to configure N_T transmission signals that are actually transmitted x_1, x_2, …, x_N_T.
Here, the weight matrix plays the role of appropriately allocating to each antenna the transmission information in accordance with the transmission channel situation, and so on. Such transmission signals x_1, x_2, …, x_N_T could be expressed as follows using vector x.

[115] [Equation 5]

$$\mathbf{x} = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_i \\ \vdots \\ x_{N_T} \end{bmatrix} = \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1N_T} \\ w_{21} & w_{22} & \cdots & w_{2N_T} \\ \vdots & & \ddots & \\ w_{i1} & w_{i2} & \cdots & w_{iN_T} \\ \vdots & & \ddots & \\ w_{N_T1} & w_{N_T2} & \cdots & w_{N_TN_T} \end{bmatrix} \begin{bmatrix} \hat{s}_1 \\ \hat{s}_2 \\ \vdots \\ \hat{s}_j \\ \vdots \\ \hat{s}_{N_T} \end{bmatrix} = \mathbf{W}\hat{\mathbf{s}} = \mathbf{WPs}$$

[116] Here, w_ij indicates the weight between the ith transmission antenna and the jth transmission information, and W expresses this in a matrix format. This matrix W is referred to as weight matrix or precoding matrix.

[117] On the other hand, the transmission signal (x) described previously could be divided into the case in which spatial diversity is used and the case in which space multiplexing is used.

[118] If spatial multiplexing is used, different signals are transmitted after being multiplexed, so that the elements in the information vector s have different values, whereas when spatial diversity is used the same signals are transmitted through many channels so that the elements in the information vector s have the same value.

[119] Of course, we could consider mixing spatial multiplexing and spatial diversity as well.
Namely, we could consider the case in which same signals are transmitted using spatial diversity through three transmission antennas, with each of the remaining signals transmitted by spatial multiplexing.

[120] Next, if there are N_R reception antennas, we could express reception signals of each antenna y_1, y_2, …, y_N_R with vector y as follows:

[121] [Equation6]

$$\mathbf{y} = \left[y_1, y_2, \cdots, y_{N_R}\right]^{\mathrm{T}}$$

[122] On the other hand, when modeling channels for a multiple input and multiple output antenna communication system, it would be possible to identify each channel according to the transmission and reception antenna index, and we could indicate a channel that passes through the transmission antenna j to the reception antenna i as h_ij. Here, we should note that regarding the index order of h_ij the reception antenna index comes first, followed by the transmission antenna index.

[123] We could express such channels by bundling them and expressing them in vectors or matrix format.
A vector format example is provided below.

[124] Figure 6 is a drawing that illustrates a single reception antenna channel among multiple transmission antennas.

[125] As illustrated in Figure 6, it is possible to express a channel wherein signals are transmitted from N_T transmission antennas to the reception antenna i as follows:

[126] [Equation 7]

$$\mathbf{h}_i^T = \left[h_{i1}, h_{i2}, \cdots, h_{iN_T}\right]$$

[127] Also, it would be possible to express all channels that pass from N_T transmission antennas to N_R reception antennas based on the matrix format of equation 7 as follows:

[128] [Equation 8]

$$\mathbf{H} = \begin{bmatrix} \mathbf{h}_1^{\mathrm{T}} \\ \mathbf{h}_2^{\mathrm{T}} \\ \vdots \\ \mathbf{h}_i^{\mathrm{T}} \\ \vdots \\ \mathbf{h}_{\mathrm{N_R}}^{\mathrm{T}} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1N_T} \\ h_{21} & h_{22} & \cdots & h_{2N_T} \\ \vdots & & \ddots & \\ h_{i1} & h_{i2} & \cdots & h_{iN_T} \\ \vdots & & \ddots & \\ h_{N_R1} & h_{N_R2} & \cdots & h_{N_RN_T} \end{bmatrix}$$

[129] On the other hand, due to the fact that with actual channels additive white Gaussian noise (AWGN) is added after passing through the channel matrix H, the white noise added to each of N_R reception antennas could be expressed as follows:

[130] [Equation 9]

$$\mathbf{n} = \left[n_1, n_2, \cdots, n_{N_R}\right]^{\mathrm{T}}$$

[131] Based on the transmission signal, reception signal, channel, and white noise modeling described previously, it would be possible to express each of these elements in a multiple input multiple output antenna communication system with the following relationships:

[132] [Equation 10]

$$\mathbf{y}=\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_i \\ \vdots \\ y_{N_R} \end{bmatrix}=\begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1N_T} \\ h_{21} & h_{22} & \cdots & h_{2N_T} \\ \vdots & & \ddots & \\ h_{i1} & h_{i2} & \cdots & h_{iN_T} \\ \vdots & & \ddots & \\ h_{N_R1} & h_{N_R2} & \cdots & h_{N_RN_T} \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_j \\ \vdots \\ x_{N_T} \end{bmatrix}+\begin{bmatrix} n_1 \\ n_2 \\ \vdots \\ n_i \\ \vdots \\ n_{N_R} \end{bmatrix}=\mathbf{Hx}+\mathbf{n}$$

[133] On the other hand, the number of rows and the number of columns in the channel matrix H that indicate the state of the channel are determined by the number of transmission and reception antennas. As examined previously, the number of rows becomes the number of reception antennas N_R and the number of columns becomes the number of transmission antennas N_T for the channel matrix H. Namely, the channel matrix H becomes an N_RXN_T matrix.

[134] Generally, the rank of a matrix is determined by the lower of the number of independent rows and the number of independent columns. Therefore, the rank of a matrix cannot be greater than the number of rows or the number of columns. In equation form, for example, the rank of the channel matrix H (rank (H)) is restricted as follows:

[135] [Equation 11]

$$rank(\mathbf{H}) \leq \min(N_T, N_R)$$

[136] Also, when we perform Eigen value decomposition on a matrix, the rank could be defined as the number of Eigen values other than 0 among the ranked Eigen values. Similarly, when we perform singular value decomposition (SVD) on a matrix, the rank could be defined as the number of singular values other than 0. Therefore, in a channel matrix, the physical meaning of the rank is the maximum number of different information pieces that could be sent by a given channel.

[137] In the statement, the “rank” regarding MIMO transmission indicates the number of channels through which signals can be independently transmitted at a specific point in time from a specific frequency resource, and the “number of layers” refers to the number of signal streams transmitted through each channel. Due to the fact that the number of layers transmitted by a transmission end corresponds to the number of ranks, the rank refers to the number of layers unless indicated otherwise.

[138]

[139] <u>Carrier aggregation</u>

[140] The communication environments considered by the embodiments under the present invention include multi-carrier support environments. Namely, a multi-carrier system or carrier aggregation (CA) system as used under the present invention refers to any system that aggregates two or more component carriers equipped with bandwidths that are smaller than the target bandwidth when configuring the target broadband in order to support a broadband.

[141] Under the present invention, a multi-carrier refers to carrier aggregation (or carrier wave aggregation), and here carrier aggregation refers to not only aggregation of continuous carriers but also aggregation of non-contiguous carriers. Also, the number of component carriers aggregated between the downlink and the uplink could be set

up differently. If the number of downlink component carriers (hereinafter to be referred to as “DL CC”) and the number of uplink component carriers (hereinafter to be referred to as “UL CC”) are identical, this type of aggregation is referred to as symmetric aggregation, and if the numbers are different this type of aggregation is referred to as asymmetric aggregation. Such carrier aggregation terms could be used with carrier wave aggregation, bandwidth aggregation, spectrum aggregation, and so on.

[142] Carrier aggregation involving the aggregation of two or more component carriers targets supporting of up to 100MHz bandwidth in LTE-A systems. When aggregating two or more carriers with the bandwidth of less than the target bandwidth, the bandwidth of the carrier being aggregated could be restricted to the bandwidth used by the existing system in order to maintain backward compatibility with the existing IMT system. For example, the existing 3GPP LTE system could support {1, 4, 3, 5, 10, 15, and 20} MHz bandwidths, and the 3GPP LTE-advanced system (namely, LTE-A) could support bandwidths greater than 20MHz by using only the above bandwidths in order to be compatible with the existing system. Also, the carrier aggregation system used under the present invention could be configured to support carrier aggregation by defining new bandwidths regardless of the bandwidth used by the existing system.

[143] The LTE-A system uses the cell concept in order to manage radio resources.

[144] The carrier aggregation environment described previously could refer to multiple cells. Although a cell is defined as a pair of the downlink resource (DL CC) and uplink resource (UL CC), the uplink resource is not a required element. Therefore, a cell could be composed of only a downlink resource, or with a downlink resource and an uplink resource. If a given user equipment has a configured serving cell, it could have a DL CC and a UL CC, but if a given user equipment has two or more configured serving cells, the number of DL CC’s it has equals the number of cells, and the number of UL CC could be equal to or less than the number of DL CC’s.

[145] Or, conversely, DL CC and UL CC could be configured. Namely, if a given user equipment has multiple configured serving cells, a carrier aggregation environment in which the number of UL CC is greater than the number of DL CC could be supported. Namely, carrier aggregation could be understood as aggregation of two or more cells with different carrier frequencies (cell’s central frequency). The term “cell” used here is different from the term “cell” covered by the base station as its domain.

[146] Cells used by the LTE-A system include primary cells (PCell) and secondary cells (SCell). P cells and S cells could be used as serving cells. In the case of a user equipment that is in the RRC_CONNECTED state but for which carrier aggregation has not been configured or carrier aggregation is not supported, there is a serving cell composed of only P cells. On the other hand, in the case of a user equipment at the RRC_CONNECTED state, with carrier aggregation already configured, there could be more than one serving cells, and the entire serving cells include a P cell and one or more S cells.

[147] Serving cells (P cells and S cells) could be set up through RRC parameters. The PhysCellID has integers from 0 to 503 as the cells’ physical level identifiers. The SCellIndex is a short identifier used in order to identify S cells, and integers ranging from 1 to 7 are used. The ServCellIndex is a short identifier used in order to identify serving cells (P cells or S cells), and integers ranging from 0 to 7 are used. Z is applied to P cells, and SCellIndex is assigned in advance in order to apply to S cells. Namely, the cell with the smallest ServCellIndex cell ID (or cell index) becomes the P cell.

[148] The P cell refers to the cell that operates in the primary frequency (or primary CC). A user equipment could be used for performing the initial connection establishment process or for performing the connection re-configuration process, and could designate cells indicated in the handover process. Also, the P cell refers to the cell that is at the center of communication related to control among the serving cells configured in the carrier aggregation environment. Namely, a user equipment is able to be allocated the PUCCH at its P cell to transmit, and only the P cell can be used for acquiring system information or changing the monitoring process. The E-UTRAN (Evolved Universal Terrestrial Radio Access) could change only the P cell for the handover process using

the RRC connection reconfiguration message that includes mobility control information to a user equipment that supports carrier aggregation environments.

[149] The S cell may refer to a cell operating on a secondary frequency (or Secondary Component Carrier, CC). Only one P cell is allocated to a given UE, whereas one or more S cells may be allocated. An S cell can only be configured after the RRC connection has been established and can be used to provide additional radio resources. In a carrier aggregation environment, the serving cells excluding the P cell—that is, the S cells—do not include a PUCCH. When an S cell is added to a UE that supports the carrier aggregation environment, all system information related to the operation of the associated cells in the RRC_CONNECTED state can be provided through dedicated signaling. Any changes to the system information can be controlled by the removal or addition of S cells, and in such cases, the RRC Connection Reconfiguration message may be used. The E-UTRAN may use dedicated signaling, which includes UE-specific parameters, rather than broadcasting within the associated S cell.

[150] After the initial security activation process starts, it would be possible to configure a network that includes more than one S cell by adding the E-UTRAN to the P cell configured at the outset of the connection configuration process. Under a carrier aggregation environment, the P cell and the S cell can operate as respective component carriers. In the embodiments presented below, the primary component carrier (PCC) could have the same meaning as the P cell, and the secondary component carrier (SCC) could have the same meaning as the S cell.

[151] Figure 7 illustrates the component carrier and carrier aggregation in a radio communication system to which the present invention could be applied.

[152] Figure 7 (a) illustrates a single carrier structure used in the LTE system. A component carrier has DL CC and UL CC. A component carrier could have a frequency range of 20MHz.

[153] Figure 7 (b) illustrates a carrier aggregation structure used in the LTE_A system. Figure 7 (b) illustrates a case in which 3 component carriers with the frequency size of 20MHz have been aggregated. Although there are 3 DL CCs and 3 UL CCs, there is no limit to the number of DL CCs or number of UL CCs. In the case of carrier aggregation, the UE is able to monitor 3 CCs simultaneously, is able to receive downlink signals/data, and is able to transmit uplink signals/data.

[154] If N DL CCs are managed in a given cell, the network could allocate M ($M \leq N$) DL CCs. At this time, the user equipment is able to monitor only M DL CCs and receive M DL signals. Also, the network is able to allocate the main DL CC to the user equipment by prioritizing L ($L \leq M \leq N$) DL CCs, and in such a case the UE must monitor L DL CCs. Such a method could be applied in the same way for uplink transmissions as well.

[155] The linkage between the downlink resource's carrier wave frequency (or DL CC) and the uplink resource's carrier wave frequency (or, UL CC) could be addressed by the higher level message such as the RRC message or by the system information. For example, the DL resource and the UL resource could be aggregated by a linkage defined by the SIB2 (system information block type 2). Specifically, the linkage could mean the mapping relationship between the DL CC to which the PDCCH that carries the UL grant and the UL CC that uses the UL grant, or could mean the mapping relationship between the DL CC (or UL CC) to which data for HARQ is transmitted and the UL CC (or DL CC) to which the HARQ ACK/NACK signals are transmitted.

[156] If more than one S cell is configured in a user equipment, the network could activate or deactivate configured S cells. The P cell is always activated. The network activates or deactivates S cells by transferring activation/deactivation MAC control elements.

[157] The activation/deactivation MAC control element has a fixed size, and is composed of a single octet that includes 7 C fields and a single R field. The C field is configured for each S cell index, and addresses the activation/deactivation state of the S cell. If the C field's value is set as "1," the S cell with the applicable S cell index is activated, and if it is set as "0," the S cell with the applicable S cell index is deactivated.

[158] Also, the user equipment maintains a timer for each configured S cell (sCellDeactivationTimer), and the related S cells are deactivated when the timer expires. The same initial timer value is applied to each instance of the timer (sCellDeactivationTimer), and it is set by the RRC signaling. When S cells are added or handed over, the initial S cells are deactivated.

[159] The user equipment carries out the following operations for each of the S cells configured in each TTI:

[160] - When the user equipment receives the activation/deactivation MAC control element that activates the S cell in a specific TTI (sub-frame n), the user equipment activates the S cell at the TTI (sub-frame n+8 or afterwards) corresponding to the stipulated timing, and the timer related to the applicable S cell is (re)started. When we say that a given user equipment activates S cells, it means that CQI (channel quality indicator)/PMI (precoding matrix indicator)/RI (rank indication)/PTI (precoding type indicator) for S cells are reported, and general S cell operations such as PDCCH monitoring in the S cell and PDCCH monitoring for S cells are applied.

[161] - When the user equipment receives the activation/deactivation MAC control element that deactivates the S cell in a given TTI (sub-frame n) or if the timer related to the S cell activated by a given TTI (sub-frame n) expires, the user equipment deactivates the S cell at the TTI (sub-frame n+8 or afterwards) corresponding to the stipulated timing, and the applicable S cell's timer stops, and all HARQ buffers related to the applicable S cells are flushed.

[162] - When the PDCCH activated in the S cell addresses uplink grant or downlink assignment, or if the PDCCH in the serving cell that schedules activated S cells addresses uplink grants or downlink assignments for activated S cells, the user equipment restarts the timer related to the applicable S cell.

[163] - When the S cell becomes deactivated, the user equipment does not transmit the SRS in the S cell, does not report the CQI/PMI/RI/PTI for the S cell, does not transmit the UL-SCH in the S cell, nor monitors the PDCCH in the S cell.

[164]

[165] Random access procedure

[166] Let's examine the random access procedure provided by the LTE/LTE-A system below.

[167] The random access procedure is used when the user equipment aligns uplink with the base station or receives uplink radio resources. After the user equipment's power is turned on, the user equipment obtains downlink alignment with the initial cell and receives system information. From the system information, usable random access preamble sets and information on radio resources used for transmitting random access preambles are obtained. Radio resources used for transmitting random access preambles could be specified as aggregation of at least one sub-frame index and the index in the frequency domain. The user equipment transmits random access preambles from the random access preamble set, and the base station that receives the random access preamble transmits to the user equipment the timing alignment (TA) value for uplink alignment through random access responses. As a result, the user equipment acquires uplink alignment.

[168] The random access procedure the procedure included in the FDD (frequency division duplex) and TDD (time division duplex) methods. The random access procedure is unrelated to the cell size, and if carrier aggregation (CA) has been set up it is unrelated to the number of serving cells either.

[169] First, the following cases involve the performance of the random access procedure by the user equipment:

[170] - If the user equipment conducts initial access in the RRC idle state without RRC connection with the base station.

[171] - If the user equipment performs the RRC connection re-establishment procedure.

[172] - If the user equipment accesses the target cell for the first time in the handover process.

[173] - If the random access procedure is requested by the base station

[174] - If it becomes necessary to transmit data downlink under the situation in which uplink time alignment is absent (non-aligned) during RRC connection.

[175] - If uplink time alignment is absent (non-aligned) during RRC connection, or if it becomes necessary to transmit data uplink while designated radio resources that are used for requesting radio resources have not been allocated.

[176] - If the user equipment's positioning is being carried out while timing advance is necessary during RRC connection.

[177] - If the recovery procedure is being carried out during radio link failure or handover failure.

[178] In 3GPP Rel-10, applying a TA (timing advance) value that could be applied to a single cell (e.g., a P cell) to multiple cells in a radio connection system that supports carrier aggregation was considered. However, a UE can aggregate multiple cells that belong to different frequency bands (namely, substantially separated on the frequency bands) or multiple cells with different propagation characteristics. Also, in the case of some cells, if a small cell such as the RRH (remote radio header) (namely, a repeater), a femto cell, a pico cell, and so on or a secondary base station (SeNB) is positioned within a cell in order to expand the coverage or eliminate the coverage hole, the user equipment communicates with the based station (namely the macro base station (macro eNB) through a single cell, and if communication is carried out with the secondary base station through another cell multiple cells could have different transmission delay characteristics. In this case, if uplink transmission wherein a single TA value is applied to multiple cells is used alignment of uplink signals transmitted in multiple cells could be seriously impacted. Therefore, it would be preferable to have multiple TA's under the CA situation in which multiple cells have been aggregated, and independently allocating TA's for specific cell group units in order to support multiple TA (multiple TA) is considered in 3GPP Rel-11. This is referred to as the TA group (TAG: TA group), and the TAG could include more than one cell, and the same TA could be applied to more than one cells included in the TAG. In order to support such a multiple TA, the MAC TA command control element is composed of 2 bits of TAG identifiers (TAG ID) and 6 bits of TA command fields.

[179] A user equipment for which carrier aggregation has been configured carries out the random access process when the random access procedure described previously occurs. In the case of the TAG (namely, pTAG: primary TAG) to which the P cell belongs, the TA determined based on the P cell as before, or adjusted through the random access procedure related to the P cell could be applied to all cells within the pTAG. On the other hand, in the case of the TAG composed only of S cells (namely, sTAG: secondary TAG), the TA, which is determined based on a specific S cell within the sTAG, could be applied to all cells within the applicable sTAG, and at this time the TA could be acquired by the random access procedure initiated by the base station. Specifically, the S cell within the sTAG is configured with the support of the RACH (random access channel), and the base station requests access to the RACH in the S cell. Namely, RACH transmission is started by the base station in the S cells by the PDCCH order transmitted from the P cell. The response message for the S cell preamble is transmitted through the P cell by using RA-RNTI. The TA determined based on the S cell successfully completed through random access could be applied to all cells within the applicable sTAG. As described, the random access procedure could be carried out in the S cell in order to acquire the timing alignment of the sTAG to which the applicable S cell belongs.

[180] With the LTE/LTE-A system, during the process in which the random access preamble (RACH preamble) is selected both the contention based random access procedure wherein the user equipment selects and uses a single preamble within a given set and the non-contention based random access procedure wherein the base station uses only the random access preamble allocated to a specific user equipment are provided. However, the non-contention based random access procedure could be used for user equipment positioning and/or sTAG timing advance alignment during the handover process described previously or when the base station commands. After the random access procedure is completed the general uplink/downlink transmission occurs.

