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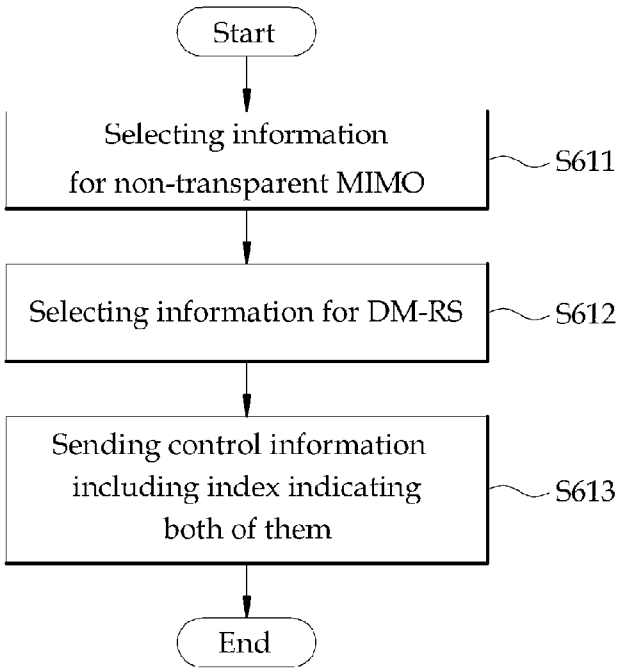
[Continued on next page]

(54) Title: BASE STATION, TERMINAL AND METHOD IN MULTI-USER MULTIPLE-INPUT MULTIPLE-OUTPUT

(57) Abstract: The present invention relates to Multiple Input Multiple Output(MIMO) in wireless communication system.

[Fig. 7]



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Description

Title of Invention: BASE STATION, TERMINAL AND METHOD IN MULTI-USER MULTIPLE-INPUT MULTIPLE-OUTPUT

Technical Field

[1] The present invention relates to Multiple Input Multiple Output(MIMO) in wireless communication system.

Background Art

[2] There are a number of multi-antenna transmission schemes or transmission such as transit diversity, closed-loop spatial multiplexing or open-loop spatial multiplexing.

Disclosure of Invention

Solution to Problem

[3] In accordance with an aspect, there is provided a method in the multiuser Multiple-Input Multiple-Output system, comprising: selecting an information for a non-transparent multiuser Multiple-Input Multiple-Output which comprises the total rank and (the total number of layers) one specific terminal's own information; selecting an information related to a demodulation reference(DM-RS) which; and sending the specific terminal an index indicating both the information on the non-transparent MU-MIMO and the information related to the DM-RS.

[4] In accordance with other aspect, there is provided a method in the Multiple-Input Multiple-Output(MIMO), comprising: sending to the specific terminal an index indicating both the information on the non-transparent MU-MIMO and the information related to the DM-RS; and sending to the specific terminal a demodulation reference(DM-RS).

[5] In accordance with another aspect, there is provided a base station in the multi-user Multiple-Input Multiple-Output(MU-MIMO), comprising: a layer mapper mapping a codeword to the layers together with the signalling comprise an index indicating both the information on the non-transparent MU-MIMO and the information related to the DM-RS in control channel; a precoder precoding a mapped set of symbols using a precoding matrix; a resource element mapper mapping a precoded set of symbols for each antenna port to resource elements; and an OFDM signal generator generating an OFDM signal for each antenna port to specific terminal among all the terminals.

[6] In accordance with further another aspect, there is provided a terminal in the multi-user Multiple-Input Multiple-Output(MU-MIMO), comprising; a RF receiver complex-valued time-domain OFDM signal for each antenna port from the base station; a decoder decoding the received complex-valued time-domain OFDM signal into the original information based on the DL signalling includes an index indicating both the

information on the non-transparent MU-MIMO and the information related to the DM-RS and patterned DM-RSs from the base station where the information on the non-transparent MU-MIMO comprises the total rank(the total number of layers) and specific terminal's own information and the information related to the DM-RS comprises the DM-RS pattern; and a interference cancellator to do interference cancellation using the signaled information and patterned DM-RSs.

[7]

Brief Description of Drawings

[8] FIG.1 is a system configuration of MU-MIMO(Multi-User Multi-Input Multi-Output) wireless communication system.

[9] FIG.2 is the block diagram of a base station according to the other embodiment

[10] FIG.3 is an indicator table of DL signaling information to support non-transparent MU-MIMO according to another embodiment.

[11] FIG. 4 is a pattern of DM-RS in the resource block for rank 2 and 4.

[12] FIG.5 is the diagram of a RS resource allocator and a RS generator according to another embodiment.

[13] FIG.6 is the flowchart of a method for DL control signaling of non-transparent MU-MIMO according to another embodiment.

[14] FIG.7 is the flowchart of a method for sending the MIMO mode, the information on non-transparent MU-MIMO and the used DM-RS related information at the form of an indicator index.

[15] FIG.8 is flowchart of the DM-RS indicator table generation algorithm of FIG.3.

[16] FIG.9 is the block diagram of a terminal according to another embodiment

[17] FIG.10 is the flowchart of a method for operating received control signal and DM-RS in MU-MIMO wireless communication system.

[18] It will be appreciated that for simplicity and clarity of illustration, elements illustrated in the drawings have not necessarily been drawn to scale. For example, the dimensions of some of the elements are exaggerated relative to other elements for purposes of promoting and improving clarity and understanding. Further, where considered appropriate, reference numerals have been repeated among the drawings to represent corresponding or analogous elements.

[19]

Mode for the Invention

[20] Hereinafter, embodiments of the present invention will be described in detail with reference to the attached drawings.

[21] There are two types of multiple-input and multiple-output(MIMO) such as a single-user MIMO(SU-MIMO) and a multi-user MIMO(MU-MIMO).

[22] In single-user MIMO(SU-MIMO), all the spatial layers within allocated resource blocks are addressed to the same mobile terminal or UE. In the case of multi-user MIMO(MU-MIMO), different spatial layers within allocated resource blocks can be addressed to different mobile terminals or UEs. Under correlated antenna scenarios, multi-user MIMO(MU-MIMO) can improve cell capacity as orthogonal spatial beams can be created for mobile terminals at different spatial locations in the cell.

[23] For example, the LTE(Long Term Evolution) system supports multi-user MIMO(MU-MIMO) for the correlated channel conditions with single layer transmission to the mobile terminal. The LTE(Long Term Evolution) system does not limit the number of mobile terminals that can be scheduled using the same resource blocks.

[24] FIG.1 is a system configuration of MU-MIMO(Multi-User Multi-Input Multi-Output) wireless communication system according to one embodiment.

[25] Referring to FIG.1, a multi-user MIMO(MU-MIMO) wireless communication system 100 is a set of advanced MIMO technologies that exploit the availability of multiple independent radio terminals 120 to 140 in order to enhance the communication capabilities of each individual terminal.

[26] As described above, in multi-user MIMO(MU-MIMO) 100, different spatial layers of a base station 110 can be addressed to different mobile terminals or UEs 120 to 140.

[27] The base station 110 refers to a fixed station communicating with the terminals 120 to 140. The base station 110 may be a Node-B, eNB(evolved Node-B), BTS(Base Transceiver System), Access Point or Relay Node.

[28] The terminals 120 to 140 refer to the user terminal in wireless communication system. The terminals 120 and 130 may be UE(User Equipment) of WCDMA, LTE and HSPA, MS(Mobile Station) of GSM, UT(User Terminal), SS(Subscriber Station) or a wireless device and so on.

