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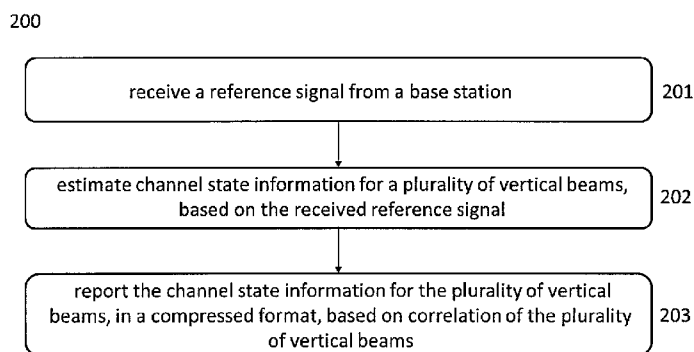


Fig. 2

(57) Abstract: Embodiments of the present disclosure provide a method in a user equipment for reporting channel state information of multiple vertical beams. The method comprises receiving a reference signal from a base station, estimating channel state information for a plurality of vertical beams, based on the received reference signal, and reporting the channel state information for the plurality of vertical beams, in a compressed format, based on correlation of the plurality of vertical beams. A method in a corresponding base station, and corresponding apparatus are also provided.



METHOD AND APPARATUS FOR CHANNEL STATE INFORMATION FEEDBACK FOR FULL DIMENSIONAL MIMO

TECHNICAL FIELD

[0001] The non-limiting and exemplary embodiments of the present disclosure generally
5 relate to the technical field of radio communications, and specifically to a method and apparatus
for channel state information (CSI) feedback enhancement in a wireless system with
three-dimensional (3D) multiple-input-multiple-output (MIMO) technique.

BACKGROUND

[0002] This section introduces aspects that may facilitate a better understanding of the
10 disclosure. Accordingly, the statements of this section are to be read in this light and are not to
be understood as admissions about what is in the prior art or what is not in the prior art.

[0003] MIMO techniques have been known as an effective way for improving spectrum
efficiency (SE) in wireless communication systems. For example, MIMO has been adopted as
a key feature of Long Term Evolution (LTE)/LTE-Advanced (LTE-A) system developed by the
15 third generation project partnership (3GPP). Conventional one-dimensional (horizontal
domain) antenna array can provide flexible beam adaption in the azimuth domain only through
the horizontal domain precoding process, wherein a fixed down-tilt is applied in the vertical
direction. It has been found recently that full MIMO capability can be exploited through
leveraging a two dimensional antenna planar such that a user-specific elevation beamforming
20 and spatial multiplexing in the vertical domain are also possible.

[0004] A Study Item of 3GPP Release 12 proposed to study user specific beamforming and
full dimensional MIMO (i.e., 3D MIMO) with 2D antenna arrays (also known as Active
Antenna System (AAS)). It can potentially improve transmit and/or receive gain, and reduce
intra/inter-cell interference. A Study Item (SI) of 3GPP Release 13 has started to discuss
25 improvement schemes for the user specific beamforming and the full dimensional MIMO, the
hot topics of which include CSI reference signals (CSI-RS) design and CSI feedback schemes.
The main targets of the SI are high system performance, low complexity and low
standardization effort.

SUMMARY

[0005] Various embodiments of the disclosure aim at providing CSI for FD-MIMO with
30 low overhead, whereby enabling flexible scheduling and inter-cell interference avoidance.

Other features and advantages of embodiments of the disclosure will also be understood from the following description of specific embodiments when read in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of embodiments of the disclosure.

