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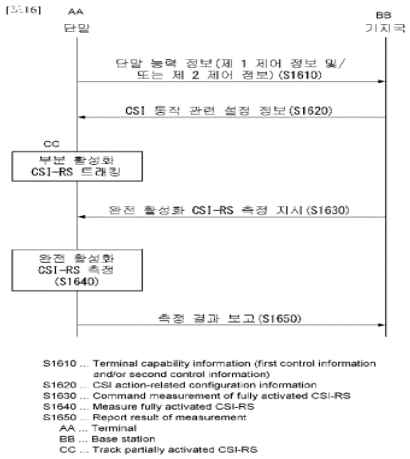
[continued on next page]

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

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



(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, terminal-capability information 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: The present specification relates to a method for feeding back channel-state information (CSI) in a wireless communication system, carried out by a terminal, comprising: a step of transmitting terminal-capability information for a CSI-related action, to a base station; a step of receiving configuration information for the CSI-related action from the base station; a step of tracking partially activated CSI reference signals (CSI-RSs); a step of measuring a fully activated CSI-RS; and a step of reporting the results of the measurement to the base station.

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Specification

Title of invention: METHOD FOR CSI FEEDBACK IN WIRELESS COMMUNICATION SYSTEM, AND APPARATUS THEREFOR

Technical Field

[1] The present invention relates to a wireless communication system, and more particularly to a method for feeding back CSI from a terminal based on a reference signal and an apparatus supporting the same.

Background Art

[2] Mobile communication systems have been developed to provide voice services without interfering with user activity. However, the scope of mobile communication systems has expanded to data services in addition to voice, and more advanced mobile communication systems are required because the explosive increase in traffic is currently causing a shortage of resources, while users are demanding higher-speed services.

[3] Requirements for a next-generation mobile communication system include support for: accommodating explosive data traffic, significantly increasing transfer rate per user, accommodating a substantially increased number of connected devices, very low end-to-end latency, and high energy efficiency. To this end, research has been carried out on various technologies, such as dual connectivity, massive multiple input multiple output (massive MIMO), in-band full duplex, non-orthogonal multiple access (NOMA), super wideband support, and device networking.

Detailed Description of the Invention

Technical Problem

[4] An object of the present specification is to provide a method for transmitting and receiving terminal-capability information related to CSI operations.

[5] Another object of the present specification is to provide a method for tracking a partially activated CSI-RS and performing measurement and reporting on a fully activated CSI-RS only so as to reduce latency in a CSI feedback procedure.

[6] Another object of the present specification is to provide a method for initializing or updating a window related to CSI measurement.

[7] The technical objects of the present invention are not limited to the foregoing, and a person of ordinary skill in the art to which the invention pertains will be able clearly to understand further technical objects not described above based on the disclosure below.

Means of Solving the Problem

[8] The present specification relates to a method for feeding back channel-state information (CSI) in

a wireless communication system, wherein the method is carried out by a terminal and comprises: a step of transmitting, to a base station, information regarding the capability of the terminal for CSI-related operation; a step of receiving CSI-related operation configuration information from the base station, the CSI-related operation configuration information comprising at least one of: partial activation CSI-related operation index information indicating a CSI-related operation of performing partial activation, or full activation CSI-related operation index information indicating a CSI-related operation of performing full activation, a step of tracking a partially activated CSI-RS (reference signals); a step of measuring a fully activated CSI-RS; and a step of reporting the result of the measurement to the base station.

[9] In addition, in the present specification, the step of measuring the fully activated CSI-RS comprises: a step of receiving a first message indicating activation of the measurement of the fully activated CSI-RS from the base station and a step of measuring the fully activated CSI-RS activated by the first message.

[10] In addition, in the present specification, the CSI-related operation is characterized in that it relates to at least one of CSI-RS, CSI-IM (Interference Management), or a CSI process.

[11] In addition, in the present specification, the terminal-capability information comprises: first control information indicating a maximum number of the CSI-related operations capable of full activation at the same time, and second control information indicating a maximum number of CSI-related operations capable of partial activation at the same time.

[12] In addition, in the present specification, the step of tracking the partially activated CSI-RSs comprises synchronizing the partially activated CSI-RSs in time and/or frequency.

[13] In addition, in the present specification, the tracking is performed by applying a particular reference signal (RS) included in the CSI-related operation setting information and a quasi co-location (QCL) assumption.

[14] In addition, in the present specification, the fully activated CSI-RS is selected from among the partially activated CSI-RSs.

[15] In addition, in the present specification, the first message is MAC (Media Access Control), CE (Control Element), or DCI (Downlink Control Information).

[16] In addition, in the present specification, the method further comprises a step of receiving third control information related to a CSI-RS measurement window from the base station, and the step of measuring the CSI-RS comprises a step of initializing or updating the CSI-RS measurement window when the first message is received; a step of repeatedly measuring a CSI-RS over a particular interval from a point in time at which the CSI-RS measurement window is initialized or updated; and a step of averaging the measurement results.

[17] In addition, in the present specification, if the CSI feedback is periodic CSI feedback, the point in time at which the CSI-RS measurement window is initialized or updated is a particular reference resource point in time related to a rank indicator (RI) report first generated after the specific period.

[18] In addition, in the present specification, the first message is characterized in that it is received from the base station for each respective CSI process.

[19] In addition, in the present specification, the first message is characterized in that it comprises a beam-change indicator (BCI) signaling that provides notification of a change in a beamforming-related matrix.

[20] In addition, in the present specification, the terminal for feeding channel-state information (CSI) back in a wireless communication system comprises a radio frequency (RF) unit that sends or receives a radio signal, and a processor that controls the RF unit, and is characterized in that it exercises control so that: terminal-capability information for a CSI-related operation is transmitted to a base station; CSI-related operation configuration information is received from the base station, wherein the CSI-related operation configuration information comprises at least one of partial activation CSI-related operation index information indicating a CSI-related operation of performing partial activation and full activation CSI-related operation index information indicating a CSI-related operation of performing full activation; partially activated CSI-RSs (reference signal) are tracked; a fully activated CSI-RS is measured; and the measurement result is reported to the base station.

Effects of the Invention

[21] According to the present specification, there is an effect that latency in a CSI feedback procedure can be reduced by sending CSI configuration-related information to a terminal at the MAC level or PHY level.

[22] In addition, by initializing or updating a CSI measurement-related window at a point in time at which the activation of CSI measurement is indicated or a point in time at which notification is given of a CSI setting change, the present specification has the effect that more accurate CSI can be fed back because the past environment is not incorporated into CSI measurement unnecessarily.

[23] The effects that may be obtained from the present invention are not limited to those mentioned above; a person of ordinary skill in the art to which the present invention pertains will be able clearly to understand further effects that are not described above, based on the disclosure below.

Brief Description of the Drawings

[24] The attached drawings, which are included as part of the detailed description of the present invention to aid in understanding it, provide embodiments of the present invention and, in combination with the detailed description, describe the technical features of the present invention.

[25] FIG. 1 shows the structure of a radio frame in a wireless communication system to which the present invention is applicable.

[26] FIG. 2 illustrates a resource grid for a downlink slot in a wireless communication system to which the present invention is applicable.

[27] FIG. 3 shows the structure of a downlink subframe in a wireless communication system to which the present invention is applicable.

[28] FIG. 4 shows the structure of an uplink subframe in a wireless communication system to which the present invention is applicable.

[29] FIG. 5 is a configuration diagram for a conventional multi-input multi-output (MIMO) antenna communication system.

[30] FIG. 6 shows channels from a plurality of transmitting antennas to a single receiving antenna.

[31] FIG. 7 shows an example of component carriers and a carrier aggregation in a wireless communication system to which the present invention is applicable.

[32] FIG. 8 is a diagram for illustrating a contention-based random access procedure in a wireless communication system to which the present invention is applicable.

[33] FIG. 9 illustrates reference signal patterns mapped to downlink resource block pairs in a wireless communication system to which the present invention is applicable.

[34] FIG. 10 is a diagram illustrating a CSI-RS configuration in a wireless communication system to which the present invention is applicable.

[35] FIG. 11 illustrates a system in which a base station or a terminal has a plurality of transmission/reception antennas capable of AAS-based three-dimensional (3D) beamforming in a wireless communication system to which the present invention is applicable.

[36] FIG. 12 illustrates RSRP for each antenna port of an RRM-RS according to an embodiment of the present invention.

[37] FIG. 13 illustrates RRM-RS antenna port grouping levels according to an embodiment of the present invention.

[38] FIG. 14 is a diagram illustrating antenna ports and antenna port groups of RRM-RSs arrayed in two-dimensional indices according to an embodiment of the present invention.

[39] FIGS. 15 to 17 are drawings showing examples of CSI measurement and reporting methods proposed in the present specification.

[40] FIG. 18 illustrates a block diagram of a wireless communication apparatus according to an embodiment of the present invention.

Modes for Carrying Out the Invention

[41] Below, preferred embodiments according to the present invention will be described in detail with reference to the attached drawings. The detailed description set forth below in connection with the attached drawings is intended to describe illustrative embodiments and is not intended to represent the sole embodiments in which the present invention can be implemented. The detailed description below contains specific details in order to provide an understanding of the present invention. However, a person of skill in the art will recognize that the present invention may be carried out without these specific details.

[42] In some cases, to avoid obscuring the concepts of the present invention, well-known structures and devices are omitted, or core functions of the respective structures and apparatus

may be shown in a block diagram form.

[43] In the specification, "base station" refers to a terminal node of a network that communicates directly with a terminal. In the present document, particular operations described as being carried out by a base station may, in some cases, be performed by an upper node of a base station. In other words, it is obvious that various operations that are carried out for communication with a terminal in a network made up of a plurality of network nodes comprising a base station may be carried out by the base station or by network nodes other than the base station. "Base station" (BS) is generally interchangeable with terms such as fixed station, Node B, evolved-NodeB (eNB), base transceiver system (BTS), access point (AP), and the like. In addition, a "terminal" may be fixed or movable and is interchangeable with terms such as user equipment (UE), mobile station (MS), user terminal (UT), mobile subscriber station (MSS), subscriber station (SS), advanced mobile station (AMS), wireless terminal (WT), Machine-Type Communication (MTC) device, Machine-to-Machine (M2M) device, Device-to-Device (D2D) device, or the like.

[44] Below, "downlink" refers to communication from the base station to the terminal, and "uplink" refers to communication from the terminal to the base station. In a downlink, a transmitter may be part of the base station and a receiver may be part of the terminal. In an uplink, a transmitter may be part of the terminal and a receiver may be part of the base station.

[45] Specific terms used in the following description are provided to aid in understanding the present invention; and the use of such specific terms may be modified into other forms within the scope of the present invention without departing from its technical concept.

[46] The following technology may be used in a variety of radio access systems, such as code division multiple access (CDMA), frequency division multiple access (FDMA), time division multiple access (TDMA), orthogonal frequency division multiple access (OFDMA), single carrier-FDMA (SC-FDMA), non-orthogonal multiple access (NOMA), and so forth. CDMA may be implemented as a radio technology such as universal terrestrial radio access (UTRA) or CDMA2000. TDMA may be implemented as a radio technology such as Global System for Mobile communications (GSM)/General Packet Radio Service (GPRS)/Enhanced Data Rates for GSM Evolution (EDGE). OFDMA may be implemented as a radio technology such as IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Evolved-UTRA (E-UTRA), and so forth. UTRA is a part of a universal mobile telecommunications system (UMTS). The third-generation partnership project (3GPP) long term evolution (LTE) is part of an evolved UMTS (E-UMTS) using evolved-UMTS terrestrial radio access (E-UTRA) and adopts OFDMA for downlink and SC-FDMA for uplink. LTE-A (advanced) is an evolution of 3GPPLTE.

[47] The embodiments of the present invention may be based on standard documents set forth in at least one of the radio access systems IEEE 802, 3GPP, and 3GPP2. In other words, steps or parts of the embodiments of the present invention

that are not described so as to clearly present the technical concept of the present invention may be based on such documents. In addition, all terms disclosed in this document may be explained based on these standard documents.

[48] For the sake of clarity, the description focuses primarily on 3GPP LTE/LTE-A, but the technical features of the present invention are not limited thereto.

[49]

[50] **General wireless communication system to which the present invention is applicable**

[51] FIG. 1 shows a structure of a radio frame in a wireless communication system to which the present invention is applicable.

[52] 3GPP LTE/LTE-A supports a type 1 radio frame structure applicable to Frequency Division Duplexing (FDD) and a type 2 radio frame structure applicable to Time Division Duplexing (TDD).

[53] In FIG. 1, the size of the radio frame in the time domain is expressed as a multiple of the time unit $T_s = 1/(15000*2048)$. Downlink and uplink transmission consists of a radio frame having an interval of $T_f = 307200 * T_s = 10$ ms.

[54] FIG. 1(a) illustrates a type 1 radio frame structure. The type 1 radio frame is applicable to both full duplex and half duplex FDD.

[55] The radio frame consists of 10 subframes. One radio frame consists of 20 slots with a length of $T_{slot} = 15360*T_s = 0.5$ ms; each respective slot is assigned an index from 0 to 19. One subframe consists of two consecutive slots in the time domain, and the ith subframe consists of slot 2i and slot 2i + 1. The time taken in sending one subframe is called a transmission time interval (TTI). For example, the length of one subframe may be 1 ms, and the length of one slot may be 0.5 ms.

[56] In FDD, uplink transmission and downlink transmission are distinguished in the frequency domain. There is no restriction in full duplex FDD; however, in half duplex FDD operation, a terminal cannot perform transmission and reception at the same time.

[57] One slot comprises a plurality of orthogonal frequency division multiplexing (OFDM) symbols in the time domain and comprises a plurality of resource blocks (RBs) in the frequency domain. Because 3GPP LTE uses OFDMA in downlink, an OFDM symbol is for expressing one symbol period. The OFDM symbol may also be called an SC-FDMA symbol or a symbol period. The resource block is a resource allocation unit and comprises a plurality of consecutive subcarriers in one slot.

[58] FIG. 1(b) shows a type 2 frame structure.

[59] A type 2 radio frame consists of two half frames each having a length of $153600*T_s = 5$ ms. Each half frame consists of five subframes each having a length of $30720*T_s = 1$ ms.

[60] In a type 2 frame structure of a TDD system, the uplink-downlink configuration is a rule that indicates how uplink and downlink are allocated (or reserved) with respect to all subframes.

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

[62] [Table 1]

Uplink-Downlink configu-ration	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] Referring to Table 1, for each subframe of the radio frame, "D" indicates a subframe for downlink transmission, "U" indicates a subframe for uplink transmission, and "S" indicates a special subframe that consists of three fields: a downlink pilot time slot (DwPTS), a guard period (GP), and an uplink pilot time slot (UpPTS).

[64] DwPTS is used for initial cell search, synchronization, or channel estimation by a terminal. UpPTS is used for a base station to perform channel estimation and for a terminal to synchronize uplink transmission. The GP is a period for removing interference between uplink and downlink that arises in an uplink owing to the multi-path delay of a downlink signal.

[65] Each subframe i consists of a slot 2i and a slot 2i + 1, each having length T_slot = 15360*T_s = 0.5 ms.

[66] Uplink-downlink configurations may be classified into seven types: the location and/or number of downlink subframes, special subframes, and uplink subframes differ for each type.

[67] A point in time when there is a switch from downlink to uplink or from uplink to downlink is called a switching point. Switch-point periodicity refers to a period in which a switch between an uplink subframe and a downlink subframe switch is repeated; 5 ms and 10 ms are both supported. In the case of a 5 ms downlink-uplink switch-point period, the special subframe S is present in each half frame; in the case of a 5 ms downlink-uplink switch-point period, the special subframe S is present only in the first half frame.

[68] In all seven configurations, the 0th and 5th subframes and the DwPTSs are periods for downlink transmission only. The UpPTSs, and subframes

immediately subsequent to the subframes are always periods for uplink transmission.

[69] Both the base station and the terminal may be aware of such uplink-downlink configurations as system information. Whenever uplink-downlink configuration information is changed, the base station may notify the terminal of a change in the uplink-downlink allocation state of a radio frame by sending only the index of the configuration information. In addition, configuration information is a kind of downlink control information; as in the case of scheduling information, configuration information may be transmitted through a physical downlink control channel (PDCCH) and may also be transmitted via a broadcast channel to all terminals within a cell as broadcast information.

[70] Table 2 shows a configuration of a special subframe (length of DwPTS/GP/UpPTS).

[71] [Table 2]

Special subframe configuration	Normal cyclic prefix in downlink			Extended cyclic prefix in downlink		
	DwPTS	UpPTS		DwPTS	UpPTS	
		Normal cyclic prefix in uplink	Extended cyclic prefix in uplink		Normal cyclic prefix in uplink	Extended cyclic prefix in uplink
0	$6592 \cdot T_s$	$2192 \cdot T_s$	$2560 \cdot T_s$	$7680 \cdot T_s$	$2192 \cdot T_s$	$2560 \cdot T_s$
1	$19760 \cdot T_s$			$20480 \cdot T_s$		
2	$21952 \cdot T_s$			$23040 \cdot T_s$		
3	$24144 \cdot T_s$			$25600 \cdot T_s$		
4	$26336 \cdot T_s$			$7680 \cdot T_s$	$4384 \cdot T_s$	$5120 \cdot T_s$
5	$6592 \cdot T_s$	$4384 \cdot T_s$	$5120 \cdot T_s$	$20480 \cdot T_s$		
6	$19760 \cdot T_s$			$23040 \cdot T_s$		
7	$21952 \cdot T_s$			–	–	–
8	$24144 \cdot T_s$			–	–	–

[72] The structure of the radio frame according to the example of FIG. 1 is merely illustrative; the number of subcarriers comprised in a radio frame, the number of slots comprised in a subframe, or the number of OFDM symbols contained in a slot may be changed in a variety of ways.

[73] FIG. 2 illustrates a resource grid for a downlink slot in a wireless communication system to which the present invention is applicable.

[74] Referring to FIG. 2, a downlink slot comprises a plurality of OFDM symbols in the time domain. For purposes of illustration, here, one downlink slot is described as comprising seven OFDM symbols, and one resource block is described as comprising 12 subcarriers in the frequency domain, but the invention is not limited thereto.

[75] Each element on the resource grid is referred to as a resource element; one resource block (RB) comprises 12x7 resource elements. The number of resource blocks contained in the downlink slot, N^DL, is subordinated to the downlink transmission bandwidth.

[76] The structure of the uplink slot may be the same as that of the downlink slot.

[77] FIG. 3 shows the structure of a downlink subframe in a wireless communication system

to which the present invention is applicable.

[78] Referring to FIG. 3, a maximum of three former OFDM symbols in the first slot of the subframe make up a control region to which control channels are allocated; the remaining OFDM symbols make up a data region to which a physical downlink shared channel (PDSCH) is allocated. Examples of downlink control channels used in 3GPP LTE include Physical Control Format Indicator Channels (PCFICH), Physical Downlink Control Channels (PDCCH), Physical Hybrid-ARQ Indicator Channels (PHICH), and the like.

[79] A PCFICH is transmitted in the first OFDM symbol of a subframe and carries information on the number of OFDM symbols used for transmitting control channels in the subframe (in other words, the size of the control region). A PHICH is a response channel to the uplink and carries an Acknowledgement (ACK)/Not-Acknowledgement (NACK) signal for a hybrid automatic repeat request (HARQ). Control information transmitted through a PDCCH is referred to as downlink control information (DCI). The downlink control information comprises uplink resource allocation information, downlink resource allocation information, or an uplink transmission (Tx) power control command for a given terminal group.

[80] A PDCCH may carry resource allocation and transmission format of a downlink shared channel (DL-SCH) (also called a downlink grant); resource allocation information of an uplink shared channel (UL-SCH) (also called an uplink grant); paging information in a paging channel (PCH); system information in the DL-SCH; resource allocation for an upper-layer control message, such as a random access response transmitted in the PDSCH; an aggregate of transmission power control commands for individual terminals in a given group; voice over IP (VoIP) activation; and the like. A plurality of PDCCHs may be transmitted in a control region, and a terminal may monitor the plurality of PDCCHs. A PDCCH is made up of an aggregate of one or a plurality of continuous control channel elements (CCEs). A CCE is a logical allocation unit used to provide a coding rate based on a state of a radio channel to the PDCCH. A CCE corresponds to a plurality of resource element groups. The PDCCH format and the number of usable PDCCH bits are determined based on a correlation between the number of CCEs and the coding rate provided by the CCEs.

[81] The base station determines the PDCCH format according to the DCI that is intended to be transmitted to the terminal and attaches a cyclic redundancy check (CRC) to the control information. The CRC is masked with a unique identifier (referred to as a radio network temporary identifier (RNTI)) based on the PDCCH's owner or purpose. In the case of a PDCCH for a particular terminal, the CRC may be masked with a unique identifier of the terminal, for example, a cell-RNTI (C-RNTI). Alternatively, in the case of a PDCCH for a paging message, the CRC may be masked with a paging indication identifier, such as a paging-RNTI (P-RNTI). In the case of a PDCCH for the system information—or more specifically, a system information block (SIB)—the CRC may be masked with a system information identifier or a system information

RNTI (SI-RNTI). To indicate the random access response, which is a response to transmission of a random access preamble by the terminal, the CRC may be masked with a random access RNTI (RA-RNTI).

[82] An enhanced PDCCH (EPDCCH) carries terminal-specific (UE-specific) signaling. An EPDCCH is located in a terminal-dedicated physical resource block (PRB). Thus, as described above, a PDCCH may be transmitted in a maximum of three OFDM symbols in the first slot of the subframe, but an EPDCCH may be transmitted in a resource region other than the PDCCH. The start time (in other words, the symbol) of the EPDCCH within the subframe may be configured in the terminal through higher layer signaling (such as RRC signaling or the like).

[83] An EPDCCH may carry transmission format, resource allocation, and HARQ information related to DL-SCH; transmission format, resource allocation, and HARQ information related to UL-SCH; resource allocation information related to a Sidelink Shared Channel (SL-SCH) and a Physical Sidelink Control Channel (PSCCH); and the like. Multiple EPDCCHs may be supported, and the terminal may monitor a set of EPCCHs.

[84] An EPDCCH may be transmitted using one or more consecutive enhanced CCEs (ECCEs), and the number of ECCEs per single EPDCCH may be specified for each EPDCCH format.

[85] Each ECCE may be made up of a plurality of resource element groups (EREGs: enhanced resource element group). EREGs are used to define the mapping of ECCEs to REs. There are 16 EREGs per PRB pair. Except for the REs that carry the DMRS within each PRB pair, all REs are numbered from 0 to 15 in order of increasing frequency and then in order of increasing time.

[86] A terminal may monitor a plurality of EPDCCHs. For example, one or two EPDCCH sets may be configured in one PRB pair in which the terminal monitors EPDCCH transmission.

[87] By merging different numbers of ECCEs, different coding rates can be realized for EPCCHs. An EPCCH may use localized transmission or distributed transmission, and the mapping of ECCEs to REs in the PRB may differ accordingly.

[88] FIG. 4 shows the structure of an uplink subframe in a wireless communication system to which the present invention is applicable.

[89] Referring to FIG. 4, the uplink subframe may be divided in the frequency domain into a control region and a data region. A physical uplink control channel (PUCCH) that carries uplink control information is allocated to the control region. A physical uplink shared channel (PUSCH) that carries user data is allocated to the data region. To maintain a single carrier characteristic, a single terminal does not transmit the PUCCH and the PUSCH at the same time.

[90] A resource block (RB) pair in the subframe is allocated to the PUCCH for one terminal. The RBs included in the RB pair occupy respectively different subcarriers in each of two slots. The RB pair allocated to the PUCCH is said to be frequency-hopping at the slot boundary.

[91]

[92] **Multi-Input Multi-Output (MIMO)**

[93] MIMO technology uses multiple transmitting (Tx) antennas and multiple receiving (Rx) antennas to break away from the heretofore conventional single transmitting antenna and single receiving antenna. In other words, MIMO technology is a technology for achieving increased capacity or enhanced performance by using a multiple input multiple output antenna on the transmitter side or the receiver side of the wireless communication system. "MIMO" will be referred to as "MIMO antenna."