[29] The term layer is synonymous with stream. For spatial multiplexing, at least two layers must be used. The number of layers of the base station 110 is always less than or equal to the number of antennas.

[30] The multi-user MIMO(MU-MIMO) wireless communication system 100 is non-transparent applied to several embodiment.

[31] The term "non-transparent" in respect of MU-MIMO wireless communication system 100 means that one terminal 120 receiving a data transmission knows at least whether or not another terminal 130 is co-scheduled in the same resource blocks. For non-transparent MU-MIMO 100, downlink signaling needs to indicate to one terminal 120 whether a downlink data transmission to another terminal 130 is taking place in the same resource block. For transparent MU-MIMO, no downlink signaling is provided to indicate to a terminal whether a downlink transmission to another terminal is taking

place in the same resource block.

[32] In short, the terminals 120 to 140 must be informed of which DM-RS pattern is being used. The base station 110 can inform the terminals 120 to 140 of the DMRS pattern used either by dynamic signaling or by higher layer signaling. By non-transparent MU-MIMO 100, the terminals 120 to 140 can know other scheduled terminal's information.

[33] The main advantage of non-transparent MU-MIMO 100 is that assistance may be given to the terminals 120 to 140 to support more advanced receiver processing. This can include techniques such as selecting optimized MMSE (Minimum Mean Square Error) combining weights in the receiver, or non-linear interference cancellation techniques.

[34] Multiple access MIMO, MIMO-SDMA, many transmit antenna MIMO-SDMA, Co-operative MIMO, Network MIMO and Ad-hoc MIMO are all family terminologies within MU-MIMO applied to several embodiments as described below.

[35] FIG.2 is the block diagram of a base station in MU-MIMO wireless communication system according to the other embodiment.

[36] Referred to FIG.2, the base station 200 in MU-MIMO wireless communication system according to the other embodiment comprises a channel encoder 210, a scrambler 220, a modulation mapper 230, a layer mapper 240, a precoder 250, a resource element mapper 260, a RS-related apparatus 270 and a OFDM signal generator 280. The channel encoder 210, the scrambler 220 and the modulation mapper 230 may be omitted or combined with other elements.

[37] The channel encoder 210 encodes the data from the higher layer and control information into coded bits. The control information may include not only general information on downlink scheduling assignments, uplink scheduling grants and power control commands but also the MIMO mode, an information on non-transparent MU-MIMO and the used DMRS related information. The MIMO mode, the information on non-transparent MU-MIMO and the used DM-RS related information may be included in DCI format of coded control information at the form of an indicator index as described below referring to FIG.3.

[38] FIG.3 is an indicator table of DL signaling information to support non-transparent MU-MIMO according to another embodiment.

[39] Referring to FIG.3, an indicator table of DL signaling information to support non-transparent MU-MIMO according to another embodiment may comprise an index at the column as well as the MIMO mode, the information on non-transparent MU-MIMO and the used DM-RS related information at the row.

[40] The following limitation is considered in this table that is: (1)Not more than 4 UEs are co-scheduled.

[41] (2)Not more than 2 layers per UE with 2 orthogonal DM RS ports

[42] (3)Not more than 4-layer transmission in total for MU-MIMO transmission.

[43] By puts certain number of limits to the MU-MIMO operation, the size of the DMRS indicator table can be reduced so that the overhead can be reduced accordingly.

[44] The index of the indication table of FIG.3 refers to a DM-RS index because it indicates the DM-RS related information such as a DM-RS pattern. But the index of the indication table of FIG.3 may refer to any other wording because it indicates the DM-RS related information as well as the MIMO mode and the information on non-transparent MU-MIMO.

[45] The MIMO mode may be either SU-MIMO where all the spatial layers within allocated resource blocks are addressed to the same mobile terminal or UE or MU-MIMO where different spatial layers can be addressed to different mobile terminals or UEs.

[46] The information on non-transparent MU-MIMO may include the total rank at the base station 110 and the specific scheduled mobile terminal's rank and antenna port information.

[47] The total rank may mean the total number of layers at the base station. The total rank of the base station 110 is more than or equal to each terminal's rank. The total rank of the base station 110 may be 1 to 8. In case of MU-MIMO, the maximum total rank of the base station 110 may be 4, but it be limited thereof. In case of SU-MIMO, the maximum total rank of the base station 110 may be limited thereof.

[48] The specific scheduled mobile terminal's rank is the number of layers at the specific mobile terminal such as the terminal 120. Of course, each terminal's rank is less than or equal to the total rank of the base station 110. In case of MU-MIMO, the maximum number of each terminal's rank may be 2, but it be limited thereof. In case of SU-MIMO, the maximum number of each terminal's rank may be limited thereof.

[49] The antenna ports information indicates which antenna port is using for each terminal.

[50] For terminal's perspective, each of terminals 120 to 140 knows the total interference information based on the total rank and its own rank. Each of terminals 120 to 140 can know the other terminals's ranks which is equal to the difference between the total rank and its own rank.

[51] The DM-RS related information may include a used DM-RS pattern which may inform each terminal 120 to 140 of which DM-RS pattern is being used.

[52] The special DM-RS pattern may be various. For example, the special DM-RS pattern may be either a DM-RS pattern 1 or a DM-RS pattern 2. Each of DM-RS patterns may have its own DM-RS rank. The number in the parenthesis of the indication table of FIG.3 refers to its own DM-RS rank of each pattern. For example, Pattern 1(2) of DM-RS pattern means that the DM-RS pattern is DM-RS pattern 1 and the number of DM-

RS rank is 2.

[53] There is the relation between DM-RS pattern rank and the total rank by the following table 1.

[54] Table 1

[Table 1]

Total Rank	1	2	3	4	5	6	7	8
DM-RS Rank	1	2	4		8			

[55] In DM-RS pattern 1 for rank 2(Pattern 1(2)), DM-RSs of layers 0 and 1 are repeatedly allocated into the same 12 REs(Resource elements) of each resource block with different orthogonal cover code such as walsh code.

[56] In DM-RS pattern 2 for rank 4(Pattern 1(4)), DM-RSs of layers 0 and 1 are repeatedly allocated into the same 12 REs(Resource elements) of each resource block and DM-RSs of layers 2 and 3 are repeatedly allocated into another same 12 REs of each resource block.

[57] In DM-RS pattern 2 for rank 8(Pattern 1(8)), DM-RSs of layers 0 to 3 are repeatedly allocated into the same 12 REs(Resource elements) of each resource block and DM-RSs of layers 4 to 7 are repeatedly allocated into another same 12 REs of each resource block.

[58] Referring to FIG.3 again, DM-RS indices 0, 3, 8, 15-19 are used for the normal SU-MIMO transmission mode for rank 1-8. DM-RS indices 1 and 2 are used for the MU-MIMO transmission mode for the total rank 2 with two transmission layers. DM-RS indices 4 to 7 are used for the MU-MIMO transmission mode for the total rank 3 with three transmission layers. DM-RS indices 9 to 14 are used for the MU-MIMO transmission mode for the total rank 4 with four transmission layers. As a result, the total number of bits for DM-RS indices is 5. If the total rank at the base station 110 is transferred to the terminal separated from another information, the minimum number of the total bits for the specific DM-RS index which may indicate all of the specific total rank, the specific terminal's rank, the specific DM-RS pattern, the specific DM-RS antenna port and the specific MIMO mode is 6 because it needs 2 or 3 bits for the total rank at the base station 110.

[59] The scrambler 220 scrambles coded bits in each of the codewords to be transmitted on a physical channel.