- 5 [0006] In a first aspect of the disclosure, there is provided a method in a wireless system with 3D MIMO. The method comprises receiving a reference signal from a base station, estimating channel state information for a plurality of vertical beams, based on the received reference signal, and reporting the channel state information for the plurality of vertical beams, in a compressed format, based on correlation of the plurality of vertical beams.
- 10 [0007] In one embodiment of the disclosure, reporting the channel state information for the plurality of vertical beams, in a compressed format, based on correlation of the plurality of vertical beams may comprise reporting a M-bits indicator for a first vertical precoding vector of a plurality of vertical precoding vectors, and reporting a D-bits indicator for a second vertical precoding vector of the plurality of vertical precoding vectors, which indicates an offset of the
- 15 second vertical precoding vector relative to the first vertical precoding vector.
- [0008] In another embodiment, reporting the channel state information for the plurality of vertical beams, in a compressed format, based on correlation of the plurality of vertical beams may comprise reporting an index of a combination of multiple vertical precoding vectors in a predefined set of combinations.
- 20 [0009] In still another embodiment, reporting the channel state information for the plurality of vertical beams, in a compressed format, based on correlation of the plurality of vertical beams may comprise reporting a plurality of vertical precoding vectors, by reporting only a first vertical precoding vector of the plurality of vertical precoding vectors explicitly and reporting other vertical precoding vectors implicitly.
- 25 [0010] In some embodiments, reporting the channel state information for the plurality of vertical beams, in a compressed format, based on correlation of the plurality of vertical beams may comprise reporting a channel quality indicator for each of the plurality of vertical beams, in a compressed format, based on the correlation of the plurality of vertical beams, and wherein the channel quality indicator indicates channel quality of a vertical channel or channel quality of a
- 30 three dimensional channel. In one embodiment, reporting a channel quality indicator for each of the plurality of vertical beams, in a compressed format, based on the correlation of the plurality of vertical beams may comprise reporting a L-bits channel quality indicator for a first vertical beam of the plurality of vertical beams, and reporting a K-bits offset of an channel quality indicator for a second vertical beam relative to the channel quality indicator for the first

vertical beam. In another embodiment, the K-bits offset is selected from a set of non-negative values or a set of non-positive values.

[0011] In an embodiment, reporting the channel state information for the plurality of vertical beams, in a compressed format, based on correlation of the plurality of vertical beams
5 may comprise reporting the channel state information for the plurality of vertical beams in a physical uplink control channel PUCCH.

[0012] In another embodiment, reporting a channel quality indicator for each of the plurality of vertical beams may comprise reporting a channel quality indicator for a first vertical beam of the plurality of vertical beams, in a first physical uplink control channel PUCCH, and reporting
10 a channel quality indicator for a second vertical beam of the plurality of vertical beams, in a second PUCCH different from the first PUCCH; and wherein the channel quality indicator indicates channel quality of a three dimensional channel.

[0013] In a second aspect of the disclosure, there is provided a method in a wireless system with 3D MIMO. The method comprises transmitting a reference signal to a device, receiving
15 channel state information for a plurality of vertical beams from the device, and wherein the channel state information is estimated by the device based on the reference signal and then compressed when being transmitted by the device based on correlation of the plurality of vertical beams.

[0014] In one embodiment of the disclosure, receiving the channel state information for a plurality of vertical beams may comprise receiving a M-bits indicator for a first vertical precoding vector of a plurality of vertical precoding vectors, and receiving a D-bits indicator for a second vertical precoding vector of the plurality of vertical precoding vectors, which indicates an offset of the second vertical precoding vector relative to the first vertical precoding vector.

[0015] In another embodiment, receiving the channel state information for a plurality of
25 vertical beams may comprise receiving an index indicating a combination of multiple vertical precoding vectors in a predefined set of combinations.

[0016] In still another embodiment, receiving the channel state information for a plurality of vertical beams may comprise receiving an indicator which indicates a first vertical precoding vector of a plurality of vertical precoding vectors explicitly and indicates a second vertical precoding vector of the plurality of vertical precoding vectors implicitly.
30

[0017] In some embodiments of the disclosure, receiving the channel state information for a plurality of vertical beams may comprise receiving a channel quality indicator for each of the plurality of vertical beams, wherein the channel quality indicator indicates channel quality of a vertical channel or channel quality of a three dimensional channel. In one embodiment,

receiving a channel quality indicator for each of the plurality of vertical beams may comprise receiving a L-bits channel quality indicator for a first vertical beam of the plurality of vertical beams, and receiving a K-bits offset of a channel quality indicator for a second vertical beam relative to the channel quality indicator for the first vertical beam. In another embodiment, the
5 K-bits offset is selected from a set of non-negative values or a set of non-positive values.

[0018] In another embodiment, receiving channel state information for a plurality of vertical beams may comprise receiving the channel state information for the plurality of vertical beams in a physical uplink control channel PUCCH.