[94] More specifically, MIMO antenna technology does not depend on a single antenna path in order to receive one total message and completes total data by collecting a plurality of data pieces received through a plurality of antennas. As a result, MIMO antenna technology may increase the data transfer rate within a particular system range and may also increase the system range via a particular data transfer rate.

[95] Because next-generation mobile communication requires a much higher data transfer rate than existing mobile communication, it is anticipated that an efficient MIMO antenna technology will be required. In such a situation, MIMO communication technology is a next-generation mobile communication technology that is capable of wide application in mobile communication terminals and relays and, due to the expansion of data communication, has attracted attention for its ability to overcome limitations on transmission in other forms of mobile communication.

[96] Among the various transmission efficiency improvement technologies researched in recent years, MIMO antenna technology has attracted the greatest attention in recent years as a method that may greatly improve communication capacity and transmission/ reception performance without additional frequency allocation or increased power.

[97] FIG. 5 is a configuration diagram for a conventional multi-input multi-output (MIMO) antenna communication system.

[98] Referring to FIG. 5, when the number of transmitting antennas increases to N_T and the number of receiving antennas increases to N_R at the same time, transfer rate may be improved and frequency efficiency may be greatly improved, because, unlike a case using a plurality of antennas only in the transmitter or in the receiver, the theoretical channel transmission capacity increases proportionally to the number of antennas. In this case, the transfer rate depending on an increase in channel transmission capacity may theoretically increase to a value obtained by multiplying a maximum transfer rate (R_o) in the one-antenna case by a rate increase rate (R_i) given below.

[99] [Equation 1]

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

[100] In other words, for example, in a MIMO communication system using four transmitting antennas and four receiving antennas, a transfer rate may be obtained that is four times higher than for a single antenna system.

[101] MIMO antenna technology of this kind may be divided into spatial diversity schemes that elevate transmission reliability by using symbols passed through various channel paths and spatial multiplexing schemes that improve the transfer rate by transmitting a plurality of data symbols at the same time using a plurality of transmitting antennas. In addition, there has recently been a great deal of research on schemes that seek to properly acquire respective advantages by appropriately combining these two schemes.

[102] The respective schemes will be described below in somewhat greater detail.

[103] First, spatial diversity schemes include space-time block code series and space-time trellis code series schemes that use diversity gain and coding gain at the same time. In general, trellis code schemes are excellent in bit error rate improvement performance and in the degrees of freedom for code generation, but space-time block code is simple in terms of operational complexity. In the case of such a spatial diversity gain, a quantity may be obtained that corresponds to a multiple ($N_T \times N_R$) of the number (N_T) of transmitting antennas and the number (N_R) of receiving antennas.

[104] Second, the spatial multiplexing technique is a method by which different data arrays are transmitted from the respective transmitting antennas; in this case, mutual interference occurs among data transmitted from the transmitter to the receiver at the same time. The receiver receives the data after using an appropriate signal processing technique to remove this interference. The noise removal schemes that may be used here include a maximum likelihood detection (MLD) receiver, a zero-forcing (ZF) receiver, a minimum mean square error (MMSE) receiver, diagonal-Bell Laboratories layered space-time (D-BLAST), vertical-Bell Laboratories layered space-time (V-BLAST), and the like; in particular, when channel information is knowable on the transmitter side, a singular value decomposition (SVD) scheme or the like may be used.

[105] Third, a technique may be used that combines spatial diversity and spatial multiplexing. If only spatial diversity gain is acquired, the performance enhancement gain as a function of an increase in diversity degree gradually becomes saturated; and if only spatial multiplexing gain is acquired, transmission reliability deteriorates in the radio channel. Schemes have been studied that acquire both gains while solving the problem; the schemes include space-time block code (Double-STTD), space-time BICM (STBICM), and the like.

[106] For the purpose of describing the communication method in the MIMO antenna system described above in greater detail, it may be mathematically modelled as indicated below.

[107] First, it is assumed that there are N_T transmitting antennas and N_R receiving antennas, as shown in FIG. 5.

[108] First, with respect to a transmission signal, if N_T transmitting antennas are provided, N_T may be expressed as the vector given below, because N_T is the maximum amount of

transmittable information.

[109] [Equation 2]

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

[110] Transmission power may differ for the respective transmission information s_1, s_2, s_N_T and in this case, when the respective transmission power is P_1, P_2, . . . , P_N_T, the transmission information with transmission power adjusted may be expressed as the vector given below.

[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] In addition, the transmission power-adjusted transmission information according to Equation 3 may be expressed as described below as a 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] The transmission power-adjusted information vector according to Equation 4 is multiplied by a weight matrix **W** to constitute N_T transmission signals x_1, x_2, . . . , x_N_T that are actually transmitted. The weight matrix here serves to appropriately distribute the transmission information to the respective antenna according to factors such as the transmission channel status. These transmission signals x_1, x_2, . . . , x_N_T may be expressed as follows, using vector x.

[115] [Formula 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] Therein, w_ij represents a weight between the ith transmitting antenna and the jth transmission information; and **W** represents this as a matrix. This matrix **W** is called a weight matrix or a precoding matrix.

[117] Dividing the above-described transmission signal x into transmission signals may be considered for a case using spatial diversity and a case using spatial multiplexing.

[118] In the spatial multiplexing case, all components of the information vector ***s*** have different values because different signals are multiplexed and sent; in contrast, in the spatial diversity

case, all components of the information vector ***s*** have the same value because the same signal is sent via a plurality of channel paths.

[119] Of course, it is also possible to consider a method that mixes spatial multiplexing and spatial diversity. Thus, for example, a case may also be considered in which the same signal is transmitted using spatial diversity via three transmitting antennas, and the remaining different signals are respectively spatially multiplexed and sent.

[120] Next, if the number of receiving antennas is N_R, then the received signals y_1, y_2, . . . , y_N_R of the respective antennas are expressed as a vector **y**, as follows.

[121] [Equation 6]

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

[122] If channels are modeled in a MIMO antenna communication system, the respective channels may be distinguished based on the transmitting/receiving antenna indexes; a channel passing through a receiving antenna i from a transmitting antenna j is represented as h_ij. Note here that the sequence of indexes in h_ij is such that the receiving antenna index is first and the transmitting antenna index is later.

[123] These channels can also be gathered into one and expressed in vector and matrix forms. An exemplary representation of the vector will be described below.

[124] FIG. 6 shows channels from a plurality of transmitting antennas to a single receiving antenna.

[125] A channel that arrives at receiving antenna i from a total of N_T transmitting antennas, as shown in FIG. 6, may be expressed as below.

[126] [Equation 7]

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

[127] In addition, all the channels passing through N_R receiving antennas from N_T transmitting antennas may be represented as below in the matrix form shown in Equation 7 above.

[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] In an actual channel, additive white Gaussian noise (AWGN) is added after passing through the channel matrix **H** given above, and thus the white noises n_1, n_2, . . . , n_N_R that are added to the respective N_R receiving antennas may be expressed in vector form as below.

[130] [Equation 9]

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

[131] Through modeling of the transmission signal, the reception signal, the channel, and the white noise as described above in the MIMO antenna communication system, these may be respectively expressed through a relationship given below.

[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] The number of rows and columns of the channel matrix **H**, which represents the status of the channel, is determined by the number of transmitting and receiving antennas. In the case of the channel matrix **H**, the number of rows is equivalent to N_R, which is the number of receiving antennas; the number of columns is equivalent to N_T, which is the number of transmitting antennas. In other words, the channel matrix **H** is an N_R x N_T matrix.

[134] In general, the rank of a matrix is defined as the least of the numbers of independent rows or independent columns. Accordingly, the rank of the matrix cannot be greater than the number of rows or columns. As an exemplary equation, the rank of the channel matrix **H** (*rank*(**H**)) is limited as follows.

[135] [Equation 11]

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

[136] In addition, when the matrix is subjected to eigenvalue decomposition, the rank may be defined as the number of eigenvalues that are nonzero. By a similar method, when the rank is subjected to singular value decomposition, the rank may be defined as the number of nonzero singular values. Therefore, a physical meaning of the rank of the channel matrix may be considered to be the maximum number of different information items that are able to be sent in a given channel.

[137] In the present specification, a "rank" for MIMO transmission represents the number of paths by which a signal may be independently transmitted at a particular point in time and in a particular frequency resource, and the "number of layers" represents the number of signal streams transmitted via each path. Unless specifically mentioned otherwise, "rank" has the same meaning as "number of layers" because, in general, the transmitter side transmits layers in a number corresponding to the rank number used for transmitting the signal.

[138]

[139] **Carrier aggregation**

[140] The communication environments considered in the embodiments of the present invention comprise all multi-carrier support environments. In other words, "multi-carrier system" or "carrier aggregation (CA) system" as used in the present invention refers to a system that aggregates and uses one or more component carriers (CCs) that, at the time of configuring a target wideband in order to support a wideband, have a bandwidth smaller than that of the target band.

[141] In the present invention, "multi-carrier" means an aggregation of carriers (or carrier aggregation), and "carrier aggregation" refers to both an aggregation among continuous carriers and an aggregation among non-contiguous carriers. In addition, the number of component carriers aggregated may be configured differently for downlink and uplink. If the number of downlink component carriers (hereinafter "DL CC") and the number of uplink component carriers (hereinafter "UL CC") are the same, this is referred to as a "symmetric aggregation"; if the number of downlink component carriers and the number of uplink component carriers are different, this is referred to as an "asymmetric aggregation." The term "carrier aggregation" may be used interchangeably with terms such as "bandwidth aggregation" or "spectrum aggregation."

[142] In an LTE-A system, carrier aggregation configured by combining two or more component carriers is intended to support a bandwidth of up to 100 MHz. If one or more carriers having a bandwidth smaller than the target band are combined, the bandwidth of the combined carriers may be limited to a bandwidth used in an existing IMT system in order to maintain backward compatibility with the existing system. For example, an existing 3GPP LTE system supports bandwidths of 1.4, 3, 5, 10, 15, and 20 MHz, and a 3GPP LTE-advanced (LTE-A) system may be configured to support a bandwidth greater than 20 MHz by using only these bandwidths for compatibility with the existing system. In addition, the carrier aggregation system used in the present invention may be designed to support carrier aggregation by defining a new bandwidth regardless of the bandwidth used in the existing system.

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

[144] The above-described carrier aggregation environment may be referred to as a multiple-cell environment. A cell is defined as a combination of a pair of a downlink resource (DL CCs) and an uplink resource (UL CC), but the uplink resource is not required. Therefore, a cell may be made up of a downlink resource alone, or both a downlink resource and an uplink resource. If a particular terminal has only one configured serving cell, the cell may have one DL CC and one UL CC, but if the particular terminal has two or more configured serving cells, it has as many DL CCs as cells, and the number of UL CCs may be equal to or less than the number of DL CCs.

[145] Alternatively, the DL CCs and UL CCs may be configured in the opposite way. In other words, if the particular terminal has a plurality of configured serving cells, a carrier aggregation

environment with more UL CCs than DL CCs may also be supported. Thus, carrier aggregation may be understood as aggregation of two or more cells having respectively different carrier frequencies (the central frequencies of the cells). "Cell" here needs to be distinguished from the ordinary use of the term "cell" to refer to an area covered by a base station.

[146] A cell used in an LTE-A system comprises a primary cell (PCell) and a secondary cell (SCell). P cells and S cells may be used as serving cells. In the case of a terminal that is in the RRC_CONNECTED state but does not have a configured carrier aggregation or does not support carrier aggregation, only one serving cell is present, consisting of the P cell alone. In contrast, in the case of a terminal that is in the RRC_CONNECTED state and has a configured carrier aggregation, one or more serving cells may be present and all serving cells comprise a P cell and one or more S cells.

[147] The serving cells (P cells or S cells) may be configured through an RRC parameter. PhysCellId is a physical-layer identifier of the cell and has integer values from 0 to 503. SCellIndex is a short identifier used for identifying the S cell and has integer values from 1 to 7. ServCellIndex is a short identifier used to identify the serving cell (P cell or S cell) and has integer values from 0 to 7. A value of 0 is applied to the P cell, and SCellIndex is pre-assigned for application to the S cell. Thus, the cell having the smallest cell ID (or cell index) in ServCellIndex becomes the P cell.

[148] "P cell" refers to a cell that operates on a primary frequency (or a primary CC). The terminal may be used to perform an initial connection establishment process or a connection reestablishment process and also to designate a cell indicated during a handover process. In addition, "P cell" refers to a cell that becomes the center of control-related communication among serving cells that have been configured in the carrier aggregation environment. In other words, the terminal may allocate and transmit a PUCCH in its own P cell only and may only use the P cell to acquire system information or change a monitoring procedure. In a terminal that supports a carrier aggregation environment, evolved universal terrestrial radio access (E-UTRAN) may also change only the P cell for the handover procedure using an RRC connection reconfiguration message (RRCConnectionReconfiguration) of an upper layer that comprises mobility control information (mobilityControlInfo).

[149] "S cell" may refer to a cell that operates on a secondary frequency (or secondary CC). It may be the case that one P cell and one or more S cells are allocated to a particular terminal. An S cell may be configured after RRC connection establishment and may be used to provide an additional radio resource. Among the serving cells configured in the carrier aggregation environment, there is no PUCCH in the remaining cells other than the P cell, namely, the S cells. When S cells are added to a terminal that supports the carrier aggregation environment, E-UTRAN may provide all system information associated with the operation of an associated cell that is in an RRC_CONNECTED state through a dedicated signal. A change of the system information may be controlled by releasing and adding the associated S cell; in this case, an

upper-layer RRC connection reconfiguration message (RRCConnectionReconfiguration) may be used. In E-UTRAN, instead of broadcasting in the relevant S cell, dedicated signaling may be carried out with different parameters for each terminal.

[150] After an initial security activation process has started, the E-UTRAN is able to configure a network that comprises one or more S cells added to a P cell initially configured in the connection establishment process. In a carrier aggregation environment, the P cell and S cells may operate as the respective component carriers. In the embodiments described below, "primary component carrier" (PCC) may be used with the same meaning as P cell, and "secondary component carrier" (SCC) may be used with the same meaning as S cell.

[151] FIG. 7 shows an exemplary embodiment of component carriers and a carrier aggregation in a wireless communication system to which the present invention is applicable.

[152] FIG. 7(a) illustrates a single-carrier structure used in an LTE system. The component carriers comprise a DL CC and a UL CC. A single component carrier may have a frequency range of 20 MHz.

[153] FIG. 7(b) illustrates a carrier aggregation structure used in an LTE-A system. FIG. 7(b) shows a case in which three component carriers having a frequency magnitude of 20 MHz are combined. There are three DL CCs and three UL CCs respectively, but there is no limit on the number of DL CCs and the number of UL CCs. In the case of carrier aggregation, the terminal may monitor three CCs at the same time and may receive downlink signals/data and transmit uplink signals/data.

[154] If there are N DL CCs being managed in a particular cell, the network may allocate M ($M \leq N$) DL CCs to the terminal. In this case, the terminal is able to monitor only the M limited DL CCs and receive DL signals. In addition, the network may give priority to L ($L \leq M \leq N$) DL CCs to allocate a primary DL CC to the terminal; in this case, the UE must monitor the L DL CCs. Such a scheme is applicable in the same way to uplink transmission.

[155] A linkage between a carrier frequency (or DL CC) of the downlink resource and a carrier frequency (or UL CC) of the uplink resource may be indicated by an upper-layer message such as an RRC message or by the system information. For example, a combination of the DL resource and the UL resource may be configured by a linkage defined by system information block type 2 (SIB2). Specifically, "linkage" may refer to a mapping relationship between a DL CC, which transmits a PDCCH that carries a UL grant, and a UL CC that uses the UL grant; and it may also refer to a mapping relationship between the DL CC (or UL CC) in which data for HARQ is transmitted and the UL CC (or DL CC) in which a HARQ ACK/NACK signal is transmitted.

[156] If one or more S cells are configured in a terminal, the network may activate or deactivate the configured S cell(s). The P cell is always activated. The network activates or deactivates the

S cell(s) by transmitting an activation/deactivation MAC control element.

[157] The activation/deactivation MAC control element has a fixed size and consists of a single octet comprising seven C-fields and one R-field. A C-field is configured for each S cell index (SCellIndex), and indicates the activation/deactivation state of the S cell. If the value of the C-field is set to "1," it indicates that the S cell with the corresponding S cell index is activated; and if the value of the C-field is set to "0," it indicates that the S cell with the corresponding S cell index is deactivated.

[158] In addition, the terminal maintains a timer for each configured S cell (sCellDeactivationTimer) and deactivates the associated S cell when the timer expires. The same initial timer value is applied to each instance of the timer (sCellDeactivationTimer) and is configured by RRC signaling. When S cell(s) are added or after handover, the initial S cell(s) are in a deactivated state.

[159] The terminal carries out the following operations on each of the respective S cell(s) configured in each TTI.

[160] - If the terminal receives an activation/deactivation MAC control element that activates an S cell in a particular TTI (subframe n), the terminal activates the S cell in a TTI (subframe n + 8 or thereafter) corresponding to a predetermined timing and starts (or restarts) the timer associated with the S cell. The terminal activating the S cell means that the terminal applies a routine S cell operation, such as transmitting a sounding reference signal (SRS), reporting a channel quality indicator (CQI)/precoding matrix indicator (PMI)/rank indication (RI)/precoding type indicator (PTI) for the S cell, monitoring a PDCCH in the S cell, and monitoring a PDCCH for the S cell.

[161] - If the terminal receives an activation/deactivation MAC control element that deactivates an S cell in a particular TTI (subframe n), or if a timer associated with a particular TTI (subframe n)-activated S cell expires, the terminal deactivates the S cell in the corresponding TTI (subframe n + 8 or later) on a predetermined timing, stops the timer of the S cell, and flushes all HARQ buffers associated with the S cell.

[162] - If a PDCCH in an activated S cell indicates an uplink grant or downlink assignment or a PDCCH in a serving cell that schedules the activated S cell indicates an uplink grant or downlink assignment for the activated S cell, the terminal restarts the timer associated with the S cell.

[163] - If the S cell is deactivated, the terminal does not transmit an SRS in the S cell, does not report a CQI/PMI/RI/PTI for the S cell, does not transmit an UL-SCH in the S cell, and does not monitor a PDCCH in the S cell.

[164]

[165] <u>Random access procedure</u>

[166] Below, a random access procedure provided by an LTE/LTE-A system

is described.

[167] A random access procedure is used for a terminal to obtain uplink synchronization with a base station or to have uplink radio resources allocated to it. After the terminal is powered on, the terminal obtains downlink synchronization with an initial cell and receives system information. From the system information, the terminal obtains information about a set of available random access preambles and radio resources used for transmitting a random access preamble. The radio resources used for transmitting the random access preamble may be specified as a combination of one or more subframe indexes and an index in the frequency domain. The terminal transmits a random access preamble randomly selected from the set of random access preambles, and a base station that has received the random access preamble sends a timing alignment (TA) value for uplink synchronization to the terminal via a random access response. The terminal obtains uplink synchronization as a result.

[168] Random access procedures are common to frequency division duplexing (FDD) and time division duplexing (TDD). Random access procedures are not related to a cell size and are also not related to the number of serving cells if carrier aggregation (CA) has been configured.

[169] First, cases in which a terminal may perform a random access procedure include the following.

[170] - The terminal performs initial access in an RRC idle state because it does not have an RRC connection with a base station

[171] - The terminal performs an RRC connection reestablishment procedure

[172] - The terminal accesses a target cell for the first time in a handover process

[173] - The random access procedure is requested by a command from a base station

[174] - During the RRC connection state there is data to be transmitted via downlink in an uplink non-synchronized state

[175] - During the RRC connection state, there is a data to be transmitted via uplink in an uplink non-synchronized state or in a state in which the designated radio resources used to request radio resources have not been allocated

[176] - During the RRC connection state, positioning of the terminal is performed in a state in which timing advance is necessary

[177] - A recovery process is performed when a radio link failure or handover failure occurs

[178] 3GPP Rel-10 considered applying a timing advance (TA) value applicable to one particular cell (such as a P cell) to a plurality of cells in common in a radio access system supporting carrier aggregation. However, a terminal may aggregate a plurality of cells in different frequency bands (namely, greatly spaced in the frequency) or a plurality of cells having different propagation characteristics. In addition, in the case of a particular cell, if a remote radio header (RRH) (i.e., repeater), a small cell such as a femto

cell or a pico cell, or a secondary base station (SeNB) has been disposed within the cell, the plurality of cells may have different delay properties if the terminal communicates with a base station (i.e., a macro eNB) via one cell and communicates with a secondary base station (SeNB) through another cell in order to expand coverage or remove a coverage hole. In this case, if the terminal performs uplink transmission using a scheme of applying one TA value to a plurality of cells, this may have a severe impact on the synchronization of an uplink signal transmitted in the plurality of cells. Accordingly, it may be preferable for a plurality of TAs to be used in a CA state in which a plurality of cells have been aggregated; 3GPP Rel-11 considers independently allocating TAs for each particular cell group as a unit. This is referred to as a TA group (TAG); a TAG may include one or more cells, and the same TA is applicable to one or more cells included in a TAG. In order to support such multiple TAs, an MAC TA command control element consists of a 2-bit TAG identifier (ID) and a 6-bit TA command field.

[179] If a terminal in which carrier aggregation has been configured carries out the above-described random access procedure in relation to a P cell, a random access procedure is carried out. In the case of the TAG to which the P cell belongs (i.e., the primary TAG (pTAG)), in the same manner as conventionally, a TA that has been determined based on the P cell or has been adjusted via a random access procedure accompanying the P cell is applicable to all cell(s) in the pTAG. In contrast, in the case of a TAG made up of only S cells (namely, a secondary TAG (sTAG)), a TA determined with respect to a particular S cell within the sTAG is applicable to all cell(s) within the corresponding sTAG; in this case, the TA may be obtained by a random access procedure started by the base station. Specifically, the S cell is configured as a random access channel (RACH) resource within the sTAG, and the base station requests RACH access in the S cell in order to determine the TA. In other words, the base station initiates RACH transmission in the S cells in response to a PDCCH order transmitted in the P cell. A response message for an S cell preamble is transmitted via a P cell using an RA-RNTI. The terminal may apply a TA, which has been determined based on an S cell to which random access has been successfully completed, to all the cell(s) within the corresponding sTAG. In this manner, the random access procedure may be performed in an S cell as well in order to obtain the timing alignment of an sTAG to which the S cell belongs.

[180] In a process of selecting a random access preamble (RACH preamble) in an LTE/LTE-A system, there are provided both: a contention-based random access procedure for a terminal to randomly select one preamble from a particular set and use the selected preamble; and a non-contention-based random access procedure for using a random access preamble allocated only to a particular terminal by a base station. In this case, the non-contention-based random access procedure may be used for only terminal positioning and/or timing advance alignment for an sTAG, if so requested in the above-described handover process or in response to a command

from the base station. After the random access procedure has been completed, a routine uplink/downlink transmission occurs.

[181] A relay node (RN) also supports both a contention-based random access procedure and a non-contention-based random access procedure. When the relay node carries out a random access procedure, it suspends the RN subframe configuration at that point in time. In other words, it temporarily discards the RN subframe configuration. Subsequently, at the point in time at which a random access procedure is completed successfully, the RN subframe configuration is restarted.

[182] FIG. 8 is a diagram for illustrating a contention-based random access procedure in a wireless communication system to which the present invention is applicable.

[183] (1) First message (Msg 1, message 1)

[184] To begin with, the terminal randomly selects a random access preamble (RACH preamble) from a set of random access preambles indicated via system information or a handover command, and selects and transmits a PRACH (physical RACH) resource that is able to transmit the random access preamble.

[185] The random access preamble is transmitted as six bits in an RACH transport channel; the 6 bits consist of a random identifier (random identity) of five bits for identifying the terminal that has transmitted the RACH and one bit for indicating additional information (for example, indicating the size of a third message Msg3).

[186] A base station that has received the random access preamble from the terminal decodes the random access preamble and obtains an RA-RNTI. The RA-RNTI associated with the PRACH in which the random access preamble has been transmitted is determined by the time-frequency resource of the random access preamble that the terminal transmitted.