[60] The modulation mapper 230 modulates scrambled bits to generate complex-valued

modulation symbols.

[61] The layer mapper 240 maps the complex-valued modulation symbols onto one or several transmission layers.

[62] The precoder 250 precodes the complex-valued modulation symbols on each layer for transmission on the antenna ports. The precoder 250 precodes data and control information($\bar{\mathbf{d}}_1$ and $\bar{\mathbf{d}}_2$) by means of each of precoding matrices($\mathbf{C}_1$ and $\mathbf{C}_2$).

[63] The resource element mapper 260 maps complex-valued modulation symbols for each antenna port to resource elements.

[64] The RS related apparatus 270 generally generate a downlink reference signal(RS) such as a DM-RS(demodulation reference signal) and provides the generated the reference signal with resource element mapper 260 to perform allocation function into time-frequency resource. The DM-RS may be used in order to transfer the precoding matrix $\mathbf{C}_i$ from the base station 110 to the terminals 120 to 140 in the MIMO wireless communication system 100. The terminals 120 to 140 can recover the information $\bar{\mathbf{d}}_i$ for its own data when it know the precoding matrix $\mathbf{C}_i$.

[65] If the base station 110 configures the MU-MIMO transmission to at least two terminals 120 and 130, each with a different layer, each terminal must also know on which layer it is going to receive the transmission, and use the appropriate DM-RS antenna port for channel estimation and demodulation.

[66] FIG. 4 is one example of a pattern of a DM-RS in the resource block for rank 2 and 4.

[67] Referring to FIG.4, the DM-RS is allocated into the resource blocks with special DM-RS pattern. The top view of FIG.4 shows special DM-RS pattern for rank 2 with two transmission layers. In a DM-RS pattern for rank 2, DM-RSs of layers 0 and 1 are repeatedly allocated into the same 12 REs(Resource elements) of each resource block with different orthogonal cover code such as walsh code. The bottom view of FIG.4 shows special DM-RS pattern for rank 4 with four transmission layers. In DM-RS pattern for rank 4, DM-RSs of layers 0 and 1 are repeatedly allocated into the same 12 REs(Resource elements) of each resource block and DM-RSs of layers 2 and 3 are repeatedly allocated into another same 12 REs of each resource block.

[68] The DM-RS is allocated into the resource blocks with special DM-RS pattern where the DM-RS may use 12 REs for rank 1-2 and 24 REs for rank 3-4 using an orthogonal cover code of length two (OCC=2) or four (OCC=4).

[69] If the base station 110 configures the MU-MIMO transmission to at least two terminals 120 and 130, each with a different layer, each terminal must also know on which layer it is going to receive the transmission based on the information for non-transparent MU-MIMO as shown in FIG.3. Based on the DM-RS pattern as shown in FIG.4, each of the terminals 120 to 140 can know its own precoding matrix

$$\mathbf{C}_i$$

from the base station 110 and then can recover the information

$$\bar{\mathbf{d}}_i$$

for its own data when it know the precoding matrix

$$\mathbf{C}_i$$

.

[70] FIG.5 is the diagram of a RS resource allocator and a RS generator of the RS-related apparatus 270 in FIG.2 according to another embodiment. Referring to FIG.2 and FIG.5, the RS related apparatus 270 may comprise a RS generator 510 and a RS resource allocator 520. The RS generator 510 generates the downlink DM-RS(demodulation reference signal). The RS resource allocator 520 provides the

generated the downlink DM-RS with resource element mapper 260 to perform allocation function into time-frequency resource with special DM-RS pattern as shown in FIG.4.

[71] If the total rank and its own rank and the number of antenna ports is known at each of the terminals 120 to 140, each of the terminals 120 to 140 can know its own precoding matrix

$\mathbf{C}_i$

from the base station 110 and then can recover the information

$\bar{\mathbf{d}}_i$

for its own data when it know the precoding matrix

$\mathbf{C}_i$

based on the DM-RS pattern as shown in FIG.4. It will be described below that each of the terminals 120 to 140 cancels the interference and recovers the information

$\bar{\mathbf{d}}_i$

for its own data by using the total rank, specific terminal's own rank and antenna port and DM-RS pattern, referring to FIG.10.

[72] Referring to FIG.2 again, the OFDM signal generator 280 generates complex-valued time-domain OFDM signal for each antenna port.

[73] Although the base station 200 in non-transparent MIMO communication system 100 is described above, a method for DL control signaling of non-transparent MU-MIMO is described below.

[74] FIG.6 is the flowchart of a method for DL control signaling of non-transparent MU-MIMO according to another embodiment.

[75] Referring to FIG.6, at first a method for DL control signaling of non-transparent MIMO according to another embodiment 600 may send to the specific mobile terminal the control information including not only general information on downlink scheduling assignments, uplink scheduling grants and power control commands but also the MIMO mode, an information on non-transparent MU-MIMO and the used DMRS related information. The MIMO mode, the information on non-transparent MU-MIMO and the used DM-RS related information may be included in DCI format of coded control information at the form of an indicator index as described below referring to FIG.3.

[76] The specific DM-RS index may designate the specific total rank, the specific terminal's rank, the specific DM-RS pattern, the specific DM-RS antenna port and the specific MIMO mode as described above. For example, the specific indicator index 6 designate the total rank 3, the specific terminal's rank 1, the specific DM-RS pattern Pattern 2(4), the specific DM-RS antenna port 2 and the MU-MIMO mode. The specific indicator index 7 designate the total rank 3, the specific terminal's rank 2, the specific DM-RS pattern Pattern 2(4), the specific DM-RS antenna port 0, 1 and the MU-MIMO mode.

[77] FIG.7 is the flowchart of a method for sending the MIMO mode, the information on non-transparent MU-MIMO and the used DM-RS related information at the form of an indicator index.

[78]

[79] *Referring to FIG.7, at first the information for a non-transparent MIMO which comprises the total rank and one specific terminal's own information is selected at S611.

[80] The information related to a demodulation reference(DM-RS) is selected at S612.

[81] The DM-RS index indicating both the information on the non-transparent MU-MIMO and the information related to the DM-RS is sent to the specific terminal at S613. The index also indicates the specific MIMO mode for the specific terminal.

[82] FIG.8 is flowchart of the DM-RS indicator table generation algorithm of FIG.3.

[83] At first the index of the number of total layers i is set to be 1 at S614.

[84] Next it is determined that i is less then or equal to 8 at S615.

[85] If i is less then or equal to 8, the number of the mobile terminal's rank j is set to be 1 at S616. If not, the process is finished.

[86] Next it is determined that j is less than or equal to i at S617.

[87] If j is less then or equal to i, index for each possible antenna port allocation is added at S618. If not, i=i+1 and let go the S615.

[88] After the S618, j=j+1 at S619 and let go to the S614.

[89] If the iteration of S615 to S619 is finished, the DM-RS index table is generated. As a result, the DM-RS index table of the DM-RS indices 0 to 19 is generated.

[90] The DM-RS indices 0, 3, 8, 15-19 are used for the normal SU-MIMO transmission mode for rank 1-8. DM-RS indices 1 and 2 are used for the MU-MIMO transmission mode for the total rank 2 with two transmission layers. DM-RS indices 4 to 7 are used for the MU-MIMO transmission mode for the total rank 3 with three transmission layers. DM-RS indices 9 to 14 are used for the MU-MIMO transmission mode for the total rank 4 with four transmission layers.

[91] The index is contained in DCI format of control information. The control information may be transmitted from the base station to the terminal via a control channel, for

example PDCCH(Physical Downlink Control Channel).