[181] On the other hand, the relay node (RN) also supports both the contention based random access procedure and the non-contention based random access procedure. When the relay node performs the random access

procedure, the RN sub-frame configuration at that point is suspended. Namely, this means that the RN sub-frame configuration is closed temporarily. Afterwards, at the point at which the random access procedure is successfully completed the RN sub-frame configuration is restarted.

[182] Figure 8 is a drawing to describe the contention based random access procedure in a radio communication system to which the present invention could be applied.

[183] (1) Message 1 (Msg 1)

[184] First, the user equipment randomly selects a random access preamble (RACH preamble) from a random access preamble set addressed through the system information or handover command, and then selects and transfers a PRACH (physical RACH0 resource to transfer the random access preamble.

[185] The random access preamble is transmitted in 6 bits at the RACH transmission channel, and the 6 bit is composed of a random 5-bit identity to identify the user equipment that transmitted the RACH, and 1 bit to indicate additional information (e.g., addresses the size of message 3 (Msg 3)).

[186] The base station that received the random access preamble from the user equipment decodes the preamble, and then obtains the RA-RNTI. The RA-RNTI related to the PRACH to which the random access preamble is transmitted is determined by the time-frequency resource of the random access preamble the applicable user equipment transmitted.

[187] (2) Message 2 (Msg 2)

[188] The base station transmits to the user equipment a random access response addressed to the RA_RNTI acquired through the preamble in message 1. The random access response could include a random access preamble index/identifier, an uplink grant that notifies the uplink radio resource, a temporary identifier (TC-RNTI), a time alignment command (TAC), and so on. The TAC is the information that addresses the time alignment value sent by the base station to the user equipment to maintain the uplink time alignment. The user equipment renews the uplink transmission timing by using the time alignment value. When the user equipment renews time alignment, the time alignment timer is started or restarted. The UL grant includes the uplink support allocation and the TPC (transmit power command) used for transmitting the scheduling message (message 3), which will be described later. The TPC is used in order to determine the transmission power for the scheduled PUSCH.

[189] After transmitting the random access preamble, the user equipment attempts to receive its random access response within the random access response window addressed by the base station through system information or handover command, detects the PDCCH masked with the RA_RNTI corresponding to the PRACH, and then receives the PDSCH addressed by the detected PDCCH. The random access response information could be transmitted in the MAC PDU (MAC packet data unit) format, and the MAC PDU could be transmitted through the PDSCH. It is preferable for the PDCCH to include information on the user equipment that must receive the PDSCH, the frequency and time information of the PDSCH's radio resource, the PDSCH's transmission format, and so on. As described previously, if the user equipment successfully detects the PDCCH being transmitted to itself the user equipment will be able to appropriately receive the random access response transmitted to the PDSCH in accordance with the PDCCH information.

[190] The random access response window refers to the maximum time period for the user equipment that transmitted preamble to wait in order to receive the random access response message. The random access response window starts from the sub-frame after the 3 sub-frames from the last sub-frame to which the preamble is transmitted, and has the length of the "ra-ResponseWindowSize." Namely, the user equipment waits in order to receive the random access response during the random access window acquired after the 3 sub-frames from the sub-frame at which the preamble stopped being transmitted. The user equipment is able to acquire the random access window size ("ra-ResponseWindowsize") parameter value through the system information, and the random access window size could be determined as a value between 2 to 10.

[191] When the user equipment successfully receives the random access response that contains the random access preamble classifier/identifier that is identical to the random access preamble transmitted to the base station, random access response monitoring is stopped. On the other hand, if the random access response message is not received until the random access response window is stopped, or if an effective random access response with the same random access preamble classifier as the random access preamble transmitted to the base station is not received, it is deemed that reception of the random access response has failed, and the user equipment may retransmit the preamble.

[192] As described previously, the reason that the random access preamble classifier is necessary in the random access response is that it would be necessary to provide information regarding to which UE the UL grant, TC-RNTI, and TAC are effective, due to the fact that a single random access response could include random access response information for one or more UEs.

[193] (3) Message 3 (Msg 3)

[194] If the user equipment receives a random access response that is effective to itself, the user equipment processes information items that include the random access response. Namely, the user equipment applies the TAC, and stores the TC-RNTI. Also, the user equipment uses the UL grant in order to transfer to the base station data stored in the user equipment’s buffer or newly generated data. For the initial access by the user equipment, the RRC connection request communicated through the CCCH after being generated in the RRC level could be included in message 3 and delivered, and in the case of the RRC connection reestablishment procedure, the RRC connection reestablishment request generated in the RRC level and delivered through the CCCH could be included in message 3 and delivered. Also, the NAS access request message could be included.

[195] Message 3 must include the user equipment’s identifier. With the contention based random access procedure, it is not possible for the base station to determine which UE must perform the random access procedure, and it would be necessary to identify UE in order to resolve contentions later.

[196] There are two methods to include the user equipment’s identifier. With the first method, if the user equipment has an effective cell identifier (C-RNTI) allocated at the applicable cell prior to the random access procedure, the user equipment transfers its cell identifier through the uplink transfer signal corresponding to the UL grant. On the other hand, if an effective cell identifier was not allocated prior to the random access procedure, the user equipment transfers information that includes its own identifier (e.g., S-TMSI or random number)). Generally, the unique identifier is longer than the C-RNTI. For transfers in the UL-SCH, user equipment-specific scrambling is used. However, if the user equipment has not been allocated with the C-RNTI, scrambling cannot be based on the C-RNTI, and instead the TC-RNTI received at the random access response is used. Although the user equipment transmits data that corresponds to the UL grant, a contention resolution timer is started in order to resolve contentions.

[197] (4) Message 4

[198] If the base station receives the C-RNTI of the applicable user equipment through message 3, the base station transfers message 4 to the user equipment using the C-RNTI received. On the other hand, if the unique identifier (namely, the S-TMSI or random number)) is received from the user equipment through message 3, message 4 is transmitted to the user equipment using the TC-RNTI allocated to the applicable user equipment in the random access response. Here, message 4 could be the RRC connection setup message that includes the C-RNTI.

[199] After transmitting data including its identifier through the UL grant included in the random access response, the user equipment waits for the base station’s instruction. Namely, the user equipment attempts to receive the PDCCH in order to receive specific messages. Also, there are two methods to receive the PDCCH. As mentioned previously, if the user equipment’s own identifier included in the 3 messages transmitted in response to the UL grant is C-RNTI, the user equipment attempts to receive the PDCCH using its own C-RNTI, and if the identifier is a

unique identifier (namely, S-TMSI or a random number), the user equipment will attempt to receive the PDCCH using the TC-RNI included in the random access response. Afterwards, in the case of the former, if the user equipment received the PDCCH through its own C-RNTI prior to the expiration of the contention resolution timer, the user equipment determines that the random access procedure was carried out normally, and terminates the random access procedure, in the latter case, if the PDCCH was received through the TC-RNTI before the expiration of the contention resolution timer, the user equipment checks the data delivered by the PDSCH addressed by the PDCCH. If the data contains its own identifier, the user equipment determines that the random access procedure has been carried out, thereby ending the random access procedure. The message acquires the C-RNTI through message 4, and afterwards the user equipment and the network send and receive the user equipment' dedicated message by using C-RNTI.

[200] Next, how to resolve contentions in the random access will be described.

[201] The reason that contentions occur in carrying out random access is that basically the number of random access preambles is restricted. Namely, due to the fact that the base station is not able to assign dedicated random access preambles to all UE, the user equipment randomly selects and transfers one of the common random access preambles. As result, there are instances in which two or more UE select the same random access preamble through the same radio resource (PRACH resource), but the base station determines that a single random access preamble has been transmitted from a single user equipment. As a result, the base station transfers the random access response to the user equipment, and predicts that the random access response will have been received by a single user equipment. However, due to the fact that contentions could occur as described previously, two or more UE receive a single random access response, and as a result each user equipment carries out operations in accordance with the reception of the random access response. Namely, the issue wherein two or more UE transfer different data sets to the same radio resource using a single UL grant included in the random access response could occur. Accordingly, these data transfers could all fail, and it is possible that the base station will receive data only from a specific user equipment depending on the locations of the UE or depending on the transfer power. In the case of the latter, due to the fact that two or more UE assume that data transfers have succeeded, the base station must provide information to the UE that failed to transfer data regarding the failure situation. Namely, providing information regarding contention failure or success is referred to as contention resolution.

[202] There are two methods to resolve contention situations. One method involves using the contention resolution timer, and another method involves transferring identifiers of successful UE to UE. The former method is used if the user equipment already has its own C-RNTI prior to the random access procedure. Namely, a user equipment that already has the C-RNTI transfers its C-RNTI in accordance with the random access response, and then operates the contention resolution timer. Then, prior to the expiration of the contention resolution timer, when the PDCCH information addressed by its C-RNTI is received, the user equipment determines that it has succeeded, and normally completes random access. Conversely, if the user equipment fails to receive the PDCCH transfer addressed by its own C-RNTI prior to the expiration of the contention resolution timer, the user equipment determines that it has failed, thereby carrying out the random access process again, or may notify the upper level of its failure. The latter contention resolution method, namely in the case of the method wherein the identifier of the successful user equipment is transmitted, is used if the user equipment does not have its own cell identifier prior to the random access procedure. Namely, if the user equipment doesn't have its own cell identifier, an identifier higher than the cell identifier (S-TMSI or random number) is transmitted in accordance with the UL grant information included in the random access response, and the user equipment starts the contention resolution timer. Before the collision resolution timer expires, if the data that includes its high level identifier is transmitted to the DL-SCH, the user equipment determines that the random access procedure has succeeded. On the other hand, prior to the expiration of the contention resolution timer, if the

data that includes its high level identifier is not received with the DL-SCH, the user equipment determines that the random access procedure has failed.

[203] On the other hand, the operation in the non-contention based random access procedure, contrary to the contention-based random access process, terminates only with the transmission of message 1 and transmission of message 2. However, as message 1, the user equipment is assigned by the base station a random access preamble prior to transmitting to the base station a random access preamble, and this assigned random access preamble is transmitted to the base station as message 1, and by receiving a random access response from the base station the random access procedure is terminated.

[204]

[205] Reference signal (RS)

[206] Due to the fact that data is transmitted through radio channels in radio communication systems, signals could become distorted while being transmitted. In order for the receiving end to accurately receive distorted signals, distortion of received signals must be corrected using channel information. In order to detect channel information, a signal transmission method that both the transmitting side and the receiving side know and a method whereby channel information is detected by using the extent of distortion when signals are transmitted through channels are mainly used. The signal described above is referred to as reference signal (RS).

[207] Also, recently most mobile communication systems have moved away from using a single transmission antenna and a single reception antenna when transmitting packets, to use multiple transmission antennas and multiple reception antennas in order to improve data transmission and reception efficiency. When transmitting and receiving data using multiple input and output antennas the channel state between the transmission antenna and the reception antenna must be detected in order to accurately receive signals. Therefore, each transmission antenna must have a separate reference signal.

[208] In mobile communication systems, the RS could be classified into two types depending on the purpose. One RS type is used for acquiring channel information and the other RS type is used for demodulating data. Since the purpose of the former is for the UE to acquire downlink channel information, transmission must be carried out with via broadband, and even if the UE does not receive downlink data from a specific sub-frame, it must be able to receive and measure the RS. Also, this is used for measuring handovers, and so on. The latter is the RS that is transmitted along with the applicable resources when the base station transmits downlink, and the UE is able to estimate channels by receiving the applicable RS, and therefore is able to demodulate data. This RS must be transmitted to the domain to which data is being transmitted.

[209] Downlink reference signals include a single common reference signal (CRS) to acquire information regarding the channel state shared by all UEs within a given cell, to measure the handover, and so on, and dedicated reference signals (dedicated RS) that are used for demodulating data for specific UE. It would be possible to provide information for demodulation and channel measurement purposes by using such reference signals. Namely, the DRS is used only for demodulating purposes, and the CRS is used for acquiring channel information and demodulating data.

[210] The receiving side (namely, a user equipment) measures the channel state from the CRS, and sends feedback to the transmitting side (namely, the base station) indicators related to channel state such as CQI (channel quality indicator), PMI (precoding matrix index) and/or RI (rank indicator). The CRS is also referred to as cell-specific reference signal (RS). On the other hand, reference signals related to feedback of channel state information (CSI) could be defined as CSI-RS.

[211] The DRS could be transmitted through resource elements if data demodulation on the PDSCH becomes necessary. The user equipment is able to receive information regarding the existence of the DRS through the higher level, and is valid only if the corresponding PDSCH has been mapped. The DRS could be referred to as user equipment-specific reference signal or demodulation reference signal.

[212] Figure 9 illustrates a reference signal pattern mapped on a downlink resource block pair in a radio communication system to which the present invention could be applied.

[213] When we refer to Figure 9, we can see that a downlink block pair could be expressed as a single sub-frame in the time domain x 12 sub-carrier waves in the frequency domain in the units in which the reference signal is being mapped. Namely, on the time axis (x axis) a resource block pair has the length of 14 OFDM symbols if it has a normal cyclic prefix (CP) (in the case of Figure 9 (a)), and has the length of 12 OFDM symbols if it has an extended cyclic prefix (CP) (in the case of Figure 9 (b)). In the resource block lattice, the resource elements (Res) that are indicated as “0,” “1,”, “2,”, and “3” refer to the DRS locations of the CRS of the antenna port indexes “0,” “1,” “2,” and “3,” respectively, and the resource elements that are indicated as “D” refer to the location of the DRS.

[214] To describe the CRS in more detail below, the CRS is used in order to estimate the physical antenna’s channel, and it is distributed to the entire frequency bandwidth as the reference signal that could be received commonly by all user equipment located within the cell. Namely, this CRS is a cell-specific signal, which is transmitted for each sub-frame for the bandwidth. Also, the CRS could be used for channel state information (CSI) and data demodulation.

[215] The CRS is defined in diverse formats depending on the antenna array. In 3GPP LTE systems (e.g., Release-8), the RS for up to 4 antenna ports is transmitted depending on the number of transmission antennas of the base station. The downlink signal transmission side has three types of antenna array including a single transmission antenna, 2 transmission antennas, and 4 transmission antennas. For example, if the base station has 2 transmission antennas, CRS is transmitted for the 0^{th} and the 1^{st} antenna ports, and if the base station has 4 antennas, CRS is transmitted to the 0^{th} to the 3^{rd} antennas. If the base station has 4 transmission antennas, the CRS pattern for the RB is as illustrated in Figure 9.

[216] If the base station uses a single transmission antenna, a reference signal for the single antenna port is arrayed.

[217] If the base station uses 2 transmission antennas, the reference signal for the 2 transmission antenna ports is arrayed using the time division multiplexing (TDM) method and/or frequency division multiplexing (FDM) method. Namely, in order to distinguish each antenna port, the reference resource allocates different time resources and/or different frequency resources.

[218] Furthermore, if the base station uses 4 transmission antennas, the reference signal for the 4 transmission antenna ports is arrayed using the TDM method and/or FDM method. The channel information measured by the downlink signal’s reception side (user equipment) could be used in order to demodulate transmitted data using such transmission methods as single antenna transmission , transmission diversity, closed-loop spatial multiplexing, open-loop spatial multiplexing, or multi-user multiple input multiple output antenna (MIMO) method.

[219] If multiple input multiple output antennas are supported, when the reference signal is transmitted from a given antenna port the reference signal is transmitted to the specified resource elements in accordance with the reference signal’s pattern, and is not transmitted to specified resource elements for other antenna ports. Namely, reference signals among different antennas do not overlap.

[220] To describe the DRS in more detail below, the DRS is used in order to demodulate data. The precoding weight used for specific user equipment with the multiple input multiple output antenna transmission is used without modification in order for each transmission antenna to estimate the corresponding channel when the user equipment receives the reference signal.

[221] 3GPP LTE systems (e.g., Release-8) support up to 4 transfer antennas and the DRS for rank 1 beam forming is defined. The DRS for rank 1 beam forming indicates the reference signal for antenna port index 5 as well.

[222] An LTE-A system, which is an advanced form of the LTE system, must be designed in order to be able to support up to 8 transmission antennas as the base station’s downlink. Therefore, the RS for up to 8 transmission

antennas must be supported as well. Due to the fact that in an LTE system the downlink RS is defined for only up to 4 antenna ports, so if the base station in an LTE-A system has between 4 and 8 downlink transmission antennas the RS for these antenna ports must be additionally defined and designed. To accommodate up to 8 transmission antenna ports, both the RS for channel measurement and the RS for data demodulation must be designed.

[223] One of the important considerations in designing the LTE-A system is backward compatibility. In other words, the LTE user equipment must be able to operate well in the LTE-A system, and the system must support this as well. From the RS transmission perspective, in the time-frequency domain in which the CRS defined by the LTE is transmitted to the entire bandwidth for each sub-frame the RS for up to 8 transmission antennas must be additionally defined. In the LTE-A system, if the RS pattern is added to the entire bandwidth for each sub-frame for up to 8 transmission antennas as with the existing LTE's CRS method, the RS overhead becomes excessively large.

[224] Therefore, the RS to be newly designed in the LTE-A system is broadly classified into two types, which are the RS for channel measurement to select MCS, PMI, and so on (CSI-RS: channel state information-RS, channel state indication-RS, etc.) and the RS for demodulating data transmitted to 8 transmission antennas (DM-RS: data demodulation-RS).

[225] Unlike with the conventional CRS, which is used for measuring channels handovers, and so on as well as for demodulating data, the CSI-RS for channel measurement purposes is designed mainly for channel measurement purposes. Also, it could be used for handover measurements, and so on. Since the CSI-RS is used only to acquire channel state information, it may not have to be transmitted for each sub-frame, unlike with the CRS. In order to reduce the CSI-RS's overhead, the CSI-RS is transmitted intermittently on the time axis.

[226] For data demodulation purposes, dedicated DM-RS is transmitted to the scheduled UE in the applicable time-frequency domain. Namely, the DM-RS for a given UE is transmitted to the domain in which the applicable UE has been scheduled, namely to the time-frequency domain to receive data.

[227] In an LTE-A system, the eNB must transmit CSI-RS for all antenna ports. Since transmitting the CSI-RS for up to 8 transmission antenna ports at each sub-frame requires excessive overhead, the CSI-RS must be transmitted intermittently in the time axis rather than for each sub-frame in order to reduce the overhead. Namely, the CSI_RS could be transmitted periodically with an integer multiple for a sub-frame, or could be transmitted in a specific transmission pattern. At this time, the frequency or pattern at which the CSI-RS is transmitted could be set up by the eNB.

[228] In order to measure the CSI-RS, the UE must know information regarding the CSI-RS's transmission sub-frame index for each CSI-RS antenna port in the cell in which it belongs, the CSI-RS resource element (RE)'s time-frequency location within the transmission sub-frame, the CSI-RS sequence, and so on.

[229] The eNB in the LTE-A system must transmit the CSI-RS to each of up to 8 antenna ports. The resources used for transmitting CSI-RS to different antenna ports must be orthogonal to each other. When the eNB transmits the CSI-RS to different antenna ports, the CSI-RS for each of the antenna ports is mapped on different REs to be able to orthogonally allocate these resources in the FDM/TDM method. Also, transmissions could be carried out with the CDM method whereby the CSI-RS for different antenna ports is mapped on orthogonal codes.

[230] When the eNB provides information on the CSI-RS to the UE in its cell, information regarding the time-frequency wherein the CSI-RS is mapped for each antenna port must be provided first. Specifically, the sub-frame numbers to which the CSI-RS is transmitted, the CSI-RS transmission frequency, the sub-frame offset to which the CSI-RS is transmitted, the OFDM symbol number to which the CSI_RS RE of a specific antenna is transmitted, the frequency spacing, the offset or shift value on the frequency axis, and so on are types of information that must be provided.

[231] The CSI-RS is transmitted through 1, 2, 4, or 8 antenna ports. Here, the antenna ports used are each p = 15, p = 15, 16, p = 15,…, 18, p = 15,.., 22. The CSI-RS could be defined only for the sub-carrier spacing △f = 15kHz.

[232] The (k', l') (here, k' is the sub-carrier wave index within a resource block, and l' is the OFDM symbol in a slot.) and n_s conditions are determined by the CSI-RS configuration of Table 4 or Table 5 below.