[187] (2) Second message (Msg 2, message 2)

[188] The base station transmits to the terminal a random access response, addressed by the RA-RNTI obtained via the preamble of the first message. The random access response may comprise a random access (RA) preamble index/identifier, an uplink (UL) grant providing notification of uplink radio resources, a temporary cell identifier (TC-RNTI), and a time alignment command (TAC). The TAC is information that indicates a time alignment value that is transmitted from the base station to the terminal in order to maintain an uplink time alignment. The terminal uses the time alignment value to update an uplink transmission timing. When the terminal updates the time alignment, it starts or restarts a time alignment timer. The UL grant comprises an uplink resource allocation, which is used for transmitting a scheduling message (third message) described below, and a transmit power command (TPC). The TPC is used to determine the transmission power for a scheduled PUSCH.

[189] After transmitting the random access preamble, the terminal attempts to receive its own random access response within a random access response window indicated by the base station via system information or a handover command by detecting a PDCCH masked with an RA-RNTI corresponding to the PRACH and receiving a PDSCH indicated by the detected PDCCH. Information about the random access response may be transmitted in the form of a MAC PDU (packet data unit), and the MAC PDU may be sent via the PDSCH. The PDCCH preferably comprises: information about the terminal that is intended to receive the PDSCH; information about the frequency and time of the radio resources of the PDSCH; the transmission format of the PDSCH; and the like. As described above, once the terminal has successfully detected the PDCCH transmitted to it, it may suitably receive the random access response transmitted via the PDSCH, based on the PDCCH information.

[190] The random access response window refers to a maximum time period during which the terminal that transmitted the preamble waits to receive a random access response message. The random access response window has a length "ra-ResponseWindowSize" that starts from a subframe following three subframes from the last subframe in which the preamble is transmitted. In other words, the terminal waits to receive the random access response during a secured random access window starting three subframes after the subframe in which the preamble has been transmitted. The terminal may obtain the parameter value of a random access window size "ra-ResponseWindowsize" via the system information, and the random access window size may be determined as a value from 2 to 10.

[191] When the terminal successfully receives a random access response having the same random access preamble index/identifier as the random access preamble transmitted to the base station, it stops monitoring for the random access response. In contrast, if a random access response message has not been received by the time the random access response window is terminated or a valid random access response has not been received that has the same random access preamble index as the random access preamble transmitted to the base station, the random access response reception is considered to have failed, and the terminal may then retransmit the preamble.

[192] As described above, the reason the random access preamble index is necessary for the random access response is to provide notification that the UL grant, the TC-RNTI, and the TAC are valid for a given terminal because a single random access response may comprise random access response information for one or more terminals.

[193] (3) Third message (Msg 3, message 3)

[194] When the terminal receives a valid random access response, it processes each respective item of information comprised in the random access response. In other words, the terminal applies the TAC to each of the pieces of information and stores a TC-RNTI. In addition, the terminal uses the UL grant to send either data that is stored in the buffer of the terminal or newly generated data to the base station. In the case of a first connection by the terminal, an RRC connection request generated in the RRC layer and sent via a CCCH may be included in the third

message and transmitted; in the case of an RRC connection reestablishment procedure, an RRC connection reestablishment request generated in the RRC layer and transferred via a CCCH may be included in the third message and transmitted. In addition, the third message may comprise an NAS connection request message.

[195] The third message must comprise an identifier of the terminal. In a contention-based random access procedure, the base station is unable to determine which terminals perform the random access procedure; this is because the terminal must be identified in order to subsequently perform a collision resolution.

[196] There are two methods of including the terminal identifier. In the first method, if the terminal has already had a valid cell identifier (C-RNTI) allocated in the relevant cell prior to a random access procedure, the terminal sends its own cell identity via an uplink transmission signal that corresponds to the UL grant. In contrast, if a valid cell identity has not been allocated to the terminal prior to the random access procedure, the terminal sends an uplink transmission signal that comprises its own unique identifier (such as an S-TMSI or a random number). In general, the unique identifier is longer than a C-RNTI. In transmission on a UL-SCH, terminal-specific scrambling is used. However, if a C-RNTI has not been allocated to the terminal, the scrambling cannot be based on the C-RNTI, and instead a TC-RNTI is used that has been received in the random access response. If the terminal has transmitted data corresponding to the UL grant, a timer for a collision resolution (a contention resolution timer) is started.

[197] (4) Fourth message (Msg 4, message 4)

[198] When the base station has received the C-RNTI of the relevant terminal via the third message from the terminal, it transmits a fourth message to the terminal using the received C-RNTI. In contrast, when the base station has received a unique identifier (such as an S-TMSI or random number) via the third message from the terminal, it transmits the fourth message to the terminal using a TC-RNTI allocated to the corresponding terminal in a random access response. In this case, the fourth message may correspond to an RRC connection setup message that comprises a C-RNTI.

[199] After the terminal has transmitted data comprising its own identifier via the UL grant included in the random access response, it awaits an instruction from the base station for a collision resolution. In other words, the terminal attempts to receive a PDCCH in order to receive a particular message. There are also two methods for receiving a PDCCH. As mentioned above, in the third message transmitted in response to the UL grant, if the terminal's own identifier is a C-RNTI, then the terminal attempts to receive a PDCCH using its C-RNTI; if the identifier is a unique identifier (namely, an S-TMSI or a random number), then the terminal attempts to receive a PDCCH using a TC-RNTI included in the random access response. Next, in the former case, if the terminal has received a PDCCH through its own C-RNTI before a collision resolution timer expires, then the terminal determines that the random access procedure has been carried out normally and terminates the random access procedure. In the latter case, if a PDCCH has been received via a TC-RNTI before the collision resolution timer has expired, then the terminal

checks data in which a PDSCH indicated by the PDCCH is transferred. If the terminal's own unique identifier has been included in the content of the data, the terminal determines that the random access procedure has been carried out normally and terminates the random access procedure. The terminal obtains a C-RNTI through a fourth message; subsequently, the terminal and network transmit/receive a terminal-dedicated message using the C-RNTI.

[200] Below, a method for collision resolution in random access is described.

[201] The reason a collision occurs in random access is that the number of random access preambles is fundamentally limited. That is, because a base station cannot assign every terminal a random access preamble unique to the terminal, the terminal randomly selects one of the shared random access preambles and transmits the selected random access preamble. It may therefore occur that, although two or more terminals select the same random access preamble and send it through the same radio resource (PRACH resource), the base station determines the received random access preambles to be one random access preamble transmitted by one terminal. The base station consequently transmits a random access response to the terminal and expects that the random access response will be received by one terminal. But because a collision may occur as described above, two or more terminals will receive one random access response, and thus the base station will carry out an operation for each terminal based on the reception of each respective random access response. In other words, the problem arises that two or more terminals transmit different data in the same radio resources using a single UL grant included in the random access response. As a result, the transmission of all the data may fail, or the base station may receive only the data of a particular terminal, depending on the location or transmission power of the terminals. In the latter case, because each of the two or more terminals assumes that the transmission of its own data was successful, the base station must report the failure to the terminals that have failed in contention. Thus, this provision of information about the failure or success of contention is called collision resolution (or contention resolution).

[202] There are two methods for collision resolution: in one method, a collision resolution timer is used, and in the other method, the identifier of the successful terminal is transmitted to the terminals. The first of these is used when a terminal already has a unique C-RNTI prior to the random access process. In other words, the terminal that already has the C-RNTI transmits data comprising its C-RNTI to a base station in response to a random access response and actuates a collision resolution timer. In addition, when PDCCH information indicated by its own C-RNTI is received before the collision resolution timer expires, the terminal determines that it was successful in the contention and ends random access normally. In contrast, if the terminal does not receive a PDCCH indicated by its own C-RNTI before the collision resolution timer expires, the terminal determines that it failed in the contention; it may carry out a random access process again or it may notify a higher layer of the failure. The latter of the two collision resolution methods, namely, the method of transmitting the identifier of the successful terminal, is used if a

terminal does not have a unique cell identifier prior to the random access process. In other words, if the terminal does not have its own cell identifier, the terminal transmits data comprising an identifier (or an S-TMSI or a random number) higher than the cell identifier, based on UL grant information included in the random access response, and actuates a collision resolution timer. If data comprising the terminal's own higher identifier is transmitted via the DL-SCH before the collision resolution timer expires, the terminal determines that the random access process has succeeded. In contrast, if data including its own higher identifier is not transmitted and received via the DL-SCH before the collision resolution timer expires, the terminal determines that the random access process has failed.

[203] In contrast to the operation of the contention-based random access procedure shown in FIG. 8, operation in a non-contention-based random access procedure is terminated by the transmission of the first message and the second message alone. However, before a terminal transmits a random access preamble to a base station as the first message, the base station allocates the random access preamble to the terminal, and the terminal sends this allocated random access preamble to the base station as the first message and receives a random access response from the base station, whereupon the random connection procedure ends.

[204]

[205] **Reference signal (RS)**

[206] In wireless communication systems, because data is transmitted over a radio channel, signals may be distorted during transmission. For the receiver side to accurately receive a distorted signal, the distortion of the received signal needs to be corrected using channel information. The principal methods used for detecting channel information are: a signal transmission method in which both the transmitting side and the receiving side are known, and a method of detecting channel information using a degree of distortion when the signal is transmitted through the channel. The above-mentioned signal is referred to as a pilot signal or a reference signal (RS).

[207] In addition, when packets are transmitted in the majority of recent mobile communication systems, a method is used by which transmission/reception data efficiency may be improved by adopting a plurality of transmitting antennas and a plurality of receiving antennas, instead of a single transmitting antenna and a single receiving antenna. When data is transmitted and received using MIMO antennas, in order to receive a signal accurately, a channel state between the transmitting antennas and the receiving antennas needs to be detected. Therefore, the respective transmitting antennas must have individual reference signals.

[208] RSs in wireless communication systems may be broadly categorized into two types based on their purpose. There are RSs for the purpose of acquiring channel information and RSs that are used for data demodulation. Because the purpose of the former is for a UE to acquire channel information in downlink, they must be transmitted in wideband; even if the UE does not receive downlink data in a particular subframe, it must be able to receive and measure the RSs. They are also used for measuring a handover or the like. The latter are RSs sent together with a resource when a base station sends a downlink; if a UE receives the corresponding reference signal, then the UE is able to perform channel estimation and therefore may

demodulate the data. Such an RS must be transmitted in the domain in which the data is transmitted.

[209] Downlink reference signals include: common reference signals (common RS, CRS) shared by all terminals for acquiring information on channel state and performing measurements associated with handover or the like; and dedicated reference signals (DRS) used for a data demodulation for only a particular terminal. Information for demodulation and channel measurement may be provided by using such reference signals. In other words, a DRS is used only for demodulating data, and a CRS is used for two purposes: acquiring channel information and demodulating data.

[210] The receiving side (namely, the terminal) measures the channel state based on the CRS and feeds back the indicators associated with the channel quality, such as the channel quality indicator (CQI), the precoding matrix index (PMI), and/or the rank indicator (RI) to the transmitting side (namely, the base station). The CRS is also referred to as a cell-specific RS. On the contrary, a reference signal associated with feedback of channel-state information (CSI) may be defined as CSI-RS.

[211] The DRS may be transmitted via resource elements when data demodulation on the PDSCH is required. The terminal may receive whether the DRS is present through the higher layer and whether the DRS is valid only when the corresponding PDSCH is mapped. The DRS may be referred to as a terminal-specific reference signal (UE-specific RS) or a demodulation RS (DMRS).

[212] FIG. 9 illustrates a reference signal pattern mapped to a downlink resource block pair in a wireless communication system to which the present invention is applicable.

[213] Referring to FIG. 9, a downlink resource block pair, as a unit in which a reference signal is mapped, may be represented by one subframe in the time domain x 12 subcarriers in the frequency domain. Thus, on the time axis (x-axis), a resource block pair has a length of 14 OFDM symbols in the case of a normal cyclic prefix (CP) (as in FIG. 9(a)) and has a length of 12 OFDM symbols in the case of an extended cyclic prefix (CP) (as in FIG. 9(b)). The resource elements (REs) represented as "0," "1," "2," and "3" in the resource block lattice refer to the positions of the CRSs of the respective antenna port indexes "0," "1," "2," and "3," and the resource elements represented as "D" refers to the position of the DRS.

[214] The CRS is described in somewhat greater detail below; a CRS is used to estimate a channel of a physical antenna and is distributed in an entire frequency band as a reference signal that may be commonly received by all terminals located in a cell. In other words, the CRS is transmitted over broadband in each subframe as a cell-specific signal. In addition, the CRS may be used for channel quality information (CSI) and data demodulation.

[215] The CRS is defined as various formats according to an antenna array on the transmitting side (base station). The RSs are transmitted for a maximum of four antenna ports based on the number of transmitting antennas of a base station in the 3GPP LTE system (for example, release-8). The downlink signal transmitting side has three types of antenna arrays: a single transmitting antenna, two transmitting antennas, and four transmitting antennas. For example, if the number of transmitting antennas of a base

station is two, CRSs are transmitted for antenna ports 0–1, and if the number of transmitting antennas is four, CRSs are transmitted for antenna ports 0–3, respectively. If the number of transmitting antennas of the base station is four, the CRS pattern is as shown in FIG. 9.

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

[217] If the base station uses two transmitting antennas, reference signals for two transmitting antenna ports are arrayed by using a time division multiplexing (TDM) scheme and/or a frequency division multiplexing (FDM) scheme. In other words, different time resources and/or different frequency resources are allocated to the respective reference signals for two antenna ports so that the antenna ports are distinguished from each other.

[218] Additionally, if the base station uses four transmitting antennas, then reference signals for four transmitting antenna ports are arrayed using a TDM and/or FDM scheme. Channel information measured by a downlink signal receiving side (terminal) may be used to demodulate data transmitted using a transmission scheme such as single transmitting antenna transmission, transmission diversity, closed-loop spatial multiplexing, open-loop spatial multiplexing, or multi-user MIMO.

[219] If MIMO antennas are supported, when a reference signal is transmitted from a particular antenna port, the reference signal is transmitted to the positions of particular resource elements according to a pattern of the reference signal, and is not transmitted to the positions of the particular resource elements for another antenna port. In other words, reference signals do not overlap among different antennas.

[220] Below, DRSs will be described in somewhat greater detail; DRSs are used for demodulating data. The precoding weights used for a particular terminal in MIMO antenna transmission are used unchanged to estimate a corresponding channel coupled with a transport channel transmitted from each transmitting antenna when the terminal has received a reference signal.

[221] A 3GPP LTE system (for example, release-8) supports up to a maximum of four transmitting antennas, and a DRS for rank 1 beamforming is defined. A DRS for rank 1 beamforming also indicates a reference signal for antenna port index 5.

[222] In an LTE-A system, which is an advanced version of an LTE system, a base station must be designed to support a maximum of eight transmitting antennas for downlink. Accordingly, RSs for a maximum of eight transmitting antennas must also be supported. Because downlink RSs are defined for a maximum of four antenna ports in an LTE system, if a base station has at least four and a maximum of eight downlink transmitting antennas in an LTE-A system, the reference signals for these antenna ports must be defined and designed additionally. The RSs for a maximum of eight transmitting antenna ports must be designed for two kinds of reference signals, namely, the above-described RSs for channel measurement and RSs for data demodulation.

[223] Backward compatibility is an important consideration in designing LTE-A systems; namely, an LTE terminal should operate normally without problems in an LTE-A system as well, and the

LTE-A system should also support this. From the RS transmission standpoint, RSs for a maximum of eight transmitting antenna ports should additionally be defined in the time-frequency domain in which a CRS defined in LTE is transmitted in the entire band of each subframe. In the LTE-A system, if reference signal patterns for a maximum of eight transmitting antennas are added to the full band for each subframe according to the same scheme as the CRS of a conventional LTE system, the RS overhead becomes excessive.

[224] Accordingly, the RSs newly designed in LTE-A systems may be divided into two kinds: channel-state information-RS (CSI-RS, or channel state indication-RS) for the purpose of channel measurement for selecting MCS, PMI and the like; and data demodulation-RS (DM-RS) for demodulating data transmitted via eight transmitting antennas.

[225] A CSI-RS for the purpose of channel measurement is characterized in that it is designed principally for the purpose of channel measurement, unlike a conventional CRS that is used at the same time for purposes such as channel measurement or handover measurement, and for data demodulation. Of course, it may also be used for purposes of measuring handover and the like. Because the CSI-RS is transmitted only for the purpose of obtaining channel-state information, it need not be transmitted in each subframe, unlike the CRSs. To reduce overhead, the CSI-RS is intermittently transmitted on the time axis.

[226] A DM-RS is exclusively (dedicatedly) transmitted to a UE that is scheduled for data demodulation in the corresponding time-frequency domain. In other words, the DM-RS of a particular UE is only transmitted in the domain in which the UE is scheduled, i.e., the time-frequency domain in which data is received.

[227] In an LTE-A system, an eNB must transmit CSI-RSs for all antenna ports. Because transmitting CSI-RSs for a maximum of eight transmitting antenna ports in every subframe has the drawback of excessive overhead, to reduce such overhead, the CSI-RSs should be transmitted intermittently on the time axis. Thus, CSI-RSs may be transmitted periodically at every integer multiple of a subframe, or in a particular transmission pattern. In this case, an eNB may configure the period or pattern of CSI-RS transmission.

[228] To measure CSI-RSs, a UE must know information for each of respective CSI-RS antenna ports in the cell to which it belongs, such as information relating to the transmission subframe index, the time-frequency position of the CSI-RS resource element (RE) in the transmission subframe, and the CSI-RS sequence.

[229] In an LTE-A system, an eNB must transmit a respective CSI-RS for a maximum of eight antenna ports. The resources used for transmitting the CSI-RSs of different antenna ports must be orthogonal to one another. When an eNB transmits CSI-RS for different antenna ports, by mapping the CSI-RS for each respective antenna port to a different RE, the resources may be orthogonally allocated in an FDM/TDM scheme. Alternatively, CSI-RSs for different antenna ports may be transmitted

in a CDM scheme in which they are mapped to mutually orthogonal codes.

[230] When an eNB provides CSI-RS-related information to a UE in its own cell, information regarding the time-frequency in which the CSI-RS for each antenna port is mapped must be provided. Specifically, such information includes subframe numbers on which the CSI-RS is transmitted, the period of the CSI-RS being transmitted, the subframe offset in which the CSI-RS is transmitted, the OFDM symbol number in which the CSI-RS RE of a particular antenna is transmitted, the frequency spacing, and the offset or shift value of the RE on the frequency axis.

[231] The CSI-RS is transmitted via 1, 2, 4 or 8 antenna ports. In this case, the antenna ports that are used are respectively p = 15, p = 15,16, p = 15, . . . , 18, or p = 15, . . . , 22. The CSI-RS may be defined only for the subcarrier interval $\Delta f = 15$ kHz.

[232] The conditions (k′, l′) (where k′ is a subcarrier index in a resource block, and l′ represents an OFDM symbol index in a slot) and n_s are determined according to the CSI-RS configuration shown in Table 4 or Table 5 below.

[233] Table 3 illustrates the mapping of (k′, l′) in a conventional CP according to a CSI-RS configuration.

[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′) according to a CSI-RS configuration for an extended CP.

[236] [Table 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] Referring to Table 3 and Table 4, in CSI-RS transmission, different configurations are defined with a maximum of 32 (for a normal CP) or a maximum 28 (for an extended CP) in order to decrease the inter-cell interference (ICI) in a multi-cell environment comprising a heterogeneous network (HetNet) environment.

[238] CSI-RS configurations differ depending on the number of antenna ports in a cell and the CP; adjacent cells may have as many different configurations as possible. In addition, CSI-RS configurations may be divided into cases of application to both an FDD frame and a TDD frame and application to a TDD frame only.

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

[240] FIG. 10 shows CSI-RS configurations in a wireless communication system to which the present invention is applicable.

[241] FIG. 10(a) shows 20 CSI-RS configurations that may be used in CSI-RS transmission by one or

two CSI-RS antenna ports; FIG. 10(b) shows 10 CSI-RS configurations that may be used by four CSI-RS antenna ports; and FIG. 10(c) shows five CSI-RS configurations that may be used for CSI-RS transmission by eight CSI-RS antenna ports.

[242] In this manner, the radio resource (namely, the RE pair) in which the CSI-RS is transmitted is determined based on the respective CSI-RS configuration.

[243] When one or two CSI-RS antenna ports are configured for transmitting the CSI-RS for a particular cell, the CSI-RS is transmitted on the radio resource according to the CSI-RS configuration, from among the 20 CSI-RS configurations shown in FIG. 10(a), that has been configured.

[244] Similarly, when four CSI-RS antenna ports are configured for transmitting the CSI-RS for a particular cell, the CSI-RS is transmitted on the radio resource according to the CSI-RS configuration, from among the ten CSI-RS configurations shown in FIG. 10(b), that has been configured. In addition, when eight CSI-RS antenna ports are configured for transmitting the CSI-RS for a particular cell, the CSI-RS is transmitted on the radio resource according to the CSI-RS configuration, from among five CSI-RS configurations shown in FIG. 10(c), that has been configured.

[245] The CSI-RS for each respective antenna port is CDM'd and transmitted to the same radio resource for each pair of antenna ports (namely, {15,16}, {17,18}, {19,20}, {21,22}). Taking antenna ports 15 and 16 by way of example, although the CSI-RS complex symbols are the same for antenna ports 15 and 16, respectively, the CSI-RS complex symbols are multiplied by different orthogonal codes (such as Walsh codes) and are mapped to the same radio resource. The complex symbol of the CSI-RS for antenna port 15 is multiplied by [1, 1] and the complex symbol of the CSI-RS for antenna port 16 is multiplied by [1, –1], and the complex symbols are mapped to the same radio resource. This procedure is identical for antenna ports {17,18}, {19,20}, and {21,22}.

[246] A UE may detect the CSI-RS for a particular antenna port by multiplying a code that has been multiplied by the transmitted symbol. Thus, to detect the CSI-RS for antenna port 15, the multiplied code is multiplied by [1 1], and, to detect the CSI-RS for antenna port 16, the multiplied code is multiplied by [1 −1].

[247] Referring to FIGS. 10(a) to 10(c), if the same CSI-RS configuration index corresponds to two radio resources, then a radio resource according to a CSI-RS configuration with a large number of antenna ports comprises a radio resource according to a CSI-RS configuration with a small number of antenna ports. For example, in the case of CSI-RS configuration 0, the radio resource for eight antenna ports comprises all of the radio resources both for four antenna ports and for one or two antenna ports.

[248] A plurality of CSI-RS configurations may be used in a cell. Zero or one CSI-RS configurations only may be used for a non-zero power (NZP) CSI-RS, and zero or several CSI-RS configurations may be used for the zero power CSI-RS.

[249] For every bit that is configured as 1 in the Zero Power CSI-RS (ZP-CSI-RS), which is the bitmap of 16 bits configured by a high layer, the UE assumes a power transmission of zero for the REs (except in the case of overlap with an RE that assumes an NZP CSI-RS by a higher layer) that correspond to the four

CSI-RS columns in Table 3 and Table 4 above. The most significant bit (MSB) corresponds to the lowest CSI-RS configuration index, and the next bit in the bitmap corresponds to the next CSI-RS configuration index in order.

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

[251] In the case of frame structure type 2 (TDD), the CSI-RS is not transmitted in: a subframe that collides with a special subframe, synchronization signal (SS), PBCH, or SIB 1 (SystemInformationBlockType1) message transmission; or a subframe that is configured for transmitting a paging message.

[252] In addition, if the CSI-RS for a certain antenna port that belongs to an antenna port set S (S = {15}, S = {15,16}, S = {17,18}, S = {19,20} or S = {21,22}) is transmitted in an RE, then the RE is not used for transmitting a PDSCH or a CSI-RS of another antenna port.

[253] Because the time-frequency resources used for transmitting the CSI-RS cannot be used for transmitting data, the data throughput decreases as CSI-RS overhead increases. In consideration of this, rather than the CSI-RS being configured to be transmitted in every subframe, it is configured to be transmitted in a predetermined transmission period that corresponds to a plurality of subframes. In this case, CSI-RS transmission overhead may be significantly decreased compared to a case in which the CSI-RS is transmitted in every subframe.

