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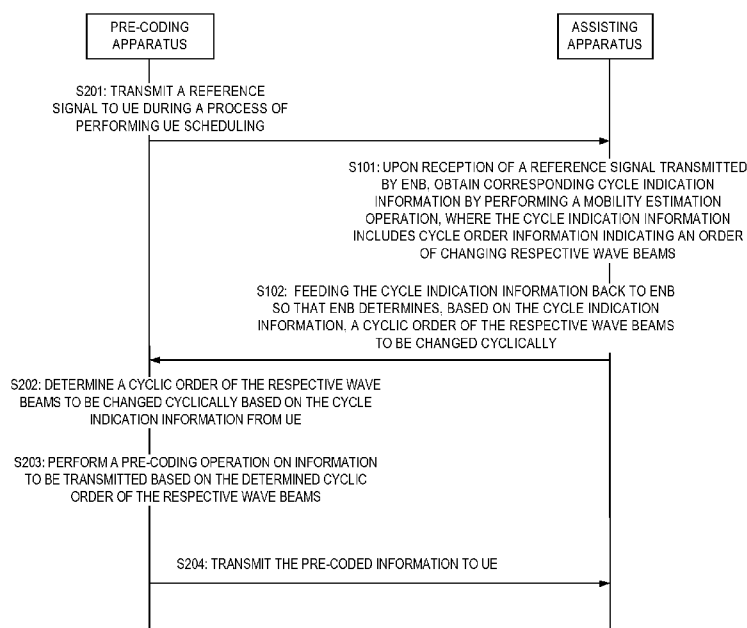


FIG. 1

(57) Abstract: The object of the present invention is to provide methods and apparatuses for performing pre-coding. The method includes steps of: upon reception of a reference signal transmitted by eNB, obtaining corresponding cycle indication information by performing a mobility estimation operation, the cycle indication information including cycle order information indicating an order of changing respective wave beams; feeding the cycle indication information back to eNB so that eNB determines, based on the cycle indication information, a cyclic order of the respective wave beams to be changed cyclically. The present invention has the following advantages: UE can perform estimation on its mobility state and feed back to eNB a cyclic order of the respective wave beams to be changed cyclically and information of a change frequency, so that eNB can pre-code information to be transmitted based on the cyclic order and change frequency, thereby obtaining a higher diversity gain and beam-forming gain.

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METHODS AND APPARATUSES FOR PERFORMING PRE-CODING

FIELD

[0001] Embodiments of the present disclosure generally relate to the field of wireless communications, and more specifically, to a method and apparatus for performing pre-coding.

5 BACKGROUND

[0002] Two-dimensional multiple-input multiple-output (MIMO) transmission is studied and adopted in LTE systems. The conventional antenna array is generally arranged horizontally and forms a wave beam on a horizontal plane. However, in the recent 3GPP conferences there is proposed a three-dimensional MIMO channel propagation model.

10 [0003] To explore more potential benefits of the three-dimensional wireless channel, the two-dimensional active antenna array (AAA) system has been employed to form a three-dimensional wave beam in the horizontal and vertical directions so that the closed-loop MIMO transmission mode can support more antenna ports. Considering high mobility of the user equipment (UE), the open-loop scheme can also benefit from the advanced antenna
15 configuration.

[0004] The open-loop MIMO scheme based on a demodulation reference signal (DMRS) has been discussed in the LTE system R14 and many companies have proposed transparent or non-transparent transmission schemes.

[0005] For example, in the current LTE system, the open-loop (OL) transmission scheme is
20 defined in TM2 (transmission model 2) and TM3. TM2 is space frequency block coding (SFBC) of diversity transmission with a rank of 1, and TM3 is a large delay cyclic diversity transmission (LD-CDD) with a rank ranging from 1 to 4. The improved solution for the open-loop MIMO system is to adopt the advanced antenna configuration and antenna ports and to support more optimized wave beam beam-forming gain and diversity gain through
25 channel estimation based on DMRS instead of based on cell specific reference signal (CRS).

[0006] The system model fed back by double Precoding Matrix Indicator (PMI) can be represented by the following equation:

$$\mathbf{y} = \mathbf{H}\mathbf{W}_1\mathbf{W}_2\mathbf{s} + \mathbf{n} \quad (1)$$

where $\mathbf{y}$ represents a signal received by a UE, $\mathbf{s}$ represents a signal transmitted by an eNB, $\mathbf{n}$
30 represents a noise vector, $\mathbf{H}$ represents a channel response matrix from transmitting antenna

ports to receiving antenna ports, and W_1W_2 represents a pre-coding matrix, where W_1 represents a long-term broadband pre-coding matrix which can be fed back by the UE or selected cyclically from the available codebook and W_2 represents a short-term pre-coding matrix selected cyclically from the available codebook randomly. W_1 is used to reduce channel dimension and W_2 is used for open-loop pre-coding. This open-loop MIMO is referred to as a semi-open-loop MIMO scheme. If both W_1 and W_2 are selected from the codebook or its subset cyclically, it is referred to as a pure open-loop MIMO scheme.

[0007] However, for a pre-coding matrix that should be selected cyclically, the eNB generally performs the cyclical selection based on a predetermined cyclic order and cycle frequency without taking mobility of the UE into consideration. When the UE moves fast, it may be impossible to select an accurate wave beam during the pre-coding process to align to the UE, failing to achieve a high wave beam beam-forming gain and diversity gain.

SUMMARY

[0008] The object of the present invention is to provide methods and apparatuses for performing pre-coding.

[0009] In an aspect of the present invention, there is provided a method of assisting in performing pre-coding in a UE, where a common pre-coding codebook is stored in an eNB and the UE included in a MIMO system, and the eNB pre-codes transmission information based on a first pre-coding matrix corresponding to a long-term wave beam or a cyclically changed wave beam and a second pre-coding matrix corresponding to a cyclically changed wave beam, the method comprising steps of:

a. upon reception of a reference signal transmitted from the eNB, obtaining corresponding cycle indication information by performing a mobility estimation operation, where the cycle indication information includes cycle order information indicating an order of changing respective wave beams; and

b. feeding the cycle indication information back to the eNB so that the eNB determines, based on cycle indication information, a cyclic order of the respective wave beams to be changed cyclically.