[233] Table 3 illustrates the mapping of (k', l') from the CSI-RS configuration in the normal CP.

[234] [Table 3]

	CSI reference signal configuration	Number of CSI reference signals configured					
		1 or 2		4		8	
		(k',l')	$n_s \bmod 2$	(k',l')	$n_s \bmod 2$	(k',l')	$n_s \bmod 2$
Frame structure type 1 and 2	0	(9,5)	0	(9,5)	0	(9,5)	0
	1	(11,2)	1	(11,2)	1	(11,2)	1
	2	(9,2)	1	(9,2)	1	(9,2)	1
	3	(7,2)	1	(7,2)	1	(7,2)	1
	4	(9,5)	1	(9,5)	1	(9,5)	1
	5	(8,5)	0	(8,5)	0		
	6	(10,2)	1	(10,2)	1		
	7	(8,2)	1	(8,2)	1		
	8	(6,2)	1	(6,2)	1		
	9	(8,5)	1	(8,5)	1		
	10	(3,5)	0				
	11	(2,5)	0				
	12	(5,2)	1				
	13	(4,2)	1				
	14	(3,2)	1				
	15	(2,2)	1				
	16	(1,2)	1				
	17	(0,2)	1				
	18	(3,5)	1				
	19	(2,5)	1				
Frame structure type 2 only	20	(11,1)	1	(11,1)	1	(11,1)	1
	21	(9,1)	1	(9,1)	1	(9,1)	1
	22	(7,1)	1	(7,1)	1	(7,1)	1
	23	(10,1)	1	(10,1)	1		
	24	(8,1)	1	(8,1)	1		
	25	(6,1)	1	(6,1)	1		
	26	(5,1)	1				
	27	(4,1)	1				
	28	(3,1)	1				
	29	(2,1)	1				
	30	(1,1)	1				
	31	(0,1)	1				

[235] Table 4 illustrates the mapping of (k', l') from the CSI-RS configuration from the extended CP.

[236] [Figure 4]

	CSI reference signal configuration	Number of CSI reference signals configured: 1 or 2		4		8	
		(k',l')	$n_s \bmod 2$	(k',l')	$n_s \bmod 2$	(k',l')	$n_s \bmod 2$
Frame structure type 1 and 2	0	(11,4)	0	(11,4)	0	(11,4)	0
	1	(9,4)	0	(9,4)	0	(9,4)	0
	2	(10,4)	1	(10,4)	1	(10,4)	1
	3	(9,4)	1	(9,4)	1	(9,4)	1
	4	(5,4)	0	(5,4)	0		
	5	(3,4)	0	(3,4)	0		
	6	(4,4)	1	(4,4)	1		
	7	(3,4)	1	(3,4)	1		
	8	(8,4)	0				
	9	(6,4)	0				
	10	(2,4)	0				
	11	(0,4)	0				
	12	(7,4)	1				
	13	(6,4)	1				
	14	(1,4)	1				
	15	(0,4)	1				
Frame structure type 2 only	16	(11,1)	1	(11,1)	1	(11,1)	1
	17	(10,1)	1	(10,1)	1	(10,1)	1
	18	(9,1)	1	(9,1)	1	(9,1)	1
	19	(5,1)	1	(5,1)	1		
	20	(4,1)	1	(4,1)	1		
	21	(3,1)	1	(3,1)	1		
	22	(8,1)	1				
	23	(7,1)	1				
	24	(6,1)	1				
	25	(2,1)	1				
	26	(1,1)	1				
	27	(0,1)	1				

[237] When we refer to Table 3 and Table 4, we can see that in the transmission of the CSI-RS, up to 32 (in the case of normal CP) or up to 28 (in the case of extended CP) different configurations are defined in order to reduce inter-cell interferences (IC) in multi-cell environments including heterogeneous networks (HetNet).

[238] The CSI-RS configuration is different depending on the number of antenna ports within a cell and depending on the CP, and neighboring cells could have different configurations. Also, the CSI-RS configurations could be classified into the case in which the configuration is applied to both the FDD frames and the TDD frames and the case in which the configuration is applied only to the TDD frames depending on the frame structure.

[239] Based on Table 3 and Table 4, (k’, l’) and n_s are determined according to the CSI-RS configuration, as well as the time-frequency resource that each CSI-RS antenna port uses for CSI-RS transmission purposes.

[240] Figure 10 is a drawing that illustrates the CSI-RS configuration in a radio communication system to which the present invention could be applied.

[241] Figure 10 (a) illustrates 20 CSI-RS configurations that could be used for CSI-RS transmission by 2 CSI-RS antenna ports, Figure 10 (b) illustrates 10 CSI-RS configurations that could be used by 4 CSI-RS antenna ports, and Figure 10 (c) illustrates 5 CSI-RS configurations that could be used for CSI-RS transmission by 8 CSI-RS antenna ports.

[242] As described, radio resources (namely, the RE pair) to which the CSI-RS is transmitted are determined according to each CSI-RS configuration.

[243] When 1 or 2 antenna ports are set up in order to transmit the CSI-RS for a given cell, the CSI-RS is transmitted in the radio resource in accordance with CSI-RS configuration among 20 CSI-RS configurations illustrated in Figure 10 (a).

[244] Likewise, if 4 antenna ports are configured in order to transmit the CSI-RS for a given cell, the CSI RS is transmitted from the radio resource in accordance with the CSI-RS configuration among the 10 CSI-RS configurations illustrated in Figure 10 (b). Also, if 8 antenna ports are configured in order to transmit the CSI-RS for a given cell, the CSI-RS is transmitted from the radio resource in accordance with the CSI-RS configuration among the 5 CSI-RS configurations illustrated in Figure 10 (c).

[245] For each pair of the 2 antenna ports (namely, {15, 16}, {17, 18}, {19, 20}, and {21, 22}), the CSI-RS for each antenna port becomes subject to CDM for the same radio resource and then transmitted. In the case of the antenna ports 15 and 16, although the CSI-RS complex symbol for each of antenna port 15 and antenna port 16 is identical, different orthogonal codes (e.g., Walsh code) are multiplied to be mapped on the same radio resource. In the CSI-RS complex symbol for antenna port 15, [1, 1] is multiplied, and for the CSI-RS complex symbol for antenna port 16 [1 -1] is multiplied to be mapped on the same radio resource. This is the same for the antenna ports {17, 18}, {19, 20}, and {21, 22}.

[246] The UE is able to detect the CSI-RS for a given antenna port by multiplying the code that has been multiplied to the transmitted symbol. Namely, in order to detect the CSI-RS for antenna port 15, the multiplied code [1 1] is multiplied, and the multiplied code [1 -1] is multiplied in order to detect the CSI-RS for antenna port 16.

[247] When we refer to Figure 10 (a) to (c), we can see that if the same CSI-RS configuration index applies, the radio resource in accordance with the CSI-RS configuration with more antenna ports includes the radio resource in accordance with the CSI-RS configuration with fewer CSI-RS antenna ports. For example, in the case of the CSI-RS configuration 0, the radio resource for 8 antenna ports includes the radio resources for 4 antenna ports and 1 or 2 antenna ports as well.

[248] Multiple CSI-RS configurations could be used in a single cell. For non-zero power (NZP) CSI-RS, only 0 or 1 CSI-RS configurations are used, and 0 or many CSI-RS configurations could be used for zero power (ZP) CSI-RS.

[249] The UE assumes zero transmission power in the REs corresponding to the 4 CSI-RS columns of Table 3 and Table 4 (except in cases of overlap with REs where NZP CSI-RS is assumed, as configured by the higher level), for each bit set to 1 in the 16-bit bitmap ZP CSI-RS (ZeroPowerCSI-RS) configured by the higher level. The most significant bit (MSB) belongs to the lowest CSI-RS configuration index, and the next bit in the bit map belongs to the next CSI-RS configuration index in accordance with the order.

[250] The CSI-RS is transmitted only in the sub-frame that satisfies the downlink slot and CSI-RS sub-frame configuration that meet the conditions of (n_s mod 2) in Table 3 and Table 4 above.

[251] In the case of the frame structure type 2 (TDD), the CSI-RS is not transmitted in special sub-frames, synchronization signals (SS), sub-frames that do not conflict with the PBCH or SIB 1 (SystemInformation BlockType1) message transmissions or sub-frames configured for paging message transmissions.

[252] Also, the RE to which the CSI-RS for an antenna port belonging to the antenna port set S (S = {15}, S = {15, 16}, S = {19, 20}, or S = {21, 22}) is not used for transmitting the PDSCH or the CSI-RS of another antenna port.

[253] Due to the fact that the time-frequency resources used for transmitting the CSI-RS cannot be used for data transmissions, as the CSI-RS overhead increases the data processing amount (throughput) decreases. In consideration of this, the CSI-RS is not configured to be transmitted for each sub-frame, but is configured to be

transmitted for each transmission period applicable for many sub-frames. In this case, the CSI-RS transmission overhead could decrease substantially compared to the case in which the CSI-RS is transmitted for each sub-frame.

[254] The sub-frame frequency for CSI-RS transmission (hereinafter to be referred to as “CSI transmission frequency”) (T_CSI_RS) and sub-frame offset (△_CSI-RS) are as shown in Table 5 below.

[255] Table 5 illustrates CSI-RS sub-frame configurations.

[256] [Table 5]

CSI-RS-SubframeConfig I_{CSI-RS}	CSI-RS periodicity T_{CSI-RS} (subframes)	CSI-RS subframe offset Δ_{CSI-RS} (subframes)
0 - 4	5	I_{CSI-RS}
5 - 14	10	$I_{CSI-RS}-5$
15 - 34	20	$I_{CSI-RS}-15$
35 - 74	40	$I_{CSI-RS}-35$
75 - 154	80	$I_{CSI-RS}-75$

[257] When we refer to Table 5, we can see that the CSI-RS transmission frequency (T_CSI-RS) and sub-frame offset (△_CSI-RS) are determined depending on the sub-frame configuration (I_CSI-RS).

[258] The CSI-RS sub-frame configuration of Table 5 could be determined by either the “SubframeConfig” field or the “zeroTxPowerSubframeConfig” fields. The CSI-RS sub-frame configuration could be configured separately for the NZP CSI-RS and the ZP CSI-RS.

[259] The sub-frame that includes the CSI-RS satisfies equation 12 below.

[260] [Equation 12]

$$\left(10n_f + \lfloor n_s/2 \rfloor - \Delta_{CSI-RS}\right) \bmod T_{CSI-RS} = 0$$

[261] In equation 12, T_CSI-RS refers to the CSI-RS transmission frequency, △_CSI-RS refers to the sub-frame offset value, n_f refers to the system frame number, and n_s refers to the slot number.

[262] In the case of the UE for which the transmission mode 9 has been configured for the serving cell, the UE could have a CSI-RS configuration set up. In the case of the UE for which transmission mode 10 has been configured, one or more CSI-RS resource configurations could be set up for the UE.

[263] The following parameter to configure each CSI-RS resource is configured for the upper level’s signaling.

[264] - If transmission mode 10 has been set up, the CSI-RS resource configuration identifier

[265] - Number of CSI-RS ports

[266] - CSI-RS configuration (refer to Table 3 and Table 4)

[267] - CSI-RS sub-frame configuration (I_CSI-RS) (refer to Table 5)

[268] - If transmission mode 9 has been set up, transmission power (P_C) for CSI feedback

[269] - If transmission mode 10 has been set up, transmission power (P_C) for CSI feedback regarding each CSI process. If the CSI sub-frame sets C_CSI, 0 and C_CSI, 1 are configured for the CSI process, P_C is set up for each CSI sub-frame of the CSI process.

[270] - Pseudo-random sequence generator parameter (n_ID)

[271] - If transmission mode 10 has been set up, the QCL scrambler identifier (qcl-ScramblingIdentity-r11) for assuming type B UE, and the upper level parameter ('qcl-CRS-Info-r11') including the MBSFN sub-frame configuration list (mbsfn-SubframeConfigList-r11)

[272] If the CSI feedback value calculated by the UE has the dB range of [-8, 15], P_C is assumed at the ratio of PDSCH EPRE for CSI-RS EPRE. Here, the PDSCH EPRE is a symbol with the PDSCH EPRE's ratio of ρ_A for the CRS EPRE.

[273] CSI-RS and PMCH are not configured together within the same sub-frame of the serving cell.

[274] If 4 CRS antenna ports are configured in the frame structure type 2, the UE shall not be configured with CSI-RS configuration indices belonging to the [20-31] set (refer to Table 3) in the case of the normal CP or to the [16-27] set (refer to Table 4) in the case of the extended CP.

[275] Regarding the UE, we can assume that the CSI-RS antenna port of the CSI-RS resource configuration has QCL relationships regarding the delay spread, Doppler spread, Doppler shift, average gain, and average delay.

[276] With the UE for which transmission mode 10 and QCL type B have been configured, we can assume that the antenna port 0-3 belonging to the CSI-RS resource configuration and the antenna port 15-22 belonging to the CSI-RS resource configuration have QCL relationships regarding the Doppler spread and the Doppler shift.

[277] In the case of the UE for which transmission 10 has been configured, one or more CSI-IM (channel-state information-interference measurement) resource configuration could be set up.

[278] The following parameters could be configured for each CSI-IM resource configuration through upper level signaling.

[279] - ZP CSI-RS configuration (refer to Table 3 and Table 4)

[280] - ZP CSI RS sub-frame configuration (I_CSI-RS) (refer to Table 5)

[281] CSI-IM resource configuration is identical to one of the ZP CSI-RS configurations already set up.

[282] The CSI-IM resource and the PMCH are not configured within the same sub-frame of the serving cell.

[283] In the case of the UE for which transmission mode 1-9 has been configured, a single ZP CSI-RS resource configuration could be set up for the UE. In the case of the UE for which transmission mode 10 has been set up, one or more ZP CSI-RS resource configurations could be set up for the UE regarding the serving cell.

[284] The following parameters could be set up for ZP CSI-RS resource configuration through upper level signaling.

[285] - ZP CSI-RS configuration list (refer to Table 3 and Table 4)

[286] - ZP CSI-RS sub-frame configuration (I_CSI-RS) (refer to Table 5)

[287] The ZP CSI-RS and the PMCH are not configured simultaneously with the same sub-frame of the serving cell.

[288]

[289] <u>Cell measurement/measurement report</u>

[290] The UE reports to the base station (or network) cell measurement results for one or more methods to guarantee the UE's mobility (e.g., handover, random access, cell search, etc.).

[291] In the 3GPP LTE/LTE-A system, the cell-specific reference signal (CRS) is transmitted through the 0^{th}, 4^{th}, 7^{th}, and 11^{th} OFDM symbols within each sub-frame on the time axis, and this is used for cell measurement purposes. However, the UE carries out cell measurement using the CRS received from each of the serving cell and neighboring cells.

[292] Cell measurement includes the measurement of RRM (radio resource management) such as the reference signal reception power wherein signal strength of the serving cell and the neighboring cells or the total received power relative to the signal strength, and so on, are measured, received signal strength indicator (RSSI), reference signal received quality (RSRQ), and so on as well as radio link monitoring (RLM) to determine radio link failures by measuring the link quality with the serving cell.

[293] RSRP is the linear average of power distribution of the RE to which the CRS is transmitted within the measurement frequency bandwidth. To determine the RSRP, the CRS (R0) falling under the antenna port "0" category could be used. Also, in order to determine the RSRP, the CRS (R1) falling under the antenna port "1"

category could be additionally used. The UE could determine the number of the Res used within the measurement frequency bandwidth and the measurement period used by the UE to determine the RSRP to the extent that the applicable measurement accuracy requirements are satisfied. Also, power per RE could be determined by the amount of energy received within the remaining parts of the symbol excluding the cyclic prefix (CP) level.

[294] RSSI is derived from the linear average of the total received power sensed from all sources by the applicable UE including the serving cell of the co-channel, non-serving cells, noise from neighboring channels, thermal noise, and so on in the OFDM symbols including the RS falling under the antenna port "0" category within the measurement bandwidth. If specific sub-frames are addressed in order to carry out RSRQ measurement based on the upper level signaling, the RSSI is measured through all OFDM symbols within the addressed sub-frames.

[295] The RSRQ is derived from $N \times RSRP/RSSI$. Here, N refers to the number of RB's of the RSSI measurement bandwidth. Also, in the above equation measurements of the numerator and the denominator could be derived from the same RB set.

[296] The base station is able to deliver configuration information for measurement purposes to the UE through the upper level signaling (e.g., RRC connection reconfiguration message).

[297] RRC connection reconfiguration messages include radio resource configuration dedicated ("radioResourceConfigDedicated") information element (IE) and measurement configuration ("measConfig") IE.

[298] "measConfig" IE specifies measurements to be carried out by the UE, and includes not only the measurement gap's configuration but also configuration information for intra-frequency mobility, inter-frequency mobility, and inter-RAT mobility.

[299] Especially, "measConfig" IE includes "measObjectToRemoveList," which indicates the list of the measurement objects ("measObject") to be removed from measurement as well as "measObjectToAddModList," which indicates a list of objects to be newly added or modified. Also, "measObject" includes "MeasObjectCDMA2000," "MeasObjectEUTRA," "MeasObjectGERAN," and so on depending on the communication technology.

[300] "RadioResourceConfigDedicated" is used in order to set up/modify/release the radio bearer, to modify the MAC's main configuration, to modify the semi-persistent scheduling setup, or to modify the dedicated physical configuration.

[301] "RadioResourceConfigDedicated" IE includes the "measSubframePattern-Serv" field that addresses the time domain measurement resource restriction pattern to measure the serving cell. Also, "measSubframeCellList" to address neighboring cells to be measured by the UE as well as "measSubframePattern-Neigh" that addresses the time domain measurement resource restriction pattern to measure neighboring cells is included.

[302] The time domain measurement resource restriction pattern configured for measurement cells (including the serving cell and neighboring cells) could address at least a single sub-frame per radio frame for carrying out RSRQ measurement. RSRQ measurement is not carried out except at sub-frames addressed by the time domain measurement resource restriction pattern set up by the measurement cell.

[303] As described, the RSRQ must be measured for the UE (e.g., 3GPP Rel-10) only at periods set up by the sub-frame pattern to measure the serving cell ("measSubframePattern-Serv") and by the sub-frame pattern ("measSubframePattern-Neigh") for measuring neighboring cells.

[304] Although with the RSRP measurements within such patterns are not restricted, for accuracy requirements it would be preferable to make measurements within such patterns.

[305]

[306] <u>OCL between antenna ports (quasi co-located)</u>

[307] QC/QCL (quasi co-located or quasi co-location) could be defined as follows.

[308] If we assume that two antenna ports are in the QC/QCL relationship (or become QC/OCL), the UE could assume that the large-scale properties of the signal transmitted through an antenna port could be inferred from the

signal transmitted through another antenna port. Here, the large-scale properties could include at least one of delay spread, Doppler spread, frequency shift, average received power, and received timing.

[309] Also, the following could be defined. If we assume that two antenna ports are in the QC/QCL relationship (or become QC/QCL), the UE could assume that large-scale properties of the channel through which a symbol is transmitted over an antenna port could be inferred from a radio channel through which a symbol is transmitted over another antenna port. Here, the large-scale properties could include at least one of delay spread, Doppler spread, Doppler shift, average gain, and average delay.

[310] Namely, when we say that two antenna ports are in the QC/QCL relationship (or become QC/QCL), it means that the large-scale properties of a radio channel from an antenna port are identical to those of the radio channel from the other antenna port. When we take into consideration multiple antenna ports over which the RS is transmitted, if it is assumed that antenna ports over which two different types of RS are transmitted are in the QCL relationship we will be able to substitute the large-scale properties of the radio channel from one type of antenna port with the large-scale properties of the radio channel from another type of antenna port.

[311] This statement does not distinguish these definitions related to the QC/QCL. Namely, the QC/QCL concept could follow any one of these concepts. Or in another similar format, the QC/QCL concept could be modified to the format in which transmission could take place from the co-location between antenna ports for which the QC/QCL concept holds (e.g., the UE could assume that the antenna ports are transmitted from the identical transmission point), and the concept of the present invention includes such similar modifications. Under the present invention, the definitions relating to the QC/QCL will be used interchangeably for convenience of explanation.

[312] In accordance with the QC/QCL concept, the UE will not be able to assume identical large-scale properties between radio channels from the applicable antenna ports regarding non-QC/QCL antenna ports. Namely, in this case the terminal must carry out independent processing for each non-QC/QCL antenna port configured for each of timing acquisition and tracking, frequency offset estimation and compensation, delay estimation and Doppler estimation, and so on.