[254] The subframe period for CSI-RS transmission (hereinafter the "CSI-RS transmission period") (T_CSI-RS) and the subframe offset (Δ_CSI-RS) are represented in Table 5 below.

[255] Table 5 illustrates the configuration of a CSI-RS subframe.

[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] Referring to Table 5, the CSI-RS transmission period (T_CSI-RS) and the subframe offset (ΔCSI-RS) are determined according to the CSI-RS subframe configuration (I_CSI-RS).

[258] The CSI-RS subframe configuration in Table 5 may be configured as either one of the ‘SubframeConfig' field and the ‘zeroTxPowerSubframeConfig' field above. The CSI-RS subframe configuration may be separately configured for an NZP CSI-RS and a ZP CSI-RS.

[259] The subframe that comprises 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 represents the CSI-RS transmission period, Δ_CSI-RS represents the subframe offset value, n_f represents the system frame number, and n_s represents the slot number.

[262] In the case of a UE in which transmission mode 9 is set for a serving cell, a single CSI-RS resource configuration may be configured in the UE. In the case of a UE in which transmission mode 10 is set for a serving cell, one or more CSI-RS resource configuration(s) may be configured in the UE.

[263] For each CSI-RS resource configuration, the parameters may be set as follows via higher-layer signaling.

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

[265] - Number of CSI-RS ports

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

[267] - CSI-RS subframe configuration (I_CSI-RS) (see Table 5)

[268] - If transmission mode 9 is set, the transmission power (P_C) for the CSI feedback

[269] - If transmission mode 10 is set, then the transmission power (P_C) for CSI feedback with respect to each CSI process. If the CSI subframe sets CCSI,0 and CCSI,1 are set by a higher layer with respect to the CSI process, then P_C is set in each CSI subframe set of the CSI process.

[270] - The pseudo-random sequence generator parameter (n_ID)

[271] - If transmission mode 10 is set, then a QCL scrambling identifier (qcl-ScramblingIdentity-r11) for assuming a Quasi Co-Located (QCL) type-B UE, the CRS port count (crs-PortsCount-r11), and the higher-layer parameter ('qcl-CRS-Info-r11) that comprises the MBSFN subframe configuration list (mbsfn-SubframeConfigList-r11) parameter

[272] If the CSI feedback value obtained by the UE has the value in the range of [-8, 15] dB, then P_C is assumed to be the ratio of the PDSCH EPRE to the CSI-RS EPRE. Herein, the PDSCH EPRE corresponds to the symbol in which the ratio of PDSCH EPRE to the CRS EPRE is ρ_A.

[273] In the same subframe of a serving cell, the CSI-RS and the PMCH are not configured together.

[274] When four CRS antenna ports are configured in frame structure type 2, the CSI-RS configuration index belonging to the [20–31] set in the case of a normal CP (see Table 3) or to the [16–27] set in the case of the extended CP (see Table 4) is not configured in a UE.

[275] A UE may assume that the CSI-RS antenna port of the CSI-RS resource configuration has the QCL relation with the delay spread, the Doppler spread, the Doppler shift, the average gain, and the average delay.

[276] A UE for which transmission mode 10 and QCL type B are configured may assume that the antenna ports 0–3 corresponding to the CSI-RS resource configuration and the antenna ports 15–22

corresponding to the CSI-RS resource configuration have the QCL relation with the Doppler spread and the Doppler shift.

[277] In the case of a UE for which transmission mode 10 is configured, one or more Channel-State Information–Interference Measurement (CSI-IM) resource configurations may be set for the serving cell.

[278] The following parameters may be configured for each CSI-IM resource configuration through higher-layer signaling.

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

[280] - ZP CSI RS subframe configuration (I_CSI-RS) (see Table 5)

[281] The CSI-IM resource configuration is the same as one of the configured ZP CSI-RS resource configurations.

[282] In the same subframe in a serving cell, the CSI-IM resource and the PMCH are not configured at the same time.

[283] For a UE in which transmission modes 1–9 are set, a ZP CSI-RS resource configuration may be configured in the UE for a serving cell. In the case of a UE for which transmission mode 10 is configured, one or more ZP CSI-RS resource configurations may be set in the UE for the serving cell.

[284] The following parameters may be configured for a ZP CSI-RS resource configuration through higher-layer signaling.

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

[286] - ZP CSI-RS subframe configuration (I_CSI-RS) (see Table 5)

[287] The ZP CSI-RS and the PMCH are not configured at the same time in the same subframe in a serving cell.

[288]

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

[290] For one or several methods among the several methods (handover, random access, cell search, etc.) for guaranteeing the mobility of a terminal, the UE reports the result of a cell measurement to a base station (or network).

[291] In 3GPP LTE/LTE-A systems, a cell-specific reference signal (CRS) is transmitted via the 0th, 4th, 7th and 11th OFDM symbols in each subframe on the time axis, and is generally used for cell measurement. In other words, a terminal performs cell measurement using a CRS that is received from a serving cell and a neighbor cell, respectively.

[292] The concept of cell measurement encompasses radio resource management (RRM) measurement that measures the signal strength of the serving cell and the neighbor cell or the signal strength in comparison with total reception power, and the like, including measuring the reference signal receive power (RSRP), the received signal strength indicator (RSSI), the reference signal received quality (RSRQ), and the like, and radio link monitoring (RLM) measurement that is able to evaluate radio link

failure by measuring the link quality from the serving cell.

[293] The RSRP is a linear average of the power distribution of an RE in which a CRS is transmitted in a measurement frequency band. To determine the RSRP, a CRS(R0) may be used that corresponds to antenna port 0. In addition, to determine the RSRP, a CRS(R1) may also be used that corresponds to antenna port 1. The number of REs used in the measurement frequency band and the measurement interval that the UE uses in order to determine the RSRP may be determined by the UE within the limits that satisfy the corresponding measurement accuracy requirements. In addition, the power per RE may be determined by the energy received in the part of the symbol other than the cyclic prefix (CP).

[294] The RSSI is obtained from OFDM symbols comprising the RS that corresponds to antenna port 0 in the measurement band as the linear average of the total reception power detected by the relevant UE from all sources including the serving cell and the non-serving cell of the same co-channel, interference from adjacent channels, thermal noise, and the like. If a particular subframe is indicated by higher-layer signaling for carrying out RSRQ measurement, the RSSI is measured through all the OFDM symbols in the indicated subframes.

[295] The RSRQ is obtained as N × RSRP/RSSI. Where N represents the number of RBs in the RSSI measurement bandwidth. In addition, the measurement of the numerator and the denominator in the above formula may be obtained from the same RB set.

[296] A base station may forward the configuration information for the measurement to a UE via higher-layer signaling (such as an RRC Connection Reconfiguration message).

[297] An RRC Connection Reconfiguration message comprises a radio resource configuration dedicated ("radioResourceConfigDedicated") information element (IE) and a measurement configuration (‘measConfig') IE.

[298] The "measConfig" IE specifies the measurement that the UE must perform and comprises configuration information for measurement gap configuration as well as intra-frequency mobility, inter-frequency mobility, and inter-RAT mobility.

[299] In particular, the "measConfig" IE comprises a "measObjectToRemoveList" that represents a list of measurement objects ("measObject") to be removed from the measurement and a "measObjectToAddModList" that represents a list to be newly added or amended. In addition, "measObject"s comprise "MeasObjectCDMA2000," "MeasObjctEUTRA," "MeasObjectGERAN," and so forth depending on the communication technology.

[300] The "RadioResourceConfigDedicated" IE is used to configure/modify/release the radio bearer, to modify the MAC main configuration, to modify the semi-persistent scheduling (SPS) configuration, and to modify the dedicated physical configuration.

[301] The "RadioResourceConfigDedicated" IE comprises a "measSubframePattern-Serv" field that indicates the time domain measurement resource restriction pattern for serving cell measurement. In addition, the "RadioResourceConfigDedicated" IE comprises a "measSubframeCellList" indicating the neighbor cell that the UE will measure, and "measSubframePattern-Neigh" indicating the time domain measurement resource restriction pattern for neighbor cell measurement.

[302] The time domain measurement resource restriction pattern configured for the measured cells (including the serving cell and the neighbor cell) may indicate at least one subframe per radio frame for carrying out the RSRQ measurement. The RSRQ measurement is carried out only for the subframe indicated by the time domain measurement resource restriction pattern configured for measured cells.

[303] As such, a UE (such as a 3GPP Rel-10) must measure the RSRQ only in the interval configured by the subframe pattern (‘measSubframePattern-Serv') for serving cell measurement and the subframe pattern (‘measSubframePattern-Neigh') for neighbor cell measurement.

[304] However, although RSRP measurement is not restricted to this pattern, it is preferable that measurement for the accuracy requirement be done only within this pattern.

[305]

[306] **Quasi co-located (QCL) between antenna ports**

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

[308] If two antenna ports have a QC/QCL relation (or are QC/QCL'd), a terminal may assume that the large-scale properties of a signal sent via one antenna port may be inferred from a signal sent via the other antenna port. These large-scale properties comprise one or more of delay spread, Doppler spread, frequency shift, average received power, and received timing.

[309] They may also be defined as follows. If two antenna ports have a QC/QCL relation (or are QC/QCL'd), a terminal may assume that the large-scale properties of a channel in which a symbol is sent via one antenna port may be inferred from a radio channel in which a symbol is sent via the other antenna port. Large-scale properties in this case comprise one or more of delay spread, Doppler spread, Doppler shift, average gain, and average delay.

[310] Thus, if two antenna ports have a QC/QCL relation (or are QC/QCL'd), it means that the large-scale properties of the radio channel from one antenna port are the same as the large-scale properties of the radio channel from the other antenna port. Considering a plurality of antenna ports in which an RS is

transmitted, if the antenna ports on which two different kinds of RSs are transmitted have a QCL relation, the large-scale properties of the radio channel based on one kind of one antenna port may be replaced with the large-scale properties of the radio channel based on the other kind of antenna port.

[311] In the present specification, the above QC/QCL-related definitions are not distinguished. In other words, the QC/QCL concept may comply with any one of the above definitions. In a similar but different format, the QC/QCL concept definition may be changed into a format in which antenna ports having an established QC/QCL assumption may be assumed to be transmitted at the same location (co-location) (for example, a terminal may assume antenna ports are transmitting from the same transmission point); the concept of the present invention encompasses such similar modifications. For convenience of description, the above definitions related to QC/QCL are used interchangeably in the present invention.

[312] According to the QC/QCL concept, a terminal cannot assume that radio channels from these antenna ports have the same large-scale properties as non-QC/QCL antenna ports. Thus, in this case, for each configured non-QC/QCL antenna port, a terminal must respectively independently process timing acquisition and tracking, frequency offset estimation and compensation, delay estimation, and Doppler estimation.

[313] A terminal can advantageously carry out the following operations between antenna ports for which QC/QCL may be assumed:

[314] - With respect to delay spread and Doppler spread, the terminal may apply the same power-delay profile, delay spread and Doppler spectrum, and Doppler-spread estimation for a radio channel from any one antenna port to a Wiener filter or the like that is used when conducting channel estimation for a radio channel in other antenna ports.

[315] - With respect to frequency shift and received timing, the terminal may perform time and frequency synchronization on any one antenna port and then apply the same synchronization to demodulating other antenna ports.

[316] - With respect to average received power, the terminal may average the measurement of the reference signal received power (RSRP) over two or more antenna ports.

[317] For example, if a DMRS antenna port for downlink data channel demodulation has been QC/QCL'd with the CRS antenna port of a serving cell, the terminal may improve reception performance of a DMRS-based downlink data channel by applying the same large-scale properties of the radio channel estimated from its own CRS antenna port when conducting channel estimation via the corresponding DMRS antenna port.

[318] This is because an estimated value regarding a large-scale property can be more reliably obtained from a CRS because the CRS is a reference signal that is broadcast at a relatively high density in every subframe and over the full band. In contrast, because a DMRS is transmitted terminal-specifically with respect to a particular scheduled RB, and the precoding matrix of a precoding resource block group

(PRG) unit that is used by a base station for transmission may also be changed, a valid channel received by the terminal may vary among PRG units; accordingly, even if a plurality of PRGs have been scheduled in the terminal, performance deterioration may occur when the DMRS is used to estimate the large-scale property of a radio channel over a wide band. In addition, a CSI-RS may also have a transmission period of from several to several tens of milliseconds, and because each resource block has also low density of an average of one resource element per antenna port, performance degradation may occur if the CSI-RS is used to estimate a large-scale characteristic of a radio channel.

[319] In other words, by assuming QC/QCL between antenna ports, a terminal may be used for detection/reception, channel estimation, and channel state reporting of a downlink reference signal.

[320]

[321] **Restricted RLM and RRM/CSI measurement**

[322] As a method of interference coordination, an aggressor cell may use a silent subframe (which may be called an almost blank subframe (ABS)) in which the transmission power/activity of partial physical channels are reduced (where reducing the transmission power/activity may comprise an operation for configuring the transmission power/activity to zero power); and a victim cell may take this into consideration in conducting time-domain inter-cell interference coordination for scheduling the UE.

[323] In this case, from the standpoint of the victim cell UE, the interference level may vary considerably as a function of the subframe.

[324] In such a situation, in order to perform a radio resource management (RRM) operation for more accurately measuring radio link monitoring (RLM) or RSRP/RSRQ in each subframe or measuring channel-state information (CSI) for link adaptation, the monitoring/measurement may be restricted to sets of subframes having a uniform interference characteristic. In a 3GPP LTE system, restricted RLM and RRM/CSI measurement are defined as follows.

[325] To sense the downlink radio link quality of a P cell, the UE monitors the downlink link quality based on a cell-specific reference signal (CRS). The terminal estimates downlink radio link quality, and compares the estimated value with threshold values Q_out and Q_in in order to monitor the downlink radio link quality of the P cell.

[326] The threshold value Q_out is defined as a level at which a downlink radio link cannot be reliably received, and corresponds to a 10% block error rate (BER) in a hypothetical PDCCH transmission in which a PCFICH error has been taken into consideration based on the transmission parameters enumerated in Table 6 below.

[327] The threshold value Q_in is defined as a level at which downlink radio link quality can be significantly more reliably received compared to the downlink radio link quality at threshold value Q_out,

and corresponds to a 2% BER of a hypothetical PDCCH transmission in which a PCFICH error has been taken into consideration based on transmission parameters enumerated in Table 7 below.

[328] The radio link quality is monitored if higher-layer signaling indicates a particular subframe for a restricted RLM.

[329] Certain requirements are applied when a time-domain measurement resource restriction pattern for carrying out RLM measurement is configured by a higher layer, and also when a time domain measurement resource restriction pattern configured for a cell under measurement indicates at least one subframe per radio frame for carrying out RLM measurement.

[330] If CRS assistance information is provided, the above requirements may be satisfied if the number of transmitting antenna ports of one or more cells to which CRS assistance information has been provided differs from the number of transmitting antenna ports of a cell in which RLM is carried out.

[331] If the terminal is not provided with CRS assistance information or the CRS assistance data is not valid for the entire evaluation period, a time-domain measurement restriction is applicable under a collision between a CRS and an ABS configured in a non-multicast broadcast single frequency network (non-MBSFN) subframe.

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

[333] [Table 6]

Attribute	Value
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; single antenna port used for CRS transmission by P cell 1 dB; two or four antenna ports used for CRS transmission by P cell
Ratio of PCFICH RE energy to average RS RE energy	4 dB; single antenna port used for CRS transmission by P cell 1 dB; two or four antenna ports used for CRS transmission by P cell

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

[335] [Table 7]

Attribute	Value
DCI Format	1C
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; single antenna port used for CRS transmission by P cell –3 dB; two or four antenna ports used for CRS transmission by P cell
Ratio of PCFICH RE energy to average RS RE energy	4 dB; single antenna port used for CRS transmission by P cell 1 dB; two or four antenna ports used for CRS transmission by P cell

[336] The downlink radio link quality for a P cell is monitored by the UE in order to indicate the out-of-sync status/in-sync status to a higher layer.

[337] In a non-DRX mode operation, a physical layer of a UE measures (assesses) the radio link quality that has been evaluated for a previous time interval, taking into consideration the threshold values Q_out and Q_in of each radio frame.

[338] If higher-layer signaling indicates a particular subframe for a restricted RLM, the measurement of radio link quality is not performed in other subframes that are not indicated by the higher-layer signaling.

[339] If the radio link quality is poorer than the threshold value Q_out, the physical layer of the UE indicates out-of-sync to a higher layer in the radio frame whose radio link quality has been measured. If the radio link quality is better than threshold value Q_in, the physical layer of the UE indicates in-sync to a higher layer in the radio frame whose radio link quality has been measured.

[340]

[341] **Massive MIMO**

[342] Introducing an active antenna system (AAS) has been considered in a wireless communication systems starting from LTE Release-12 (Rel-12).

[343] "AAS" refers to a system in which each antenna is respectively configured to include an active device such as an amplifier, in contrast to existing passive antenna systems, in which an amplifier and an antenna wherein signal phase and size are adjustable are separated.

[344] Because of the use of an active antenna, an AAS does not require a separate cable, a connector, other hardware, or the like for connecting an amplifier to the antenna; it therefore features high efficiency in terms of energy and operating costs. In particular, the AAS enables advanced MIMO techniques, such as forming an accurate beam pattern or three-dimensional beam pattern in which a beam direction and a beam

width have been taken into consideration, because the AAS supports an electronic beam control scheme for each antenna.

[345] With the introduction of advanced antenna system such as AASs, massive MIMO structures having a plurality of input/output antennas and a multi-dimensional antenna structure have also been considered. For example, in contrast to a conventional straight-line antenna array, if a two-dimensional antenna array is formed, then a three-dimensional beam pattern may be formed by the active antenna of the AAS. From the standpoint of a transmitting antenna, if the three-dimensional beam pattern is used, a semi-static or dynamic beam may be formed in the vertical direction of a beam in addition to the horizontal direction; for example, applications may be considered such as forming a sector in the vertical direction.

[346] In addition, from the standpoint of a receiving antenna, when a receiving beam is formed using a massive receiving antenna, the effect of increased signal power as a function of antenna array gain may be anticipated . Accordingly, in the case of an uplink, a base station may receive a signal transmitted by a terminal via a plurality of antennas; this has the advantage that the terminal is able to configure its own transmission power to be very low, in order to reduce the effect of interference, by taking into consideration the gain of the massive receiving antenna.

[347] FIG. 11 illustrates a system in which a base station or a terminal has a plurality of transmitting/receiving antennas capable of AAS-based three-dimensional (3D) beamforming in a wireless communication system to which the present invention is applicable.

[348] FIG. 11 is a diagrammatic representation of the above-described embodiment and illustrates a 3D MIMO system using a two-dimensional antenna array (namely, a 2D-AAS).

[349]

[350] **Cell coverage of massive MIMO**

[351] A multiple antenna system, such as, for example, a system having N transmitting antennas, may conduct beamforming so that the received power is increased by a maximum of N-fold at a particular position, assuming that the total transmission power is transmitted in the same way as in a single antenna system.

[352] Even in a base station with multiple antennas, a channel over which a CRS, a PSS/SSS, a PBCH, and broadcast information are sent does not perform beamforming in a particular direction, so that all UEs within a base station coverage area can receive them.

[353] In contrast, a PDSCH, which is a channel that transfers unicast information to a particular UE, carries out beamforming according to the UE's location and link status so as to improve transmission efficiency. In other words, the transmission data stream of the PDSCH is precoded in order to form a beam in a particular direction and is transmitted via a plurality of antenna ports. Therefore, if, for example, the transmission power of the CRS and the transmission power of the PDSCH are the same, the received power of a precoded PDSCH beamformed toward the UE may be increased up to a maximum of N-fold of the average received power of a CRS at that particular UE.

[354] Heretofore, in LTE Rel-11 systems, base stations having a maximum of eight transmitting antennas have been considered; this means that the received power of a precoded PDSCH may be eight times greater than average received power of a CRS. However, in the future, with the number of transmitting antennas

of a base station reaching 100 or more with the introduction of massive MIMO systems, the difference between the received power of a CRS and of a precoded PDSCH may be a factor of 100 or more. In conclusion, with introduction of massive MIMO systems, the coverage area of a CRS transmitted by a particular base station and the coverage area of a DM-RS-based PDSCH do not coincide.

[355] In particular, such phenomena may be significant if there is a large difference between two adjacent base stations in the number of transmitting antennas. A representative example is a case in which a macro cell having 64 transmitting antennas and a micro cell (such as a pico cell) having a single transmitting antenna are adjacent to each other. Because a UE served in an initial massive MIMO deployment process expects that the initial number of antennas may be increased from many macro cells, in the case of a heterogeneous network in which macro cells, micro cells and pico cells are mixed, there is a large difference among adjacent base stations in the number of transmitting antennas.

[356] For example, in the case of a pico cell with a single transmitting antenna, the coverage areas of the CRS and the PDSCH are the same. In the case of a macro cell with 64 transmitting antennas, the coverage area of the PDSCH is greater than the coverage area of the CRS. Accordingly, if initial access and handover are determined based on only RSRP or RSRQ, which is the reception quality of the CRS, at the boundary of the macro cell with a pico cell, a base station capable of providing the maximum quality of the PDSCH cannot be selected as a serving cell. As a simple solution for this problem, the PDSCH received power of a base station having N transmitting antennas may be assumed to be N times greater, but this is not the optimal solution in view of cases in which the base station cannot beamform in all possible directions.

[357]

[358] **RRM-RS**

[359] In the present patent, a method is proposed for transmitting a precoded reference signal (RS) and carrying out RRM measurement on it. Below, in the present specification, a precoded RS for such a purpose is referred to as an "RRM-RS." The RRM-RS is made up of a plurality of antenna ports, and beamforming is configured differently for each antenna port so that the UE can measure the RSRP for each transmission beam. For example, if a base station is able to beamform in M directions, an RRM-RS is configured consisting of M ports.

[360]

[361] **Period and multiplexing of RRM-RS**

[362] An M-port RRM-RS may be subjected to CDM or divided into FDM/TDM for transmission in the same subframe. In other words, a transmission signal may be transmitted for each antenna port of the M-port RRM-RS, using a different transmission RE in the same subframe; or orthogonal scrambling code may be used between antenna ports so that they may be distinguished without interference.

[363] In contrast, the number of antenna ports of an RRM-RS that are capable of transmitting in one

subframe at the same time may be configured as K, and transmission may be divided over (M/K) subframes.

[364] In this case, the configuration parameters of the RRM-RS comprise a total number M of antenna ports and a number K of antenna ports that are transmitted in one subframe at the same time. The configuration parameter of the RRM-RS also comprises an RRM-RS transmission period P and an offset O. In this case, the RRM-RS transmission period is defined as the spacing of subframes in which an RRM-RS is transmitted. For example, if P = 10, O = 5, M = 64, and K = 32, then the RRM-RS is transmitted in subframes having subframe indices (SFIs) of 5, 15, 25, 35, . . . ; in the subframe with SFI = 5, the 31st RRM-RS is transmitted in antenna port 0; in the subframe with SFI = 15, the 63rd RRM-RS is transmitted in antenna port 32; in the subframe with SFI = 25, the 31st RRM-RS is transmitted again in antenna port 0.

[365] In contrast, in a scheme in which an RRM-RS transmission period is defined as a spacing of subframes in which RSs of the same antenna port are transmitted, and the antenna ports of an RRM-RS are divided among (M/K) subframes, the antenna ports are divided among (M/K) contiguous subframes and transmitted. For example, if P = 20, O = 5, M = 64, and K = 32, then the RRM-RS is transmitted in subframes having SFIs of 5, 6, 25, 26, 45, 46 . . . ; in the subframe with SFI = 5, the 31st RRM-RS is transmitted in antenna port 0; in the subframe with SFI = 6, the 63rd RRM-RS is transmitted in antenna port 32; in the subframe with SFI = 25, the 31st RRM-RS is transmitted again in antenna port 0.

[366]

[367] **<u>RSRP measurement and reporting</u>**

[368] The RSRP of the RRM-RS is measured and reported for each antenna port. A plurality of RRM-RSs may be configured in a UE.