[0019] In still another embodiment, receiving a channel quality indicator for each of the
10 plurality of vertical beams may comprise receiving a channel quality indicator for a first vertical beam of the plurality of vertical beams, in a first physical uplink control channel PUCCH, and receiving a channel quality indicator for a second vertical beam of the plurality of vertical beams, in a second PUCCH different from the first PUCCH; and wherein the channel quality indicator indicates channel quality of a three dimensional channel.

[0020] In a third aspect of the disclosure, there is provided an apparatus in a wireless system
15 with three dimensional multiple input multiple output. The apparatus comprises a receiver, configured to receive a reference signal from a base station, an estimator, configured to estimate channel state information for a plurality of vertical beams, based on the received reference signal, and a transmitter, configured to report the channel state information for the plurality of
20 vertical beams, in a compressed format, based on correlation of the plurality of vertical beams.

[0021] In a fourth aspect of the disclosure, there is provided an apparatus in a wireless
system with three dimensional multiple input multiple output. The apparatus comprises a transmitter, configured to transmit a reference signal to a device, and a receiver, configured to receive channel state information for a plurality of vertical beams from the device, wherein the
25 channel state information is estimated by the device based on the reference signal and then compressed when being transmitted by the device based on correlation of the plurality of vertical beams.

[0022] In a fifth aspect of the disclosure, there is provided an apparatus in a wireless system
with three dimensional multiple input multiple output. The apparatus comprises a processor
30 and a memory, said memory containing instructions executable by said processor whereby said apparatus is operative to perform the method of the first aspect of the disclosure.

[0023] In a sixth aspect of the disclosure, there is provided an apparatus in a wireless
system with three dimensional multiple input multiple output. The apparatus comprises a processor and a memory, said memory containing instructions executable by said processor

whereby said apparatus is operative to perform the method of the second aspect of the disclosure.

[0024] According to the various aspects and embodiments as mentioned above, by utilizing correlation between multiple vertical beams, the CSIs for the multiple vertical beams can be reported with reduced overhead, and thus physical resources required for the multiple CSIs feedback can be reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The above and other aspects, features, and benefits of various embodiments of the disclosure will become more fully apparent, by way of example, from the following detailed description with reference to the accompanying drawings, in which like reference numerals or letters are used to designate like or equivalent elements. The drawings are illustrated for facilitating better understanding of the embodiments of the disclosure and not necessarily drawn to scale, in which:

[0026] Fig. 1 illustrates an exemplary 3D MIMO system where embodiments of the present invention may be implemented;

[0027] Fig. 2 illustrates an exemplary flowchart of a method in a user equipment according to an embodiment of the present disclosure;

[0028] Fig. 3A illustrates a schematic diagram of a two-dimensional antenna array at a base station side;

[0029] Figs. 3B-3D illustrate some exemplary procedures between an eNB and UE related to the CSI feedback for multiple vertical beams;

[0030] Fig. 4 illustrates a flow chart of a method in a base station according to an embodiment of the disclosure;

[0031] Fig. 5 illustrates a schematic block diagram of an apparatus in a user equipment according to an embodiment of the present disclosure;

[0032] Fig. 6 illustrates a schematic block diagram of an apparatus in a base station according to an embodiment of the present disclosure; and

[0033] Fig. 7 illustrates a simplified block diagram of two apparatus suitable for use in practicing the embodiments of the present disclosure.

DETAILED DESCRIPTION

[0034] Hereinafter, the principle and spirit of the present disclosure will be described with reference to the illustrative embodiments. It should be understood, all these embodiments are given merely for the skilled in the art to better understand and further practice the present disclosure, but not for limiting the scope of the present disclosure. For example, features illustrated or described as part of one embodiment may be used with another embodiment to yield still a further embodiment. In the interest of clarity, not all features of an actual implementation are described in this specification.

[0035] References in the specification to “one embodiment”, “an embodiment”, “an example embodiment” etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is associated with the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0036] It shall be understood that, although the terms “first” and “second” etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and similarly, a second element could be termed a first element, without departing from the scope of example embodiments. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed terms.

[0037] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of example embodiments. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises”, “comprising”, “has”, “having”, “includes” and/or “including”, when used herein, specify the presence of stated features, elements, and/or components etc., but do not preclude the presence or addition of one or more other features, elements, components and/or combinations thereof.