[92] It is assumed that there is total rank 3 at the base station 110 as an example. It is assumed that the terminal (UE1) is in rank 2 with antenna port 0 and 1, the terminal 2(UE2) is in rank 1 with antenna port 2.

[93] For example, the specific indicator index 6 designate the total rank 3, the specific terminal's rank 1, the specific DM-RS pattern Pattern 2(4), the specific DM-RS antenna port 2 and the MU-MIMO mode. The specific indicator index 7 designate the total rank 3, the specific terminal's rank 2, the specific DM-RS pattern Pattern 2(4), the specific DM-RS antenna port 0, 1 and the MU-MIMO mode.

[94] The specific indicator indices for the terminals are shown in the table 2.

[95] Table 2

[Table 2]

UE ID	1	2
DM-RS index	7	6

[96]

[97] Referring to FIG.6 again, the downlink DM-RS(demodulation reference signal) is generated and patterned into time-frequency resource with special DM-RS pattern pattern shown in FIG.4 at S620.

[98] Finally, the patterned DM-RSs are transferred from the base station 110 to the terminals 120 to 140 in form of complex-valued time-domain OFDM signal for each antenna port at S630.

[99] The DM-RS may be used in order to transfer the precoding matrix

$\mathbf{C}_i$

from the base station 110 to the terminals 120 to 140 in the MIMO wireless communication system 100. The terminals 120 to 140 can recover the information

$\bar{\mathbf{d}}_i$

for its own data when it know the precoding matrix

$\mathbf{C}_i$

. For example, in DM-RS pattern for rank 2, DM-RSs of layers 0 and 1 are repeatedly allocated into the same 12 REs(Resource elements) of each resource block with OCC=2. In DM-RS pattern for rank 4, DM-RSs of layers 0 and 1 are repeatedly allocated into the same 12 REs(Resource elements) of each resource block and DM-RSs of layers 2 and 3 are repeatedly allocated into another same 12 REs of each resource block.

[100] In DM-RS pattern 2 for rank 8(Pattern 1(8)), DM-RSs of layers 0 to 3 are repeatedly allocated into the same 12 REs(Resource elements) of each resource block and DM-RSs of layers 4 to 7 are repeatedly allocated into another same 12 REs of each resource block with OCC=4.

[101] If the base station 110 configures the MU-MIMO transmission to at least two terminals 120 and 130, each with a different layer, each terminal must also know on which layer it is going to receive the transmission based on the DM-RS index indicating both the information on the non-transparent MU-MIMO and the information related to the DM-RS contained in the DCI format of the control information as shown in FIG.3 and table 1. Based on the DM-RS pattern as shown in FIG.4, each of the terminals 120 to 140 can know its own precoding matrix

$\mathbf{C}_i$

from the DMRS pattern the base startion 110 and then can recover the information

$\bar{\mathbf{d}}_i$

for its own data when it know the precoding matrix

$\mathbf{C}_i$

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[102] For as an example of the specific indicator indices of table 2, there is the total rank 3 with antenna ports 0 to 2 at the base station where the DMRS pattern information at all of the terminals is described in table 3.

[103] Table 3

[Table 3]

antenna port 0	antenna port 1
UE1	UE1
antenna port 2	antenna port 3
UE2	Not used

[104] One of the terminals UE1 is in rank 2 with antenna ports o and 1 where the DM-RS pattern at one of the terminals UE1 is described in table 4. The transmission from other antenna port, for example an antenna port 2, is an interference to be removed using the interference cancellation in view of one of the terminals UE1.

[105] Table 4

[Table 4]

antenna port 0	antenna port 1
UE1	UE1
antenna port 2	antenna port 3
Interference	Not used

[106]

[107] The other of the terminals UE2 is in rank 1 with antenna port 2 where the DM-RS pattern at the other of the terminals UE2 is described in table 4. The transmission from

other antenna port, for example an antenna ports 0 and 1, is an interference to be removed using the interference cancellation in view of the other of the terminals UE2.

[108] Table 5

[Table 5]

antenna port 0	antenna port 1
Interference	Interference
antenna port 2	antenna port 3
UE2	Not used

[109] FIG.9 is the block diagram of a terminal according to another embodiment.

[110] Referring to FIG.9, a terminal 700 according to another embodiment comprises a RF receiver 710, a decoder 720 and an interference cancellator 730.

[111] The RF receiver 710 receives complex-valued time-domain OFDM signal for each antenna port from the base station.

[112] The decoder 720 decodes the received complex-valued time-domain OFDM signal into the original information such as the control information ,then the data from the base station 110 to the terminals 120 to 140. The decoded information includes the control information including not only general information on downlink scheduling assignments, uplink scheduling grants and power control commands but also the MIMO mode, an information on non-transparent MU-MIMO and the used DMRS related information. The MIMO mode, the information on non-transparent MU-MIMO and the used DM-RS related information may be included in DCI format of coded control information at the form of an indicator index of FIG.3.

[113] The interference cancellator 730 is configured to remove the interference from the other terminal included in the MU-MIMO using the control information and the patterned DM-RSs.

[114] The interference cancellation using the control information and patterned DM-RSs is described below referring to FIG.10.

[115] FIG.10 is the flowchart of a method for operating received control signal and DM-RS

in MU-MIMO wireless communication system.

[116] In the method for operating received control information and patterned DM-RS 600 in MU-MIMO wireless communication system, the terminal 700 receives the control information as shown in FIG.3 and patterned DM-RSs as shown in FIG.4 from the base station 110 to the terminals 120 to 140 by means of complex-valued time-domain OFDM signal for each antenna port at S810.

[117] Next, the terminal 700 separate its own data from all the data by means of interference cancellation technique at S820.

[118] The terminal 700 can know the total rank and its own rank and the number of antenna ports from the control information on non-transparent MU-MIMO.

[119] It will be described below that each of the terminals 120 to 140 cancels the interference and recovers the information for its own data by using the total rank, specific terminal's own rank and antenna port as well as DM-RS at terminal's perspective.

[120] Based on the DM-RS indicator index, not only the MIMO mode and the used DMRS pattern but also the total rank (the total number of layers) at the base station 110 and the specific scheduled terminal's rank and antenna ports information are known by the mobile terminal 700. The mobile terminal 700 can know the total interference information.

[121] If the terminal 700 is in MU-MIMO, the rank of the interference is the difference between the total rank between this terminal's own rank.

[122] If it is assumed that total interference rank is

$$R_{interference}$$

for the terminal i and the number of the terminal 700 in MU-MIMO is N, then the following expression is derived.

[123]

$$R_{interference} = \sum_{\substack{j=1 \\ j \neq i}}^{N} R_j = R_{total} - R_i$$

[124] If it is assumed that the number of Tx antennas at the base station 110 is Nt and the

number of Rx antennas is Nr at the terminal i, the received signal can be expressed as follows.

[125] $$Y = HC_iX_i + \sum_{\substack{j=1 \\ j\neq i}}^{N} H\,C_jX_j + n = \tilde{H}_iX_i + \sum_{\substack{j=1 \\ j\neq i}}^{N} \tilde{H}_j\,X_j + n$$

[126] where H is NrXNt channel matrix at the terminal i and

$\mathbf{C}_i$

is the

$Nt \times R_i$

precoding matrix for the terminal i. Moreover, n is the noise at the terminal. If we use

$\tilde{\mathbf{H}}_i = \mathbf{HC}_i$

to express the

$Nt \times R_i$

precoding channel, the received signal can be express as

$$Y = \tilde{\mathbf{H}}_i\mathbf{X}_i + \sum_{\substack{j=1 \\ j\neq i}}^{N} \tilde{\mathbf{H}}_j\mathbf{X}_j + \mathbf{n}$$

[127] As known in the above expression, the channel matrix H can be known from the well-known downlink channel estimation. Because each terminal 700 included in the MU-MIMO 100 can also know the antenna ports information of orthogonal DMRS based on this DL signaling, the precoding matrix

$\mathbf{C}_i$

for the terminal i can be known from its own antenna ports information of orthogonal DMRS.