[369] If each cell transmits one RRM-RS, then a configuration of RRM-RSs transmitted by a serving cell and adjacent cells may be designated for the UE. A cell may transmit a plurality of RRM-RSs. If the UE reports the RSRP of an RRM-RS, it also provides notification of the number of the antenna port and the number of the RRM-RS for which the RSRP is the result of RSRP measurement.

[370] To calculate the RSRP of an RRM-RS, the average is taken of the reception signal levels of the respective antenna ports; the base station may designate a time window in which the average is calculated, or the RSRP may be calculated by averaging the reception signal levels of the antenna ports of RRM-RSs over a predetermined period of time (for example, 200 ms). Alternatively, the RSRP may be calculated by filtering the average received power obtained in each respective time window again.

[371] A UE in which a plurality of RRM-RSs has been configured measures the RSRP of each antenna port of each of RRM-RS. If R RRM-RSs have been configured in a UE and the number of antenna ports of the rth RRM-RS is M_r, then the RSRP of the mth antenna port of the rth RRM-RS is defined as RSRP(r, m). The UE aligns the RSRP(r, m), and reports the RSRP of L antenna ports chosen from among these that are strongly received.

[372] By slightly modifying the above scheme, the UE aligns the RSRP(r,m) and selects the RSRPs of

antenna ports that belong to the aligned RSRP(r,m) and that are received strongly, and limits reporting to RSRPs of ports that are within a certain difference compared to the RSRP of the selected antenna ports, in other words, max(RSRP(r,m)). Thus, the RSRP of a maximum of L antenna ports, which have an RSRP difference greater than a certain threshold value expressed as an RSRP ratio or dB scale, is reported as follows.

[373] [Equation 13]

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

[374] As another example, a reference antenna port may be designated for the UE. It is preferable that the antenna port of a precoded CSI-RS configured in the UE and an RRM-RS transmitted by a serving cell with same beam direction be designated as a reference antenna port. The UE reports if the m_0^{th} antenna port of the r_0^{th} RRM-RS has been designated as a reference antenna port, and the difference between the RSRP of the reference antenna port and the RSRP of another antenna port is within a certain range. In other words, the UE reports if the difference between RSRPs, expressed as an RSRP ratio or on a dB scale, exceeds a certain threshold value, as follows.

[375] [Equation 14]

$$RSRP(r,m) - RSRP(r_0,m_0) > Threshold$$

[376] FIG. 12 illustrates RSRPs for each antenna port of an RRM-RS according to an embodiment of the present invention.

[377] FIG. 12 shows exemplary RSRPs for each antenna port of an RRM-RS made up of 32 antenna ports.

[378] If the UE has been configured to report the RSRP of an antenna port having an RSRP within 5 dB of the antenna port with the greatest RSRP, then because antenna port 13 has the greatest RSRP of 40 dB as shown in FIG. 12, the UE reports antenna ports with an RSRP over 35 dB. In other words, the RSRPs of antenna ports 24, 25 and 26 are reported to a base station, along with antenna port 13.

[379]

[380] **<u>Antenna port grouping</u>**

[381] Because beamforming may be differently configured for each antenna port, there is a one-to-one correspondence of antenna ports and beams.

[382] Accordingly, an antenna port index (i) may be mapped one-to-one to a beam index (i). If the beams are indexed so that the directions of an $(i)^{th}$ beam and an $(i + 1)^{th}$ beam are adjacent, as illustrated in FIG. 12, the RSRPs between adjacent antenna ports will have similar characteristics. Such similarity is also generated between an $(i)^{th}$ beam and an $(i + c)^{th}$ beam, but the similarity falls with increasing values of c. Whether a high degree of similarity is generated between a plurality of continuous and adjacent beams is determined by the beams' gaps, widths, and degree of multi-path scattering.

[383] A base station that has received a report of RSRP measurement results based on an RRM-RS identifies an approximate location of the relevant UE and notifies the UE of a precoded CSI-RS configuration transmitted toward a corresponding point in space so that the UE is able to measure the CSI-RS and feed back CSI (such as RI, PMI and CQI) for PDSCH scheduling. In addition, a base station that has received a report on RSRP measurement results based on RRM-RSs transmitted by a plurality of cells determines, based on the RSRP measurement results, which cell the UE will be handed over to and which precoded CSI-RS will be configured for the UE in a target cell. In other words, the RSRP measurement results based on RRM-RSs provide a base station with important information that it needs in order to determine which precoded CSI-RSs will subsequently be configured for the UE.

[384] As illustrated in FIG. 12, if 4-port CSI-RSs are configured for a corresponding UE based on the RSRP measurement results so that a maximum of 4 data streams may be transmitted or the best beam switching may be rapidly performed as fading changes, then it is expected it will be optimal to generate and configure 4-port CSI-RSs having the same beam direction as RRM-RS ports 13, 24, 25 and 26, which have the greatest RSRPs. However, optimizing, generating, and transmitting a CSI-RS for each UE has too much overhead. Thus, CSI-RS transmission overhead may be reduced by a method of allowing many UEs in the same environment to share a CSI-RS. To accomplish this purpose, the precoding of the CSI-RS antenna ports in a CSI-RS configuration must be such as to exhibit a characteristic of a beam transmitted in an adjacent direction. In other words, if a 4-port CSI-RS1 with the same beam direction as RRM-RS ports 12, 13, 14 and 15, and a 4-port CSI-RS2 having the same beam direction as RRM-RS ports 24, 25, 26 and 27, have been previously configured in consideration of different served UEs, which CSI-RS should be configured for a corresponding UE may be determined based on the RRM-RS RSRP report.

[385] In a further embodiment of the present invention, an RSRP for an antenna port group is measured and reported. In the proposed scheme, antenna ports are grouped, and the RSRP of an antenna port group is calculated by averaging the RSRPs of antenna ports belonging to the antenna port group. The group may have been previously determined or a base station may designate the group. Alternatively, a UE may determine a grouping scheme and report it.

[386] As illustrated in FIG. 12, an RRM-RS consisting of 32 ports may be grouped into groups of four ports each. They may be grouped into 8 (=32/4) disjoint groups. In this case, the $(i)^{th}$ port group consists of the RRM-RS ports (4i), (4i + 1), (4i + 2), and (4i + 3). The RSRP of the $(i)^{th}$ port group is defined as the average of the RSRPs of antenna ports (4i), (4i + 1), (4i + 2), and (4i + 3).

[387] In a further embodiment, grouping may be done so as to permit overlaps between groups. If RRM-RSs consisting of 32 ports are grouped into groups of four ports each, 15 groups are formed. In this case, the $(i)^{th}$ port group consists of the RRM-RS ports (2i), (2i + 1), (2i + 2), and (2i + 3). To generalize the proposed scheme, if ports are grouped into groups of A ports each, and the port gap between adjacent

groups is configured as B, then the $(i)^{th}$ port group will consist of RRM-RS ports (B*i), (B*i + 1), ..., (B*i + A – 1). A base station may designate a configuration of parameters A and B for a UE, or the UE may select and report a configuration of parameters A and B in consideration of the channel environment and UE capability.

[388] As a modification of the proposed scheme, in selecting an antenna port group to report, a UE may consider the capability that may be obtained via the antenna port group compared to the RSRP. In this case, the UE calculates capability by taking into consideration multi-layer data transmission from a plurality of antennas in the antenna port group.

[389]

[390] **Antenna port grouping level**

[391] In the proposed scheme, a plurality of grouping methods with different sizes may be used. Thus, a method for grouping antenna ports into groups of A1 ports each and a method of grouping antenna ports into groups of A2 ports each may be used at the same time. A method of grouping antenna ports into groups of A_i ports is referred to below as "grouping level i."

[392] FIG. 13 illustrates RRM-RS antenna port grouping levels according to an embodiment of the present invention.

[393] FIG. 13 shows an exemplary grouping scheme in which four grouping levels are applied to a 16-port RRM-RS. In the illustration, grouping level 1 shows a scheme in which no grouping is performed, wherein antenna ports are grouped into one group for each port. At grouping levels 2, 3, and 4, respectively, the ports are grouped into groups of 2, 4, and 8 ports each. The drawing shows a case in which antenna port groups having the same level are configured to be disjoint.

[394] In such a multiple grouping scheme, the UE reports an RSRP for each grouping level. In other words, for each grouping level, it selects and reports the antenna group having a high RSRP. Alternatively, it may compare the RSRPs of antenna groups of different levels and report a best group and group level. In order to compare the RSRPs between antenna groups having different levels 1, the group RSRP of each level is corrected by a certain offset for comparison. If R RRM-RSs have been configured and the RSRP of the $(g)^{th}$ antenna port group of the $(l)^{th}$ grouping level of the $(r)^{th}$ RRM-RS is defined as GRSRP(r,l,g), then Adj_GRSRP(r,l,g) is calculated by correcting GRSRP(r,l,g) by an offset(r,l) that has been designated by the base station for the $(l)^{th}$ grouping level of the $(r)^{th}$ RRM-RS, as follows, and this value is compared.

[395] [Equation 15]

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

[396] In addition, in order to reduce a frequent change in the best L ports reported in a scheme for reporting the RSRPs of the best L port groups for each grouping level or for the entire grouping scheme, the RSRPs may be corrected by adding a hysteresis parameter Hy.

[397] [Equation 16]

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

[398] Whether the parameter Hy is added or subtracted here is determined according to whether the port group was included among the best L GRSRPs in a previous report. If the port group was included among the best L GRSRPs in the previous report, the parameter Hy is added to apply a bias so that a high Adj_RSRP is obtained, thereby reducing frequent changes in the port group having the best L Adj_GRSRP.

[399] In a proposed scheme, a reference antenna port group may be designated for a UE. It is preferable that the base station designate as the reference antenna port group an antenna port group of a precoded CSI-RS configured for the UE and an RRM-RS transmitted by a serving cell with the same beam direction. A reference antenna port group may be designated for the UE for each grouping level. Alternatively, a single reference antenna port group may be designated for all grouping levels. If the $(m_0)^{th}$ antenna port group of the $(l_0)^{th}$ grouping level of an $(r_0)^{th}$ RRM-RS has been designated as a reference antenna port group for the UE, then the UE reports if an Adj_GRSRP of another antenna port group exceeds a certain threshold value compared to the Adj_GRSRP of the reference antenna port group. In other words, it reports if the difference between RSRPs, expressed as an Adj_GRSRP ratio or on a dB scale, exceeds a certain threshold value, as follows.

[400] [Equation 17]

$$Adj_GRSRP(r,l,g) - Adj_GRSRP(r_0, l_0, m_0) > Threshold$$

[401] Alternatively, as a modification of the proposed scheme, a reference RSRP is specified via a currently configured CSI-RS, the RRM-RS-based RSRP result is compared to the CSI-RS-based RSRP, and the resulting RSRP is selected and reported.

[402]

[403] **<u>RRM-RS for three dimensions (3D)</u>**

[404] The above scheme proposed in the present invention is applicable with modifications if the directivity of a beam is expanded from a two-dimensional space to a three-dimensional space. The directivity of a beam in three-dimensional space is controlled by two angles: a top/bottom angle (or vertical angle) and a left/right angle (or horizontal angle). Accordingly, to determine whether an adjacent beam is present, it is efficient to index the beams using two indices, namely, a horizontal index and a vertical index. According to a feature of the present invention, for a beam index and an RRM-RS port index to have a one-to-one correspondence relation, it is preferable that the RRM-RS port is also indexed with a horizontal index and a vertical index.

[405] In the case of a 3D MIMO system having M_v beams in the vertical direction and having M_h beams in the horizontal direction, a total of (M_v × M_h) beams are possible. In the present invention, an (M_v × M_h)-port RRM-RS is configured and each antenna port is assigned a horizontal index j_h (j_h = 0, ..., M_h−1) and a vertical index j_v(j_v = 0, ..., M_v−1). A one-dimensional index i (i = 0, ...,

$M_v \times M_h-1$) and two-dimensional indices j_h and j_v are assigned to each antenna port, taking into consideration the resource mapping of the ($M_v \times M_h$)-port RRM-RS, with the relationship $(i) = f(j_h, j_v)$.

[406] FIG. 14 is a diagram illustrating antenna ports and antenna port groups of RRM-RSs arrayed in two-dimensional indices according to an embodiment of the present invention.

[407] Referring to FIG. 14, each of the antenna ports is indexed as (j_h, j_v). If the antenna ports are grouped into groups of $A_h \times A_v$ ports each by applying the scheme proposed in the present invention, and the port gap between adjacent groups is configured as B_h and B_v, then the $(i_h, i_v)^{th}$ port group will consist of RRM-RS ports ($B_h \times i_h + j_h$, $B_v \times i_v + j_v$), ($j_h = 0, A_h-1$), and ($j_v = 0, A_v-1$). A base station may designate a configuration of parameters A_h, A_v and B_h, B_v for a UE, or the UE may select and report them in consideration of the channel environment and UE capability.

[408]

[409] **Differences between RRM-RS and CSI-RS**

[410] In existing LTE/LTE-A systems, a CSI-RS is transmitted for the purpose of a CSI report. A UE reports RI, PMI, CQI, and the like as CSI. In contrast, the RRM-RS proposed in the present invention is used to measure the RSRP for each antenna port. It is preferable to use resources in which an existing CSI-RS may be configured rather than newly defining resources for RRM-RS transmission. This is because the transmission efficiency of legacy UEs is not reduced. If the RRM-RS is transmitted in a new resource, the legacy UEs do not recognize the RRM-RS, and therefore the transmission efficiency in the subframe in which the RRM-RS is transmitted will deteriorate or it will not be scheduled. Accordingly, in a scheme in which the RRM-RS is transmitted using a resource in which an existing CSI-RS may be configured, a CSI-RS configuration may be provided to a legacy UE containing the resource and the UE may be notified that data mapping will not occur in the resource.

[411] Data mapping does not occur in a plurality of CSI-RSs configured for a UE for CSI reporting. In other words, a PDSCH is mapped except for the RE in which the CSI-RS is mapped. In the proposed scheme of the present invention, for the RRM-RS as for the CSI-RS, a PDSCH may be mapped except for an RE to which the RRM-RS is mapped. However, in a modified scheme, a PDSCH may be mapped regardless of the RRM-RS. In this case, the UE must be able to receive an RRM-RS and a PDSCH from the same RE at the same time. Alternatively, to guarantee safe reception of the RRM-RS, the base station may configure the resource as a ZP-CSI-RS so that the PDSCH is not mapped to the RRM-RS.

[412]

[413] **OCL configuration of RRM-RS**

[414] If each cell transmits one RRM-RS, then a configuration of RRM-RSs that a serving cell and adjacent cells transmit may be designated for the UE. In this manner, the UE measures a gain according to the beamforming of the serving cell and a gain according to the beamforming of the adjacent cells and reports them to a network, and the gains are used as a criterion for a handover determination.

The RRM-RS may be insufficient for the purpose of tracking the signal because it is configured to have a very low transmission density. Accordingly, tracking results are used to track a high-density signal that has been reliably received, such as representatively a CRS, and to detect an RRM-RS. In other words, owing to error in an oscillator that generates a carrier frequency of the serving cell and an adjacent cell, the tracking results of the CRS of a serving cell are not appropriate for use for an RRM-RS transmitted by the adjacent cell. Accordingly, for each RRM-RS, notification is provided of a quasi co-located (QCL) CRS (or another particular CS, such as a CSI-RS) that will be used to detect the respective RRM-RS. The UE uses the large-scale properties of a channel, estimated from a QCL CRS (or another particular CS, such as a CSI-RS), to detect the RRM-RS. In this case, the large-scale properties of the channel may comprise one or more of delay spread, Doppler spread, Doppler shift, average gain, and average delay.

[415]

[416] **Extension to RSRQ**

[417] The proposed schemes of the present invention may be extended and applied to a scheme for measuring RSRQ of an RRM-RS for each antenna port. RSRQ is defined as the ratio of RSRP to RSSI. Therefore, in addition, measurement of RSSI is added. The RSSI measurement resource may be identically configured in all RRM-RSs having the same carrier frequency, namely, all the RRM-RSs configured in the same component carrier. In this case, a comparison between ports of RRM-RSs in the same component carrier is the same regardless of whether RSRP or RSRQ is used. However, a comparison between ports of RRM-RSs in heterogeneous same component carriers differs depending on whether RSRP or RSRQ is used. Accordingly, the base station designates whether RSRP or RSRQ will be used for a UE when it makes an RRM report based on an RRM-RS.

[418] In contrast, each RSSI measurement resource may be separately configured for the respective RRM-RSs. In this case, a comparison of RRM-RSs between ports will differ even within the same component carrier depending on whether RSRP or RSRQ will be used. Accordingly, the base station designates whether RSRP or RSRQ will be used for a UE when it makes an RRM report based on an RRM-RS.

[419]

[420] **Association between RRM-RS RSRP and CRS RSRP**

[421] RSRP based on an RRM-RS according to the present invention has the purpose of reflecting the beamforming gain of a base station with multiple antennas in the selection of a serving cell. Even if a particular adjacent cell has been determined to have the best beamforming based on the RSRP of the RRM-RS, if a channel broadcast by the cell is not reliably received, namely, a channel in which CRS-based demodulation is performed, then the UE cannot be handed over to that adjacent cell. Accordingly, it is necessary that the UE receive a report regarding whether an RRM-RM and a CRS transmitted by a particular base station both have good quality , and a handover decision and beam selection are made on

that basis. To this end, the UE reports the RSRP of the jth antenna port or port group of an ith RRM-RS configured in the UE and also reports the RSRP of a CRS connected to the ith RRM-RS. The CRS connected to the RRM-RS here may be a CRS that is QCL'd with the RRM-RS.

[422]

[423] Below is described a CSI measurement and reporting operation method of a terminal for reducing latency, which is proposed in the present specification.

[424] The method proposed by the present specification may be extended and applied to an amorphous cell environment or the like in addition to systems such as 3D MIMO and massive MIMO.

[425] First, a 3D-MIMO system is briefly described below.

[426] 3D-MIMO systems are among the optimal transmission schemes suitable for base stations of single-cell 2D adaptive antenna systems (AAS) based on the LTE standard (Rel-12) as discussed above, such as shown in FIG. 11, and the following operations may be considered.

[427] As shown in FIG. 11, considering an exemplary configuration of CSI-RS ports from an 8-by-8 (8x8) antenna array, vertically precoded 8-port CSI-RSs are configured/transmitted horizontally by configuring precoded CSI-RS ports one by one using UE-dedicated beam coefficients optimized for a particular target UE for each of the respective 8 antennas vertically.

[428] Accordingly, a terminal may carry out 8-port CSI feedback in a conventional way.

[429] As a result, the base station transmits to the terminal a (precoded) 8-port CSI-RS to which vertical direction beam gain has already been applied that is optimized for each terminal (or particular terminal group).

[430] Accordingly, because the terminal measures a CSI-RS experienced via a radio channel, the terminal is able to obtain a beam gain effect in the vertical direction of a radio channel in advance via a CSI measurement and reporting operation on the (vertically precoded) CSI-RS, even though it is carrying out the same feedback scheme according to a conventional horizontal direction codebook.

[431] In this case, there are methods for determining a vertical-direction beam that is optimized for each terminal, such as (1) a method using RRM report results according to a (vertically precoded) small-cell discovery RS (DRS), and (2) a method in which a base station receives a sounding RS (SRS) in the optimal reception beam direction, converts the corresponding reception beam direction to a DL-optimal beam direction based on channel reciprocity, and applies the DL-optimal beam direction.

[432] According to conventional operation, if a base station determines that the UE-dedicated best V-beam direction has changed owing to the terminal's mobility, the base station reconfigures the CSI-RS and the RRC configurations related to an associated CSI process.

[433] When it is necessary to conduct an RRC reconfiguration process in this manner, latency in the RRC

level (e.g., in units from tens to hundreds of ms) will unavoidably arise.

[434] In other words, in the network dimension, a target V-beam direction has previously been split, for example, into four directions, and separate eight port CSI-RSs that have been precoded in the respective V-directions are transmitted to the corresponding separate transmission resource location.

[435] In addition, because each UE must conduct CSI measurement and report on a particular CSI-RS configuration from among the eight port CSI-RSs, when the target V-direction is changed, the UE must carry out an RRC reconfiguration procedure with the network to change the CSI-RS configuration.

[436]

[437] Accordingly, a CSI measurement and reporting method proposed in the present specification for eliminating or significantly reducing RRC level latency is described in detail below.

[438] Namely, the method proposed by the present specification relates to a method of allocating only a single CSI process and a single uplink (UL) feedback resource to a UE and indicating, at the MAC level (or PHY level) rather than the RRC level, which CSI-RS index (and/or CSI-IM index) will be measured.

[439] A MAC CE may be used to indicate the MAC level, and DCI may be used to indicate the PHY level.

[440] Thus, in the method proposed in the present specification, a base station (or network) uses RRC signaling to configure CSI-RS configurations for a plurality of candidate CSI-RSs for a terminal, and notifies the terminal of an "activation" instruction either explicitly or implicitly with respect to at least one CSI-RS, among the plurality of candidate CSI-RSs, on which CSI-RS measurement and reporting are performed.

[441] For example, in the case where CSI-RS 1 is an activated state, if whether a terminal will move from CSI-RS 1 to CSI-RS 2 is taken into consideration, a base station may first indicate pre-activation so that the terminal can track CSI-RS 2 in advance, before the base station issues a reactivate command that actually instructs the terminal to move to CSI-RS 2.

[442] In this case, "tracking of the CSI-RS" may refer to an operation of synchronizing time and/or frequency on the CSI-RS so that the terminal can measure the CSI-RS.

[443] In other words, a pre-activated CSI-RS x may actually be activated or also may not be activated (within a particular timer time).

[444] In this case, after the terminal receives from the base station an activation message indicating activation of the CSI-RS x, it may feed full CSI reporting back to the base station after a particular y ms.

[445] In this case, the meaning of feeding back full CSI reporting may be construed as the terminal carrying out meaningful CSI feedback to the base station.

[446] The CSI feedback may be judged to be either meaningful or meaningless depending on the

number of measured samples.

[447]

[448] **Transmission of capability information**

[449] More specifically, in the present specification, first, the terminal informs the base station of its own CSI operation-related capability information in advance (for example: upon first connection) by transmitting particular capability signaling to the base station.

[450] The CSI operation-related terminal-capability information may comprise at least one of the following items of information.

[451] "CSI-related operation" here may refer to an operation related to a CSI-RS, CSI-IM and/or CSI process.

[452] A disclosure of "A and/or B" may be construed as "at least one of A or B."

[453] 1. Capability information regarding the maximum number of CSI-RSs (Nc), CSI-interference measurements (IM) (Ni), and/or CSI processes (Np in Number) that may be fully activated at the same time

[454] In this case, the reason "full activation (configuration)" is expressed is in the case of a terminal with, for example, Nc = 3, Ni = 3, Np = 4, a base station can actually configure a total of Nc = 3 CSI-RSs, Ni = 3 CSI-IMs, and Np = 4 CSI processes at the same time; in this case, all the CoMP operations in the existing Rel-11 standard can be supported.

[455] In other words, the terminal must conduct channel measurement on all of the Nc = 3 CSI-RSs, must conduct interference measurement (IM) on all of the Ni = 3 CSI-IMs, and must carry out CSI feedback on all of the Np = 4 CSI processes.

[456] 2. Capability information regarding up to how many CSI-RSs (Nc′), CSI-IMs (Ni′), and/or CSI processes (Np′) may be partially activated at the same time

[457] Here the reason for the expression "partial activation" is that it may be limited to only a particular part of the operations (e.g., CSI-RS tracking) that a terminal may perform upon "full activation"; or it may also comprise a separate additional operation.

[458] For example, for a particular terminal, the parameters in 1 above may be Nc = 1, Ni = 1, Np = 1, and at the same time the parameters in 2 may be Nc′ = 3, Ni′ = 1, Np′ = 1.

[459] In other words, the only difference is that Nc = 1 and Nc′ = 3.

[460] This may be construed to mean that the particular terminal maintains time/frequency synchronization/tracking with respect to Nc′ = 3 partially activated CSI-RSs and, of these, a particular Nc = 1 fully activated CSI-RS may be designated.

[461] Among representative methods by which the Nc = 1 CSI-RS may be designated, there are: (1) a method by which an indication may be received in the MAC layer via a MAC CE command or the like; and (2) a method by which a more dynamic indication may be received in the PHY layer via DCI signaling.