[0010] In an aspect of the present invention, there is provided a method of performing pre-coding in an eNB, where common pre-coding codebook information is stored in the eNB and a UE, the codebook information including a plurality of first pre-coding matrix sets and second pre-coding matrix sets, and the eNB pre-codes transmission information based on a

first pre-coding matrix corresponding to a long-term wave beam or a cyclically changed wave beam and a second pre-coding matrix corresponding to a cyclically changed wave beam, the method including steps of:

A. transmitting a reference signal to the UE during a process of performing UE scheduling;

B. determining a cyclic order of respective wave beams to be changed cyclically based on cycle indication information from the UE;

C. performing a pre-coding operation on information to be transmitted based on the determined cyclic order of the respective wave beams; and

D. transmitting the pre-coded information to the UE.

[0011] In an aspect of the present invention, there is further provided an assisting apparatus for assisting in performing pre-coding in a UE, where a common pre-coding codebook is stored in an eNB and the UE included in a MIMO system, and the eNB pre-codes transmission information based on a first pre-coding matrix corresponding to a long-term wave beam or a cyclically changed wave beam and a second pre-coding matrix corresponding to a cyclically changed wave beam, the assisting apparatus comprising:

a pre-estimating unit configured to obtain corresponding cycle indication information by performing a mobility estimation operation, where the cycle indication information includes cycle order information indicating an order of changing respective wave beams; and

a feedback unit configured to feed the cycle indication information back to the eNB so that the eNB determines, based on the cycle indication information, a cyclic order of the respective wave beams to be changed cyclically.

[0012] In an aspect of the present invention, there is provided a pre-coding apparatus for performing pre-coding in an eNB, where common pre-coding codebook information is stored in the eNB and a UE, and the eNB pre-codes transmission information based on a first pre-coding matrix corresponding to a long-term wave beam or a cyclically changed wave beam and a second pre-coding matrix corresponding to a cyclically changed wave beam, the pre-coding apparatus comprising:

a first transmitting unit configured to transmit a reference signal to the UE during a process of performing UE scheduling;

a second determining unit configured to determine a cyclic order of respective wave beams to be changed cyclically based on cycle indication information from the UE;

a performing unit configured to perform a pre-coding operation on information to be

transmitted based on the determined cyclic order of the respective wave beams to be changed cyclically; and

a second transmitting unit configured to transmit the pre-coded information to the UE.

[0013] The present invention has the following advantages over the prior art: the UE according to the present invention can perform estimation on its mobility state to feed back to the eNB a cyclic order of the respective wave beams to be changed cyclically and information of a change frequency so that eNB can pre-code information to be transmitted based on the cyclic order and the change frequency indicated by the UE, thereby obtaining a higher diversity gain and beam-forming gain.

10 BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Upon reading the detailed description of non-limiting implementations with reference to the following drawings, other features, objects, and advantages of the present invention will become more apparent:

[0015] Fig. 1 schematically illustrates a flowchart of a method of performing pre-coding according to the present invention; and

[0016] Fig. 2 schematically illustrates a structural diagram of an assisting apparatus for assisting in performing pre-coding in a UE and a pre-coding apparatus for performing pre-coding in an eNB according to the present invention.

[0017] In the figures, the same or like reference signs represent the same or like elements.

20 DETAILED DESCRIPTION OF EMBODIMENTS

[0018] The present invention will be described in more detail below with reference to the drawings.

[0019] Fig. 1 schematically illustrates a flowchart of a method for performing pre-coding according to the present invention. The method according to the present invention includes steps S101 and S102 performed by user equipment (UE) and steps S201, S202, S203, and S204 performed by a base station (eNB).

[0020] The method according to the present invention is implemented by a pre-coding apparatus contained in the eNB and an assisting apparatus contained in the UE.

[0021] The eNB includes, but is not limited to, a macro base station, a micro base station, a home base station, and the like.

[0022] Preferably, both the eNB and the UE are included in a MIMO system.

[0023] The eNB and UE store a common pre-coding codebook, the codebook information including a plurality of first pre-coding matrix sets and second pre-coding matrix sets, the eNB pre-coding transmission information based on a first pre-coding matrix and a second pre-coding matrix.

[0024] The first pre-coding matrix may correspond to a long-term wave beam or the first pre-coding matrix may correspond to a cyclically changed wave beam.

[0025] The second pre-coding matrix corresponds to a cyclically changed wave beam.

[0026] Reference is made to Fig. 1, where at step S201, the eNB transmits a reference signal to the UE during a process of performing UE scheduling.

[0027] Preferably, the reference signal is a Channel status Information (CSI) reference signal.

[0028] At step S101, upon reception of the reference signal from the eNB, the UE obtains corresponding cycle indication information by performing a mobility estimation operation.

[0029] The mobility estimation operation includes various pre-estimation operations for the movement direction and movement speed of the UE.

[0030] The cycle indication information includes cycle order information indicating an order of changing respective wave beams.

[0031] For example, the eNB selects a wave beam from wave beams numbered from 1 to 4 for pre-coding. Then cycle indication information may include an “ascending order” or a “descending order” to instruct the eNB to change the respective wave beams cyclically in the order of “from 1 to 4” or “from 4 to 1.”

[0032] Preferably, the cycle indication information further includes cycle frequency information indicating a frequency of changing the respective wave beams.

[0033] According to a preferred implementation of the present invention, the first pre-coding matrix corresponds to a long-term wave beam fed back by the UE and the second pre-coding matrix corresponds to a cyclically changed wave beam. The step S101 further includes steps S1011 and S1012 (not shown).

[0034] At step S1011, upon reception of the reference signal transmitted from the eNB, the UE selects a first pre-coding matrix from the codebook by performing a channel estimation

operation.

[0035] Specifically, the UE performs the channel estimation operation based on signal related information of the received reference signal and a predetermined channel estimation algorithm, to select the first pre-coding matrix from the codebook.

5 [0036] The process of performing channel estimation by the UE is apparent to those skilled in the art and thus is omitted here. Furthermore, those skilled in the art would appreciate various channel estimation algorithms and would be able to implement the channel estimation operation to select the first pre-coding matrix from the codebook by selecting an appropriate channel estimation algorithm based on actual requirements.

10 [0037] According to a first example of the present invention, the eNB and UE_1 are included in the MIMO system and store the same pre-coding matrix codebook. The eNB performs pre-coding on data to be transmitted based on a first coding matrix W1 and a second coding matrix W2, where W1 corresponds to a long-term wave beam fed back by the UE and W2 corresponds to a cyclically changed wave beam.

15 [0038] At step S201, when scheduling the UE_1, the eNB transmits a reference signal RS_1 to the UE_1. Next, the UE_1 receives the reference signal RS_1 from the eNB at step S1011 and selects a first pre-coding matrix W1_1 from the codebook by performing a channel estimation operation. Further, the UE_1 feeds the selected W1_1 back to the eNB.