[313] Regarding antenna ports for which the QC/QCL assumption could be made, the UE has the advantage that it will be able to perform the following operations:

[314] - Regarding delay spread and Doppler spread, the UE may apply the power-delay profile, delay spread and Doppler spectrum, and Doppler spread estimation results regarding a radio channel from an antenna port to the Wiener filter, and so on that are used for channel estimation regarding the radio channel from another antenna port identically.

[315] - Regarding frequency shift and received timing, the UE may apply the same synchronization to the demodulation of another antenna port after performing time and frequency synchronization for an antenna port.

[316] - Regarding average received power, the UE may average reference signal received power (RSRP) for two or more antenna ports.

[317] For example, if the DMRS antenna port for downlink data channel demodulation becomes QC/QCL with the serving cell's CRS antenna port, the UE could apply the large-scale properties of the radio channel inferred from the CRS antenna port when estimating the channel through the applicable DMRS antenna port in order to improve the performance of the downlink data channel reception based on the DMRS in the same way.

[318] That is because the CRS is a reference signal that is broadcast in each sub-frame and over the entire bandwidth at relatively high density level, so that the estimates of the large-scale properties can be acquired more stably from the CRS. On the other hand, the DMRS's transmission regarding specifically scheduled RB is UE-specific, and also since the precoding matrix of the precoding resource block group (PRG) unit used by the base station for transmission purposes could change, the effective channels received by the UE could vary by PRG unit, and

performance deterioration could occur in the event that the DMRS is used for estimating the large-scale properties of a radio channel over a wide bandwidth even if multiple PRGs have been scheduled. Also, the CSI-RS's transmission frequency could be several to tens of ms, and since the resource element's density per resource block's antenna port is low on average, performance deterioration could occur with the CSI-RS if it is used for estimating the large-scale properties of the radio channel.

[319] Namely, by assuming QC/QCL between antenna ports, the UE could be utilized for detecting/receiving, channel estimating, and channel state reporting of the downlink reference signal.

[320]

[321] Measuring restricted RLM and RRM/CSI

[322] One method of interference coordination is time domain inter-cell interference coordination (scheduled time domain inter-cell interference coordination) whereby the aggressor cell uses the silent sub-frame (or, could be referred to as almost blank sub-frame (ABS)) that reduces some physical channels' transmission power/activities (here, reducing the transmission power/activities could include the operation to set to zero power), and the UE is scheduled by the victim cell by taking this into consideration.

[323] In this case, from the perspective of the victim cell's UE the interference level could change substantially according to the sub-frame.

[324] Under such a situation, to measure channel state information (CSI) in order to carry out radio resource management (RRM) wherein more accurate radio link monitoring (RLM) or RSRP/RSRQ measurements are performed at each sub-frame or to perform link adaptation, such monitoring/measurement must be restricted to sub-frame sets that have consistent interference characteristics. In the 3GPP LTE system, restricted RLM and RRM/CSI measurements are defined as follows.

[325] The UE monitors the downlink quality based on the cell-specific reference signal (CRS) in order to monitor downlink radio quality of the Pcell. The UE estimates the quality of the radio downlink, and compares the thresholds Q_out and Q_in with the estimates in order to monitor the downlink radio quality of the Pcell.

[326] The threshold Q_out is defined as the level at which the radio downlink cannot be reliably received, and 10% block error rate (BER) of hypothetical PDCCH transmission considering the PCFICH error based on the transmission parameter indicated in Table 6 below applies.

[327] Threshold Q_in is defined as the level at which the radio downlink quality is substantially reliable compared to the radio downlink at Q_out, and 2% BER of the hypothetical PDCCH that considers the PCFICH error based on the transmission parameter indicated in Table 7 below applies.

[328] When the upper level signaling addresses a specific sub-frame for restricted RLM, radio link quality is monitored.

[329] When the time domain measurement resource restriction pattern to measure the RLM is set up by the higher level, if the time domain measurement resource restriction pattern set up for measured cells addresses at least one sub-frame for each radio frame to carry out RLM measurement, certain requirements are applied.

[330] If CRS assistance information is provided, the above requirements could be satisfied in the event that the number of transmission antenna ports of one or more cells to which CRS support information has been provided is different from the number of the transmission antenna ports at which the RLM is carried out.

[331] If the UE is not provided with CRS assistance information or if the CRS assistance data is not valid over the entire evaluation period, time domain measurement restriction could apply under the situation in which the ABS set up within in the CRS and the non-multicast broadcast single frequency network (non-MBSFN) conflicts.

[332] Table 6 illustrates the PDCCH/PCFICH transmission parameters for out-of-sync states.

[333] [Table 6]

Attributes	Values
DCI format	1A
Number of control OFDM symbols	2: Bandwidth ≥ 10 MHz

	3: 3 MHz ≤ Bandwidth ≤ 10 MHz 4: Bandwidth = 1.4 MHz
Aggregation level (CCE)	4: Bandwidth = 1.4 MHz 8; Bandwidth ≥ 3 MHz
(Ratio of PDCCH RE energy to average RS RE energy)	4 dB: the situation in which a single antenna port is used for CRS transmission by the Pcell 1 dB: the situation in which 2 or 4 antenna ports are used for CRS transmission by Pcell
(Ratio of PCFICH RE energy to average RS RE energy)	4 dB; the situation in which a single antenna port is being used for CRS transmission by the Pcell 1 dB: the situation in which 2 or 4 antenna ports are used for CRS transmission by the Pcell

[334] Table 7 illustrates the PDCCH/PCFICH transmission parameters for the in-sync state.

[335] [Table 7]

Attributes	Values
DCI format	1A
Number of control OFDM symbols	2: Bandwidth ≥ 10 MHz 3: 3 MHz ≤ Bandwidth ≤ 10 MHz 4: Bandwidth = 1.4 MHz
Aggregation level (CCE)	4
(Ratio of PDCCH RE energy to average RS RE energy)	0 dB: the situation in which a single antenna port is being used for CRS transmission - 3 dB: the situation in which 2 or 4 antenna ports are being used for CRS transmission by the Pcell
(Ratio of PCFICH RE energy to average RS RE energy)	4 dB; the situation in which a single antenna port is being used for CRS transmission by the Pcell 1 dB: the situation in which 2 or 4 antenna ports are used for CRS transmission by the Pcell

[336] The downlink radio link quality regarding the Pcell is monitored in order to address the out-of-sync status/in-sync status.

[337] In the non-DRX mode operation, the UE's physical layer assesses the radio link quality evaluated in the prior time periods by taking into consideration the thresholds (Q_out and Q_in) at each radio frame.

[338] When the higher level signaling addresses a specific sub-frame for restricted RLM, the radio link quality assessment is not performed at sub-frames other than at the addressed sub-frame.

[339] If the radio link quality is lower in quality than the threshold Q_out, the UE's physical layer directs out-of-sync to the higher level within the radio frame where the radio link quality was measured. If the radio link quality is higher than the threshold Q_in, the UE's physical layer directs in-sync to the higher level within the radio frame where radio link quality was measured.

[340]

[341] Massive MIMO

[342] For radio communication systems after the LTE Release (Rel)-12, introduction of the active antenna system (AAS) is being considered.

[343] Unlike the conventional passive antenna system in which the amplifier and the antenna, which adjust the status and size of signals, are separate, the AAS is a system where each antenna includes an active element such as an amplifier.

[344] The AAS does not need a cable, a connector, or other hardware to connect an amplifier to an antenna due to the use of an active antenna, and therefore the AAS is highly efficient in terms of energy and operation costs. Especially, due to the fact that the AAS supports the electronic beam control method for each antenna, advanced MIMO technology involving accurate beam pattern formation or 3-dimensional beam pattern formation that takes into consideration the beam direction and beam width is made possible due to the fact that the electronic beam control method is supported for each antenna.

[345] Due to the introduction of advanced antenna systems such as the AAS, large-scale MIMO structures involving multiple input multiple output antennas and multi-dimensional antenna structures are also being considered. For example, if a 2-dimensional antenna array is being formed unlike the existing 1-dimensional antenna array, it would be possible to form 3-dimensional beam patterns using active antennas of the AAS. If a 3-dimensional beam pattern is utilized from the transmission antenna's perspective, not only would it be possible to form the beam in the horizontal direction but also it would be possible to form semi-stationary or dynamic beams in the vertical direction. For example, applications such as sector formation in the vertical direction could be considered.

[346] Also, from the reception antenna perspective, when forming reception beams by utilizing a large-scale reception antenna, signal power increase due to antenna array gains could be expected. Therefore, in the case of an uplink, it would be possible for the base station to receive signals transmitted from the UE through multiple antennas, and it would be possible to set the transmission power very low by considering the large-scale reception antenna's gain in order to reduce the impact of the UE's interference.

[347] Figure 11 illustrates a radio communication system in which the base station or UE has multiple transmission/reception antennas to be able to form 3D (3-dimensional) beams based on the AAS.

[348] Figure 11 illustrates the example described previously, namely a 3D MIMO system using a 2-dimensional antenna array (namely 2D-AAS).

[349]

[350] Cell coverage of massive MIMO

[351] If it is assumed that a multiple-antenna system, for example a system with N transmission antennas, is able to transmit the entire transmission power identically when compared to single-antenna systems, beam-forming could be carried out to set the reception power at up to N times higher at a certain point.

[352] Even at a base station equipped with multiple antennas, the channel that transmits the CRS, PSS/SSS, PBCH, and broadcast information does not carry out beam forming in a certain direction to allow all UE's within the base station's coverage domain to receive signals.

[353] On the contrary, the PDSCH, which transmits unicast information to specific UEs, carries out beam forming in accordance with the applicable UE's location and link situation in order to improve transmission efficiency. Namely, the PDSCH's data transmission stream is pre-coded in order to form beams in a certain direction to be transmitted through multiple antenna ports. Therefore, if the transmission power of the CRS and the transmission power of the PDSCH are identical, it would be possible to increase up to N times the reception power of pre-coded PDSCH that has been beam-formed toward the applicable UE.

[354] Currently, base stations with up to 8 transmission antennas are considered in the LTE Rel-11 system, and this means that the pre-coded PDSCH reception power could be 8 times greater than the average CRS reception power. However, with the introduction of the massive MIMO system in the future, it would be possible for the reception power of the CRS and pre-coded PDSCH to be 100 times the present level if the base station's transmission antenna is 100 or more. In conclusion, due to the introduction of the massive MIMO system, the

CRS coverage domain to which transmissions are made by a specific base station and the coverage domain based on the DM-RS do not match.

[355] Especially, such a phenomenon could occur if the difference between two neighboring stations is substantial in terms of the number of transmission antennas. A good example could be the case in which a macro cell with 64 transmission antennas and a micro cell equipped with a single transmission antenna (e.g., pico cell) are located close to each other. Due to the fact that it is expected that the number of antennas will be increased first for the macro cell with many served UEs in the initial massive MIMO deployment process, in the case of a heterogeneous network where macro cells, micro cells, and pico cells are present, the neighboring base stations have substantially different number of antennas.

[356] For example, in the case of a pico cell equipped with a single transmission antenna, the coverage domains of the CRS and PDSCH match. However, in the case of the macro cell equipped with 64 transmission antennas, the coverage domain of the PDSCH becomes larger than the coverage domain of the CRS. Therefore, at the borderline of the macro cell and the pico cell, it would not be possible to select the base station that could provide the highest PDSCH quality as the serving cell if the initial connection and handover are determined solely based on the RSRP or RSRQ, which is the reception quality of the CRS. As a simple solution to this problem, we could assume that the PDSCH reception power of the base station equipped with N transmission antennas could be N times greater, but this is not the optimal solution when taking into consideration that it would not be possible for the base station to carry out beam-forming in all possible directions.

[357]

[358] RRM-RS

[359] Under the present patent, we propose a method to transmit pre-coded RS and to carry out RRM measurement for this. Hereinafter, we will refer to the pre-coded RS with such a purpose as “RRM-RS.” The RRM_RS is composed of multiple antenna ports, and it would be possible for the UE to measure the RSRP for each transmission beam by setting the beam-forming differently for each antenna port. For example, if it is possible for the base station to carry out beam-forming in M directions, the RRM-RS configured with the M-port is set up.

[360]

[361] Frequency and multiplexing of the RRM-RS

[362] The M-port RRM-RS could become subject to CDM or classified into FDM/TDM for transmission in the same sub-frame. Namely, the transmission signal for each antenna port of the M-port RRM-RS could be transmitted using a different transmission RE in the same sub-frame, or if transmission is carried out using the same RE orthogonal scrambling codes must be used between antenna ports in order to ensure that mutual interferences will not occur.

[363] Unlike this method, it would be possible to set the number of RRM-RS antenna ports to enable simultaneous transmission from a single sub-frame to K and transmit to (M/K) sub-frames.

[364] In this case, the RRM-RS configuration parameter includes M, which is number of entire antenna ports, and K, which is the number of antenna ports to which transmission is carried out from a single sub-frame. The RRM-RS transmission frequency P and the offset O are included as the configuration parameters of the RRM-RS. Here, the RRM-RS transmission frequency is defined as the sub-frame interval over which the RRM-RS is transmitted. For example, in the case of P=10, O=5, M=64, and K=32, the RRM-RS is transmitted to the sub-frames with the sub-frame indexes (SFI) of 5, 15, 25, and 35, the RRM-RS with the antenna ports of 0 to 31 is transmitted from the sub-frame of SFI=5, the RRM-RS of antenna ports 32 to 63 are transmitted in the sub-frame with SFI=15, and the RRM-RS is again transmitted with the antenna ports of 0 to 31 in the sub-frame of SFI=25.

[365] Contrary to this, the RRM-RS transmission frequency is defined as the interval of the sub-frames to which the antenna port’s RS is transmitted, and transmission is made by using the method in which consecutive (M/K) sub-frames are divided rather than by using the method in which the RRM-RS’s antenna ports are divided in (M/K)

sub-frames. For example, in the case of P=20, O=5, M=64, and K=32, the RRM-RS is transmitted to sub-frames with the SFI of 5, 6, 25, 26, 45, 46, and so on, the RRM-RS is transmitted to antenna port 0 to antenna port 31 in the sub-frame of SFI=5, the RRM-RS is transmitted to antenna port 32 from the sub-frame of SFI=6, and the RRM-RS is again transmitted from the antenna port 0 to antenna port 31 in the sub-frame of SFI=25.

[366]

[367] RSRP measurement and reporting

[368] The RSRP of the RRM-RS measures and reports each antenna port. The UE could be set up with multiple RRM-RS configurations.

[369] If each cell receives one RRM-RS, the UE could be assigned with the configuration of RRM-RS configurations transmitted to the serving cell and the neighboring cells. It would be possible for a single cell to be transmitted with multiple RRM-RS configurations. The UE provides information regarding the RSRP measurement results such as the specific RRM-RS and the specific antenna port.

[370] In order to calculate the RSRP of the RRM-RS, the average of the reception signal level of each antenna port is calculated, and the time window over which the average is calculated could be determined by the base station, or the RSRP could be obtained by averaging the reception signal level of each antenna port of the RRM-RS during a predetermined time interval (e.g., 200ms). Or it would be possible to obtain the RSRP that should be reported by filtering the average reception power obtained from each time window.

[371] The UE assigned with multiple RRM-RS configurations measures the RSRP of each antenna port in each RRM-RS. If R RRM-RS has been received and if the number of antenna ports of the rth RRM-RS is M_r, the RSRP of the mth antenna port of the RRM-RS is defined as RSRP (r, m). The UE arrays the RSRP (r, m) and selects and reports the RSRP of L antennas that were strongly received.

[372] By modifying the above method slightly, the UE arrays the RSRP (r, m), the antenna port that is most strongly received is selected, reporting is limited to the RSRP of the selected antenna ports, namely the RSRP of the ports that fall within a certain range compared to the max (RSRP (r, m)). Namely, the RSRPs of the maximum L antenna ports wherein the RSRP difference is higher than the threshold in terms of the RSRP ratio or dB scale are reported as follows.

[373] [Equation 13]

$$\mathrm{RSRP}\ (r, m) - \max\ (\mathrm{RSRP}\ (r, m)) > \mathrm{Threshold}$$

[374] In another example, the UE could be assigned with a reference antenna port. It would be preferable to be assigned with an antenna port of the RRM-RS that is transmitted by a serving cell that is similar to the pre-coded CSI_RS configured to the applicable UE in terms of the beam direction. The UE reports if the RSRPs of other antenna ports are within a certain range compared to the RSRP of the reference antenna port in the event that the UE is assigned as the reference antenna the m_0^{th} antenna port of the r_0^{th} RRM-RS. Namely, reporting is made in the event that the difference in the RSRP exceeds a certain threshold in terms of the RSRP ratio or dB scale.

[375] [Equation 14]

$$\mathrm{RSRP}\ (r, m) - \mathrm{RSRP}\ (r\_0, m\_0) > \mathrm{Threshold}$$

[376] Figure 12 illustrates the RSRP for each antenna port of the RRM-RS in accordance with an embodiment of the present invention.

[377] Figure 12 illustrates an embodiment of the RSRP for each antenna port of the RRM-RS composed of 32 antenna ports.

[378] If RSRPs of antenna ports with the RSRP of within 5dB compared to the antenna port with the maximum RSRP are set up to report the RSRP, since antenna port 13 has the maximum RSRP of 40dB as shown in Figure 12, those antenna ports with the RSRP exceeding 35dB must be reported. Namely, the RSRPs of the antenna ports 24, 25, and 26 including antenna port 13 are reported to the base station.

[379]

[380] Antenna port grouping

[381] Due to the fact that it is possible to configure beam forming for each antenna port, in this case the antenna port and the beam have a one to one relationship.

[382] Therefore, it would be possible to map the antenna port index (i) with the beam index (i) one to one. In the event that the beams are indexed so that the (i)th beam and the (i+1)th beam are located next to each other, the RSRPs of the antenna ports that are located next to each other show similar properties as illustrated by Figure 12. Such similarity is exhibited by the (i)th beam and the (i+c)th beam, but as the value of c increases similarity decreases. Whether high level of similarity will be exhibited by several consecutive neighboring beams is determined by the beam interval, beam width, and the extent of scattering of multi-paths.

[383] The base station receiving reports with the RSRP measurement results based on the RRM-RS finds the rough location of the applicable UE and then notifies the UE of the pre-coded CSI-RS configuration transmitted to the applicable location in order for the UE to measure the CSI-RS to provide feedback of the CSI (RI, PMI, CQI, etc.) for PDSCH scheduling purposes. Also, the base station receiving reports with the RSRP measurement results based on the RRM-RS transmitted by multiple cells determines to which cell the applicable UE is to be handed over and to which UE the pre-coded CSI-RS is to be configured from the target cell based on the RSRP measurement results. Namely, the RSRP measurement result based on the RRM-RS provides important information to the base station that is necessary to determine which pre-coded CSI-RS is to be set up for the applicable UE in the future.

[384] If 4-port CSI-RS configuration is provided in order to make it possible to transmit 4 data streams to the UE or to achieve the best beam switching rapidly in line with fading changes based on the RSRP measurement results shown in the previous Figure 12, it is expected that it would be optimal to generate 4-port CSI-RS that is identical to the beam direction of the RRM-RS ports 13, 24, 25, and 26 with the highest RSRP levels. However, the overhead is too great for the CSI-RS to optimally generate and transmit for each UE. Therefore, the best way to reduce the CSI-RS transmission overhead is for the UEs in the same environment to share the CSI-RS. In order to achieve such a goal, pre-coding of the CSI-RS antenna ports within a CSI-RS configuration must ensure that the properties of the beams transmitted to the nearby direction will be exhibited. If 4-port CSI-RS1 with the same beam direction as RRM-RS ports 12, 13, 14, and 15 and 4-port CSI-RS2 with the same beam direction as RRM-RS ports 24, 25, 26, and 27 are configured in advance by considering other served UEs, it must be possible to determine which CSI-RS would be better to set up for the applicable UE based on the RSRP report of the RRM-RS.

[385] In another embodiment of the present invention, the RSRP is measured and reported for antenna port groups. According to the proposed method, antenna ports are grouped, and then the average of the RSRP values of the antenna ports belonging to the group is calculated in order to obtain the RSRP of the applicable antenna port group. The group is predetermined, or the base station could determine the group and then notify. Also, the UE could determine the grouping method and report the method.