[462] Via such a method, the complexity and overhead for CSI feedback may always be kept the same because the terminal need only perform a single CSI feedback (in a particular CC) for a single Np = Np′ = 1 CSI process.

[463] It also has the advantage that only a CSI-RS index that the terminal must measure may be dynamically switched via signaling in the MAC layer or PHY layer using the method that the present specification proposes.

[464] In other words, the present specification provides a method for switching only a resource that is a target of measurement via RRC signaling, namely, signaling with a latency less than the CSI-RS reconfiguration latency.

[465] In the present specification, although for the sake of convenience the description is centered on CSI-RS, it will be evident that the method proposed by the present specification may be extended and applied identically to the dynamic switching of a CSI-IM index (or CSI process index).

[466] In addition, there may be an additional restriction in the form of Nc <= Nc′, Ni <= Ni′, and/or Np <= Np′ between the parameters in 1 and 2 above.

[467] In this case, the terminal must transmit the capability signaling only if such conditions are satisfied.

[468]

[469] If a base station receives the capability signaling comprising CSI operation-related terminal-capability information from the terminal, when the base station subsequently configures the corresponding terminal, it must transmit RRC signaling to the terminal in a form that does not violate the above-discussed combination of capability properties.

[470] The terminal does not anticipate a case in which these capability properties are violated and may consider it to be an error case.

[471]

[472] As described above, it is assumed that the base station is able to configure the terminal with all three CSI-RSs corresponding to Nc′ = 3 via RRC signaling.

[473] But in this case the terminal may receive from the base station a separate identifier capable of identifying that each CSI-RS index is configured in a "partial activation" state, or signaling capable of recognizing this based on a particular implicit indication.

[474] In this case, the terminal conducts time/frequency synchronization/tracking on each of the three CSI-RSs from a point in time at which the respective RRC signaling is received.

[475] Synchronization/tracking may be conducted based on information, such as a particular RS (e.g., CRS) to which a quasi co-location (QCL) assumption is applied that is included in each CSI-RS configuration.

[476] In this case, only a particular Nc = 1 CSI-RS from among the Nc′ = 3 CSI-RSs may be additionally (or at the same time) configured or indicated as "full activation" in the form of the above separate identifier.

[477] Alternatively, the Nc = 1 CSI-RS may be implicitly defined in advance as a particular index, such

as by specifying that it is always the lowest (or highest)-indexed CSI-RS.

[478] In that case, the terminal needs to conduct channel measurement for CSI feedback with respect to only the Nc = 1 fully activated CSI-RS.

[479] In other words, the terminal only conducts tracking, and not channel measurement, of the remaining Nc′ – Nc = 2 CSI-RSs.

[480] As described above, in a method of performing channel measurement with respect to only the particular Nc = 1 CSI-RS and deriving feedback contents (e.g., RI/PMI/CQI) via this measurement, together with this, an operation of calculating the feedback contents for a particular configured CSI process may be defined/configured.

[481] For example, the terminal receives a particular Np = 1 CSI process from the base station via RRC signaling, and this CSI process is defined as a combination of a particular number of CSI-RSs and CSI-IM indices.

[482] In this case, however, depending on what the fully activated Nc = 1 CSI-RS is, an operation for automatically incorporating the fully activated CSI-RS may be defined/configured so that it is recognized as the target of channel measurement of the relevant CSI process.

[483] As a further embodiment, for example, three CSI processes may be configured in a partial activation state as Np′ = 3, and the Nc′ = 3 CSI-RS indices may be configured within the respective CSI processes.

[484] Thereafter, the base station may dynamically indicate to the terminal, via MAC or PHY signaling, a particular Np = 1 fully activated CSI process.

[485] In that case, the terminal may transmit to the base station CSI feedback for the particular fully activated CSI process.

[486] As a result, a separate identifier or a particular implicit signaling method may be defined that is capable of identifying whether, for each particular CSI process, a particular CSI-RS and/or CSI-IM index indicated in conjunction with it is a fixed index or an automatically variable index as discussed above.

[487] If the particular CSI-RS and/or CSI-IM index has been indicated to be fixed as a particular index, the terminal conducts measurement on a resource that corresponds to the fixed CSI-RS and/or CSI-IM index.

[488] If the particular CSI-RS and/or CSI-IM index is configured as a variable index and the particular Nc = 1 CSI-RS is fully activated via separate MAC or PHY signaling as discussed above, the index may be applied automatically.

[489] In this case, the fully activated Nc may be two or more.

[490] For example, the fully activated Nc may be two or more for purposes such as measuring multiple CSI-RS resources in a 2D-AAS structure together via a Kronecker operation or the like.

[491] In this case, if the fully activated Nc is dynamically indicated separately, such indices may be applied automatically.

[492] As a result, it is preferable that in such a CSI process configuration, the set of candidates from which a CSI-RS and/or CSI-IM index that may be indicated in the relevant configuration may be selected is defined in an RRC configuration step.

[493] Likewise, it is evident that the configuration or indication operation is applicable to the Ni′ and Ni numbers with respect to the CSI-IM as well.

[494] FIG. 15 shows an exemplary CSI measurement and reporting method proposed in the present specification.

[495] Referring to FIG. 15, a terminal transmits to a base station capability signaling, comprising CSI operation-related terminal-capability information (S1510).

[496] The terminal-capability information comprises: first control information that indicates a maximum number of CSI-related operations capable of being fully activated at the same time; and second control information that indicates a maximum number of CSI-related operations capable of being partially activated at the same time.

[497] Subsequently, when a CSI operation-related configuration is changed, the base station transmits CSI operation-related configuration information (or CSI-related operation configuration information) to the terminal (S1520).

[498] The CSI operation-related configuration information comprises at least one of: partially activated CSI-related operation index information, indicating a CSI-related operation in which partial activation is carried out; and fully activated CSI-related operation index information, indicating a CSI-related operation in which full activation is carried out.

[499] Next, the terminal measures the fully activated CSI based on the CSI operation-related configuration information (S1530).

[500] Prior to step S1530, the terminal carries out tracking of the partially activated CSI-RSs.

[501] See above for a detailed description of CSI-RS tracking.

[502] Next, the terminal reports the measurement result to the base station (S1540).

[503]

[504] FIG. 16 shows a further example of a CSI measurement and reporting method proposed in the present specification.

[505] Because S1610, S1620, S1640. and S1650 are the same as S1510 to S1540 in FIG. 15, a detailed description thereof is omitted.

[506] After step S1620 (after the base station has sent the CSI operation-related configuration information to the terminal), the base station transmits to the terminal an indication message indicating the measurement of a fully activated CSI-RS (S1630).

[507] The indication message may be a MAC CE or DCI.

[508] In addition, it may be preferable for the fully activated CSI-RS to be selected from among the

partially activated CSI-RSs.

[509]

[510] **Point in time for initialization/updating of CSI measurement window**

[511] When a terminal receives full activation signaling of a particular CSI-RS, CSI-IM, and/or CSI process index (or indices) from a base station via MAC signaling or PHY signaling at a point in time subframe (SF) #n, the terminal may apply CSI measurement and reporting from a specific y ms following that point in time (subframe #n), namely, from a point in time SF #(n + y).

[512] In the case of periodic CSI reporting, CSI measurement and reporting is started for a specific CSI-RS, CSI-IM, and/or CSI process index (or indices) that have been newly fully activated, starting from a particular reference resource point in time associated with an RI reporting instance that first occurs after the SF #(n + y) point in time.

[513] In other words, with respect to valid reference resource points in time following the SF #(n + y) point in time, the CSI (e.g., an RI/PMI/CQI) calculated at the reference resource point in time may be defined to report these new CSI contents starting from a point in time at which an RI is first reported.

[514] Thus, this means that even if a PMI/CQI reporting instance is present before the first RI reporting point in time, it must not be based on the newly fully activated configuration, and must continue to report CSI feedback contents based on the immediately previous configuration.

[515] As a result, the terminal carries out CSI reporting based on the fully activated configuration starting from the new RI reporting instance point in time.

[516]

[517] In the above operations, configuration information related to the window over which CSI measurement is averaged may also be defined so that it is provided separately or together via RRC signaling.

[518] In addition, such an operation may be defined for only an enhanced terminal that supports configurations such as full/partial activation.

[519] In other words, conventional unrestricted observation is not permitted, and instead, measurement is averaged only within a particular [d1, d2] ms time interval.

[520] This is because it may be preferable to define measurement averaging to be carried out only within a particular bounded interval because resource configuration information for the CSI-RS and/or CSI-IM to be measured may be switched dynamically via MAC or PHY signaling.

[521] For example, if the terminal receives signaling from the base station in which resource configuration information for a CSI-RS and/or CSI-IM to be measured is dynamically switched/indicated via MAC or PHY signaling (e.g., by DCI), then the terminal may be configured to initialize or update a measurement averaging window of the CSI-RS-based channel in conjunction with this.

[522] In addition, in conjunction with the (dynamically switched/indicated) signaling, the terminal may initialize or update the measurement averaging window in which the CSI-IM-based interference is measured.

[523] Here, the significance of the measurement averaging window being initialized or updated is that the start point of the measurement window from an arbitrary random point in time is initialized or updated again from a point in time #n (or after a point in time of a particular configuration/indication, e.g., #n + k) at which the (dynamically switched/indicated) signaling is received, instead of a conventional operation in which channel measurement values from corresponding CSI-RS ports, repeatedly measured by "unrestricted observation" for CSI measurement according to the current standards, are averaged according to terminal implementation, for example, from a past arbitrary point in time to the present.

[524] Alternatively, a scheme may also be applied in which point-in-time information (e.g., in the form of a timestamp) is explicitly signaled for the point in time, starting from which the measurement window is initialized or updated, via the aforementioned signaling.

[525] For example, there may be a method of indicating time information for absolute time parameter values, such as an SFN, slot number, or the like; or a scheme in which the signaling is indicated by particular +/− delta value form with respect to a point in time at which the terminal receives it.

[526] In other words, the signaling may be limited to a role of updating/resetting only the starting point in time of a measurement averaging window.

[527] In this case (depending on a terminal implementation) the terminal may average the CSI measurement values starting from that point in time and continuing until the additional signaling is received.

[528] The signaling may be separately (independently) signaled for each CSI process. By this means, a measurement window reset may be independently applied for each process.

[529] The signaling may also be applied to reset an interference measurement averaging window for a particular CSI-IM resource.

[530] In this case, it also serves to initialize a measurement averaging window for a CSI-RS and CSI-IM pertaining to a particular CSI process.

[531] Alternatively, a scheme may also be applied in which a separate (independent) indicator is signaled for resetting an interference measurement averaging window for a CSI-IM resource.

[532] This has the effect that the past interference environment may be separated so that it is no longer reflected in an interference measurement value starting from the current point in time; as a result of notifying the terminal to reset the measurement averaging window for the particular CSI process if in an environment (e.g., eICIC, eIMTA, LAA or the like) in which there is a change in the interference environment, there is, for example, a change in the interference environment that the base station is able to predict/sense.

[533] FIG. 17 shows a further example of a CSI measurement and reporting method proposed in the present specification.

[534] Because S1710 to S1730, S1750, and S1760 are the same as S1610 to S1630, S1640 and S1650 in

FIG. 16, the detailed description thereof is omitted.

[535] Referring to FIG. 17, after step S1730, the terminal initializes or updates a CSI measurement window (S1740).

[536] Thereafter, the terminal repeatedly measures a fully activated CSI-RS in an initialized or updated CSI measurement window interval, averages the measurement results, and reports the average value to the base station (S1750 - S1760).

[537] Prior to step S1740, the base station may transmit to the terminal configuration information related to the CSI measurement window.

[538]

[539] In a further embodiment of a similar kind to the (dynamically switched/indicated) signaling above, in the present specification, the above-discussed operation related to measurement window configuration is applicable to a beamformed CSI-RS-based scheme, as follows.

[540] For an elevation beamforming and FD-MIMO operation, the following PMI feedback scenarios may be considered.

[541] 1. Precoding definition for elevation beamforming (EBF)/FD-MIMO

[542] (1) Precoding matrix/vector

[543] - P_1: wideband; updated less frequently

[544] - P_2: subband or wideband; updated more frequently

[545] - P is a function of P_1 and P_2, applied to a 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 beamformed with P_1(P_1 transparent to UE).

[550] - PMI report(s) for P_2

[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 P_1 and P_2

[555] 3) Scenario 3

[556] - UE measures both non-precoded 1- or 2-D CSI-RS ports (lower duty cycle) and CSI-RS beamformed with P_1

[557] - PMI report(s) for P_1 and P_2

[558] 4) Scenario 4

[559] - UE measures non-precoded 1- or 2-D CSI-RS ports

[560] Note: P_1 not applied to CSI-RS at eNB (P_1 indicated to UE).

[561] - PMI report(s) for P_2

[562]

[563] From among scenarios 1 to 4, for example, in a method using a beamformed CSI-RS such as scenarios 1 and 3, if a matrix P1 in which beamforming has been applied to CSI-RS ports by a base station is changed, although the terminal does not need to know the matrix P1 itself, the base station must inform the terminal in advance regarding a point in time at which P1 was changed.

[564] Accordingly, the terminal may configure/apply a suitable measurement averaging window during CSI measurement and calculation.

[565] Thus, according to the current standard, when the terminal performs channel measurement on the corresponding CSI-RS ports, according to the terminal implementation, it has been possible to improve reliability (for example, through a noise suppression effect) because the terminal averages the channel measurement values from these CSI-RS ports, which have been repeatedly measured from an arbitrary past point in time to the present by "unrestricted observation."

[566] In scenarios 1 to 4, however, because beamformed CSI-RS ports are used in P1 itself that are not known to the terminal, the base station may change P1 at a random point in time, and if the base station does not notify the terminal that the P1 has changed, a problem may arise in the accuracy of the CSI measurement and reporting, because the terminal may average together the channel measurement values of P1 prior to the change and P1′ after the change.

[567] Accordingly, to solve such a problem, the present specification provides a method in which the base station transmits to the terminal a kind of beam-change notification or beam-change indicator (BCI) signaling.

[568] Below, a "beam-change indicator" is referred to simply as a "BCI."

[569] BCI signaling may be indicated in the form of RRC signaling.

[570] More preferably, however, BCI signaling may be provided as signaling via a MAC CE or as a dynamic indication via a DCI or the like.

[571] In other words, when a terminal receives BCI signaling from a base station, it updates the starting point of a measurement averaging window that is applied during CSI derivation in the relevant CSI process to a point in time at which the relevant BCI signaling is received (or a point in time specifically indicated from this point, a point in time explicitly indicated by a separate timestamp, or the like).

[572] Thus, a scheme may also be applied in which information (e.g., in the form of a timestamp) about the point in time at which the relevant measurement window is initialized or updated from that point in time is explicitly signaled, along with BCI information (or as information associated with it).

[573] For example, there may be a method of indicating time information for absolute time parameter values, such as an SFN, slot number, or the like; or a scheme in which the signaling is indicated by particular +/− delta value form with respect to a point in time at which the terminal receives it.

[574] Thus, this BCI signaling may be limited to a role of updating/resetting only the starting point in time of a measurement averaging window.

[575] In this case, the terminal may (depending on a terminal implementation) average the CSI

measurement values from this point in time (the point in time at which the BCI signaling is received) to a subsequent point in time at which additional BCI is received.

[576] As a result, because the terminal does not know the updated matrix P1 itself, but has been instructed via the BCI that P1 has been updated, from this point in time forward, it may carry out CSI calculation and reporting (e.g., P1, P2, RI, CQI and the like) relating to the CSI process for only those CSI-RS ports to which the updated P1 has been applied, by newly averaging CSI measurement values from this point in time.

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

[578] By this means, a measurement window reset may be independently applied for each process.

[579] The BCI may also be applied to reset an interference measurement averaging window for a particular CSI-IM resource.

[580] In this case, it also functions to initialize a measurement averaging window for a CSI-RS and CSI-IM pertaining to a particular CSI process.

[581] Alternatively, a scheme may also be applied in which a separate (independent) indicator is signaled for resetting an interference measurement averaging window for a CSI-IM resource.

[582] This has the effect that the past interference environment may be separated so that it is no longer reflected in an interference measurement value starting from the current point in time; as a result of notifying the terminal to reset the measurement averaging window for the particular CSI process if in an environment (e.g., eICIC, eIMTA, LAA or the like) in which there is a change in the interference environment, there is, for example, a change in the interference environment that the base station is able to predict/sense.

[583]

[584] **General apparatus to which the present invention is applicable**

[585] FIG. 18 is a block diagram illustrating a wireless communication apparatus according to an embodiment of the present invention.

[586] Referring to FIG. 18, the wireless communication system comprises a base station (1810) and a plurality of terminals (1820) located in the vicinity of the base station (1810).

[587] The base station (1810) comprises a processor (1811), a memory (1812), and a radio frequency (RF) unit (1813). The processor (1811) implements the functions, procedures, and/or methods proposed in FIG. 1 to FIG. 17 above. The layers of the radio interface protocol may be implemented by the processor (1811). The memory (1812) is connected to the processor (1811) and stores various information for driving the processor (1811). The RF unit (1813) is connected to the processor (1811) and sends and/or receives radio signals.

[588] The terminal (1820) comprises a processor (1821), a memory (1822), and an RF unit (1823). The processor (1821) implements the functions, procedures, and/or methods proposed in FIG. 1 to FIG. 17 above. The layers of the radio interface protocol may be implemented by the processor (1821). The memory (1822) is connected to the processor (1821) and stores various information for driving the

processor (1821). The RF unit (1823) is coupled to the processor (1821) and transmits and/or receives a radio signal.

[589] The memories (1812, 1822) may exist within or outside of the processors (1811, 1821) and may be connected to the processors (1811, 1821) by various well-known means. In addition, the base station (1810) and/or terminal (1820) may have a single antenna or multiple antennas.

[590] In the embodiments described above, the components and features of the present invention are combined in certain ways. Absent an explicit indication otherwise, each component or feature should be considered optional. Each component or feature may be implemented in a way that is not combined with other components and features. In addition, it is also possible to configure an embodiment of the present invention by combining some components and/or features. The sequence of operations described in the embodiments of the present invention may be changed. Some configurations or features of an embodiment may be included in other embodiments, or may be replaced with corresponding configurations or features of other embodiments. It will be evident that, in the claims, claims not having an explicit citation relation may be combined to configure an embodiment or may be incorporated as a new claim by amendments after the application is filed.

[591] The embodiments according to the present invention may be implemented by various means, such as, for example, hardware, firmware, software, or combinations thereof. In the case of a hardware implementation, an embodiment of the present invention may be realized by one or more application specific integrated circuits (ASICs), digital signal processors (DSPs), digital signal processing devices (DSPDs), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), processors, controllers, microcontrollers, microprocessors, and the like.

[592] In the case of an implementation by firmware or software, an embodiment of the present invention may be realized in the form of a module, procedure, mathematical function, or the like for carrying out the aforementioned functions or operations. The software code may be stored in a memory and driven by a processor. The memory may be located inside or outside the processor, and may exchange data with the processor by various well-known means.

[593] It will be evident to a person of skill in the art that the present invention may be implemented in other specific ways without departing from the essential features of the present invention. Accordingly, the above detailed description should be considered illustrative and should not be construed as limiting in any respect. The scope of the present invention should be determined by a reasonable construction of the attached claims, and all modifications within the equivalent scope of the present invention are included in its scope.

Industrial Applicability

[594] Although the proposed method of the present invention for feeding back CSI in a wireless communication system has been illustrated based on examples in which the method is applied to a 3GPP LTE/LTE-A system, it is applicable to various wireless communication systems in addition to 3GPP LTE/LTE-A systems.

Claims

[Claim 1] A method for feeding back channel-state information (CSI) in a wireless communication system, characterized in that the method is carried out by a terminal and comprises:

a step of transmitting, to a base station, information regarding the capability of the terminal for CSI-related operation;

a step of receiving CSI-related operation configuration information from the base station,

wherein the CSI-related operation configuration information comprises at least one of: partial activation CSI-related operation index information indicating a CSI-related operation of performing partial activation; or full activation CSI-related operation index information indicating a CSI-related operation of performing full activation;

a step of tracking partially activated CSI reference signals (CSI-RSs);

a step of measuring a fully activated CSI-RS; and

a step of reporting the result of the measurement to the base station.

[Claim 2] The method according to Claim 1,

characterized in that the step of measuring the fully activated CSI-RS comprises:

a step of receiving a first message ordering activation of the measurement of the fully activated CSI-RS from the base station; and

a step of measuring the fully activated CSI-RS activated by the first message.

[Claim 3] The method according to Claim 1,

characterized in that the CSI-related operation relates to at least one of a CSI-RS, CSI-IM (Interference Management) or a CSI process.

[Claim 4] The method according to Claim 1,

characterized in that the terminal-capability information comprises: first control information that indicates a maximum number of CSI-related operations capable of being fully activated at the same time; and second control information that indicates a maximum number of CSI-related operations capable of being partially activated at the same time.

[Claim 5] The method according to Claim 1,

characterized in that the step of tracking the partially activated CSI-RSs comprises:

a step of synchronizing the partially activated CSI-RSs in time and/or frequency.

[Claim 6] The method according to Claim 1,

characterized in that the tracking is carried out by applying a particular RS (Reference Signal), which is included in

the CSI-related operation configuration information, and a quasi co-location (QCL) assumption.

[Claim 7] The method according to Claim 1,

characterized in that a fully activated CSI-RS is selected from among the partially activated CSI-RSs.

[Claim 8] The method according to Claim 2,

characterized in that the first message is MAC (Media Access Control), CE (Control Element) or DCI (Downlink Control Information).

[Claim 9] The method according to Claim 2,

characterized in that it further comprises a step of receiving third control information related to a CSI-RS measurement window from the base station;

wherein the step of measuring the CSI-RS comprises:

a step of initializing or updating the CSI-RS measurement window when the first message is received;

a step of repeatedly measuring a CSI-RS from a point in time at which the CSI-RS measurement window is initialized or updated over a particular period; and

a step of averaging the measurement results.

[Claim 10] The method according to Claim 9,

characterized in that if the CSI feedback is periodic CSI feedback, then the time at which the CSI-RS measurement window is initialized or updated is a particular reference resource time related to a rank indicator (RI) report first generated after the specific period.

[Claim 11] The method according to Claim 2,

characterized in that the first message is characterized in that it is received from the base station for each respective CSI process.

[Claim 12] The method according to Claim 2,

characterized in that the first message is characterized in that it comprises a beam-change indicator (BCI) signaling that provides notification of a change in a beamforming-related matrix.