[0039] Continue to illustrate the preferred implementation. At step S1012, the UE obtains
20 the corresponding cycle indication information by performing a mobility estimation operation based on the selected first pre-coding matrix.

[0040] The cycle indication information includes cycle order information of respective wave beams corresponding to the second pre-coding matrix.

[0041] Specifically, the UE calculates its current mobility estimation information based on
25 the selected first pre-coding matrix and a predetermined mobility estimation algorithm, where the mobility estimation information is used to indicate the change of UE movement. Next, the UE determines the corresponding cycle indication information based on the mobility estimation information.

[0042] Preferably, the UE can calculate the mobility estimation information based on the
30 following:

$$mobility = \frac{BI(\mathbf{W}_2^i) - BI(\mathbf{W}_2^j)}{i - j}; i \neq j \quad (2)$$

where *mobility* represents the mobility estimation information, $\mathbf{W}_2$ represents the second pre-coding matrix, $BI(\cdot)$ represents the serial number of the selected input pre-coded wave beam, i and j represent the serial numbers of sub-frame (if the same pre-code is used during the period corresponding to each sub-frame), or i and j may represent a serial number of OFDM symbol in a sub-frame (if different pre-codes are used during the period corresponding to each sub-frame).

[0043] It can be seen that the *mobility* calculated from the above equation can reflect the UE movement direction corresponding to each wave beam and the UE movement speed in each wave beam direction during the movement.

[0044] Continue with the above first example. The first pre-coding matrix $\mathbf{W1_1}$ selected by the UE_1 corresponds to four wave beams, beam_1 to beam_4, and $\mathbf{W2}$ corresponds to the wave beam selected cyclically from the four wave beams. Furthermore, the UE calculates the mobility estimation information *mobility_1* based on the above equation (2).

[0045] Preferably, the UE may calculate the average mobility estimation information based on the following:

$$mobility = \frac{1}{N} \sum_{n=1}^N \frac{BI(\mathbf{W}_2^{i_n}) - BI(\mathbf{W}_2^{j_n})}{i - j}; i_n \neq j_n \quad (3)$$

[0046] More preferably, the mobility estimation information includes mobility estimation information in the horizontal direction and vertical direction. The UE calculates the mobility estimation information in the horizontal direction and vertical direction with the following equations, respectively:

$$mobility_H = \frac{BI_H(\mathbf{W}_2^i) - BI_H(\mathbf{W}_2^j)}{i - j}; i \neq j \quad (4)$$

$$mobility_V = \frac{BI_V(\mathbf{W}_2^i) - BI_V(\mathbf{W}_2^j)}{i - j}; i \neq j \quad (5)$$

where $mobility_H$ and $mobility_V$ represent the mobility estimation information in the horizontal direction and vertical direction, respectively, and $BI_H(\cdot)$ and $BI_V(\cdot)$ represent the wave beam numbers of the selected input pre-code in the horizontal

direction and vertical direction, respectively.

[0047] Preferably, when the cycle indication information further includes cycle frequency information for indicating a frequency of changing the respective wave beams, the UE determines the corresponding cycle frequency information based on the mobility estimation information.

[0048] Preferably, the UE can calculate the mobility estimation information based on any of the above equations (2) to (5) and obtain the corresponding cycle frequency information based on the mobility estimation information. For example, the UE can determine the cycle frequency information corresponding to the calculated mobility estimation information based on the predetermined relationship between the mobility estimation information and the cycle frequency.

[0049] Preferably, the UE can determine Channel Quality Indicator (CQI) information and Rank Indication (RI) information in conjunction with the cycle indication information so as to feed them back together to the eNB.

[0050] According to a preferred implementation of the present invention, the eNB and UE can use predefined signaling information to represent the cycle indication information.

[0051] Preferably, the eNB and UE can use predefined signaling information to represent cycle indication information in the horizontal direction and vertical direction, respectively.

[0052] Preferably, the eNB and UE can use predefined signaling information to represent cycle indication information corresponding to different frequency domain bandwidths, respectively.

[0053] Preferably, the eNB and UE can use predefined signaling information to represent cycle indication information corresponding to ranks of different number of channel matrices, respectively.

[0054] Continue to illustrate the first example. The UE calculates mobility estimation information *mobility* based on the above equation (2), and the eNB and UE use the cycling indicator (CI) values shown below in Table 1 to indicate cycle indication information, each CI value corresponding to a specific cycle direction, cycle frequency, and mobility value range. In addition, the cycle direction includes a “ascending order” and a “descending order” of wave beam numbers, and both the cycle frequency and mobility estimation information *mobility* are in units of a predefined long-term feedback

interval (LFT).

Table 1

CI value	Cycle direction	Cycle frequency	<i>Mobility</i>
000	Ascending order	LFI	Larger than or equal to 0 and smaller than 1/LFI
001	Ascending order	LFI/2	Larger than or equal to 1/LFI and smaller than 2/LFI
010	Ascending order	LFI/3	Larger than or equal to 2/LFI and smaller than 3/LFI
011	Ascending order	LFI/4	Larger than or equal to 3/LFI
100	Descending order	LFI	Larger than or equal to -1/LFI and smaller than 0
101	Descending order	LFI/2	Smaller than or equal to -1/LFI and larger than -2/LFI
110	Descending order	LFI/3	Smaller than or equal to -2/LFI and larger than -3/LFI
111	Descending order	LFI/4	Smaller than or equal to -3/LFI

[0055] Then, based on the value of the calculated *mobility*₁ and the above Table 1, the UE₁ determines that the corresponding CI value is “001.”

[0056] According to another preferred implementation of the present invention, when both the first pre-coding matrix and the second pre-coding matrix correspond to the cyclically changed wave beam, the cycle indication information further includes a cyclic order of the respective wave beams corresponding to the first pre-coding matrix and the step S101 further includes a step S1013 (not shown).

[0057] At step S1013, the UE obtains the cycle indication information corresponding to the first pre-coding matrix by performing a mobility estimation operation based on the first pre-coding matrix.

[0058] Specifically, the UE obtains the cycle indication information corresponding to the first pre-coding matrix in a manner similar to performing the above steps S1011 and S1012.