[128] Based on the DMRS pattern, his antenna ports and total rank, the antenna port of all

the interference can also be known even if the terminal 700 do not know the interference of which terminals is derived.

[129] So the terminal 700 can estimate both its own precoded channel

$$\widetilde{\mathbf{H}}_j$$

and the channel of the interference

$$\widetilde{\mathbf{H}}_j$$

j=1,…,N and

$$j \neq i$$

.

[130] If the number of received antenna Nr is larger than

$$R_{total}$$

,the terminal 700 can perfectly remove the interference from all the other terminals in theory once the terminal knows its own precoded channel

$$\widetilde{\mathbf{H}}_j$$

and the channel of the interference

$$\widetilde{\mathbf{H}}_j$$

j=1,…,N and

$$j \neq i$$

. That is, if

$$\mathbf{Nr} \geq R_{total}$$

,we can find the weight matrix

$$\mathbf{W}_i$$

to make

$$\mathbf{W}_i\tilde{\mathbf{H}}_j = I$$

and

$$\mathbf{W}_i\tilde{\mathbf{H}}_j = 0$$

(j=1,…,N and

$$j \neq i$$

). This

$$\mathbf{W}_i$$

can be got by zero forcing as follows:

[131]

$$\mathbf{W}_i = (\tilde{\mathbf{H}}^{-1})_i$$

.

[132] Where

$$\tilde{\mathbf{H}} = [\tilde{\mathbf{H}}_1, \tilde{\mathbf{H}}_2, \cdots, \tilde{\mathbf{H}}_N]$$

. The terminal i can get its own date symbols as follows:

[133]

$$\hat{\mathbf{X}}_i = \mathbf{W}_i Y = \mathbf{W}_i\tilde{\mathbf{H}}_i\mathbf{X}_i + \sum_{\substack{j=1 \\ j\neq i}}^{N} \mathbf{W}_i\tilde{\mathbf{H}}_j\mathbf{X}_j + \mathbf{W}_i\mathbf{n}$$

$$= \mathbf{X}_i + \mathbf{W}_i\mathbf{n}$$

[134] As described above, it can be seen that all the interferences from other terminals are perfectly removed. So it can also have better performance than the non-transparent MU-MIMO.

[135] Moreover

$\mathbf{W}_i$

can also be got by MMSE as follows to reduce the effect of the noise

$\mathbf{n}$

:

[136] $$\mathbf{W}_i = ((\tilde{\mathbf{H}}^H \tilde{\mathbf{H}} + \sigma^2 I)^{-1} \tilde{\mathbf{H}}^H)_i$$

where

σ^2

is the variance of the noise. The

$\mathbf{W}_i$

by MMSE can make the non-transparent MU-MIMO have much better performance than the zero forcing detection. It is the optimal linear detection for the non-transparent MU-MIMO.

[137] By harmonizing the total rank indicator and the DM-RS indicator, the DL signaling overhead can be further reduced. Based on the DM-RS indicator index, the total rank (the total number of layers) at the base station and the specific scheduled terminal's rank and antenna ports information are known at the mobile terminal.

[138] So the mobile terminal can know the total interference information. It is good for the interference mitigation at the mobile terminal side. So it can also have better performance than the non-transparent MU-MIMO.

[139] The methods and systems as shown and described herein may be implemented in software stored on a computer-readable medium and executed as a computer program on a general purpose or special purpose computer to perform certain tasks. For a hardware implementation, the elements used to perform various signal processing steps at the transmitter(e.g., coding and modulating the data, precoding the modulated signals, preconditioning the precoded signals, and so on) and/or at the receiver(e.g., recovering the transmitted signals, demodulating and decoding the recovered signals, and so on) may be implemented within 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, micro-controllers, microprocessors, other electronic units designed to perform the functions described herein, or a combination thereof. In addition or in the alternative, a software implementation may be used, whereby some or all of the signal processing steps at each of the transmitter and receiver may be implemented with modules(e.g., procedures, functions, and so on) that perform the functions described herein. It will be appreciated that the separation of functionality into modules is for illustrative purposes, and alternative embodiments may merge the functionality of multiple software modules into a single module or may impose an alternate decomposition of functionality of modules. In any software implementation, the software code may be executed by a processor or controller, with the code and any underlying or processed data being stored in any machine-readable or computer-readable storage medium, such as an on-board or external memory unit.

[140] Although the described exemplary embodiments disclosed herein are directed to various MIMO precoding systems and methods for using same, the present invention is not necessarily limited to the example embodiments illustrate herein. For example, various embodiments of a MIMO precoding system and design methodology disclosed herein may be implemented in connection with various proprietary or wireless communication standards, such as IEEE 802.16e, 3GPP-LTE, DVB and other multi-user MIMO systems. Thus, the particular embodiments disclosed above are illustrative only and should not be taken as limitations upon the present invention, as the invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Accordingly, the foregoing description is not intended to limit the invention to the particular form set forth, but on the contrary, is intended to cover such alternatives, modifications and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims so that those skilled in the art should understand that they can make various changes, substitutions and alterations without departing from the spirit and scope of the invention in its broadest form.

[141] Benefits, other advantages, and solutions to problems have been described above with regard to specific embodiments. However, the benefits, advantages, solutions to problems, and any element(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential feature or element of any or all the claims. As used herein, the terms "comprises," "comprising," or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include only those elements but may include other elements

not expressly listed or inherent to such process, method, article, or apparatus.

Claims

[Claim 1] A method in the multiuser Multiple-Input Multiple-Output system, comprising:
*selecting an information for a non-transparent multiuser Multiple-Input Multiple-Output which comprises the total rank and one specific terminal's own information;
selecting an information related to a demodulation reference(DM-RS) which ; and
sending the specific terminal an index indicating both the information on the non-transparent MU-MIMO and the information related to the DM-RS.

[Claim 2] The method in claim 1, wherein the total rank is the total number of layers.

[Claim 3] The method in claim 1, wherein the information related to the DM-RS is the downlink DS-RS pattern.

[Claim 4] The method in claim 1, wherein one specific terminal's own information is one specific terminal's rank.

[Claim 5] The method in claim 1, wherein the index is selected from the tabled values based on both the information on the non-transparent MU-MIMO and the information related to the DM-RS.

[Claim 6] A method in the Multiple-Input Multiple-Output(MIMO), comprising:
sending to the specific terminal an index indicating both the information on the non-transparent MU-MIMO and the information related to the DM-RS; and
sending to the specific terminal a demodulation reference(DM-RS).

[Claim 7] The method in claim 5, wherein the information on the non-transparent MU-MIMO comprises at least one of the total rank and one specific terminal's rank.

[Claim 8] The method in claim 5, wherein the information related to DM-RS is the downlink DS-RS pattern.

[Claim 9] The method in claim 5, wherein the index is sent to the specific terminal in DCI format of a control information via a PDCCH.