[Claim 13] A terminal for feeding back channel-state information (CSI) in a wireless communication system, characterized in that the terminal comprises:

a radio frequency (RF) unit that sends or receives a radio signal, and

a processor that controls the RF unit;

wherein the terminal exercises control so that:

terminal-capability information for a CSI-related operation is transmitted to a base station;

CSI-related operation configuration information is received from the base station, wherein the CSI-related operation configuration information comprises at least one of partial activation CSI-related operation

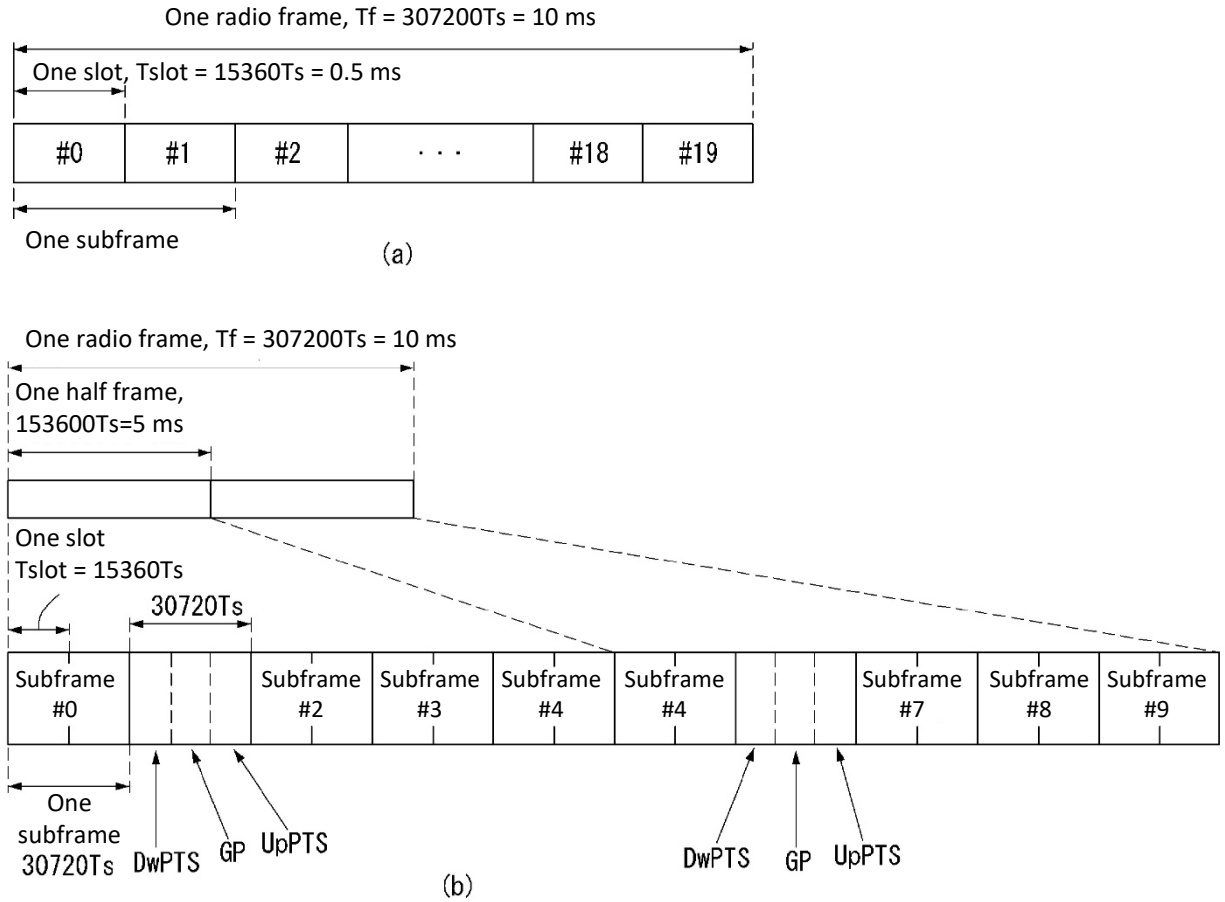
index information indicating a CSI-related operation of performing partial activation and full activation CSI-related operation index information indicating a CSI-related operation of performing full activation;

partially activated CSI-RSs (reference signals) are tracked;

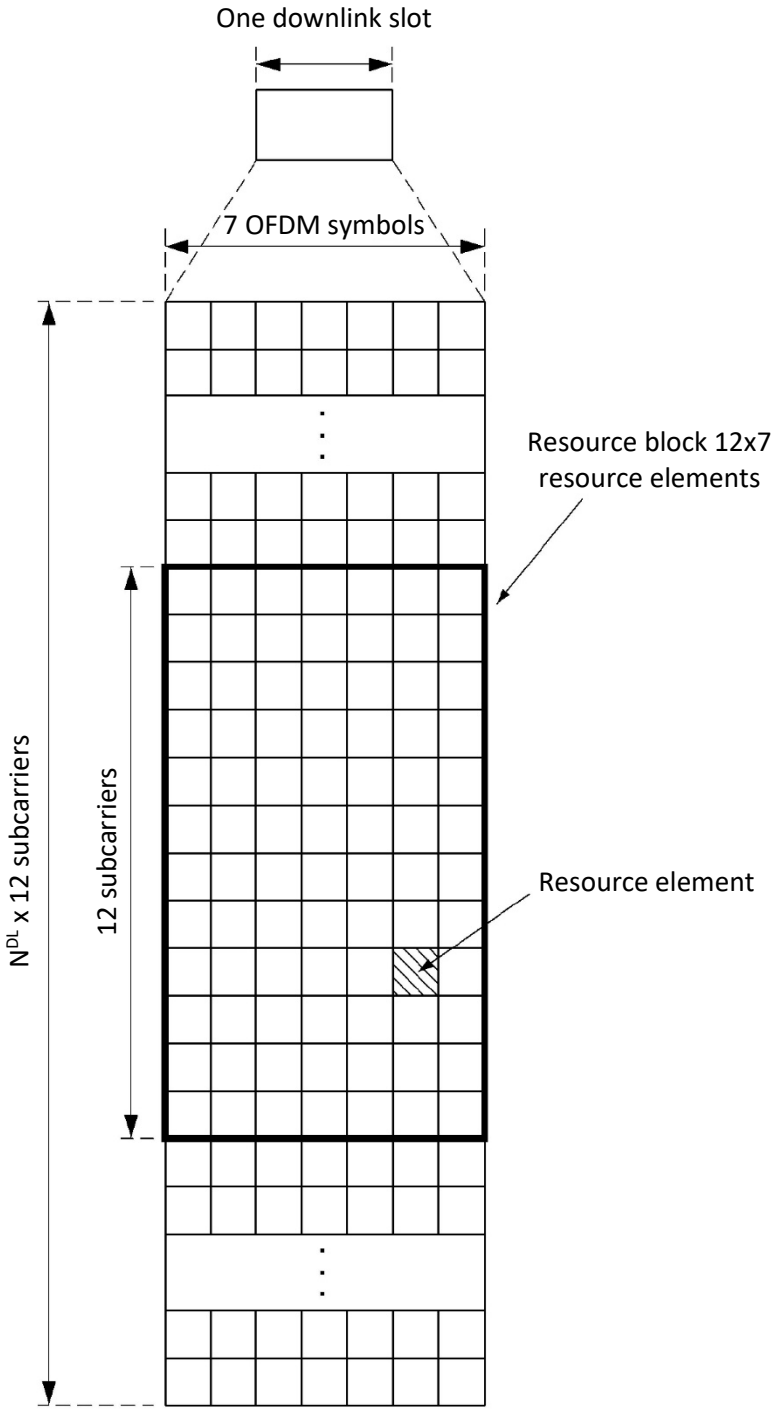
a fully activated CSI-RS is measured; and

the measurement result is reported to the base station.

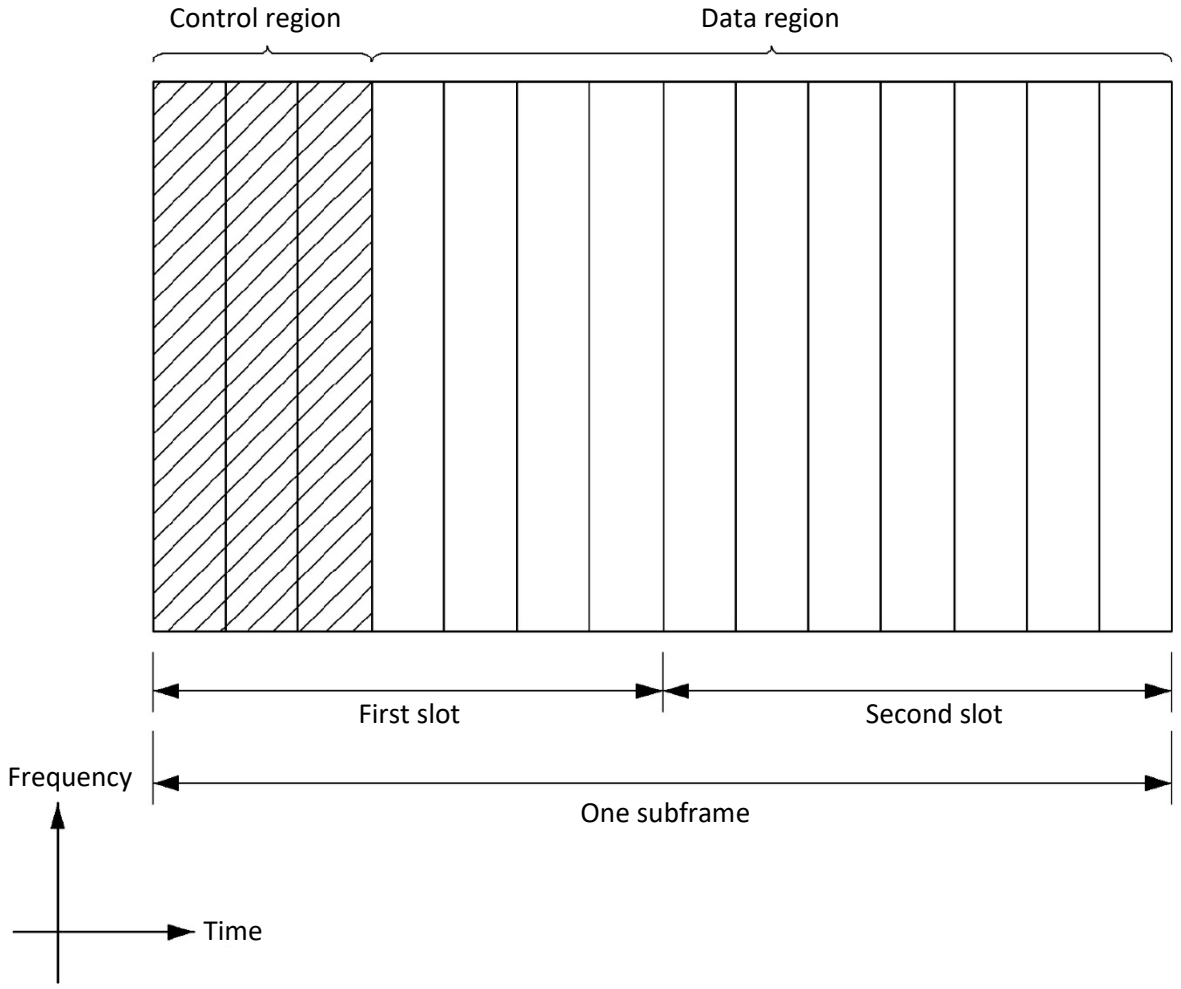
[FIG. 1]


One radio frame, Tf = 307200Ts = 10 ms
One slot, Tslot = 15360Ts = 0.5 ms
#0
#1
#2
· · ·
#18
#19
One subframe
(a)
One radio frame, Tf = 307200Ts = 10 ms
One half frame,
153600Ts=5 ms
One slot
Tslot = 15360Ts
30720Ts
Subframe #0
Subframe #2
Subframe #3
Subframe #4
Subframe #4
Subframe #7
Subframe #8
Subframe #9
One subframe 30720Ts
DwPTS
GP
UpPTS
DwPTS
GP
UpPTS
(b)

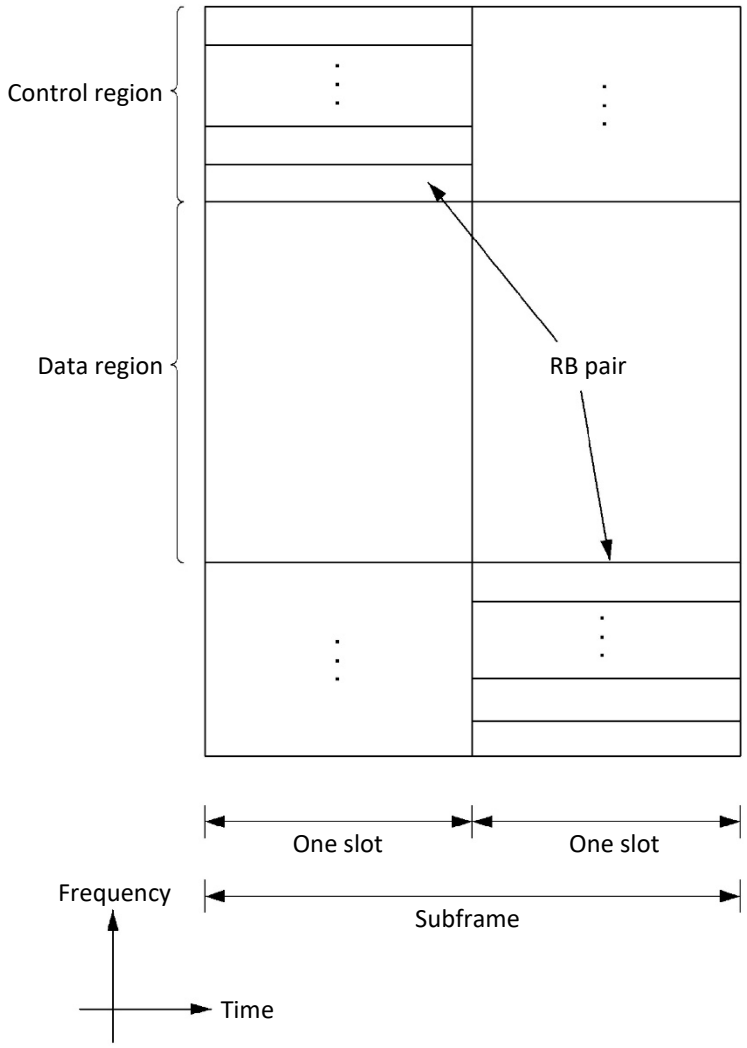
[FIG. 2]


One downlink slot
7 OFDM symbols
Resource block 12x7
resource elements
Resource element
N^{DL} x 12 subcarriers
12 subcarriers

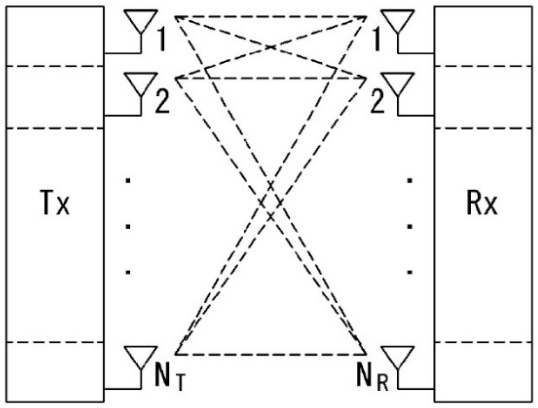
[FIG. 3]


Control region
Data region
First slot
Second slot
Frequency
One subframe
Time

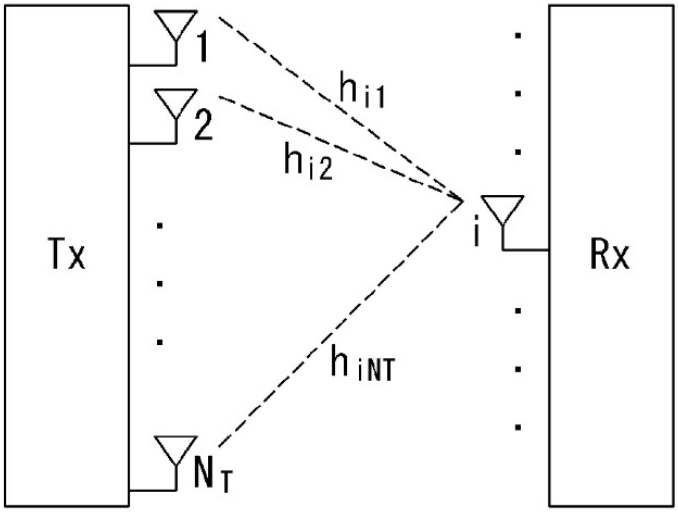
[FIG. 4]


Control region
Data region
RB pair
One slot
One slot
Frequency
Subframe
Time

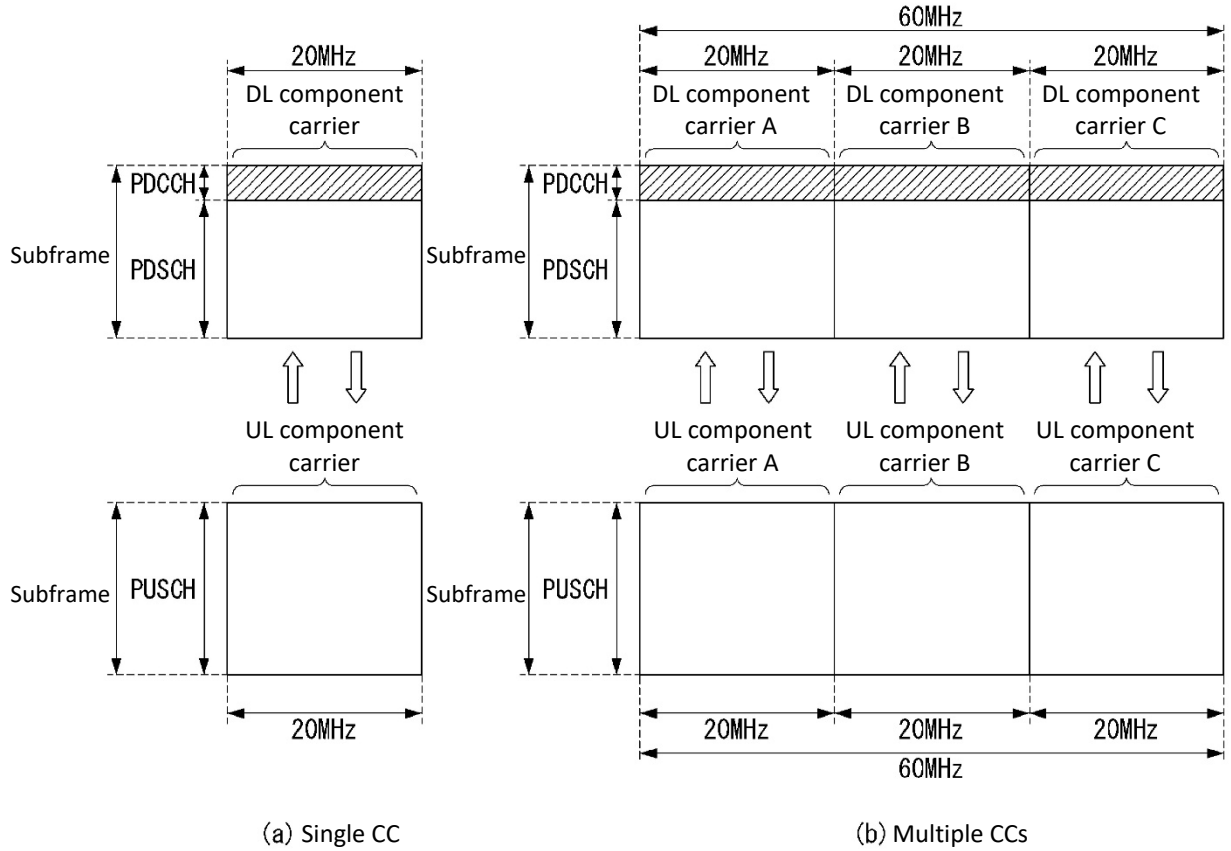
[FIG. 5]


Tx
Rx
1
2
N_T
1
2
N_R

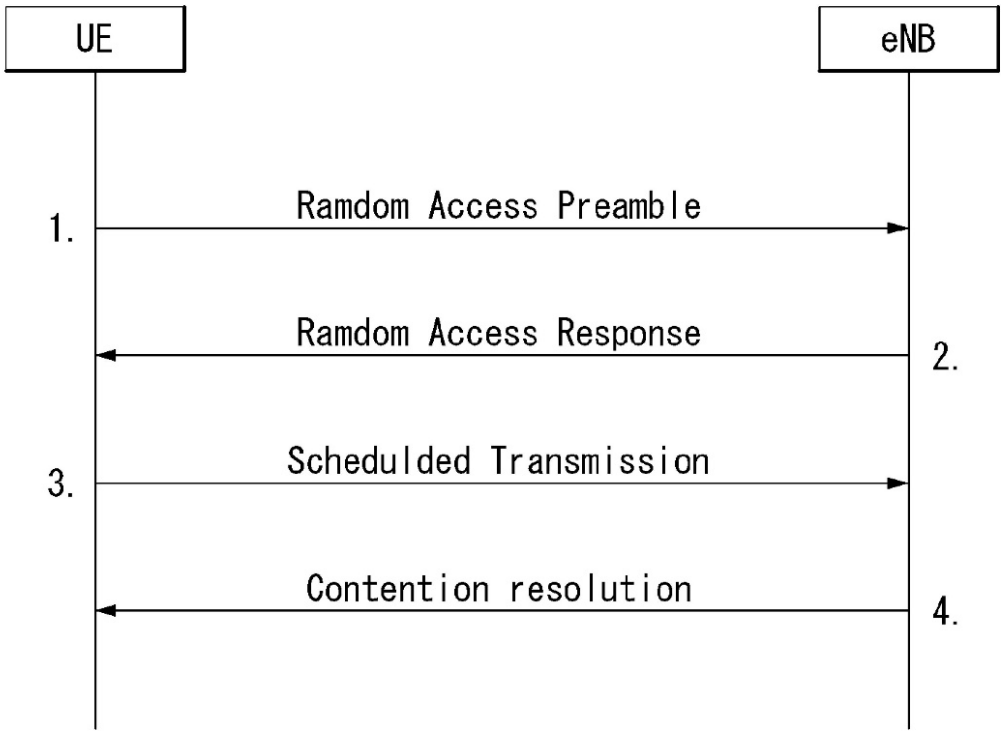
[FIG. 6]



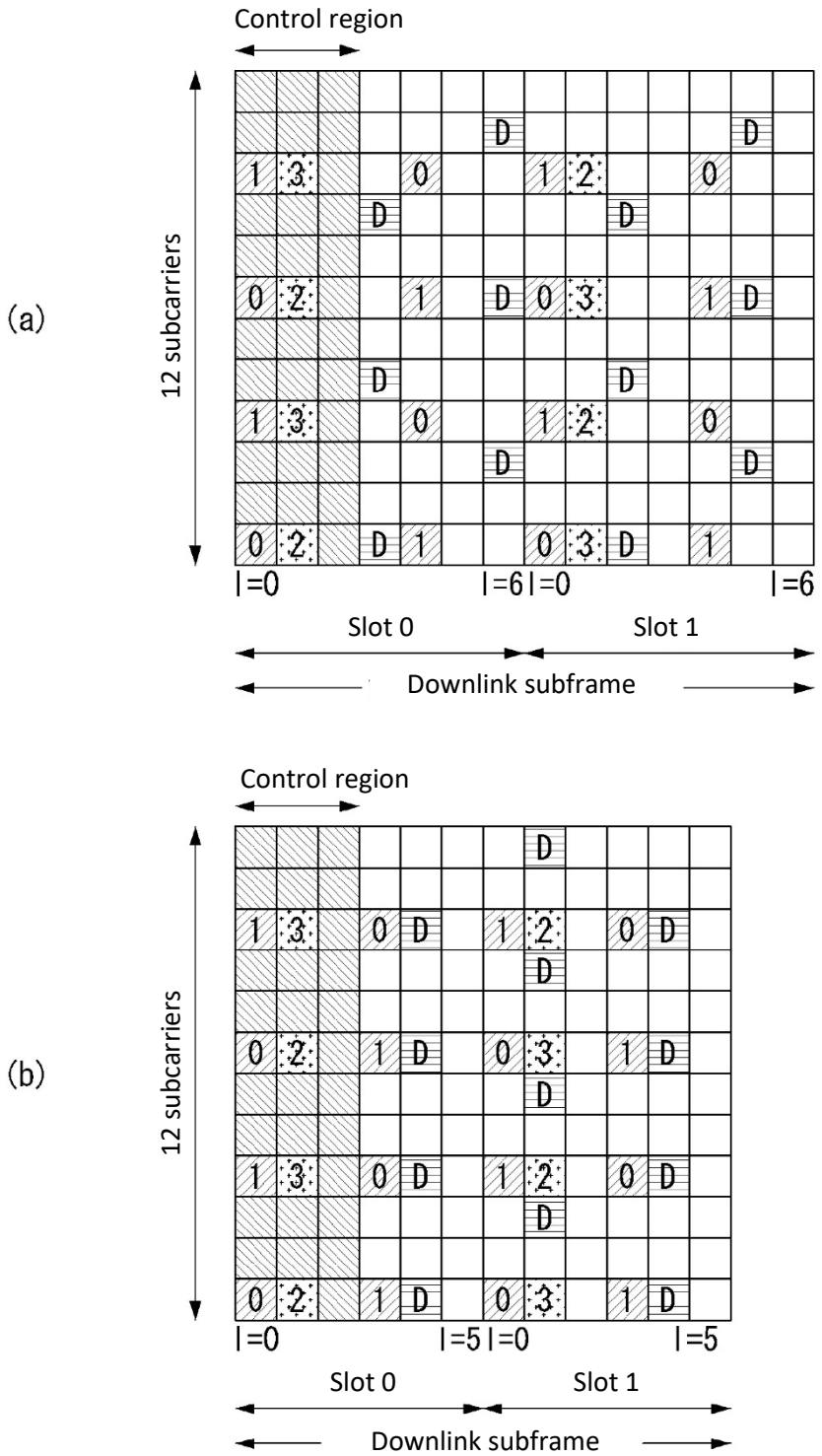
[FIG. 7]