[0059] Preferably, the UE can obtain mobility information corresponding to the second pre-coding matrix based on any of the above equations (2)-(5) and calculate the mobility estimation information corresponding to the first pre-coding matrix by the following:

$$mobility_{w_1} = \frac{BI(W_1^i) - BI(W_1^j)}{i - j}; i \neq j \quad (6)$$

where W_1 represents the first pre-coding matrix, $BI(\cdot)$ represents the W_1 serial number in the selected input pre-code, i and j represent the serial numbers of sub-frame (if the same pre-code is used during the period corresponding to each sub-frame), or i and j may represent the serial number of OFDM symbol in a sub-frame (if different pre-codes are used during the period corresponding to each sub-frame).

[0060] Still referring to Fig. 1, at step S102, the UE feeds the cycle indication information back to the eNB so that the eNB determines, based on the cycle indication information, the cyclic order of the respective wave beams to be changed cyclically.

[0061] Next, at step S202, the eNB determines the cyclic order of the respective wave beams to be changed cyclically based on the cycle indication information received from the UE.

[0062] Preferably, when the cycle indication information further includes cycle frequency information, the eNB determines the cyclic order and a change frequency of respective wave beams to be changed cyclically based on the cycle indication information.

[0063] Then, at step S203, the eNB performs a pre-coding operation on information to be transmitted based on the determined cyclic order of the respective wave beams.

[0064] Preferably, when the cycle indication information further includes the cycle frequency information, the eNB performs the pre-coding operation on information to be transmitted based on the determined cyclic order and change frequency of the respective wave beams.

[0065] Then, at step S204, the eNB transmits the pre-coded information to the UE.

[0066] Continue to illustrate the preceding first example. Based on the cycle indication information “001” from the UE_1 and the above Table 1, the eNB determines that the cyclic order of the respective wave beams corresponding to the second pre-coding matrix is an ascending order of serial numbers of the wave beams, namely, performing cycle in an order from beam_1 to beam_4, and a time interval for changing the respective wave beams is $LFI/2$. Next, based on the determined cyclic order of “from beam_1 to beam_4” and the change frequency of “ $LFI/2$ ”, the eNB performs the pre-coding operation on information to be transmitted.

[0067] Preferably, the eNB performs pre-coding on a demodulation reference signal (DMRS) based on the first coding matrix and/or the second coding matrix and transmits the pre-coded DMRS and data to be transmitted together to the UE.

5 [0068] Then, the UE performs the corresponding demodulation operation on the pre-coded information from the eNB.

[0069] Preferably, upon reception of the pre-coded DMRS from the eNB, the UE performs channel estimation on the DMRS and performs a corresponding demodulation operation on the pre-coded DMRS.

10 [0070] If the eNB only performs a pre-coding operation on the DMRS based on the first coding matrix, the UE performs a corresponding demodulation operation on the pre-coded DMRS based on the known second coding matrix.

[0071] If the eNB performs a pre-coding operation on the DMRS based on the first coding matrix and the second coding matrix, the UE performs a corresponding demodulation operation on the pre-coded DMRS.

15 [0072] According to the method of the present invention, the UE can perform estimation on its mobility state so as to feed back to the eNB information indicating a cyclic order and change frequency of respective wave beams to be changed cyclically, so that the eNB can pre-code information to be transmitted based on the cyclic order and change frequency indicated by the UE, thereby obtaining a higher diversity gain and beam-forming gain.

20 [0073] Fig. 2 schematically illustrates a structural diagram of an assisting apparatus for assisting in performing pre-coding in a UE and a pre-coding apparatus for performing pre-coding in an eNB according to the present invention;

[0074] The assisting apparatus according to the present invention includes a pre-estimating unit 101 and a feedback unit 102.

25 [0075] The pre-coding apparatus according to the present invention includes a first transmitting unit 201, a first determining unit 202, a performing unit 203, and a second transmitting unit 204.

[0076] Reference is made to Fig. 2, where during the process of performing UE scheduling, the first transmitting unit 201 transmits a reference signal to the UE.

30 [0077] Preferably, the reference signal is a Channel status information (CSI) reference signal.

[0078] Upon reception of the reference signal from the eNB, the pre-estimating unit 101 obtains corresponding cycle indication information by performing a mobility estimation operation.

[0079] The mobility estimation operation includes various pre-estimation operations for the movement direction and movement speed of the UE.

[0080] The cycle indication information includes cycle order information indicating an order for changing respective wave beams.

[0081] For example, the eNB selects a wave beam from wave beams numbered from 1 to 4 for pre-coding. Then the cycle indication information may include an “ascending order” or a “descending order” to instruct the eNB to change the respective wave beams cyclically in the order “from 1 to 4” or “from 4 to 1.”

[0082] Preferably, the cycle indication information further includes cycle frequency information indicating a frequency of changing the respective wave beams.

[0083] According to a preferred implementation of the present invention, the first pre-coding matrix corresponds to a long-term wave beam fed back by the UE and the second pre-coding matrix corresponds to a cyclically changed wave beam. The pre-estimating unit 101 further includes a channel estimating unit (not shown) and a mobility estimating unit (not shown).

[0084] Upon reception of the reference signal transmitted from the eNB, the channel estimating unit selects a first pre-coding matrix from the codebook by performing a channel estimation operation.

[0085] Specifically, the channel estimating unit performs the channel estimation operation based on signal related information of the received reference signal and a predetermined channel estimation algorithm, to select the first pre-coding matrix from the codebook.

[0086] The process of performing channel estimation by the channel estimating unit is apparent to those skilled in the art and thus is omitted here. Furthermore, those skilled in the art would appreciate various channel estimation algorithms and would be able to implement the channel estimation operation to select the first pre-coding matrix from the codebook by selecting an appropriate channel estimation algorithm based on actual requirements.

[0087] According to a first example of the present invention, the eNB and UE_1 are included in the MIMO system and store the same pre-coding matrix codebook. The

eNB performs pre-coding on data to be transmitted based on a first coding matrix W1 and a second pre-coding matrix W2, where W1 corresponds to a long-term wave beam fed back by the UE and W2 corresponds to a cyclically changed wave beam.

[0088] When the eNB schedules the UE_1, the first transmitting unit 201 transmits a reference signal RS_1 to the UE_1. Then, the UE_1 receives the reference signal RS_1 from the eNB and the channel estimating unit selects a first pre-coding matrix W1_1 from the codebook by performing a channel estimation operation. Further, the UE_1 feeds the selected W1_1 back to the eNB.

[0089] Continue to illustrate the preferred implementation of the present invention. The mobility estimating unit obtains the corresponding cycle indication information by performing a mobility estimation operation based on the selected first pre-coding matrix.

[0090] The cycle indication information includes cycle order information of respective wave beams corresponding to the second pre-coding matrix.