[Claim 10] A base station in the multi-user Multiple-Input Multiple-Output(MU-MIMO), comprising:
a layer mapper mapping a codeword to the layers where the codeword comprise an index indicating both the information on the non-transparent MU-MIMO and the information related to the DM-RS;

a precoder precoding a mapped set of symbols using a precoding matrix; a resource element mapper mapping a precoded set of symbols for each antenna port to resource elements; and
an OFDM signal generator generating an OFDM signal for each antenna port to specific terminal among all the terminals.

[Claim 11] The base station in claim 9, wherein the information on the non-transparent MU-MIMO comprises the total rank and specific terminal's own information and the information related to the DM-RS comprises the DM-RS pattern.

[Claim 12] The base station in claim 9, further comprises a RS-related generator generating a downlink DM-RS(demodulation reference signal) and providing the generated the reference signal with resource element mapper.

[Claim 13] The base station in claim 9, wherein the RS-related generator patterns the downlink DS-RS in order to support the non-transparent MU-MIMO.

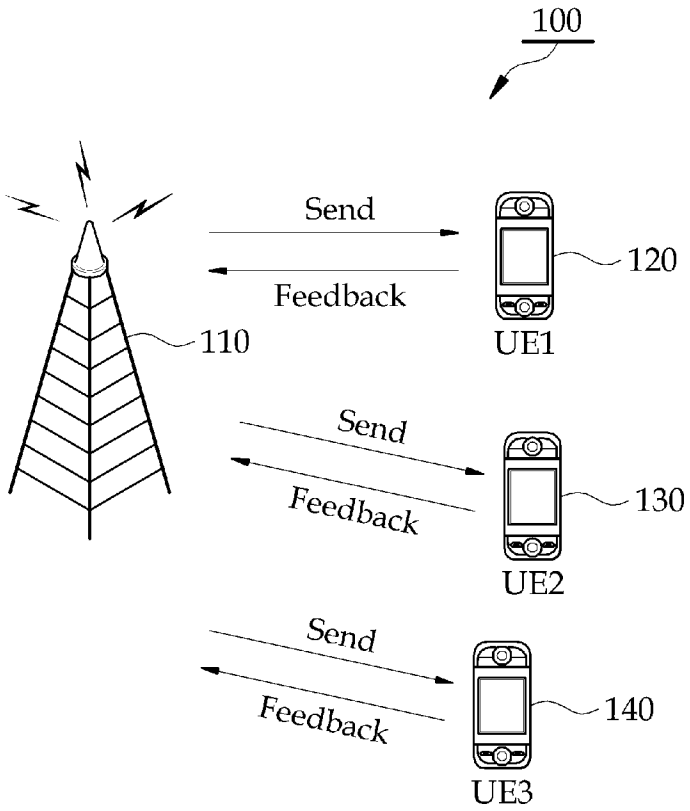
[Claim 14] A terminal in the multi-user Multiple-Input Multiple-Output(MU-MIMO), comprising;
a RF receiver complex-valued time-domain OFDM signal for each antenna port from the base station;
a decoder decoding the received complex-valued time-domain OFDM signal into the original information where the decoded information includes an index indicating both the information on the non-transparent MU-MIMO and the information related to the DM-RS and patterned DM-RSs from the base station where the information on the non-transparent MU-MIMO comprises the total rank and specific terminal's own information and the information related to the DM-RS comprises the DM-RS pattern; and
An interference cancellator 730 is configured to remove the interference from the other terminal using the control information and the patterned DM-RS.

[Claim 15] A method for operating received control signal and DM-RS in MU-MIMO wireless communication system.
Receiving the control information and patterned DM-RSs by means of complex-valued time-domain OFDM signal where the information includes an index indicating both the information on the non-transparent MU-MIMO and the information related to the DM-RS and patterned DM-RSs from the base station where the information on the

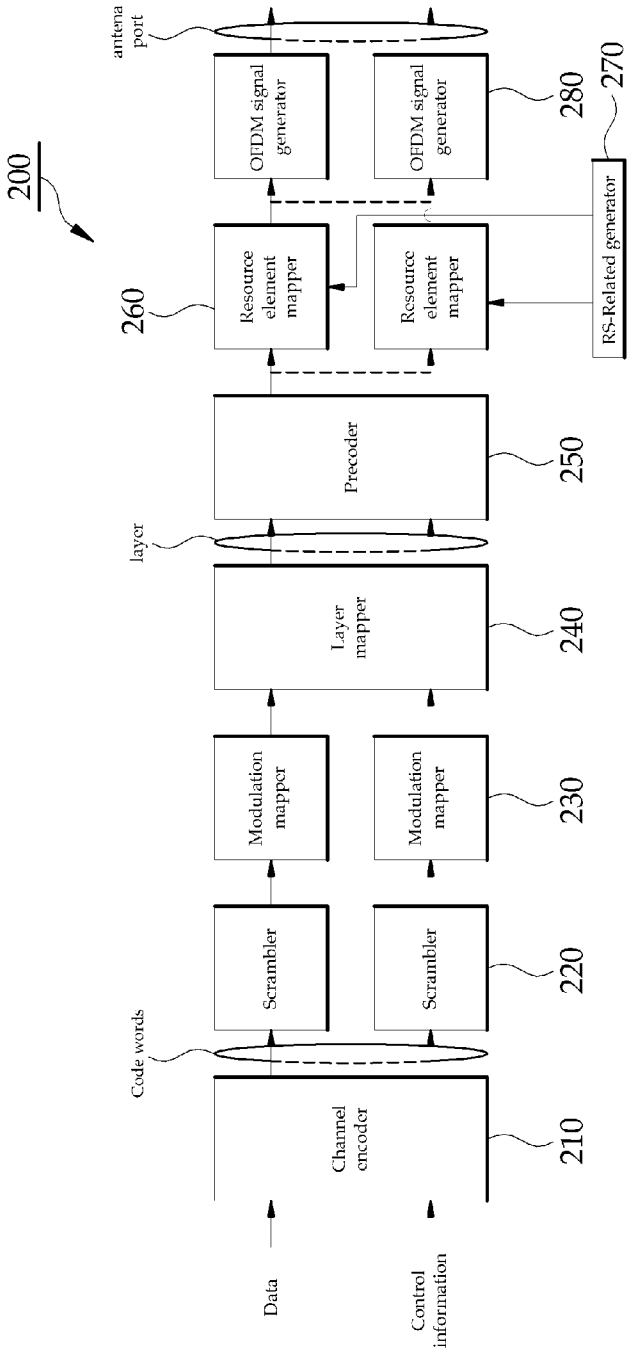
non-transparent MU-MIMO comprises the total rank and specific terminal's own information and the information related to the DM-RS comprises the DM-RS pattern

separating its own data from all the data by means of interference cancellation technique configured to remove the interference from the other terminal using the control information and the patterned DM-RS.