[0038] In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. For example, the term terminal device used herein may refer to any terminal having wireless communication capabilities or user equipment

(UE), including but not limited to, mobile phone, cellular phones, smart phone, or personal digital assistants (PDAs), portable computers, image capture device such as digital cameras, gaming devices, music storage and playback appliances, wearable devices and any portable units or terminals that have wireless communication capabilities, or Internet appliances permitting wireless Internet access and browsing and the like. Likewise, the term base station used herein may be referred to as e.g., eNB, eNodeB, NodeB, Base Transceiver Station BTS or Access Point (AP), depending on the technology and terminology used.

[0039] The following description of various embodiments aims to illustrate the principle and concept of the present disclosure. For illustrative purposes, several embodiments of the present disclosure will be described in the context of a 3GPP LTE system. Those skilled in the art will appreciate, however, that several embodiments of the present disclosure may be more generally applicable to any other wireless systems exploiting 3D MIMO technique.

[0040] In Fig. 1, an exemplary 3D MIMO system 100, in which embodiments of the present invention may be implemented, is illustrated. The wireless system 100 comprises one or more network nodes, e.g., 101 and 102, here in the form of evolved Node B, also known as eNode Bs or eNBs. It will be appreciated that the network nodes 101 could also be in the form of Node Bs, BTSs (Base Transceiver Stations), BS (Base Station) and/or BSSs (Base Station Subsystems), etc. The network nodes 101 may provide a macro cell or small cell and provide radio connectivity to a plurality of UEs, e.g., UE 103 -107. The UE can be any wireless communication device which is portable or fixed. Moreover, the UEs 103-107 may, but not necessarily, be associated with a particular end user. Though for illustrative purpose, the wireless system 100 is described to be a 3GPP LTE network, the embodiments of the present disclosure are not limited to such network scenarios and the proposed methods and devices can also be applied to other wireless networks, e.g., a non-cellular network, where 3D-MIMO technique is applied, CSI feedback overhead to support 3D-MIMO need to be reduced and the principles described hereinafter are applicable.

[0041] It is assumed in this example that both eNB 101 and eNB 102 are equipped with an AAS, thereby providing vertical beamforming gain, besides horizontal beamforming gain, due to flexible tilt control. However, serious inter-cell interference may still be introduced in the 3D MIMO system 100 with the AASs. As shown in the Fig. 1, UE 103-105 are served by eNB 1, and UE 106-107 are served by eNB 2. Both the eNB 101 and the eNB 102 may serve their UEs with one of a plurality of vertical beams, each of which corresponds to a down tilt angle. As shown in Fig. 1, a vertical beam 2 for UE 104 overlaps with a vertical beam 4 for UE 106, which means transmission from the eNB 101 to the UE 104 with the vertical beam 2 may cause

interference to UE 106, and transmission from the eNB 102 to the UE 106 with the vertical beams 4 may cause interference to UE 104. Therefore, when selecting down tilt angle for UEs, a tradeoff between vertical beamforming gain and interference to adjacent cells or UEs should be taken into consideration, in order to achieve a good system performance. In other words, although a vertical beam corresponding to a vertical precoding matrix indicator (PMI-V) reported by a specific UE, e.g., UE 104, may result in the highest throughput for the UE 104, it may introduce serious inter-cell interference, e.g., to UE 106, and degrade the system performance. Therefore, a PMI-V reported from the UE (e.g., the best PMI-V for the UE 104) may not be optimal from the aspect of the whole network performance, especially for high load traffic scenario. In addition, only one vertical beam based feedback has bad robustness, especially when the beam width is narrow or UE speed is high in vertical domain.

[0042] One way to enable a balance between vertical beamforming gain for a specific UE and the whole system performance is to allow CSI feedback for multiple vertical beams from the UE. Thereby, the eNB can determine from the multiple vertical beams a best candidate, which results in more flexible scheduling and enables a tradeoff between beamforming gain for the UE and interference to others. For example, in the example shown in Fig. 1, the eNB may transmit data with vertical beam 3 to the UE 104, in order to avoid serious interference to adjacent cell, if the gap between the vertical beam 2 and the vertical beam 3 is not too large in terms of channel quality indicator (CQI) or reference signal received power (RSRP).

[0043] Reporting CSI for multiple vertical beams implies high overhead compared with CSI feedback for a single vertical beam. One object of the embodiments of the invention is to reduce overhead required for reporting CSI for multiple vertical beams in a 3D-MIMO system.