[0091] Specifically, the mobility estimating unit further includes a calculating unit (not shown) and a first determining unit (not shown).

[0092] The calculating unit calculates current mobility estimation information of the UE based on the selected first pre-coding matrix and a pre-determined mobility estimation algorithm, where the mobility estimation information is used to indicate the change of UE movement. Next, the first determining unit determines the corresponding cycle indication information based on the mobility estimation information.

[0093] Preferably, the calculating unit can calculate the mobility information based on the following:

$$mobility = \frac{BI(W_2^i) - BI(W_2^j)}{i - j}; i \neq j \quad (2)$$

where *mobility* represents the mobility estimation information, W₂ represents the second pre-coding matrix, BI(·) represents the serial number of the selected input pre-coded wave beams, i and j represent the serial numbers of sub-frame (if the same pre-code is used during the period corresponding to each sub-frame), or i and j may represent a serial number of OFDM symbol in a sub-frame (if different pre-codes are used during the period corresponding to each sub-frame).

[0094] It can be seen that the *mobility* calculated from the equation can reflect the UE

movement direction corresponding to each wave beam and the UE movement speed in each wave beam direction during the movement.

[0095] Continue with the above first example. The first pre-coding matrix W1_1 selected by the UE_1 corresponds to four wave beams, beam_1 to beam_4, and W2 corresponds to the wave beam selected cyclically from the four wave beams. Furthermore, the calculating unit calculates the mobility estimation information *mobility*_1 based on the above equation (2).

[0096] Preferably, the calculating unit may calculate the average mobility estimation information based on the following:

$$mobility = \frac{1}{N} \sum_{n=1}^N \frac{BI(\mathbf{W}_2^{i_n}) - BI(\mathbf{W}_2^{j_n})}{i - j}; i_n \neq j_n \quad (3)$$

[0097] More preferably, the mobility estimation information includes mobility estimation information in the horizontal direction and vertical direction. The UE calculates the mobility estimation information in the horizontal direction and vertical direction with the following equations, respectively:

$$mobility_H = \frac{BI_H(\mathbf{W}_2^i) - BI_H(\mathbf{W}_2^j)}{i - j}; i \neq j \quad (4)$$

$$mobility_V = \frac{BI_V(\mathbf{W}_2^i) - BI_V(\mathbf{W}_2^j)}{i - j}; i \neq j \quad (5)$$

where *mobility*_H and *mobility*_V represent the mobility estimation information in the horizontal direction and vertical direction, respectively, and *BI*_H(·) and *BI*_V(·) represent the wave beam numbers of the selected input pre-code in the horizontal direction and vertical direction, respectively.

[0098] Preferably, when the cycle indication information further includes cycle frequency information for indicating a frequency of changing the respective wave beams, the first determining unit further includes a determining sub-unit (not shown).

[0099] The determining sub-unit determines the corresponding cycle frequency information based on the mobility estimation information.

[0100] Preferably, the UE can calculate the mobility estimation information based on any of the above equations (2) to (5) and obtain the corresponding cycle frequency information via

the determining sub-unit based on the mobility estimation information. For example, the determining sub-unit can determine the cycle frequency information corresponding to the calculated mobility estimation information based on the predetermined relationship between the mobility estimation information and the cycle frequency.

- 5 [00101] Preferably, the UE can determine Channel Quality Indicator (CQI) information and Rank Indication (RI) information in conjunction with the cycle indication information so as to feed them back together to the eNB.

[00102] According to a preferred implementation of the present invention, the eNB and UE can use predefined signaling information to represent the cycle indication information.

- 10 [00103] Preferably, the eNB and UE can use predefined signaling information to represent cycle indication information in the horizontal direction and vertical direction, respectively.

[00104] Preferably, the eNB and UE can use predefined signaling information to represent cycle indication information corresponding to different frequency domain bandwidths, respectively.

- 15 [00105] Preferably, the eNB and UE can use predefined signaling information to represent cycle indication information corresponding to ranks of different number of channel matrices, respectively.

- [00106] Continue to illustrate the first example. The calculating unit calculates mobility estimation information *mobility* based on the above equation (2), and the eNB and UE use
 20 the cycling indicator (CI) values shown below in Table 1 to indicate cycle indication information, each CI value corresponding to a specific cycle direction, cycle frequency, and mobility value range. In addition, the cycle direction includes an “ascending order” and a “descending order” of wave beam numbers, and both the cycle frequency and mobility estimation information mobility are in units of a predefined long-term
 25 feedback interval (LFT).

Table 2

CI value	Cycle direction	Cycle frequency	<i>Mobility</i>
000	Ascending order	LFI	Larger than or equal to 0 and smaller than 1/LFI
001	Ascending order	LFI/2	Larger than or equal to 1/LFI and smaller than 2/LFI
010	Ascending order	LFI/3	Larger than or equal to 2/LFI and smaller than 3/LFI

011	Ascending order	LFI/4	Larger than or equal to 3/LFI
100	Descending order	LFI	Larger than or equal to -1/LFI and smaller than 0
101	Descending order	LFI/2	Smaller than or equal to -1/LFI and larger than -2/LFI
110	Descending order	LFI/3	Smaller than or equal to -2/LFI and larger than -3/LFI
111	Descending order	LFI/4	Smaller than or equal to -3/LFI

[00107] Then, based on the value of calculated *mobility*₁ and the above Table 2, the first determining unit determines that the corresponding CI value is “001.”

[00108] According to another preferred implementation of the present invention, when both the first pre-coding matrix and the second pre-coding matrix correspond to the cyclically changed wave beams, the cycle indication information further includes a cyclic order of the respective wave beams corresponding to the first pre-coding matrix, and the pre-estimating unit 101 further includes a pre-estimating sub-unit (not shown).

[00109] The second determining unit obtains the cycle indication information corresponding to the first pre-coding matrix by performing a mobility estimation operation based on the first pre-coding matrix.

[00110] Specifically, the pre-estimating sub-unit obtains the cycle indication information corresponding to the first pre-coding matrix in a manner similar to implementing the above calculating unit and first determining unit.