[Fig. 1]


100
Send
Feedback
120
110
UE1
Send
Feedback
130
UE2
Send
Feedback
140
UE3

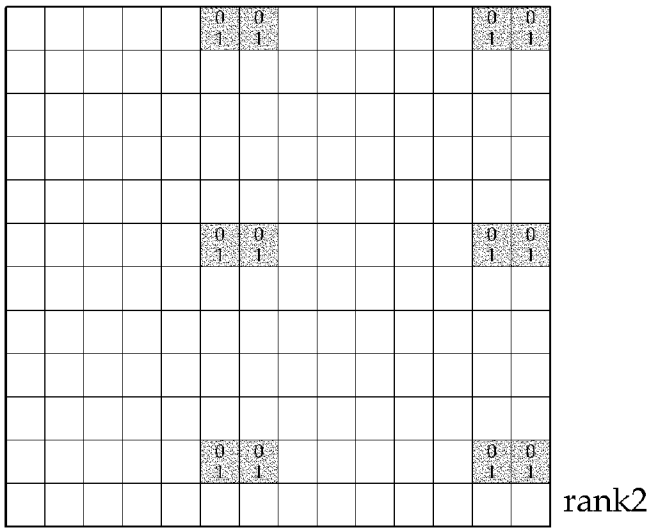
[Fig. 2]

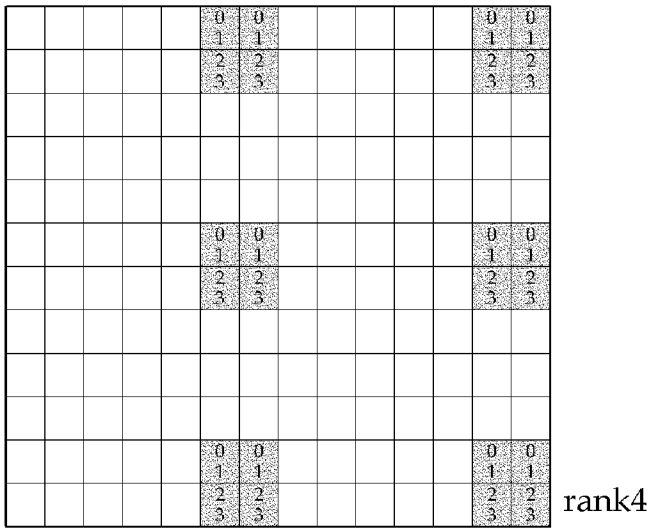

200
Data
Control information
Channel encoder
210
Code words
Scrambler
Scrambler
220
Modulation mapper
Modulation mapper
230
Layer mapper
240
layer
Precoder
250
Resource element mapper
Resource element mapper
260
RS-Related generator
270
OFDM signal generator
OFDM signal generator
280
antena port

[Fig. 3]

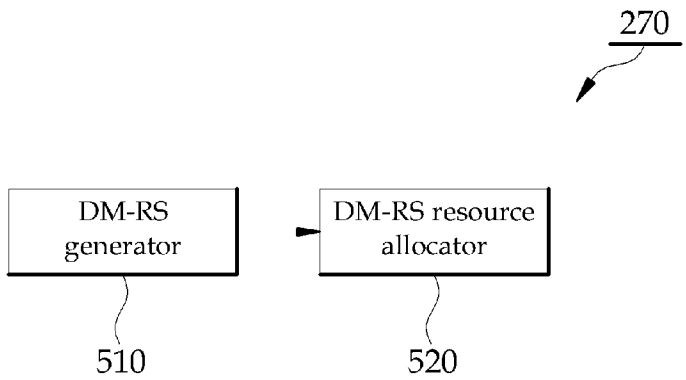
DM-RS Index	Total number Of layers	UE Rank	DM-RS pattern	DM-RS port	MIMO Mode
0	1	1	Pattern1(2)	Antenna port 0	SU-MIMO
1	2	1	Pattern1(2)	Antenna port 0	MU-MIMO
2	2	1	Pattern1(2)	Antenna port 1	MU-MIMO
3	2	2	Pattern1(2)	Antenna port 0, 1	SU-MIMO
4	3	1	Pattern2(4)	Antenna port 0	MU-MIMO
5	3	1	Pattern2(4)	Antenna port 1	MU-MIMO
6	3	1	Pattern2(4)	Antenna port 2	MU-MIMO
7	3	2	Pattern2(4)	Antenna port 0, 1	MU-MIMO
8	3	3	Pattern2(4)	Antenna port 0, 1, 2	SU-MIMO
9	4	1	Pattern2(4)	Antenna port 0	MU-MIMO
10	4	1	Pattern2(4)	Antenna port 1	MU-MIMO
11	4	1	Pattern2(4)	Antenna port 2	MU-MIMO
12	4	1	Pattern2(4)	Antenna port 3	MU-MIMO
13	4	2	Pattern2(4)	Antenna port 0, 1	MU-MIMO
14	4	2	Pattern2(4)	Antenna port 2, 3	MU-MIMO
15	4	4	Pattern2(4)	Antenna port 0, 1, 2, 3	SU-MIMO
16	5	5	Pattern3(8)	Antenna port 0, 1, 2, 3 , 4 , 5	SU-MIMO
17	6	6	Pattern3(8)	Antenna port 0, 1, 2, 3 , 4 , 5	SU-MIMO
18	7	7	Pattern3(8)	Antenna port 0, 1, 2, 3 , 4 , 5 , 6	SU-MIMO
19	8	8	Pattern3(8)	Antenna port 0, 1, 2, 3 , 4 , 5 , 6 , 7	SU-MIMO

[Fig. 4]

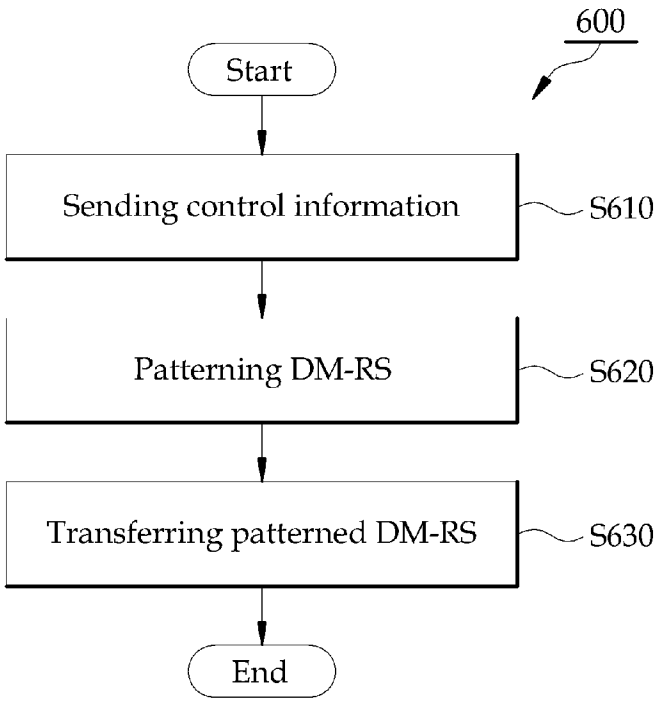

rank2


rank4

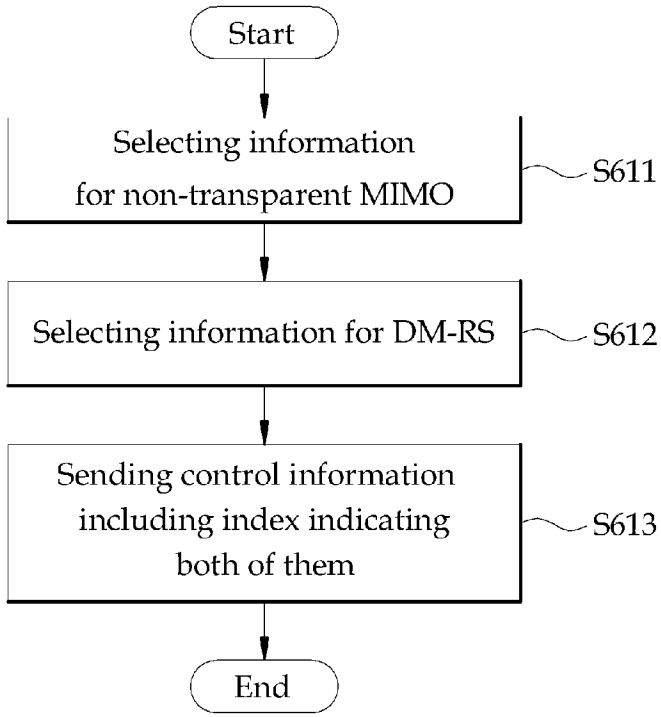
[Fig. 5]