[386] As illustrated in Figure 12 previously, in the case of the RRM-RS composed of 32 ports, it would be possible to group 4 ports. It would be possible to separate each group to from 8 (=32/4) groups. In this case, the (i)th port group is composed of RRM-RS ports (4i), (4i+1), (4i+2), and (4i+3). The RSRP of the (i)th port group is defined as the average RSRP of the antenna ports (4i), (4i+1), (4i+2), and (4i+3).

[387] In another embodiment, grouping could be carried out by allowing overlapping between groups. If the RRM-RS composed of 32-ports is grouped with 4 ports, there will be 15 groups. In this case, the (i)th port group is composed of the RRM-RS ports (2i), (2i+1), (2i+2), and (2i+3). To generalize the proposed method, if grouping is carried out by A ports and the port interval between neighboring group is set as B, the (i)th port group is composed of RRM-RS port (B*i), (B*i+1), … (B*i+A-1). Configuration of parameter A and parameter B is

determined by the based station for the UE, or the UE could select and report by taking into consideration the channel environment and the UE's capability.

[388] As a modification of the proposed method, the UE could take into consideration the capability to be obtained from the applicable antenna port group rather than from the RSRP as the method to select the antenna port group to report. In this case, the capability is calculated by taking into consideration multi-layer data transmission from multiple antennas within the antenna port group.

[389]

[390] Antenna port grouping level

[391] With the proposed method, multiple groupings with different sizes could be used. In other words, the A1 port grouping method and the A2 port grouping method could be used simultaneously. Below, the method of grouping by A_i port will be referred to as grouping level i.

[392] Figure 13 illustrates an RRM-RS antenna port grouping level in accordance with an embodiment of the present invention.

[393] Figure 13 illustrates an example of grouping the 16-port RRM-RS by applying a grouping level of 4 stages. In the example, grouping level 1 is grouped by each port. Also, grouping levels 2, 3, and 4 carry out grouping by 2 ports, 4 ports, and 8 ports, respectively. The example illustrates a case in which antenna port groups at the same level are configured disjointedly.

[394] In such a multiple grouping method, the UE reports the RSRP for each grouping level. Namely, the antenna group with the higher RSRP is selected for each grouping level and reported. Or it would be possible to report the best group and group level by comparing the RSRPs of antenna groups with different levels. In order to compare the RSRPs of antenna groups with different level 1, each level's group RSRP is corrected by a certain offset level. If the number of RRM-RS configurations assigned is R, and if the (r)th RRM-RS's (1)th grouping level's (g)th antenna port group's RSRP is defined as GRSRP (r, l, g), the assigned offset (r, l) is corrected for the (l)th grouping level of the (r)th RRM-RS from the base station as follows in order to calculate Adj_GRSRP (r, l, g) for comparison purposes.

[395] [Equation 15]

Adj_GRSRP (r, l, g) = GRSRP (r, l, g) + offset (r, l)

[396] Additionally, in order to reduce frequent changes to the best L groups reported in the method whereby the best L port group's RSRP is reported for each grouping level or for the entire grouping, the hysteresis parameter HY could be added for correcting the RSRP.

[397] [Equation 16]

Adj_GRSRP (r, l, g) = GRSRP (r, l, g) + offset (r, l) + Hy

[398] Here, whether to add or subtract Hy is determined depending on whether the applicable port group is included in the best L GRSRP. If the applicable port group is included in the best L GRSRP in the previous report, Hy is added in order to provide higher Adj_RSRP to reduce instances in which the port group with the best L Adj_GRSRP doesn't change frequently.

[399] A proposed method could be the method wherein the UE is assigned the reference antenna port group. It would be preferable for the base station to assign as reference antenna port group the RRM-RS antenna port group to which the serving cell transmits in the same beam direction as the pre-coded CSI-RS configured for the applicable UE. The UE could be assigned with a reference antenna port group for each grouping level. Or a single antenna port group could be assigned at the entire grouping level. If the UE is assigned as the reference antenna port group, the m_0^{th} antenna port group of the l_0^{th} grouping level of the r_0^{th} RRM-RS, reporting is to be made if the Adj_GRSRP of another antenna port group exceeds the threshold compared to the Adj_GRSRP of the reference antenna port group. Namely, reporting is to be made if the RSRP difference exceeds the threshold in terms of the Adj_GRSRP ratio or dB scale expression.

[400] [Equation 17]

Adj_GRSRP (r, l, g) – Adj_GRSRP (r_0, 1_0, m_0) > Threshold

[401] Also, by modifying the proposed method, selection and reporting is to be made by comparing the RSRP result based on the RRM-RS to the RSRP based on the CSI-RS by specifying through the CSI-RS currently set up.

[402]

[403] <u>3 dimensional (3D) RRM-RS</u>

[404] The method proposed previously under the present invention could be applied by modifying even if the beam's direction is expanded from the 2-dimensional space to the 3-dimensional space. The beam's direction in the 3-dimensional space is adjusted by the vertical angle and the horizontal angle. Therefore, it would be efficient to index beams with two indexes, namely the horizontal index and the vertical index in order to determine whether there are neighboring beams. In order to set up a one to one relationship between the beam index and the RRM-RS port index in accordance with the properties of the present invention, it would be preferable for the RRM-RS port to be indexed as horizontal index and vertical index.

[405] In the case of the 3D MIMO system with M_v beams in the vertical direction and M_h beams in the horizontal direction, (M_vxM_h) beams in total are possible. Under the present invention, (M_vxM_h)-port RRM-RS is set up and the horizontal index j_h (j_h=0, …, M_h-1) and the vertical index j_v (j_v=0, …, M_v-1) are assigned to each antenna port. By considering resource mapping of (M_v×M_h)-port RRM-RS, each antenna port is assigned with the 1-dimensional index I (i=0, …, M_v×M_h-1) and the 2-dimensional indexes j_h and j_v, and the relationship is (i) = f (j_h, j_v).

[406] Figure 14 is a drawing that illustrates the antenna port and the antenna port group of the RRM-RS arrayed with 2-dimensional index in accordance with an embodiment of the present invention.

[407] When we refer to Figure 14, we can see that each antenna port is indexed as (j_h, j_v). If we group A_h×A_v ports by applying the method proposed by the present invention, and then set the port interval between neighboring groups as B_h and B_v, the (i_h, i_v)th port group is composed of RRM-RS port (B_h×i_h+j_h, B_v×i_v+j_v), (j_h=0, …, A_h-1), and (j_v=0, …, A_v-1). Parameter A_h, A_v and B_h, B_v configuration could be determined by the base station for the UE, or the UE could select and report by considering the channel environment and the UE's capability.

[408]

[409] <u>Difference between the RRM-RS and the CSI-RS</u>

[410] In the conventional LTE/LTE-A system, the CSI-RS is transmitted for CSI reporting. The UE reports the RI, PMI, CQI, and so on as CSI. On the contrary, the RRM-RS proposed under the present invention is used in order to measure the RSRP for each antenna port. It would be preferable to use resources that the conventional CSI-RS can set up rather than newly defining the RRM-RS transmission resources. The reason is that this way legacy UEs do not decrease transmission efficiency. If the RRM-RS is transmitted to new resources legacy UEs do not recognize this, and as a result transmission efficiency decreases at the sub-frames to which the RRM-RS is transmitted or scheduling cannot be carried out. Therefore, the method whereby the RRM-RS is transmitted by the conventional CSI-RS using resources that can be set up could provide information to the legacy UE that data mapping is not provided for the applicable resources by carrying out CSI-RS configuration for the applicable resources.

[411] In order to provide CSI report to the UE, data mapping doesn't take place in multiple configured CSI-RSs. Namely, the PDSCH is mapped except for the REs where the CSI-RS is mapped. Under the proposed method of the present invention, the RRM-RS is mapped with the PDSCH except for the REs for which the RRM-RS is mapped as in the case of the CSI-RS. However, the PDSCH could be mapped regardless of the RRM-RS in a

modified method. In this case the UE must be able to receive both the RRM-RS and the PDSCH simultaneously from the same RE. Or the applicable resources could be set up with the ZP-CSI-RS to prevent the PDSCH from being mapped in order to guarantee safe reception of the RRM-RS by the base station.

[412]

[413] QCL setup of the RRM-RS

[414] If each cell transmits the RRM-RS, the UE will be able to be assigned with the configuration of the RRM-RSs that the serving cell and the neighboring cells transmit. Through this, the UE measures the gain from beam forming of the serving cell and the gain from the beam forming of the neighboring cells and reports this information to the network to enable the network to use the information as the basis for determining the handover. Due to the fact that the RRM-RS's transmission density is set very low, it could be insufficient for signal tracking purposes. Therefore, tracking results are utilized in order to track the CRS, which is reliable due to high density, and to detect the RRM-RS. Namely, due to the oscillator deviation that produces carrier wave frequency of the serving cell and the neighboring cells, the results tracked by the CRS of the serving cell for the RRM-RS transmitted from the neighboring cells would be insufficient. Therefore, the CRS (other specific RS such as CSI-RS) that is QCL (quasi co-located) to be used for detecting the RRM-RS must be notified for each RRM-RS. The UE uses the large-scale properties of the channels estimated from the CRS (or another RS such as CSI-RS) that went through QCL for detecting the RRM-RS. Here, the large-scale properties of a channel could include at least one of delay spread, Doppler spread, Doppler shift, average gain, and average delay.

[415]

[416] Expansion to the RSRO

[417] The methods proposed under the present invention could be applied for measuring the RSRQ for each antenna port of the RRM-RS. The RSRQ is defined as the ratio of the RSRP and the RSSI. Therefore, RSSI measurement is added. The RSSI measurement resources could be set up identically for all RRM-RSs with the same carrier wave frequency, namely those that have been set up at the same component carrier. In this case, comparison of ports of the RRM-RSs within the same component carrier could be carried out using the RSRP or RSRQ. However, comparison of ports of the RRM-RSs within different kinds of component carriers could differ depending on whether the RSRP or RSRQ is used. Therefore, the base station must determine whether the RSRP or RSRQ should be used when providing RRM reports based on the RRM-RS to the UE.

[418] Contrary to this, it would be possible to assign an RSSI measurement resource for each RRM-RS. In this case, comparison of ports of the RRM-RSs could differ even within the same component carrier. Therefore, the base station must determine whether the RSRP or RSRQ should be used when providing RRM reports based on the RRM-RS to the UE.

[419]

[420] Relationship between the RRM-RS RSRP and the CRS RSRP

[421] The purpose of the RSRP under the RRM-RS under the present invention is to reflect the beam forming gain of the base station equipped with multiple antennas on serving cell selection. Even if it is determined that beam forming of a specific neighboring cell is the best based on the RSRP of the RRM-RS, if the channels broadcast from the applicable cell, namely if the channel that carries out demodulation based on the CRS is not received stably, it would not be possible to hand over the UE to the applicable neighboring cell.

Therefore, it would be necessary for the UE to report regarding whether the RRM-RM and the CRS transmitted from a given base station have good quality and to decide handovers and beam selection based on this information. For this purpose, the UE must report the RSRP of the jth antenna port of the ith RRM-RS set up at the same time reporting the RSRP of the CRS connected to the ith RRM-RS. Here, the CRS connected to the RRM-RS could be the CRS subject to QCL with the RRM-RS.

[422]

[423] Below, we will examine the CSI measurement and reporting operation method of the UE to reduce latency under the present invention.

[424] The method proposed under the present invention could be applied to not only systems including the 3D-MIMO, massive MIMO< and so on but also environments involving amorphous cells.

[425] First, let's briefly review the 3D-MIMO system.

[426] The 3D-MIMO system is one of the methods that are optimal for single-cell 2D-AAS (adaptive antenna system) base stations illustrated in Figure 11 based on the LTE standard (Rel-12), and the following operations could be considered.

[427] As illustrated in Figure 11, in an example in which the CSI-RS ports are configured from the antenna array of 8-by-8 (8X8), a pre-coded CSI-RS port to which the "UE-dedicated beam coefficients" are applied optimized for specific target UE could be configured for 8 antennas horizontally, so that 8-port (vertically pre-coded) CSI-RS in total horizontally is set up/transmitted.

[428] Through this, the UE could perform CSI feedback for the conventional 8-port system.

[429] Eventually, the base station transmits to the UE (pre-coded) CSI-RS 8 ports to which vertical direction beam gain has already been applied optimized for each UE (or specific UE group).

[430] Therefore, due to the fact that the UE measures the CSI-RS that passed through a radio channel, the UE will be able to benefit from the effect of the vertical beam gain of the radio channel through the CSI measurement and reporting operation for the vertically pre-coded CSI-RS even if the same feedback method is performed for the conventional horizontal code book.

[431] Here, the methods to determine the vertical beam optimized for each UE include (1) the method whereby the RRM report results are based on the (vertically pre-coded) small-cell discovery RS (DRS), (2) the method whereby the UE's sounding RS (SRS) is received in the optimal reception beam direction of the base station, and the direction of the applicable beam received is modified to the beam direction that is optimal for the DL based on the channel reciprocity, and so on.

[432] If the base station determines that the UE-dedicated best V-beam direction has changed due to the UE's mobility, the base station has to reconfigure the RRC setups related to the CSI-RS and the related CSI process, and so on.

[433] However, if the RRC reconfiguration process must be carried out, the RRC level's latency (e.g., tens to hundreds of ms) inevitably occurs.

[434] Namely, at the network level, the target V-beam direction is divided into 4 parts in advance, and then pre-coded separate 8-port CSI-RS in each V direction is transmitted from the applicable separate transmission resource location.

[435] Also, due to the fact that it would be necessary for each UE to perform CSI measurement and reporting for a specific CSI-RS configuration out of 8-port CSI-RSs, when the target V-direction changes it would be necessary to carry out the RRC reconfiguration procedure with the network with the CSI-RS setup that will be changed.

[436]

[437] Therefore, we will examine in detail methods of CSI measurement reporting to eliminate or substantially reduce latency of the RRC level that are proposed in this statement.

[438] Namely, the method proposed under the statement is the method whereby a single CSI process and a single uplink feedback resource are allocated to the UE, with information on which CSI-RS index (and/or CSI-IM index) will be measured is addressed to the MAC level (or PHY level) rather than to the RRC level.

[439] For providing MAC level instruction, the MAC CE could be used, and for providing PHY level instruction the DCI could be used.

[440] Namely, under the method proposed in this statement, the base station (or network) sets up the CSI-RS configurations regarding multiple candidate CSI-RSs to the UE using the RRC signaling, and the "activation" order

is explicitly or implicitly notified to the UE regarding at least one CSI-RS that carries out CSI-RS measurement and reporting among multiple candidate CSI-RSs.

[441] For example, if CSI-RS 1 has been activated, in the event that whether to move from CSI-RS 1 to CSI-RS 2 is being considered the base station could order pre-activation first in order to allow the UE to track CSI-RS 2 before actually ordering the re-activation order to move to CSI-RS.

[442] Here, the tracking for the CSI-RS could mean the operation to set the time and/or frequency synchronization for the CSI-RS in order for the UE to measure the CSI-RS.

[443] Namely, it would be possible to let the pre-activated CSI-RS x (within specific timer period) become actually activated or not activated.

[444] Here, the UE could provide feedback to the base station with complete CSI reporting after specific y ms after receiving an activation message that orders activation of the CSI-RS x from the base station.

[445] Here, providing feedback with complete CSI reporting could be interpreted to mean that the terminal provides meaningful CSI feedback to the base station.

[446] The CSI feedback could be determined to be meaningful or not meaningful depending on the number of samples measured.

[447]

[448] Capability information transmission

[449] More specifically, under the present invention the UE transmits to the base station specific capability signaling to provide capability information related to its CSI operation to the base station in advance (e.g., at initial connection).

[450] The UE capability information related to the CSI operation could include at least one of the following information items.

[451] Here, the CSI related operations could refer to the operations related to the CSI-RS, CSI-IM, and/or CSI process.

[452] Indication of “A and/or B” could be interpreted to mean “at least one of A and B.”

[453] 1. Capability information regarding up to how many CSI-RSs (number of Ncs), CSI-IM (interference measurement) (number of Nis) and/or CSI processes (number of Nps) could be “fully activated”

[454] Here, the reason that the term “full activation (configuration)” was used is that it would be possible for the base station to simultaneously configure total Nc=3 CSI-RSs, Ni=3 CSI-IMs, and Np=4 CSI processes in the case of the UE with Nc=3, Ni=3, and Np=4, and in this case the CoMP operations of the conventional Rel-11 standard could be supported.

[455] Namely, the UE must carry out channel measurement of Nc=3 CSI=RSs, must carry out interference measurement (IM) of Ni=3 CSI-IMs, and must carry out CSI feedback for the Np=4 CSI processes.

[456] 2. Capability information regarding up to how many CSI-RSs (number of Nc’), CSI-IM (number of Ni’), and/or CSI processes (number of Np’) could be “partially activated”

[457] Here, the reason that the term “partial activation” was used is that it would be possible to limit the operations to specific operations (e.g., CSI-RS tracking) or to include additional operations from the operations that the UE could operate in the “full activation” mode.

[458] For example, a given UE could have the parameters Nc=1, Ni=1, and Np=1 in 1. At the same time having the parameters Nc’=3, Ni’=1, and Np’=1 in 2.

[459] Namely, the only difference is that Nc=1 and Nc’=3.

[460] This means that the specific UE could maintain time/frequency synchronization/tracking for partially activated CSI-RS, and that it would be possible to be assigned with “fully activated” CSI-RS with Nc=1.

[461] Leading methods to be assigned Nc=1 CSI-RS include (1) the method whereby instructions are received from the MAC layer through the MAC CE command, (2) receiving more dynamic indication at the PHY layer through DCI signaling, and so on.

[462] Due to the fact that the UE carries out single CSI feedback only or the CSI process of single Np=Np’=1 for the CSI process (from a given CC) through such a method, complexity and overhead regarding the CSI feedback could always be maintained consistently.

[463] Also, through the method proposed by the statement, the CSI-RS index that the UE must measure could be dynamically switched through MAC layer or PHY layer signaling.

[464] Namely, in the statement, the method whereby only those resources that are subject to measurement are switched through signaling that is lower in terms of latency than the CSI-RS reconfiguration latency based on RRC signaling is provided.

[465] Although the present invention describes mainly the CSI-RS for convenience of explanation, it is clear that the method proposed in the statement could be applied identically to dynamic switching of the CSI-IM index (or CSI process index).

[466] Additionally, it would be possible to have additional restrictions in the form of Nc < Nc’, Ni<=Ni’, and/or Np<=Np’ between parameters in 1. and 2. above.

[467] In such a case, the UE must transmit the capability signaling within the extent to which such conditions are satisfied.

[468]

[469] If the base station receives from the UE capability signaling including the capability information related to the CSI operation, the base station must transmit the RRC signaling to the UE in the format that does not violate the capability property combination examined previously when configuring the applicable UE later.

[470] It is not expected that the UE does not violate the capability properties, and this could be an error case.

[471]

[472] As examined previously, it is assumed that the UE can be configured with three CSI-RSs corresponding to Nc’ = 3 via RRC signaling from the base station.

[473] However, the UE would be able to receive from the base station a separate identifier to identify that “partial activation” is set up for each CSI-RS index or signaling to recognize this from a separate identifier or specific implicit indication.

[474] In such a situation, the UE performs time/frequency synchronization/tracking for each of the 3 CSI-RSs from the point at which the RRC signaling is received.

[475] This means that synchronization/tracking could be carried out based on such information as specific RS (e.g., CRS) that applies quasi co-location (QCL) assumptions included in each CSI-RS configuration.

[476] At this time, in a separate identifier format Nc=1 CSI-RS from Nc’=3 CSI-RS could be additionally (or simultaneously) configured or ordered for “full activation.”

[477] Also, it would be possible to stipulate specific indexes in advance, such as implicitly stipulating that the Nc=1 CSI-RS is always to be stipulated as lowest (highest) indexed CSI-RS.

[478] Then, the UE has to carry out channel measurement for CSI feedback only for Nc=1 “fully activated” CSI-RS.

[479] Namely, the UE carries out only tracking without carrying out channel measurement for Nc’-Nc=2 CSI-RSs.

[480] As described, for the method whereby channel measurement is carried out only for Nc-1 CSI-RS, and whereby feedback contents (e.g., RI/PMI?CQI) are derived by the measurement, the operations that calculate the feedback contents for the specific CSI process configured could be stipulated/set up.