20MHz
DL component carrier
PDCCH
PDSCH
Subframe
UL component carrier
PUSCH
Subframe
20MHz
(a) Single CC
60MHz
20MHz
20MHz
20MHz
DL component carrier A
DL component carrier B
DL component carrier C
PDCCH
PDSCH
Subframe
UL component carrier A
UL component carrier B
UL component carrier C
PUSCH
Subframe
20MHz
20MHz
20MHz
60MHz
(b) Multiple CCs

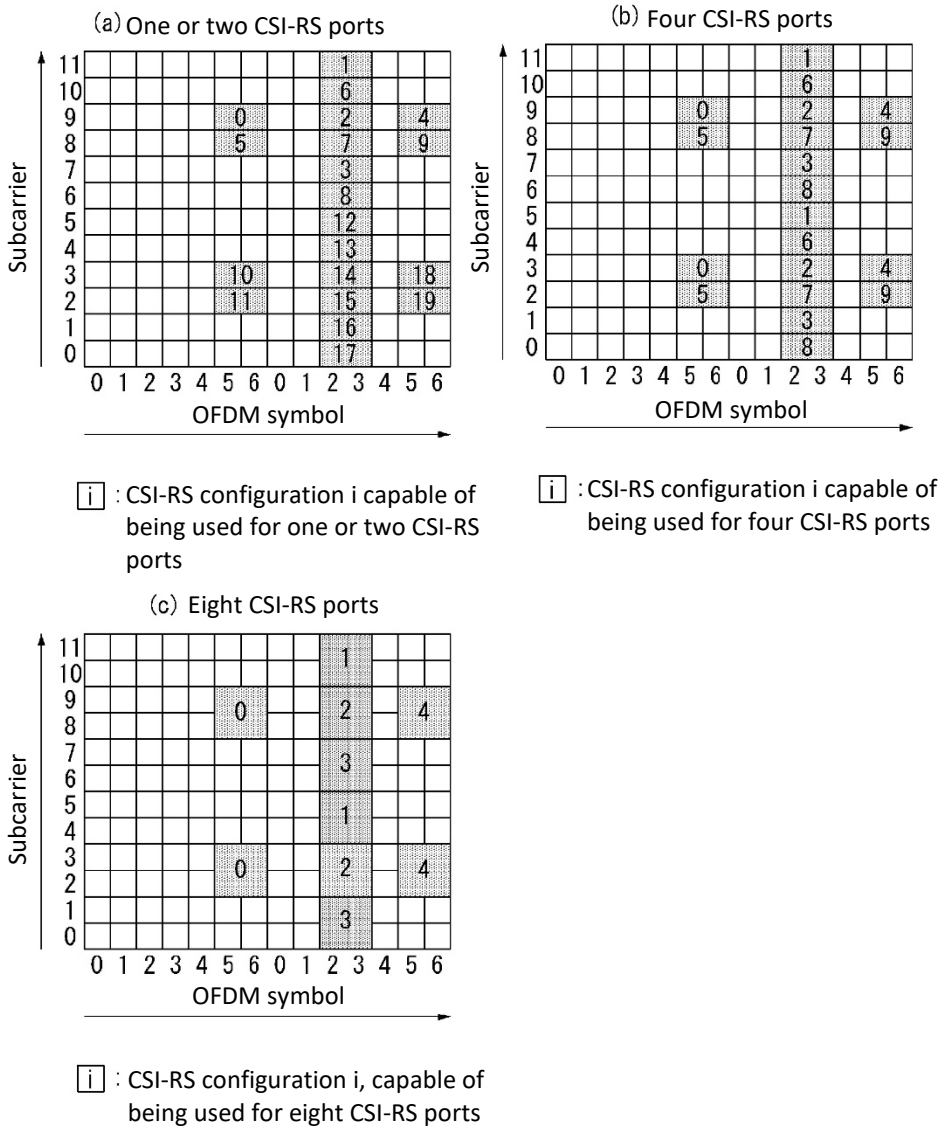
[FIG. 8]


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

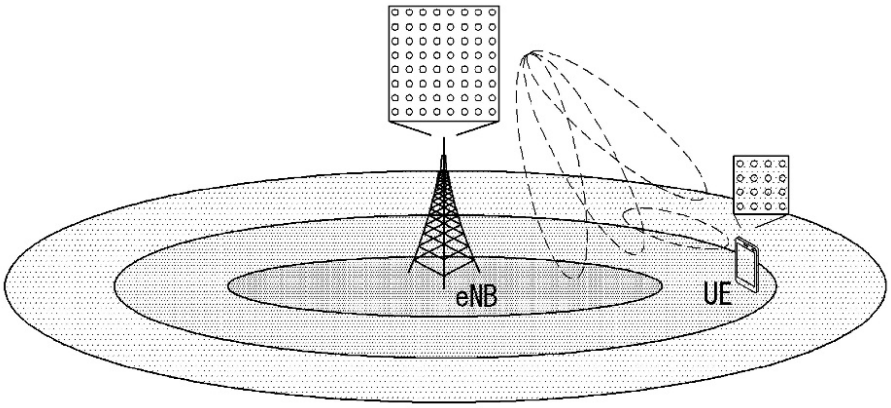
[FIG. 9]


(a)
Control region
12 subcarriers
l=0
l=6
l=0
l=6
Slot 0
Slot 1
Downlink subframe
(b)
Control region
12 subcarriers
l=0
l=5
l=0
l=5
Slot 0
Slot 1
Downlink subframe

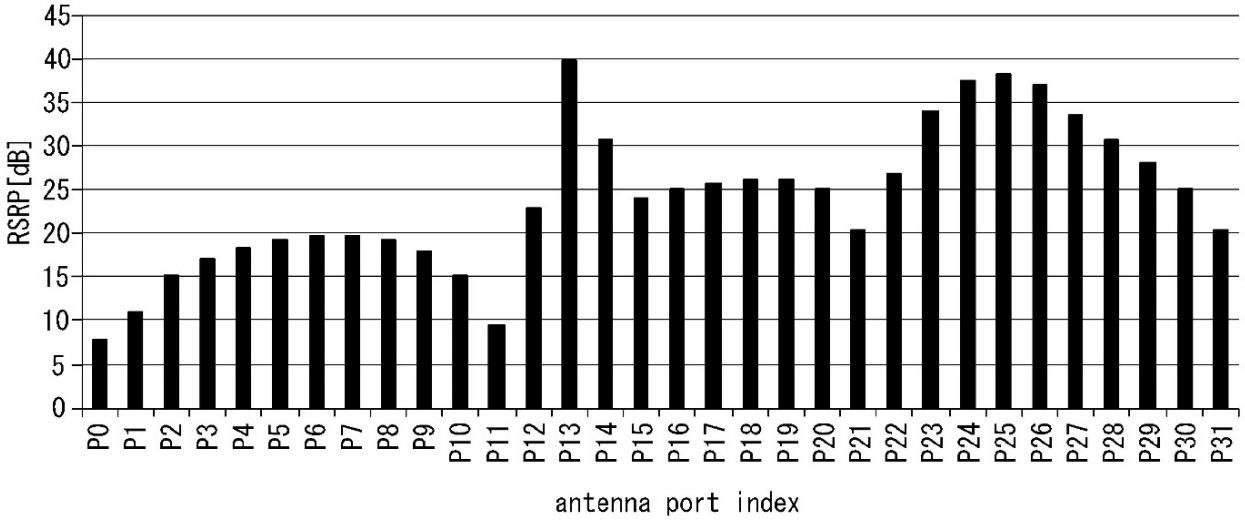
[FIG. 10]


(a) One or two CSI-RS ports
Subcarrier
OFDM symbol
i : CSI-RS configuration i capable of being used for one or two CSI-RS ports
(b) Four CSI-RS ports
Subcarrier
OFDM symbol
i : CSI-RS configuration i capable of being used for four CSI-RS ports
(c) Eight CSI-RS ports
Subcarrier
OFDM symbol
i : CSI-RS configuration i, capable of being used for eight CSI-RS ports

[FIG. 11]


eNB
UE

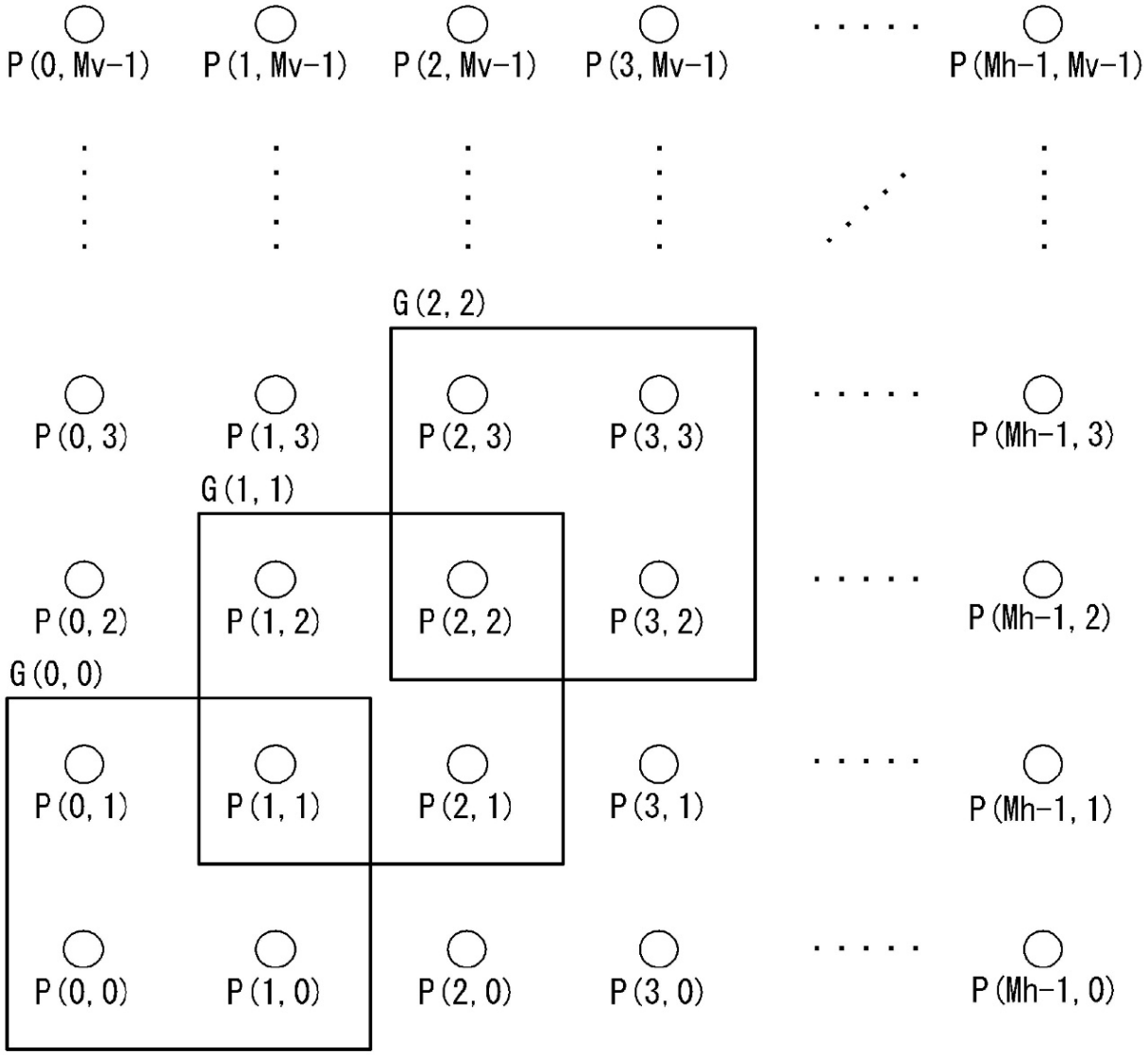
[FIG. 12]


RSRP[dB]
45
40
35
30
25
20
15
10
5
0
P0
P1
P2
P3
P4
P5
P6
P7
P8
P9
P10
P11
P12
P13
P14
P15
P16
P17
P18
P19
P20
P21
P22
P23
P24
P25
P26
P27
P28
P29
P30
P31
antenna port index

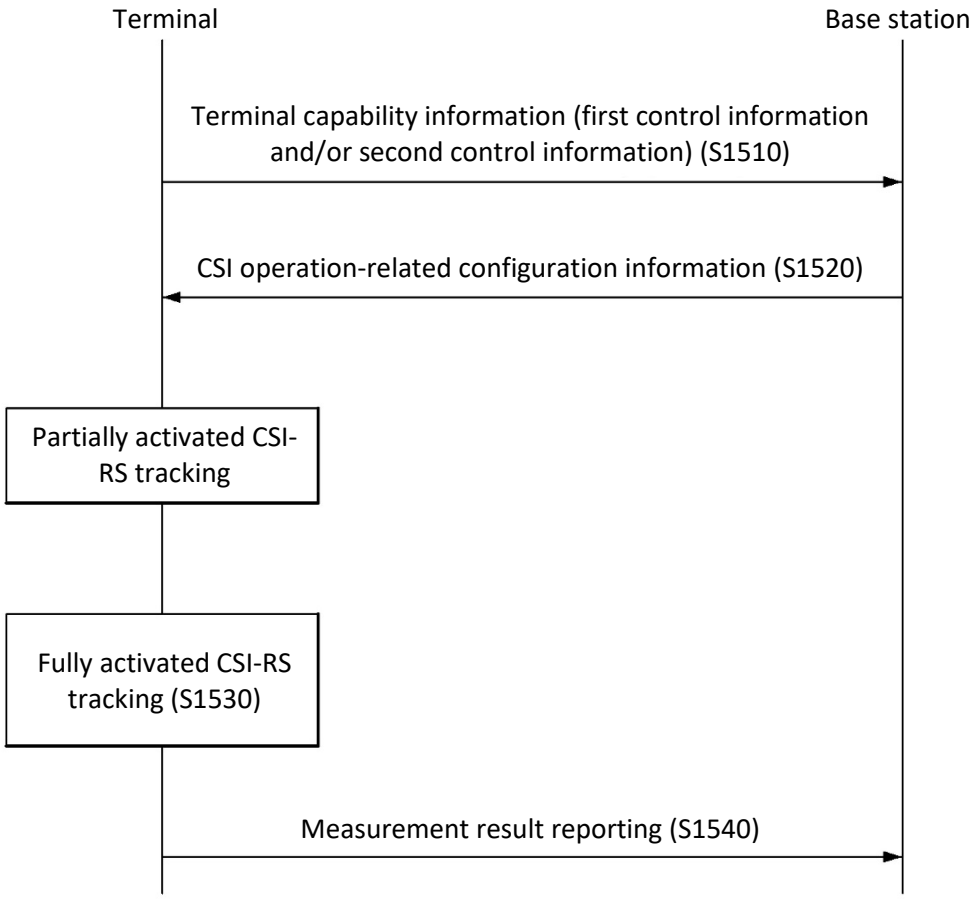
[FIG. 13]

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

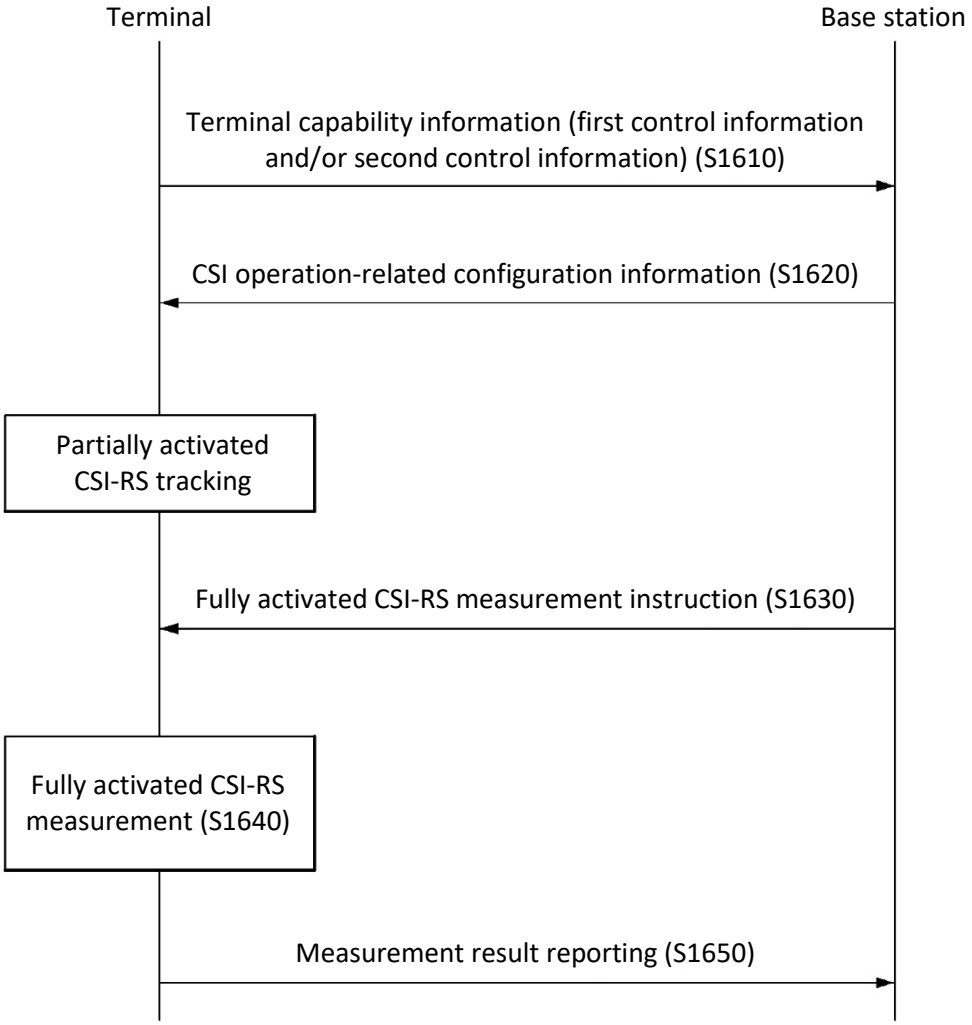
[FIG. 14]


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)

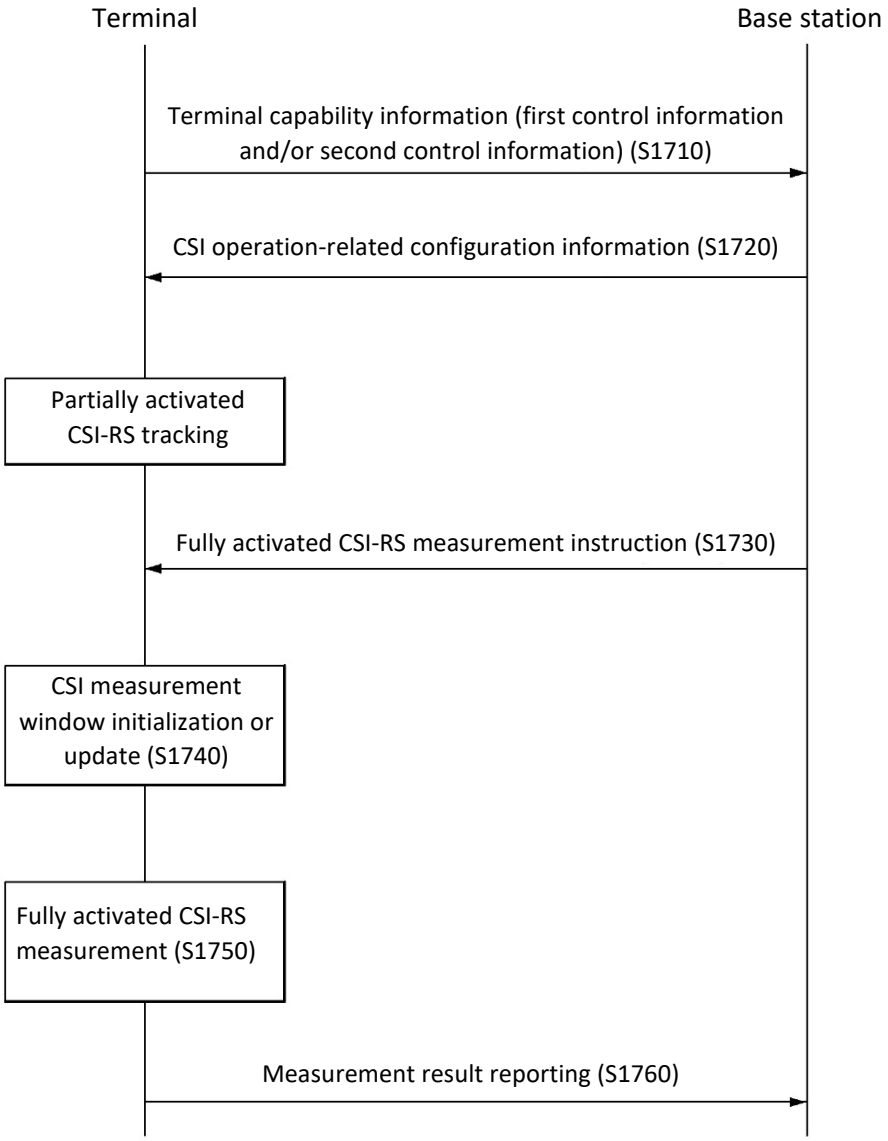
[FIG. 15]


Terminal
Base station
Terminal capability information (first control information and/or second control information) (S1510)
CSI operation-related configuration information (S1520)
Partially activated CSI-RS tracking
Fully activated CSI-RS tracking (S1530)
Measurement result reporting (S1540)

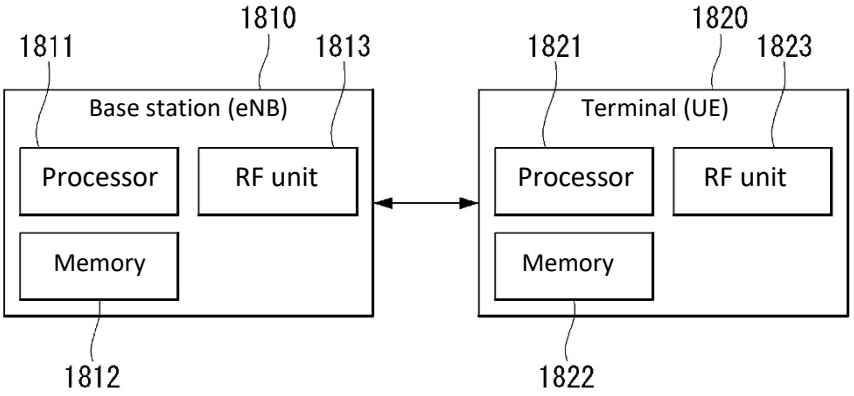
[FIG. 16]


Terminal
Base station
Terminal capability information (first control information and/or second control information) (S1610)
CSI operation-related configuration information (S1620)
Partially activated CSI-RS tracking
Fully activated CSI-RS measurement instruction (S1630)
Fully activated CSI-RS measurement (S1640)
Measurement result reporting (S1650)

[FIG. 17]


Terminal
Base station
Terminal capability information (first control information and/or second control information) (S1710)
CSI operation-related configuration information (S1720)
Partially activated CSI-RS tracking
Fully activated CSI-RS measurement instruction (S1730)
CSI measurement window initialization or update (S1740)
Fully activated CSI-RS measurement (S1750)
Measurement result reporting (S1760)

[FIG. 18]


1810
1811
1813
Base station (eNB)
Processor
RF unit
Memory
1812
1820
1821
1823
Terminal (UE)
Processor
RF unit
Memory
1822