[0044] Fig. 2 illustrates an exemplary flowchart of a method 200 for reducing CSI feedback overhead for multiple vertical beams in a 3D-MIMO system according to an embodiment of the present disclosure. The method 200 can be performed by UE, e.g., the UE 104 shown in Fig. 1, but the present disclosure is not limited thereto. The method 200 may be performed by any other suitable device which may need to report CSI.

[0045] As shown in Fig. 2, at block 201, a reference signal from a base station is received. At block 202, the UE estimates channel state information for a plurality of vertical beams, based on the reference signal received at block 201. At block 203, the UE reports the channel state information (CSI) for the plurality of vertical beams, in a compressed format, based on correlation of the plurality of vertical beams.

[0046] By reporting CSI for the plurality of vertical beams in a compressed format based on correlation of these vertical beams, overhead for the CSI feedback can be reduced with the method 200.

[0047] In an embodiment of the disclosure, the reference signal received from the base station at block 201 can be CSI reference signal (CSI-RS) for vertical CSI estimation, however, embodiments of the disclosure are not limited to this. Just for illustrative purpose, in Fig. 3A, a schematic diagram of a two-dimensional antenna array (also known as AAS) at a base station side is depicted. In one example embodiment, the reference signal received at block 201 may be CSI-RS transmitted from each antenna element of the AAS to facilitate 3D channel estimation. In another example embodiment, the reference signal received at block 201 may be CSI-RS transmitted from a column of antenna elements of the AAS to facilitate vertical channel estimation. Embodiments of the disclosure are not limited to any specific reference signal transmission scheme, as long as the reference signal is suitable for vertical channel estimation or 3D channel estimation.

[0048] In one embodiment of the disclosure, at block 201, UE may receive reference signal (which may be denoted as V_CSI-RS) for vertical CSI estimation and reference signal (which may be denoted as H_CSI-RS) for horizontal CSI estimation, respectively.

[0049] In one embodiment of the disclosure, at block 202, estimating channel state information for the plurality of vertical beams may comprise determining a plurality of vertical precoding vectors/matrix based on the received RS, e.g., by selecting, from a predefined codebook, best K vertical precoding vectors. For example, the UE may select K vertical precoding vectors which provide the highest capacity. Assuming $C_1 > C_2 > \dots > C_K > C_{K+1} > \dots > C_N$ are the capacity provided with each of the N candidate precoding vectors in the codebook, precoding vectors corresponding to C_i ($1 \leq i \leq K$) may be selected, in the embodiment. The number of the selected precoding vectors, i.e., K, may be configurable based on, e.g., a tradeoff between feedback overhead and system performance. The predefined codebook may be a DFT codebook, though embodiments of the disclosure are not limited thereto.

[0050] Alternatively, in another embodiment of the disclosure, at block 202, the UE may determine a plurality of vertical precoding vectors by selecting, from the codebook, the vertical precoding vectors which provide the highest signal to noise power ratio (SNR), or signal to noise plus interference power ratio (SINR). For example, assuming $CQI_1 > CQI_2 > \dots > CQI_K > CQI_{K+1} > \dots > CQI_N$ are the channel quality indicator provided with each of the N

candidate precoding vectors in the codebook, precoding vectors corresponding to CQI_i ($1 \leq i \leq K$) may be selected as the plurality of vertical precoding vectors, in the embodiment.

[0051] In another embodiment of the disclosure, at block 202, the UE may estimate a vertical channel matrix H based on the received RS, then derive a singular vector corresponding to the largest singular value of the channel matrix by using a singular value decomposition (SVD). Then, the UE may estimate the vertical precoding vectors by selecting vertical precoding vectors which have the highest correlation with the singular vector.

[0052] It has been observed by the inventor of the disclosure that the plurality of precoding vectors estimated at block 202 may correspond to adjacent vertical beams due to small elevation angle spread and high correlation in adjacent vertical beams. The correlation results in similarities between the plurality of precoding vectors and corresponding channel characteristics, which facilitates feedback overhead reduction/compression when reporting the CSI for the plurality of vertical beams at block 203.