[481] For example, the UE receives the Np=1 CSI process from the base station through RRC signaling, and such a CSI process is defined as the combination of specific number of CSI-RS and CSI-IM indexes.

[482] However, the fully activated CSI RS is automatically reflected depending on which is the fully activated Nc-=1 CSI-RS, so that the operations to recognize the CSI-RS subject to the applicable CSI process’s channel measurement could be defined/set up.

[483] As another example, the CSI process could be set up with three configurations in the partial activation state with Np'=3, and the Nc'=3 CSI-RS index could be set up with each CSI process.

[484] Afterwards, the base station could provide dynamic indication of Np=1 fully activated specific CSI process through the MAC or PHY signaling.

[485] Then, for the UE could transmit to the base station CSI feedback for the specific fully activated CSI process.

[486] Eventually, for each CSI process the specific CSI/RS and/or CSI-IM index synchronized to this, a separate identifier or specific implicit signaling method to identify automatically whether a given index is a fixed index or variable index could be defined.

[487] If the specific CSI-RS and/or CSI-IM index is fixed as specific index and then ordered, the UE performs measurement for the resource applicable for the fixed CSI-RS and/or CSI-IM index.

[488] The format under which if the specific CSI-RS and/or CSI-IM index is set up in a variable index format, in the event that specific Nc=1 CSI-RS is "fully activated" in the form of separate MAC or PHY signaling, the applicable index is automatically applied could be applied.

[489] Here, the number of fully activated Ncs could be 2 or more.

[490] For example, in the 2D-AAS structure the number fully activated Ncs could be 2 or more in the case in which multiple CSI-RS resources are measured through the Kronecker calculation, and so on.

[491] Even in this case, in the event that dynamic indication is provided to determine which Nc is fully activated, such indexes could be automatically applied.

[492] Eventually, regarding such CSI process configurations, it would be preferable to stipulate at the RRC configuration stage from which candidate sets the CSI-RS and/or CSI-IM indexes could be selected from the applicable configuration.

[493] Likewise, it is clear that regarding the CSI-IM the configuration or instruction operations according to the Ni' and Ni numbers could be applied.

[494] Figure 15 is a drawing that illustrates an example of the CSI measurement and reporting method proposed by the statement.

[495] When we refer to Figure 15, we can see that the UE transmits capability signaling containing the UE's capability information related to the CSI operations to the base station (S1510).

[496] The UE's capability information includes the first control information that indicates the maximum number of operations related to the CSI that can be fully activated simultaneously, and the second control information that indicates the maximum number of operations related to the CSI that can be partially activated simultaneously.

[497] Afterwards, the base station transmits the configuration information related to the CSI operations to the UE (operation configuration information related to the CSI) in the event that the configurations related to the CSI operations change (S 1520).

[498] The configuration information related to CSI operations includes at least one of the CSI operation index values that indicate operations for partial activation, which perform CSI-related procedures in a partially activated state, or the CSI operation index values that indicate operations for full activation, which perform CSI-related procedures in a fully activated state.

[499] Afterwards, the UE measures the fully activated CSI based on the configuration information related to the CSI operations (S1530).

[500] Prior to stage S1530, the UE performs tracking on the partially activated CSI-RS.

[501] We will refer to the previous pages for a detailed description regarding the CSI-RS tracking.

[502] Afterwards, the UE reports the measurement results to the base station (S1540).

[503]

[504] Figure 16 is a drawing that illustrates another embodiment of the CSI measurement and reporting method proposed in the statement.

[505] Since S1610, S1620, S1640, and S1650 are identical to Figure 15's S1510 to S1540, detailed descriptions will be omitted here.

[506] After stage S1620 (after the configuration information related to the CSI operations is transmitted by the base station to the UE), the base station transmits an instruction message to order the UE to measure the fully activated CSI-RS (S1630).

[507] The instruction message could be a MAC CE or DCI.

[508] Also, it would be preferable for the fully activated CSI-RS to be selected from partially activated CSI-RSs.

[509]

[510] CSI measurement window initialization/renewal point

[511] If the UE receives at the SF (sub-frame) #n point the signaling to fully activate specific CSI-RS, CSI-IM, and/or CSI process indexes from the base station through MAC signaling or PHY signaling, the UE could apply CSI measurement and reporting starting the specific y ms from the applicable point in time (sub-frame #n), namely from the point of SF # (n+y).

[512] In the case of periodic CSI reporting, from the specific reference resource point synchronized to the RI reporting instance that occurs initially after the SF # (n+y), CSI measurement and reporting start for new fully activated specific CSI-RS, CSI-IM, and /or CSI process indexes.

[513] Namely, it could be defined in such a way that regarding the valid reference resource points that exist after the SF # (n+y) point, new CSI contents are reported regarding the point at which the CSI (e.g., RI/PMI/CQI) calculated at the reference resource point is reported in the RI for the first time.

[514] Namely, even if the PMI/CQI reporting instance exists prior to the initial RI reporting, the new fully activated configuration should not be used, but rather the CSI feedback contents based on the configuration that was followed immediately before must continue to be reported.

[515] Eventually, the CSI reporting of the UE must be carried out in accordance with the fully activated configuration from the new RI reporting instance point.

[516]

[517] Regarding the above operations, the configuration information related to the window that averages the CSI measurements could be stipulated to be provided through RRC signaling separately or together.

[518] Also, such operations could be applied only for enhanced UEs that support such formats as the full/partial activation formats.

[519] Namely, measurements must be averaged within specific [d1,d2] ms time periods, rather than the conventional method wherein unrestricted observation is allowed.

[520] That is because it would be preferable to stipulate that measurement averaging is performed only within certain bounded periods due to the fact that the CSI-RS and/or CSI-IM resource configuration information subject to measurement could be dynamically switched through MAC or PHY signaling.

[521] For example, in the event that the UE receives, from the base station, signaling with dynamic switching/indication of CSI-RS and/or CSI-IM resource configuration information subject to measurement through MAC or PHY signaling (e.g., by DCI), the UE may be configured to initialize or update the measurement averaging window of the CSI-RS-based channel measurement accordingly.

[522] Also, the UE could synchronize with the (dynamically switched/indicated) signaling to initialize or renew the measurement averaging window of the CSI-IM-based interference measurement.

[523] Here, the meaning of initialization or renewal of the measurement averaging window is that, to exemplify based on the "unrestricted observation" for CSI measurement in accordance with the current standard, instead of the conventional operation wherein averaging is carried out in accordance with the UE embodiment of the channel measurements from the applicable CSI-RS ports repeatedly measured from a random point in the past to the present, the "measurement window starting point" of "random point" is initialized or renewed to the point in

time #n at which (dynamic switching/indicated) signaling is received (or after the specific setup/instruction point, e.g., #n+k).

[524] Or the method whereby time information (e.g., in a timestamp format) is explicitly signaled to indicate when the applicable measurement window has been initialized or renewed could be applied.

[525] For example, there could be such methods as the method wherein time information is indicated regarding absolute time parameter values such as the SFN, slot numbers, and so on, the method wherein instruction is provided in the format of specific +/-Delta value from the point at which the UE receives the signaling could be used.

[526] In other words, the signaling could be limited to playing the role of renewing/resetting the starting point of the measurement averaging window.

[527] Then, it would be possible for the UE to average the CSI measurements (in accordance with the UE's embodiment) prior to the reception of additional signaling after starting from the applicable point.

[528] The signaling could be provided for each CSI process (independently). Through this process, the measurement window reset procedure could be applied independently for each process.

[529] This signaling could be applied for resetting the interference measurement averaging window for specific CSI-IM resources.

[530] In such a situation, the measurement averaging windows for the CSI-RS and CSI-IM belonging to a given CSI process are initialized together.

[531] Also, the method whereby a separate (independent) indicator is signaled in order to reset the interference measurement averaging window for the CSI-IM resources could be applied.

[532] This has the effect of separating the past interference environment to prevent it from being reflected on the interference measurement from the current point on by notifying the UE to initialize the measurement averaging window for the specific CSI process, in the event that, for example, there are changes to the interference environment that the base station could predict/sense under the environment in which interference environment changes exist (e.g., eICIC, eIMTA, LAA, etc.).

[533] Figure 17 is a drawing that illustrates another embodiment of the CSI measurement and reporting method proposed in the statement.

[534] Since S1710 to S1730, 1750, and S1760 are identical to Figure 16's S1610 to S1630, S1640, and S1650, detailed descriptions will be omitted here.

[535] When we refer to Figure 17, we can see that after the S1730 stage, the UE initializes or renews the CSI measurement window (S1740).

[536] Afterwards, the UE repeatedly measures the fully activated CSI-RS in the initialized or renewed CSI measurement window period, averages the measurement results, and then reports the average value to the base station (S1750 – S 1760).

[537] Prior to stage S1740, the base station would be able to transmit configuration information related to the CSI measurement window with the UE.

[538]

[539] In another embodiment that is similar in format to the (dynamic switching/indication) signaling method, the statement could be applied to operations related to measurement window configuration examined previously for the beam-formed CSI-RS-based method as described below.

[540] The following PMI feedback scenarios could be considered for elevation beam-forming and FD-MIMO operations.

[541] 1. Definition of pre-coding for EBF (elevation beam-forming)/FD-MIMO

[542] (1) Precoding matrix/vector

[543] - P1: Wideband; updated less frequently

[544] - P2: Sub-band or wide-band; updated more frequently
[545] - P is a function of P1 and P2, applied to 1D or 2D antenna array.
[546] - PMI(s) are to be specified w.r.t. the above definition
[547] (2) Scenarios for CSI feedback
[548] 1) Scenario 1
[549] - UE measures CSI-RS ports beam-formed with P1 (p1 transparent to UE).
[550] - PMI report(s) for P2
[551] 2) Scenario 2
[552] - UE measures non-precoded 1-D or 2-D CSI-RS ports
[553] Note: P1 not applied to CSI-RS at eNB
[554] - PMI report(s) for P1 and P2
[555] 3) Scenario 3
[556] - UE measures both non-precoded 1- or 2-D CSI-RS ports (lower duty cycle) and CSI-RS beam-formed with P1
[557] - PMI report(s) for P1 and P2
[558] 4) Scenario 4
[559] - UE measures non-precoded 1- or 2-D CSI-RS ports
[560] Note: P1 not applied to CSI-RS at eNB (P1 indicated to UE).
[561] - PMI report(s) for P2
[562]
[563] From scenario 1 to scenario 4, the method whereby the beam-formed CSI-RS is utilized as in scenario 1 and scenario 3, for example, it wouldn't be necessary for the UE to know matrix P1 itself, but if the P1 to which the base station applied beam-forming for the applicable CSI-RS ports changes, the base station must inform the UE in advance the information related to the point in time at which the P1 changed.
[564] That way, it would be possible for the UE to set up/apply appropriate measurement averaging window at the point of CSI measurement and calculation.
[565] Namely, according to the current standards, it would be possible for the UE to increase reliability by averaging the channel measurements from the applicable CSI-RS ports repeatedly measured from a random point in the past to the present in accordance with "unrestricted observations" at the point of channel measurement for the applicable CSI-RS ports in accordance with the UE's embodiment (e.g., noise suppression effect).
[566] However, due to the fact that beam-formed CSI-RS ports not known to the UE are utilized for P1 itself under scenario 1 to scenario 4, it would be possible for the base station to change P1 itself at any random point, and due to the fact that it would be possible for the UE to average the channel measurements for P1 prior to changes and P1' after changes, so there could be accuracy issues regarding the applicable CSI measurement and reporting.
[567] Therefore, the statement provides a method whereby a type of "beam-change notification" or "beam-change indicator (BCI) signaling" is transmitted by the base station to the UE is provided.
[568] Hereinafter, "beam-change indicator" will be referred to simply as "BCI."
[569] BCI signaling could be provided in the form of RRC signaling.
[570] However, more preferably, it could be provided as signaling through the MAC CE or as dynamic indication through DCI, and so on.
[571] Namely, in the event that the UE receives BCI signaling from the base station, the UE renews the starting point of the measurement averaging window applied during CSI derivation from the applicable CSI process to the applicable BCI signaling reception point (or any specified point from this, or explicit indication based on a separate timestamp, etc.)

[572] Namely, a method whereby time information (e.g., in the timestamp format) could be explicitly signaled to notify when the applicable measurement window has been initialized or renewed along with the BCI information (or as related information).

[573] For example, the time indication method regarding absolute time parameter values such as SFN, slot numbers, and so on, or providing specific +/-Delta value information from the point at which the UE received signaling could be utilized.

[574] Namely, such BCI signaling could be limited to playing the role of renewing/resetting only the starting point of the measurement averaging window.

[575] Then, the UE would be able to average the CSI measurements (according to the UE's embodiment) from this point (from the point of BCI signaling) to the point prior to the reception of additional BCI.

[576] Eventually, even though the UE may not know the renewed matrix P1 itself, since it has been notified through the BCI that the P1 has been renewed, from this point on CSI measurements are averaged again so that the CSI calculation and reporting (e.g., P1, P2, RI, CQI, etc.) could be performed for the applicable CSI process regarding the CSI-RS-ports for which the renewed P1 has been applied.

[577] The BCI could be separately (independently) signaled for each CSI process.

[578] Through this, measurement window reset could be independently applied for each process.

[579] The BCI could be applied for resetting the interference measurement averaging window for specific CSI-IM resources.

[580] In this case, initialization of the measurement averaging window for the CSI-RS and CSI-IM belonging to a given CSI process could be performed.

[581] Also, the method whereby a separate (independent) indicator is signaled in order to reset the interference measurement averaging window for CSI-IM resources could be applied.

[582] This means that if there are changes that could be predicted/detected by the base station in an environment (e.g., eICIC, eIMTA, LAA, etc.), the UE is notified to initialize the measurement averaging window, so that the past interference environment is separated in order to prevent it from being reflected on the interference measurements going forward.

[583]

[584] <u>General devices to which the present invention could be applied</u>

[585] Figure 18 illustrates a block diagram of a radio communication device in accordance with an embodiment of the present invention.

[586] When we refer to Figure 18, we can see that there are multiple UEs (1820) located within the base station (1810) and the base station (1810) domain.

[587] The base station (1810) includes a processor (1811), a memory (1812), and the RF unit (radio frequency unit, 1813). The processor (1811) embodies the functions, processes, and/or methods proposed in Figure 1 to Figure 17 previously. The radio interface protocol levels could be embodied by the processor (1811). The memory (1812) is connected to the processor (1811) in order to store various information items in order to operate the processor (1811). The RF unit (1813) is connected to the processor (1811) in order to transmit and/or receive radio signals.

[588] The UE (1820) includes a processor (1821), a memory (1822), and the RF unit (1823). The processor (1821) embodies the functions, processes, and/or methods proposed in Figure 1 to Figure 17 previously. The radio interface protocol levels could be embodied by the processor (1821). The memory (1822) is connected to the processor (1821) in order to store various information items to operate the processor (1821). The RF unit (1823) is connected to the processor (1821) in order to transmit and/or receive radio signals.

[589] The memory (1812, 1822 could be located within or outside the processor (1811, 1821), and could be connected to the processor (1811, 1821) according to various well-known methods. Also, the base station (1810) and/or UE (1820) could have a single antenna or multiple antennas.

[590] The embodiments described up to now constitute components and properties of the present invention that have been combined in certain formats. Each component or property must be taken into consideration selectively in the absence of explicit statements. Each component or property could be embodied without being combined with other components or properties. Also, it would be possible to configure embodiments of the present invention by combining certain components and/or properties. The order of the operations that are described in the embodiments of the present invention could be changed. Some components of a certain embodiment could be included in other embodiments, and could be replaced with corresponding configurations or properties in other embodiments. It is obvious that it would be possible to configure embodiments of the present invention by combining claims that are not explicitly related or to include them as new claims after making corrections later.

[591] Embodiments in accordance with the present invention could be achieved with various means, including hardware, firmware, software, or any combination of these. In the case of embodiment by hardware, an embodiment of the present invention could be achieved using one or more ASICs (application specific integrated circuits), DSPs (digital signal processors), DSPDs (digital signal processing devices), PLDs (programmable logic devices), FPGAs (field programmable gate arrays), processors, controller, micro-controllers, microprocessors, and so on.

[592] In the case of embodiments by firmware or software, an embodiment of the present invention could be achieved in such forms as modules, procedures, functions, and so on that perform the functions or operations described herein. Software codes could be stored in the memory and operated with processors. The memory could be located within or outside the processor in order to exchange data with the processor based on various known methods.

[593] It is clear to those in the field that the present invention could be materialized in other specific forms without deviating from the required properties of the present invention. Therefore, the descriptions provided herein must be taken into consideration as illustrative descriptions rather than being interpreted restrictively in all aspects. The scope of the present invention must be determined based on reasonable interpretation of the attached claims and all modifications within the equivalent scope of the present invention must be included in the scope of the present invention.

Industrial application possibilities

[594] The method of CSI feedback of the radio communication system under the present invention was described with the focus on examples in which the method is applied to the 3GPP LTE/LTE-A system, but it would be possible to apply the method to various radio communication systems besides the 3GPP LTE/LTE-A system.

Scope of claims

[Claim 1]
The method to carry out CSI (channel state information) by UE that includes the stage in which capability information of UE regarding operations related to the CSI is transmitted to the base station; the stage in which operation configuration information related to the CSI is received from the base station, wherein operation configuration information related to the CSI includes at least one of operation index information related to partial activation CSI indicating operations related to the CSI that carries out partial activation and operation index information related to the full activation CSI which indicates operations related to the CSI that carries out full activation; the stage in which partial activation CSI-RS (reference signal) is tracked; the stage in which full activation CSI-RS is measured; and the stage in which the measurement result is reported to the base station.

[Claim 2]
The method of Claim 1 that includes the stage in which the first message that addresses activation of the measurement regarding the full activation CSI-RS is received from the base station; and the stage in which the full activation CSI-RS activated by the first message is measured.

[Claim 3]
The method of Claim 1, wherein the CSI-related operations are related to at least one of CSI-RS, CSI-IM (interference management), and CSI process.

[Claim 4]
The method of Claim 1, wherein the UE's capability information includes the first control information that indicates the maximum number of the operations related to the CSI that can be fully activated and the second control information that indicates the maximum number of operations related to the CSI that can be partially activated.

[Claim 5]
The method of Claim 1, wherein tracking the partial activation CSI-RS includes the stage in which alignment is set in terms of time and/or frequency regarding the partial activation CSI-RS.

[Claim 6]
The method of Claim 1, wherein tracking is carried out by applying specific RS (reference signal) and quasi colocation (QCL) assumptions included in the operation setup information related to the CSI.

[Claim 7]
The method of Claim 1, wherein the full activation CSI-RS is selected from the partial activation CSI-RS.

[Claim 8]
The method of Claim 2, wherein the first message is an MAC (media access control) CE (control element) or DCI (downlink control information).

[Claim 9]
The method of Claim 2 that further includes the stage in which the third control information related to the CSI-RS measurement window is received from the base station, and the CSI-RS measurement stage, if the first

message is received, includes the stage in which the CSI-RS measurement window is initialized or renewed; the stage in which CSI-RS measurement is carried out repeatedly from the point at which the CSI-RS measurement window is initialized or renewed to a specific section; and the stage in which the measurement results are averaged.