270
DM-RS generator
DM-RS resource allocator
510
520

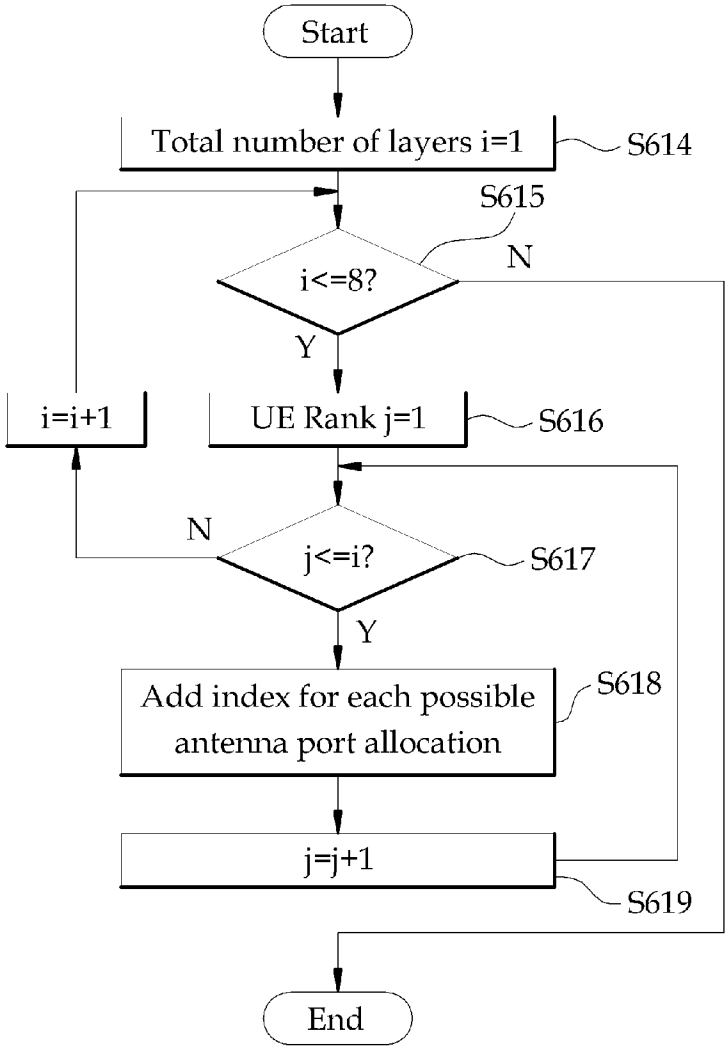
[Fig. 6]


600
Start
Sending control information
S610
Patterning DM-RS
S620
Transferring patterned DM-RS
S630
End

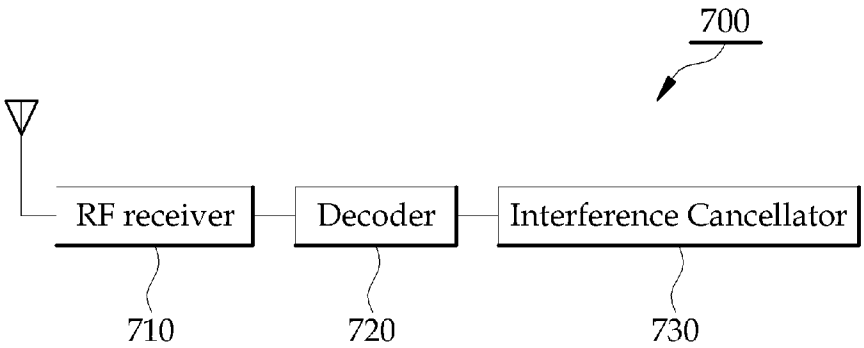
[Fig. 7]


Start
Selecting information for non-transparent MIMO
S611
Selecting information for DM-RS
S612
Sending control information including index indicating both of them
S613
End

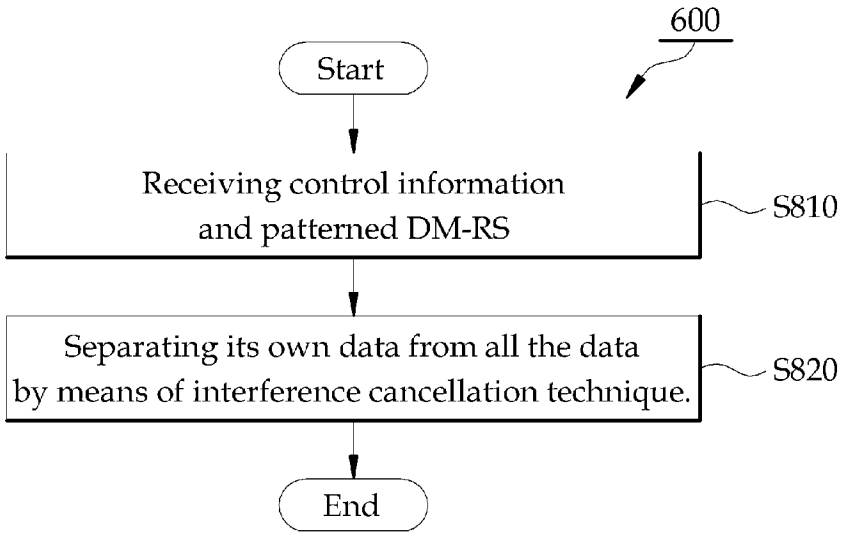
[Fig. 8]


Start
Total number of layers i=1
S614
S615
i<=8?
N
Y
i=i+1
UE Rank j=1
S616
N
j<=i?
S617
Y
Add index for each possible antenna port allocation
S618
j=j+1
S619
End

[Fig. 9]


700
RF receiver
Decoder
Interference Cancellator
710
720
730

[Fig. 10]


600
Start
Receiving control information and patterned DM-RS
S810
Separating its own data from all the data by means of interference cancellation technique.
S820
End

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2010/000911

A. CLASSIFICATION OF SUBJECT MATTER

H04B 7/04(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04B 7/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: non-transparent , rank , MU-MIMO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	"Transparency of MU-MIMO" ,(HUAWEI), 3GPP, R1-09471030, November 2009, http://www.3gpp.com/ftp/specs/html-info/TDocExMtg--R1-59--27294.htm See 2.2 Non-transparent MU-MIMO	1-15
A	"Views on Transparency of MU-MIMO" ,(MOTOROLA),3GPP,R1-094684,30 November 2009, http://www.3gpp.com/ftp/specs/html-info/TDocExMtg--R1-59--27294.htm See 2. Impact of signaling to indicate MU-MIMO allocation	1-15
A	RADIO INTERFACE TECHNOLOGY FOR IMT-ADVANCED, (HICHAN MOON) 30 November 2009 www.itu.int/ITU-D/asp/CMS/Events/2009/CoE/4Gmobile/Session10_MOON.pdf See pages 30-35	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
09 NOVEMBER 2010 (09.11.2010)	**09 NOVEMBER 2010 (09.11.2010)**
Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex-Daejeon, 139 Seonsa-ro, Seo-gu, Daejeon 302-701, Republic of Korea Facsimile No. 82-42-472-7140	Authorized officer KIM Byeong Gyun Telephone No. 82-42-481-8300

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR2010/000911

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
None			