[00111] Preferably, the calculating unit in the UE can obtain mobility information corresponding to the second pre-coding matrix based on any of the above equations (2)-(5) and the pre-estimating sub-unit in the UE calculates the mobility estimation information corresponding to the first pre-coding matrix by the following:

$$mobility_{w_1} = \frac{BI(\mathbf{W}_1^i) - BI(\mathbf{W}_1^j)}{i - j}; i \neq j \quad (6)$$

where $\mathbf{W}_1$ represents the first pre-coding matrix, $BI(\cdot)$ represents the $\mathbf{W}_1$ serial number in the selected input pre-code, i and j represent the serial numbers of sub-frame (if the same pre-code is used during the period corresponding to each sub-frame), or i and j may represent the serial number of OFDM symbol in a sub-frame (if different pre-codes are used during the period corresponding to each sub-frame).

[00112] Still referring to Fig. 2, the feedback unit 102 feeds the cycle indication information to the eNB so that the eNB determines, based on the cycle indication information, a cyclic order of the respective wave beams to be changed cyclically.

[00113] Then, the second determining unit 202 determines the cyclic order of the respective wave beams to be changed cyclically based on the cycle indication information received from the UE.

[00114] Preferably, when the cycle indication information further includes cycle frequency information, the second determining unit 202 determines the cyclic order and a change frequency of the respective wave beams to be changed cyclically based on the cycle indication information.

[00115] Next, the performing unit 203 performs a pre-coding operation on information to be transmitted based on the determined cyclic order of the respective wave beams.

[00116] Preferably, when the cycle indication information further includes the cycle frequency information, the performing unit 203 performs the pre-coding operation on information to be transmitted based on the determined cyclic order and change frequency of the respective wave beams.

[00117] Then, the second transmitting unit 204 transmits the pre-coded information to the UE.

[00118] Continue to illustrate the first coded. Based on the cycle indication information “001” from the UE_1 and the above Table 1, the second determining unit 202 determines that the cyclic order of the respective wave beams corresponding to the second pre-coding matrix is an ascending order of serial numbers of the wave beams, namely, performing cycle in an order from beam_1 to beam_4, and a time interval for changing the respective wave beams is $LFI/2$. Next, based on the determined cyclic order “from beam_1 to beam_4” and the change frequency “ $LFI/2$,” the performing unit 203 performs the pre-coding operation on information to be transmitted.

[00119] Preferably, the eNB further performs pre-coding on a demodulation reference signal (DMRS) based on the first coding matrix and/or the second coding matrix and transmits the pre-coded DMRS and data to be transmitted together to the UE.

[00120] Next, the UE performs the corresponding demodulation operation on the pre-coded information from the eNB.

[00121] Preferably, upon reception of the pre-coded DMRS from the eNB, the UE performs channel estimation on the DMRS and performs a corresponding demodulation operation on the pre-coded DMRS.

5 [00122] If the eNB only performs a pre-coding operation on the DMRS based on the first coding matrix, the UE performs a corresponding demodulation operation on the pre-coded DMRS based on the known second coding matrix.

[00123] If the eNB performs a pre-coding operation on the DMRS based on the first coding matrix and the second coding matrix, the UE performs a corresponding demodulation operation on the pre-coded DMRS.

10 [00124] According to the method of the present invention, the UE can perform estimation on its mobility state so as to feed back to the eNB information indicating a cyclic order and change frequency of respective wave beams to be changed cyclically, so that the eNB can pre-code information to be transmitted based on the cyclic order and change frequency indicated by the UE, thereby obtaining a higher diversity gain and beam-forming gain.

15 [00125] For those skilled in the art, it would be appreciated that the present invention is not limited to the details of the above exemplary embodiments. Meanwhile, without departing from the spirit or basic features of the present invention, the present invention can be implemented in other specific forms. Thus, the embodiments should, in any case, be taken as exemplary instead of non-limiting. The scope of present invention is limited by the
20 appended claims rather than the above detailed description, and thus intends to cover all the variants falling within the meaning and range of the alternatives of the claims in the present invention. Reference signs in the claims shall not be regarded as limiting to the related claims. In addition, the words “comprising” and “including” apparently do not exclude other elements and steps, and the expression “a/an” does not exclude the plural form. The
25 multiple elements or apparatuses set out in system claims may also be implemented by one element or apparatus by means of software or hardware. The expressions “first” or “second” and the like are used to indicate the name rather than any particular order.

I/We Claim:

1. A method of assisting in performing pre-coding in a UE, wherein a common pre-coding codebook is stored in an eNB and the UE included in a MIMO system, and the eNB pre-codes transmission information based on a first pre-coding matrix corresponding to a long-term wave beam or a cyclically changed wave beam and a second pre-coding matrix corresponding to a cyclically changed wave beam, the method comprising steps of:

a. upon reception of a reference signal transmitted from the eNB, obtaining corresponding cycle indication information by performing a mobility estimation operation, wherein the cycle indication information includes cycle order information indicating an order of changing respective wave beams; and

b. feeding the cycle indication information back to the eNB so that the eNB determines, based on the cycle indication information, a cyclic order of the respective wave beams to be changed cyclically.

2. The method of claim 1, wherein the first pre-coding matrix corresponds to the long-term wave beam and the second pre-coding matrix corresponds to the cyclically changed wave beam, wherein the step a comprises steps of:

a1. upon reception of the reference signal transmitted from the eNB, selecting the first pre-coding matrix from the codebook by performing a channel estimation operation; and

a2. obtaining the corresponding cycle indication information by performing a mobility estimation operation based on the selected first pre-coding matrix, wherein the cycle indication information includes cycle order information of respective wave beams corresponding to the second pre-coding matrix.

3. The method of claim 2, wherein the step a2 comprises steps of:

a21. calculating current mobility estimation information of the UE based on the selected first pre-coding matrix and a predetermined mobility estimation algorithm; and

a22. determining the corresponding cycle indication information based on the mobility estimation information, wherein the cycle indication information includes the cycle order information of respective wave beams corresponding to the second pre-coding matrix.

4. The method of claim 3, wherein the cycle indication information further includes cycle frequency information indicating a frequency of changing the respective wave beams

corresponding to the second pre-code, the step a22 further comprising a step of:

- determining corresponding cycle frequency information based on the mobility estimation information.

5 5. The method of claim 1, wherein the first pre-coding matrix and the second pre-coding matrix both correspond to the cyclically changed wave beams, and the cycle indication information further includes cycle indication information corresponding to the first pre-coding matrix, the step a further comprising a step of:

10 a3. obtaining the cycle indication information corresponding to the first pre-coding matrix by performing a mobility estimation operation based on the first pre-coding matrix.