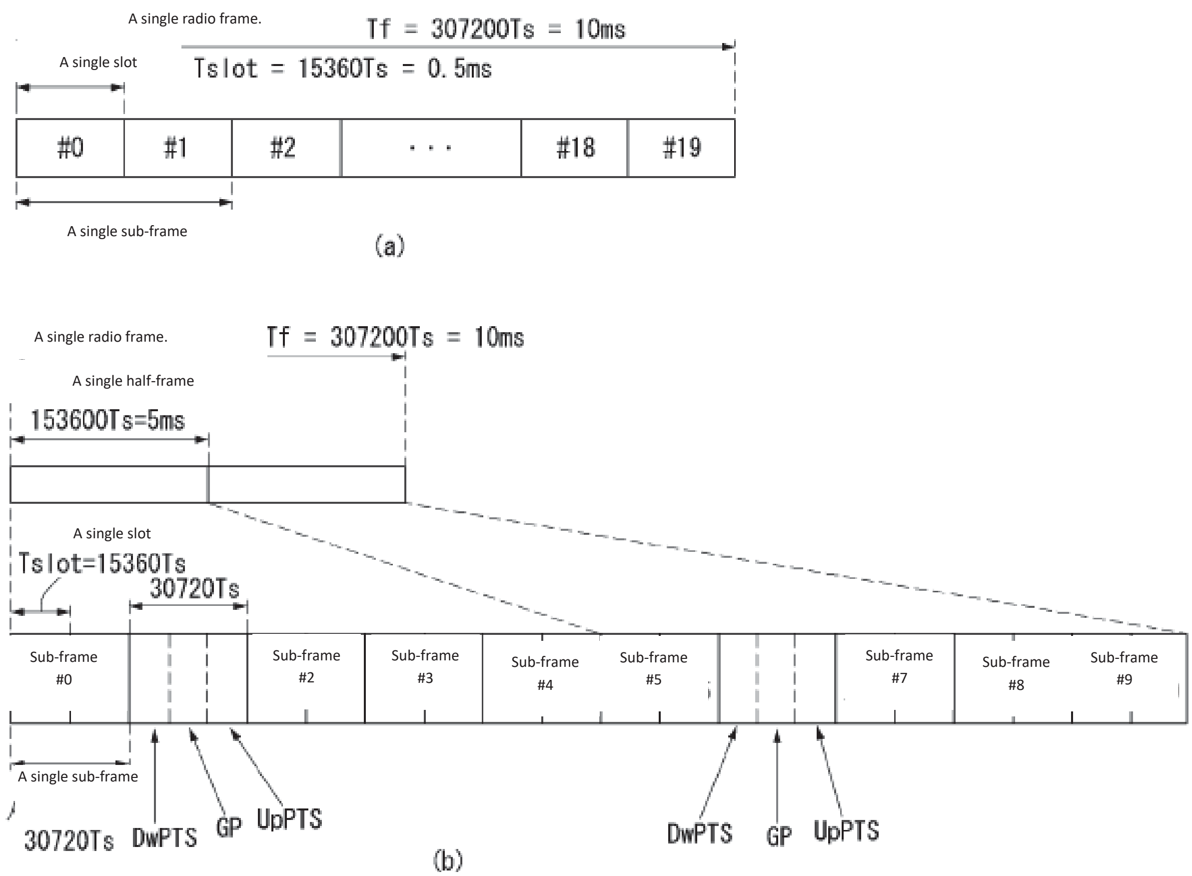
[Claim 10]
The method of Claim 9, wherein if the CSI feedback is periodic CSI feedback, the point in time at which the CSI-RS measurement window is initialized or renewed is at the point in time of a specific reference resource related to the RI (rank indicator) that occurs for the first time after the specific section.

[Claim 11]
The method of Claim 2, wherein the first message is received from the base station for each CSI process.

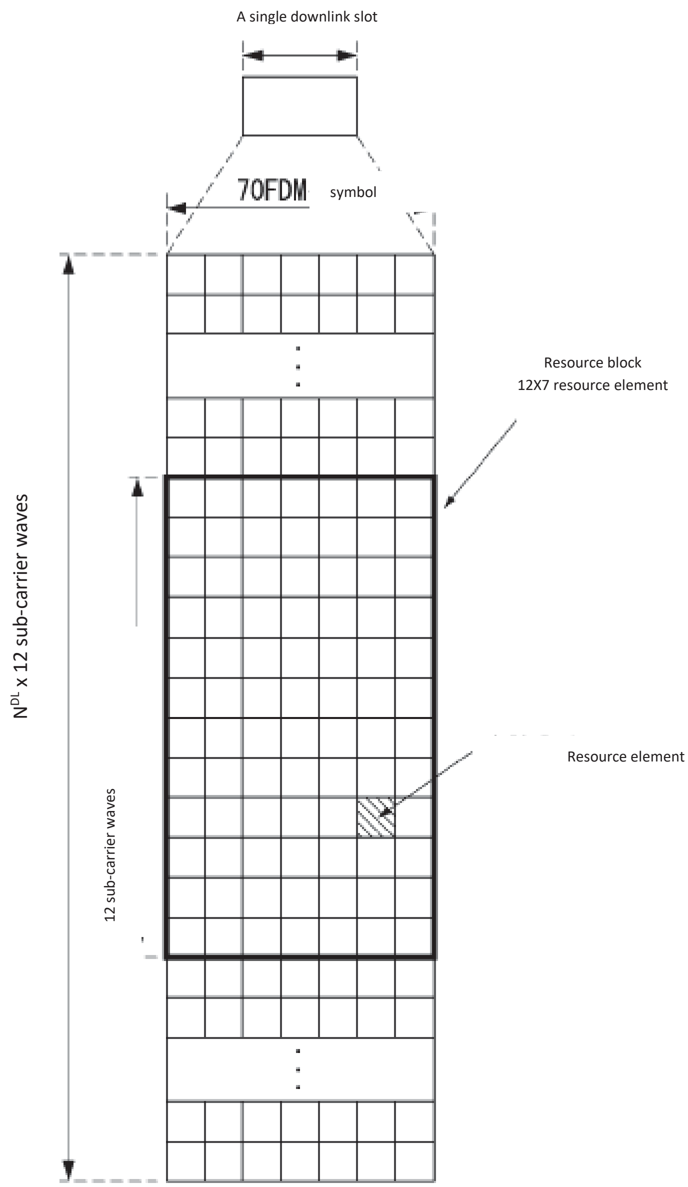
[Claim 12]
The method of Claim 2, wherein the first message is beam-change indicator (BCI) signaling that notifies changes in the matrix related to beam forming.

[Claim 13]
The user equipment that feeds back CSI (channel state information) in radio communication systems includes at least one of a RF (radio frequency) unit that transmits and receives wireless signals; and a processor that controls the RF unit, transmits the user equipment's capability information regarding the operation related to the CSI to the base station; and receives the operation configuration information related to the CSI from the base station, wherein the operation configuration information related to the CSI includes at least either of the index information related to the partial activation CSI that indicates the operation related to the CSI that carries out partial activation or operation index information related to full activation CSI that indicates operations related to the CSI that carries out full activation; measures full activation CSI-RS; and controls so that the measurements are reported to the base station.

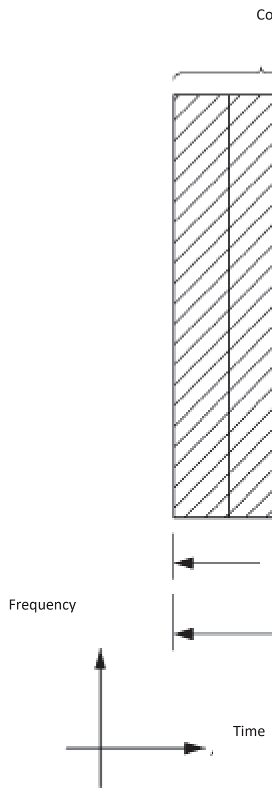
[Figure 1]


A single radio frame.
Tf = 307200Ts = 10ms
A single slot
Tslot = 15360Ts = 0.5ms
#0
#1
#2
...
#18
#19
A single sub-frame
(a)
A single radio frame.
Tf = 307200Ts = 10ms
A single half-frame
153600Ts=5ms
A single slot
Tslot=15360Ts
30720Ts
Sub-frame #0
Sub-frame #2
Sub-frame #3
Sub-frame #4
Sub-frame #5
Sub-frame #7
Sub-frame #8
Sub-frame #9
A single sub-frame
30720Ts
DwPTS
GP
UpPTS
DwPTS
GP
UpPTS
(b)

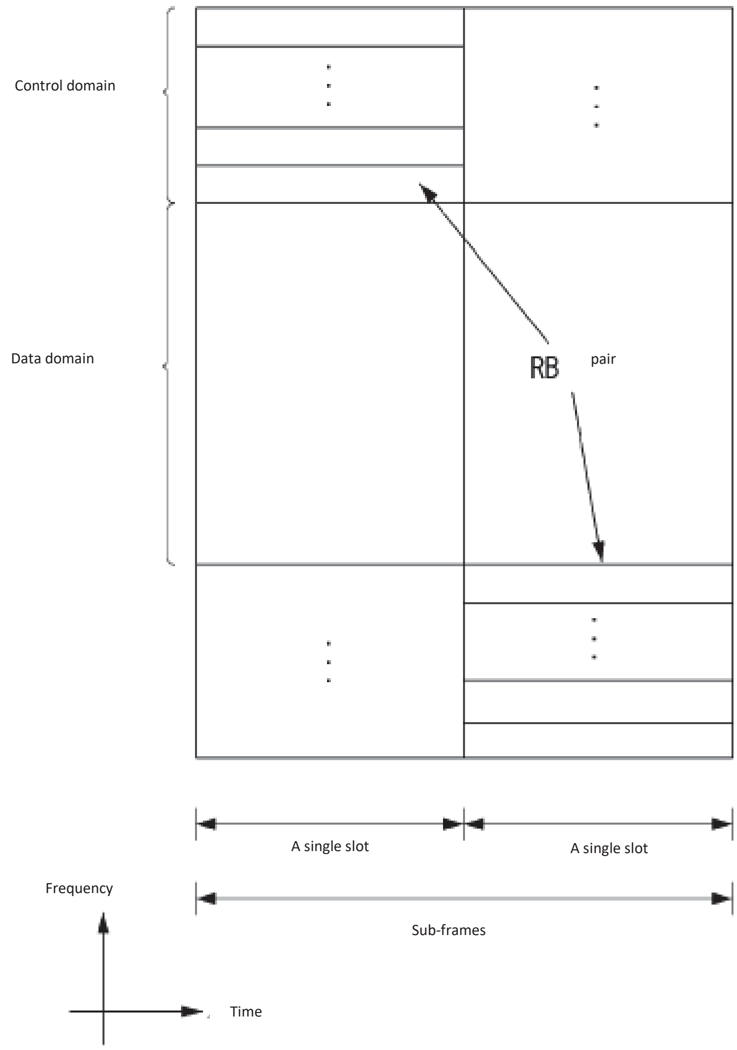
[Figure 2]


A single downlink slot
7OFDM symbol
Resource block
12X7 resource element
Resource element
N^{DL} x 12 sub-carrier waves
12 sub-carrier waves

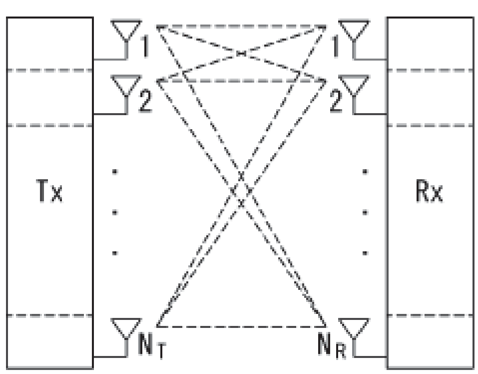
[Figure 3]


Control domain
Data domain
First slot
Second slot
Frequency
A single sub-frame
Time

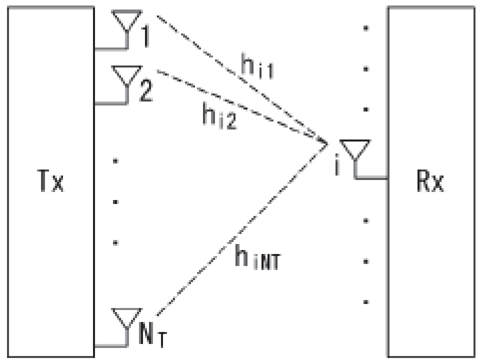
[Figure 4]



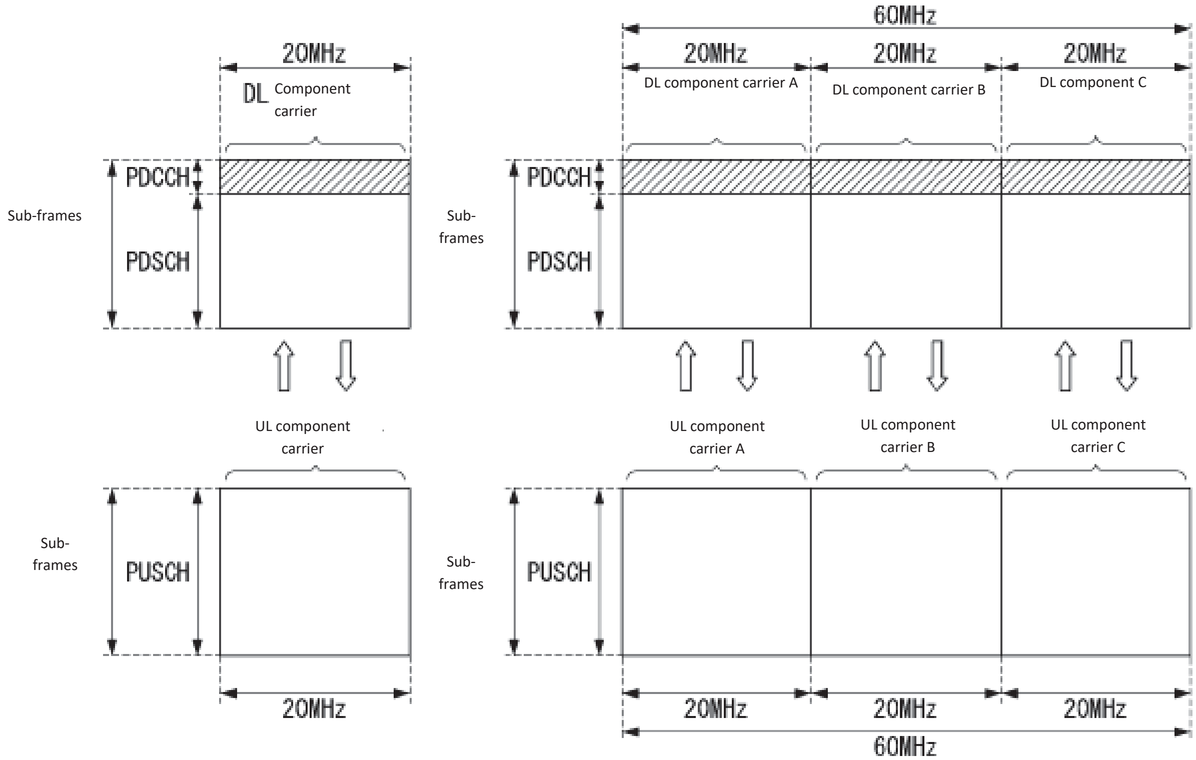
[Figure 5]



[Figure 6]



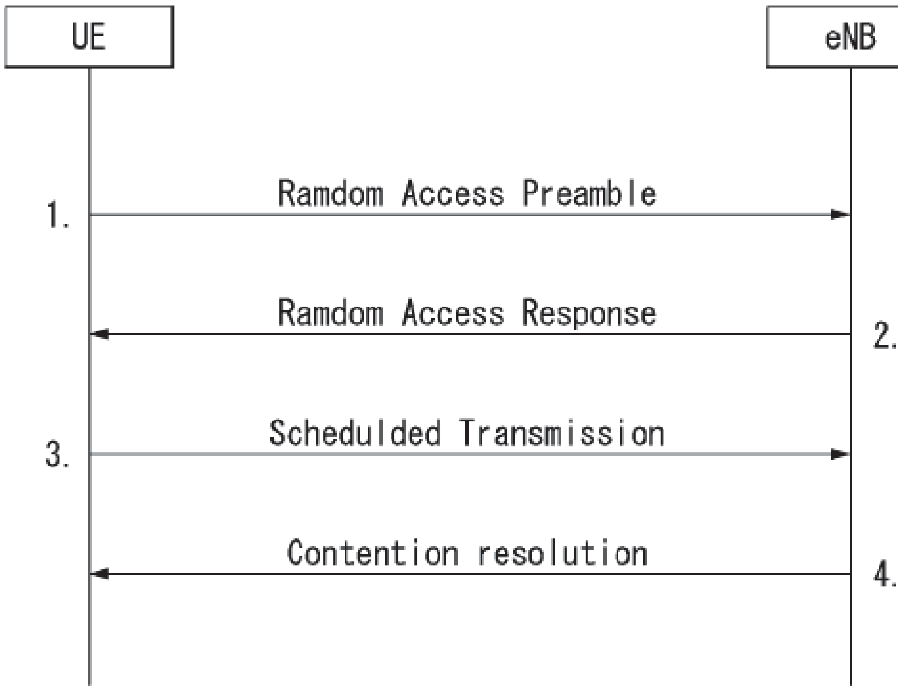
[Figure 7]



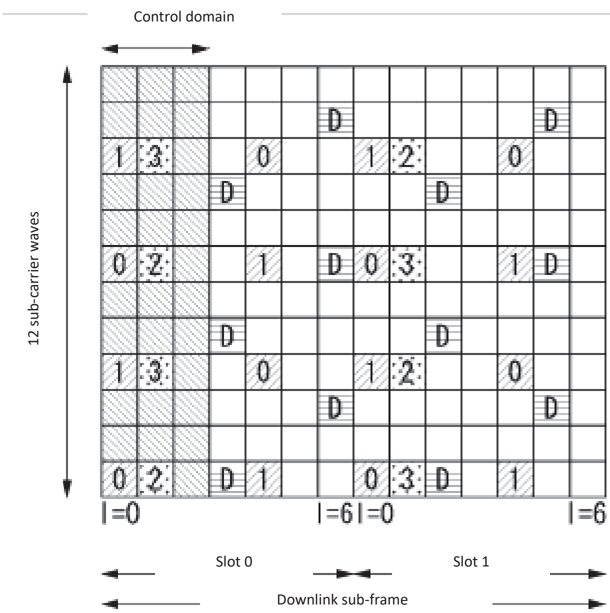
(a) Single CC

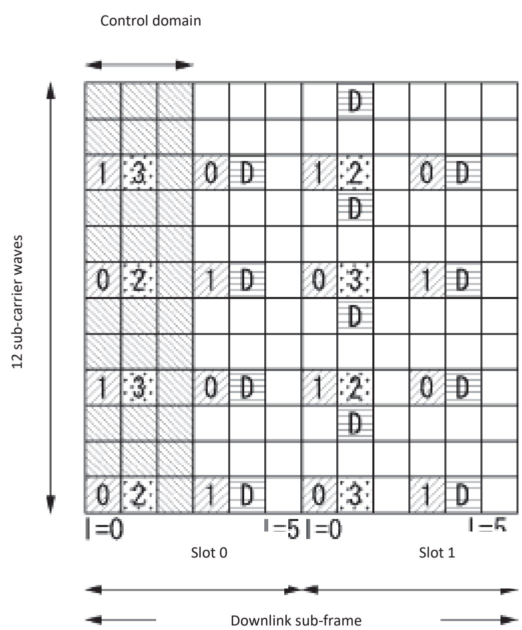
(b) Multiple CC

[Figure 8]

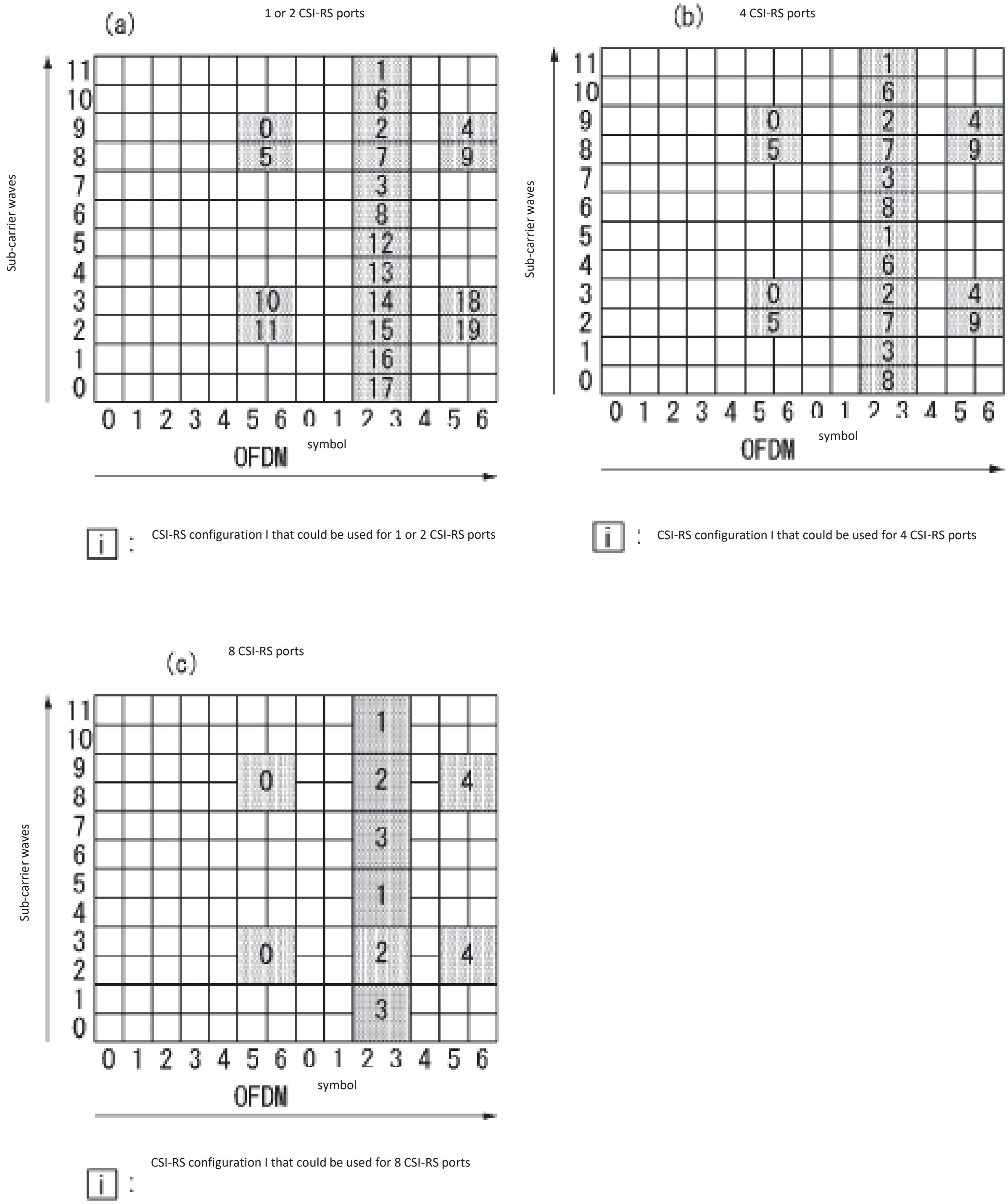

UE
eNB
Ramdom Access Preamble
1.
Ramdom Access Response
2.
Scheduled Transmission
3.
Contention resolution
4.