15 6. A method of performing pre-coding in an eNB, wherein common pre-coding codebook information is stored in the eNB and a UE, the codebook information including a plurality of first pre-coding matrix sets and second pre-coding matrix sets, and the eNB per-codes transmission information based on a first pre-coding matrix corresponding to a long-term wave beam or a cyclically changed wave beam and a second pre-coding matrix corresponding to a cyclically changed wave beam, the method comprising steps of:

A. transmitting a reference signal to the UE during a process of performing UE scheduling;

20 B. determining a cyclic order of respective wave beams to be changed cyclically based on cycle indication information from the UE;

C. performing a pre-coding operation on information to be transmitted based on the determined cyclic order of the respective wave beams; and

D. transmitting the pre-coded information to the UE.

25

7. The method of claim 6, wherein the cycle indication information further includes cycle frequency information, the step B comprising a step of:

- determining, based on the cycle indication information, the cyclic order and a change frequency of the respective wave beams to be changed cyclically; and

30 wherein the step C comprises a step of:

- performing the pre-coding operation on the information to be transmitted based on the determined cyclic order and change frequency of the respective wave beams.

8. An assisting apparatus for assisting in performing pre-coding in a UE, wherein a common pre-coding codebook is stored in an eNB and the UE included in a MIMO system, and the eNB pre-codes transmission information based on a first pre-coding matrix corresponding to a long-term wave beam or a cyclically changed wave beam and a second pre-coding matrix corresponding to a cyclically changed wave beam, the assisting apparatus comprising:

a pre-estimating unit configured to obtain corresponding cycle indication information by performing a mobility estimation operation, wherein the cycle indication information includes cycle order information indicating an order of changing respective wave beams; and

a feedback unit configured to feed the cycle indication information back to the eNB so that the eNB determines, based on the cycle indication information, a cyclic order of the respective wave beams to be changed cyclically.

9. The assisting apparatus of claim 8, wherein the first pre-coding matrix corresponds to the long-term wave beam and the second pre-coding matrix corresponds to the cyclically changed wave beam, the pre-estimating unit comprising:

a channel estimating unit configured to, upon reception of the reference signal transmitted from the eNB, select the first pre-coding matrix from the codebook by performing a channel estimation operation; and

a mobility estimating unit configured to obtain the corresponding cycle indication information by performing a mobility estimation operation based on the selected first pre-coding matrix, wherein the cycle indication information includes cycle order information of respective wave beams corresponding to the second pre-coding matrix.

10. The assisting apparatus of claim 9, wherein the mobility estimating unit comprises:

a calculating unit configured to calculate current mobility information of the UE based on the selected first pre-coding matrix and a pre-determined mobility estimation algorithm; and

a first determining unit configured to determine the corresponding cycle indication information based on the mobility estimation information, wherein the cycle indication information includes the cycle order information of respective wave beams corresponding to the second pre-coding matrix.

11. The assisting apparatus of claim 10, wherein the cycle indication information further includes cycle frequency information indicating a frequency of changing the respective wave beams corresponding to the second pre-code, the first determining unit further comprising:

5 a determining sub-unit configured to determine corresponding cycle frequency information based on the mobility estimation information.

12. The assisting apparatus of claim 8, wherein the first coding matrix and the second coding matrix both correspond to the cyclically changed wave beams, and the cycle
10 indication information further includes cycle indication information corresponding to the first pre-coding matrix, the pre-estimating unit further comprising:

a pre-estimating sub-unit configured to obtain the cycle indication information corresponding to the first pre-coding matrix by performing a mobility estimation operation based on the first pre-coding matrix.

13. A pre-coding apparatus for performing pre-coding in an eNB, wherein common pre-coding codebook information is stored in the eNB and a UE, and the eNB pre-codes transmission information based on a first pre-coding matrix corresponding to a long-term wave beam or a cyclically changed wave beam and a second pre-coding matrix corresponding
20 to a cyclically changed wave beam, the pre-coding apparatus comprising:

a first transmitting unit configured to transmit a reference signal to the UE during a process of performing UE scheduling;

a second determining unit configured to determine a cyclic order of respective wave beams to be changed cyclically based on cycle indication information from the UE;

25 a performing unit configured to perform a pre-coding operation on information to be transmitted based on the determined cyclic order of the respective wave beams; and

a second transmitting unit configured to transmit the pre-coded information to the UE.

14. The pre-coding apparatus of claim 13, wherein the cycle indication information
30 further includes cycle frequency information, the second determining unit is configured to:

- determining, based on the cycle indication information, the cyclic order and a change frequency of the respective wave beams to be changed cyclically; and

wherein the performing unit is configured to:

- performing the pre-coding operation on the information to be transmitted based on

the determined cyclic order and change frequency of the respective wave beams.