[Figure 9]

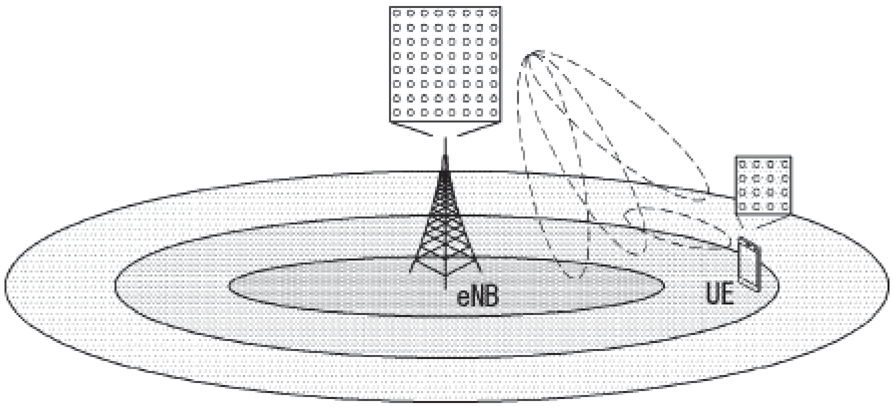

Control domain
12 sub-carrier waves
l=0
l=6
l=0
l=6
Slot 0
Slot 1
Downlink sub-frame


Control domain
12 sub-carrier waves
l=0
l=5
l=0
Slot 0
Slot 1
Downlink sub-frame

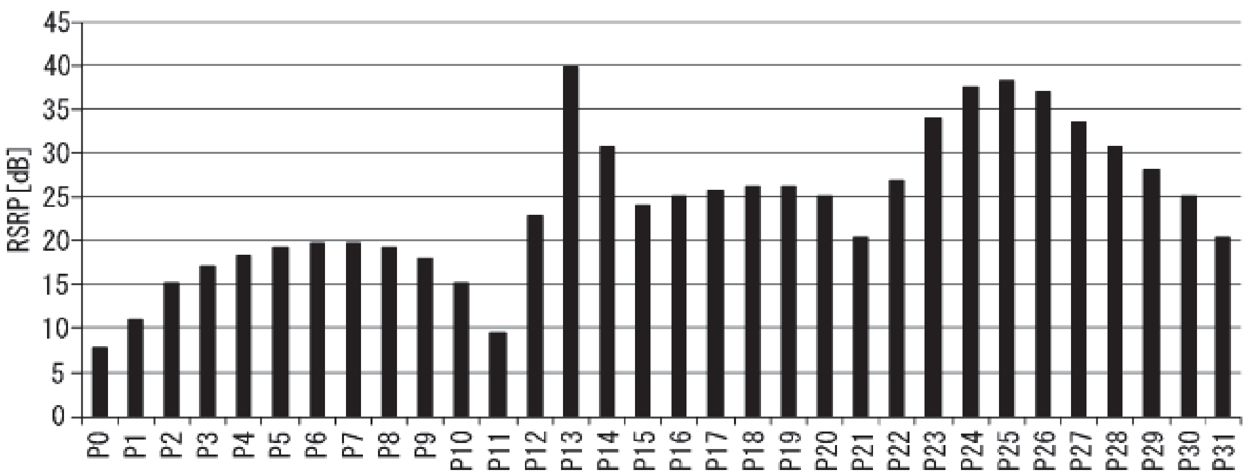
[Figure 10]


(a)
1 or 2 CSI-RS ports
Sub-carrier waves
OFDM symbol
CSI-RS configuration I that could be used for 1 or 2 CSI-RS ports
(b)
4 CSI-RS ports
Sub-carrier waves
OFDM symbol
CSI-RS configuration I that could be used for 4 CSI-RS ports
(c)
8 CSI-RS ports
Sub-carrier waves
OFDM symbol
CSI-RS configuration I that could be used for 8 CSI-RS ports

[Figure 11]



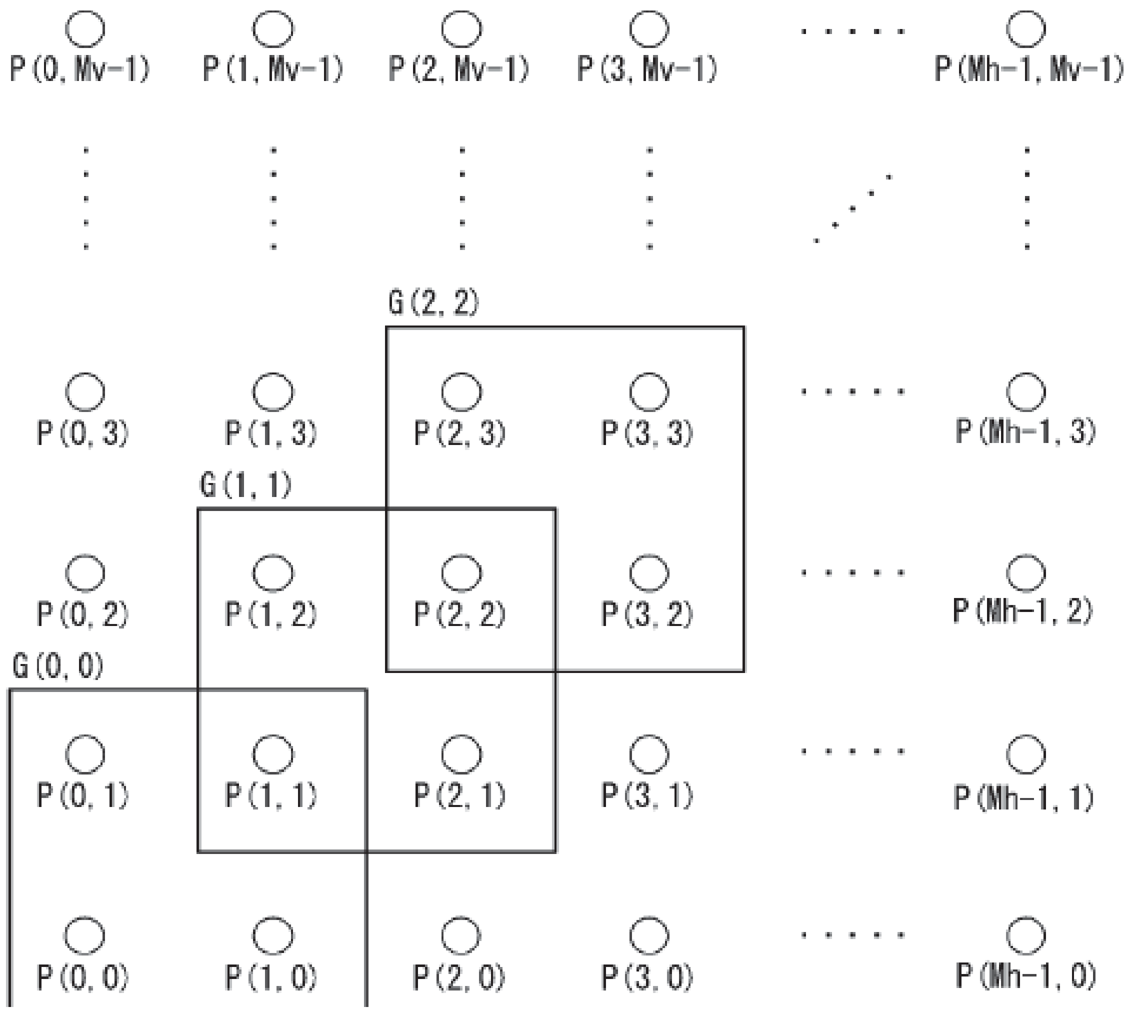
[Figure 12]



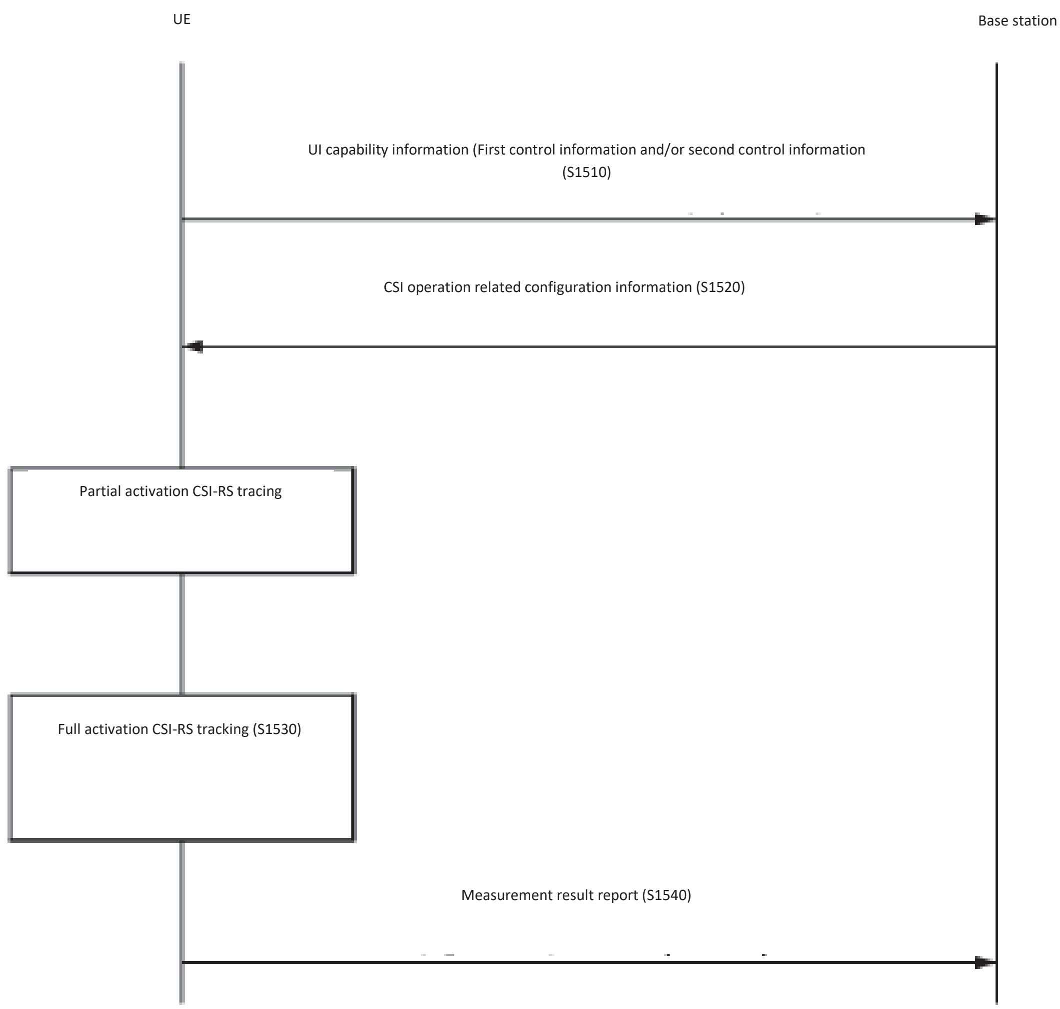
[Figure 13]

Group index for level 4 grouping	0								1							
Group index for level 3 grouping	0				1				2				3			
Group index for level 2 grouping	0		1		2		3		4		5		6		7	
Group index for level 1 grouping	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	P0	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15

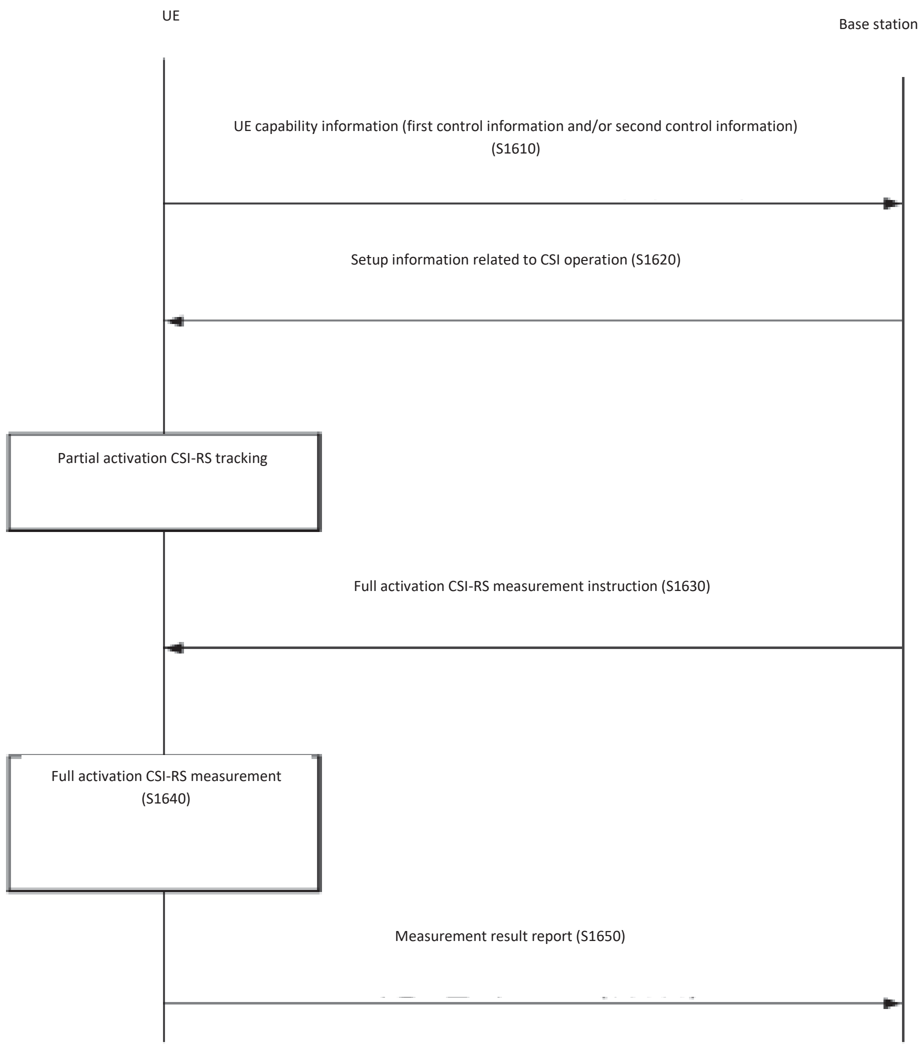
[Figure 14]


P(0, Mv-1)
P(1, Mv-1)
P(2, Mv-1)
P(3, Mv-1)
P(Mh-1, Mv-1)
G(2, 2)
P(0, 3)
P(1, 3)
P(2, 3)
P(3, 3)
P(Mh-1, 3)
G(1, 1)
P(0, 2)
P(1, 2)
P(2, 2)
P(3, 2)
P(Mh-1, 2)
G(0, 0)
P(0, 1)
P(1, 1)
P(2, 1)
P(3, 1)
P(Mh-1, 1)
P(0, 0)
P(1, 0)
P(2, 0)
P(3, 0)
P(Mh-1, 0)

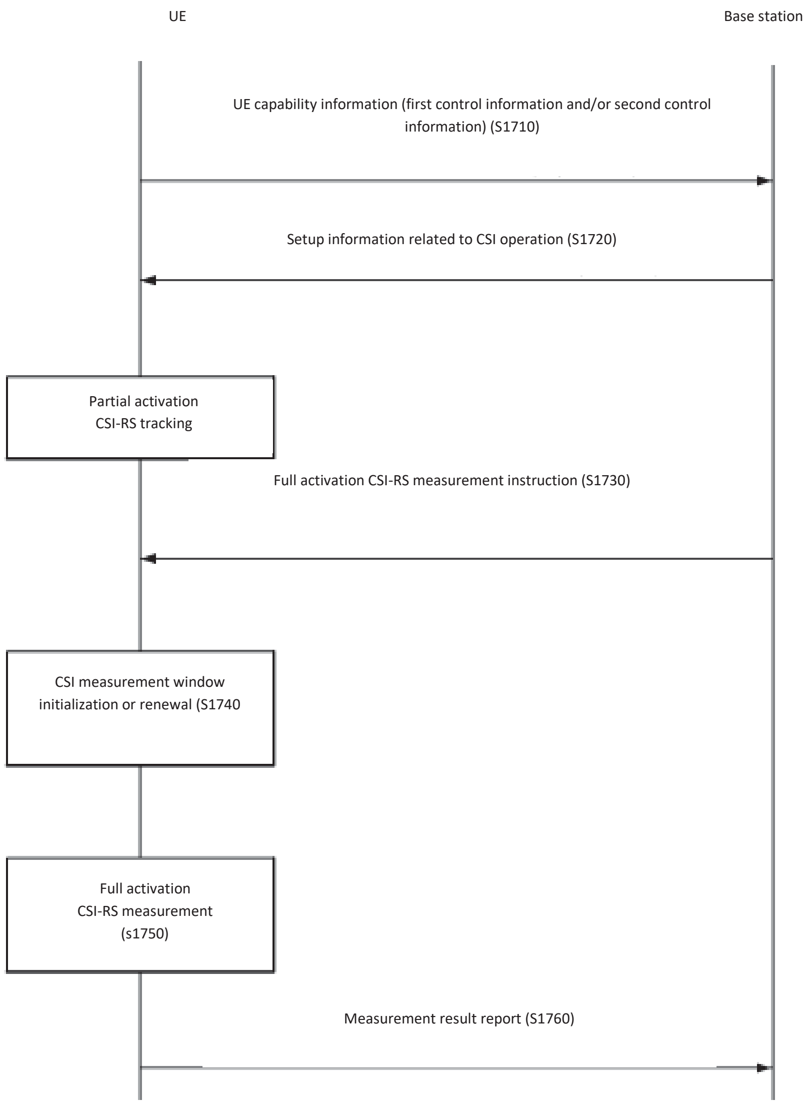
[Figure 15]


UE
Base station
UI capability information (First control information and/or second control information
(S1510)
CSI operation related configuration information (S1520)
Partial activation CSI-RS tracing
Full activation CSI-RS tracking (S1530)
Measurement result report (S1540)

[Figure 16]


UE
Base station
UE capability information (first control information and/or second control information)
(S1610)
Setup information related to CSI operation (S1620)
Partial activation CSI-RS tracking
Full activation CSI-RS measurement instruction (S1630)
Full activation CSI-RS measurement
(S1640)
Measurement result report (S1650)

[Figure 17]



[Figure 18]