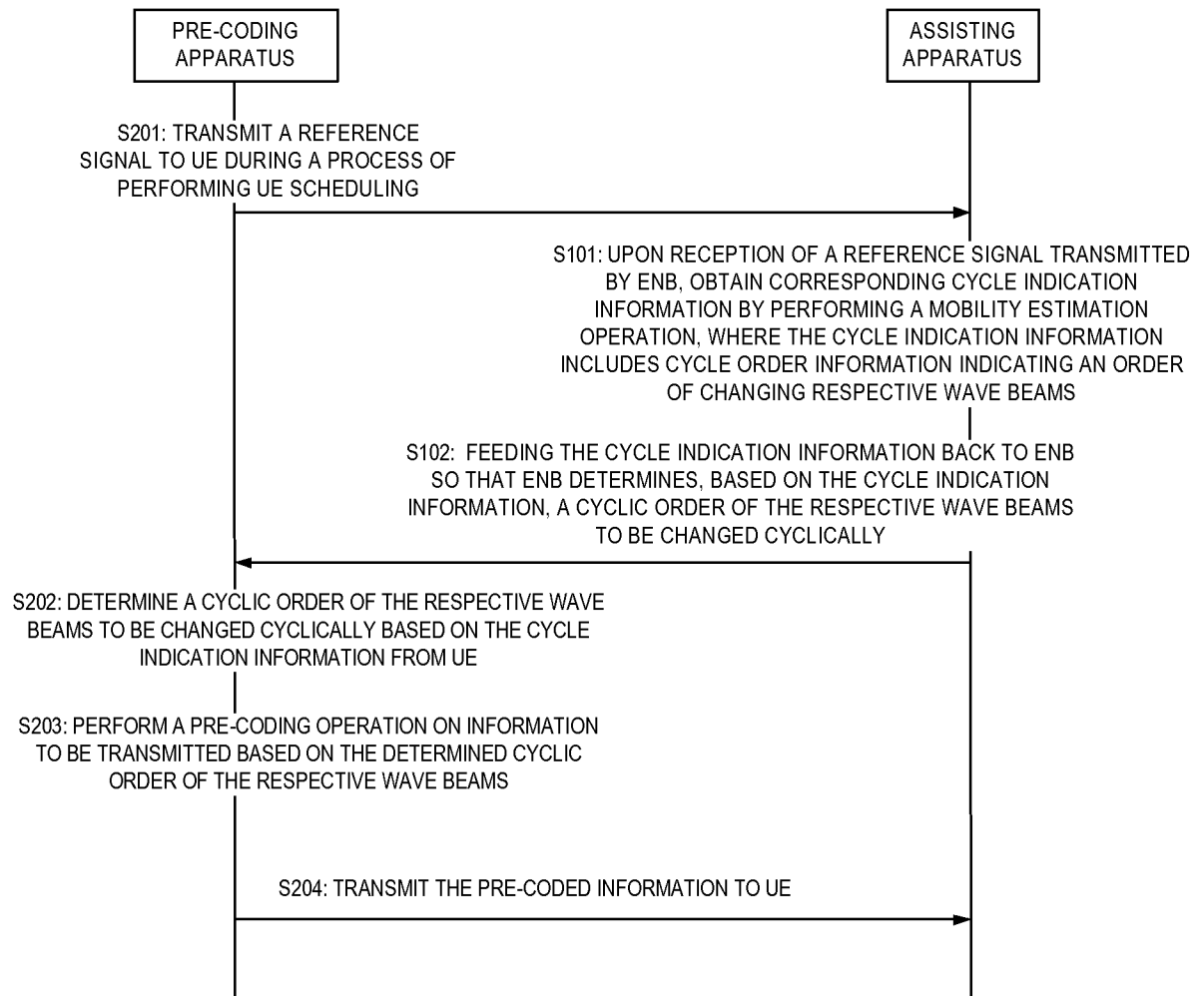


FIG. 1

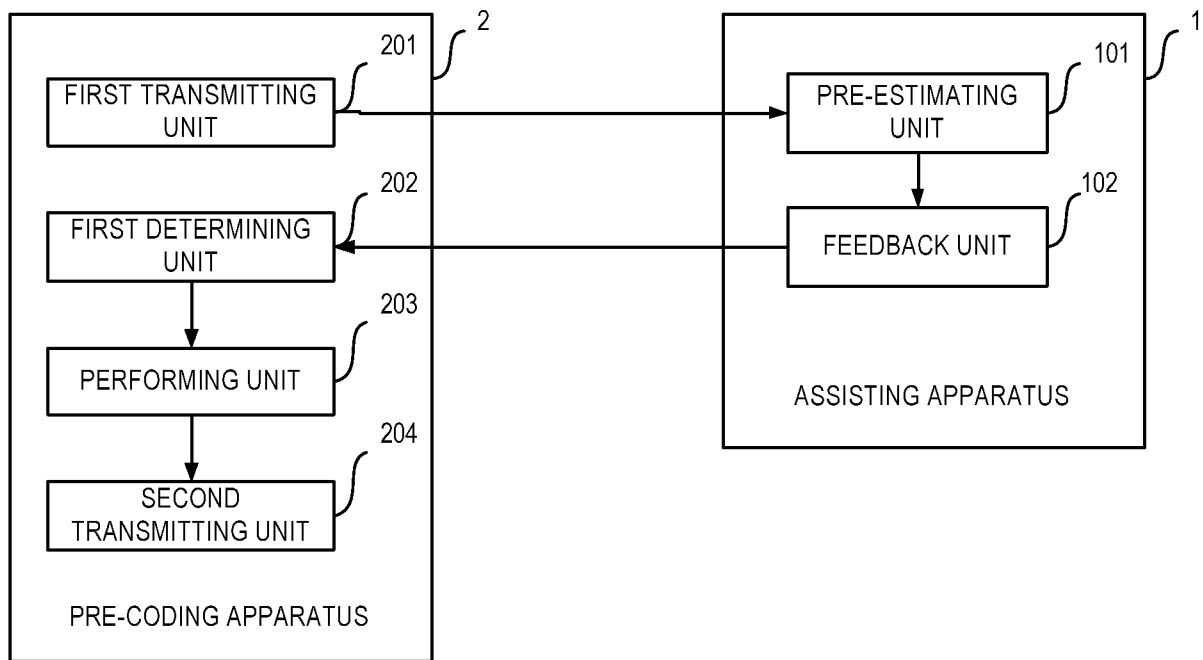


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2017/000713

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04B7/0456 H04B7/04 H04B7/06
ADD.

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

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

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

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CATT: "Discussion on DMRS based semi-open-loop MIMO", 3GPP DRAFT; R1-162289, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE vol. RAN WG1, no. Busan, Korea; 20160411 - 20160415 2 April 2016 (2016-04-02), XP051080094, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_84b/Docs/ [retrieved on 2016-04-02]	1,2,5,6, 8,9,12, 13
Y	Section 1. paragraph 3; page 1 section 2.1 paragraph 3-5; page 1 -/--	1-14



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

14 August 2017

Date of mailing of the international search report

23/08/2017

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2017/000713

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	page 2, paragraph 3 - paragraph 4 Section 2.2 paragraph 3; page 2 page 3, paragraph 1 - paragraph 3 tables I, II figures 1,2 Equation 1 ----- Y WO 2016/013750 A1 (LG ELECTRONICS INC [KR]) 28 January 2016 (2016-01-28) · & US 2017/207834 A1 (KANG JIWON [KR] ET AL) 20 July 2017 (2017-07-20) paragraphs [0010], [0012], [0018], [0086] - [0090], [0112] - [0113], [0117] - [0126], [0131] - paragraphs [0134], [0145] - [0156], [0161] - [0164], [0172] - [0174]; claims 1,3,4,7; figures 13,21-23; table 2 ----- Y LG ELECTRONICS: "Discussion on OL and Semi-OL MIMO scheme", 3GPP DRAFT; R1-162492 OL MIMO, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE · vol. RAN WG1, no. Busan, Korea; 20160411 - 20160415 2 April 2016 (2016-04-02), XP051080229, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_84b/Docs/ [retrieved on 2016-04-02] Equation 4-6 page 2, paragraph 1 page 3, paragraph 3 - paragraph 8 -----	1-14 5,12

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2017/000713

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2016013750 A1	28-01-2016	EP 3174219 A1	31-05-2017
		KR 20170035845 A	31-03-2017
		US 2017207834 A1	20-07-2017
		WO 2016013750 A1	28-01-2016