[0053] It can be appreciated that the operations performed at block 202 for estimating CSI for the plurality vertical beams are not limited to the above examples. The CSI estimated may include other or additional information, e.g., CQI, and the CSIs may be estimated in any suitable manner than what has been described above. In one embodiment of the disclosure, at block 202, CQIs for the plurality of vertical beams are estimated additionally or alternatively. The CQI for each beam can be estimated based on a channel estimation and a vertical precoding vector (e.g., determined as shown in the above embodiments) corresponding to the beam. Depending on whether a vertical CQI or a 3D CQI is to be estimated, the channel estimation can be vertical channel estimation or 3D channel estimation. The CQI may take a form of capacity, SINR, or throughput, etc., and the required calculations are known to those skilled in the art, and thus will not be detailed herein.

[0054] In one embodiment of the disclosure, at block 203, the UE may report CSIs for the plurality of vertical beams in a compressed format based on correlation of the plurality of vertical beams by reporting a M -bits indicator for a first vertical precoding vector of a plurality of vertical precoding vectors, and reporting a D -bits indicator for a second vertical precoding vector of the plurality of vertical precoding vectors, wherein the D -bits indicator indicates an offset of the second vertical precoding vector relative to the first vertical precoding vector. In one embodiment, D may be a value smaller than M which provides overhead reduction compared with reporting both the first and second vertical precoding vectors using M bits. Due to correlation between the first and second vertical precoding vectors, the offset may vary in a small range, and thus $D=1$ or $D=2$ bits may be enough to indicate the offset, in some

embodiments. It can be appreciated, however, embodiments of the disclosure are not limited to any specific value of M and D.

[0055] In Table 1A to 1C, some examples for the D-bits indicator are illustrated. In Table 1A, it is assumed that D=2 bits are used for the indicator, and 4 values (0 to 3) are used to indicate an offset level of +1, -1, +2, or -2. Both Table 1B and 1C assume a D=1 bit indicator, which can provide 2 values (0 and 1) to indicate an offset level of +1 or -1, or +2 or -2. It can be appreciated that the D bits can also be used to indicate any other suitable offset levels than those shown in the Tables.

Table 1A: Example of D=2 bits offset

value	Offset level
0	+1
1	-1
2	+2
3	-2

Table 1B: Example of D=1 bit offset

value	Offset level
0	+1
1	-1

Table 1C: Example of D=1 bit offset

value	Offset level
0	+2
1	-2

[0056] Alternatively, at block 203, the UE may report the CSI for the plurality of vertical beams in a compressed format based on correlation of the plurality of vertical beams by reporting an index of a combination of multiple vertical precoding vectors, the combination belonging to a predefined set of combinations. One example of the predefined set of combinations is shown in Table 2. In this example, each index can indicate a combination of two vertical precoding vectors (PMI_V_1 and PMI_V_2). As shown in Table 2, by defining only a limited number of allowed combinations, low feedback overhead for the index can be guaranteed. The allowed combinations can be combinations of vertical precoding vectors corresponding to adjacent vertical beams, in one embodiment. It can be appreciated by those skilled in the art that embodiments of the disclosure are not limited to a combination of any specific number of precoding vectors, or any specific combinations, that is, the predefined set of combinations can include any suitable precoding vector combinations.

Table 2. Example of Indication for a combination of two vertical precoding vectors

index	(PMI_V_1, PMI_V_2)
0	0 1
1	1 2
2	2 3
3	3 4
...	...

[0057] In one embodiment of the disclosure, at block 203, the UE may report a plurality of vertical precoding vectors by reporting only a first vertical precoding vector of the plurality of vertical precoding vectors explicitly, and reporting other vertical precoding vectors implicitly. For example, the UE may report only the best vertical precoding vector PMI_V_1 using M bits, while implicitly indicate to the base station other vertical precoding vectors as PMI_V_1+1, and PMI_V_1-1, etc. That is to say, UE may report only part of the plurality of vertical precoding vectors explicitly, and the report can be used by the base station to derive other vertical precoding vectors implicitly based on correlation between the vertical precoding vectors.

[0058] In some embodiments, at block 203, the UE may report a CQI for the plurality of vertical beams in a compressed format, based on the correlation of the plurality of vertical beams. The channel quality indicator may indicate channel quality of a vertical channel or channel quality of a three dimensional channel. The CQI may be reported together with the vertical precoding vectors (also denoted as PMI_V herein) or separately.

[0059] As one example, the UE may report a CQI for each of the plurality of vertical beams in a compressed format, by reporting a L-bits CQI for a first vertical beam of the plurality of vertical beams, and reporting a K-bits offset of an CQI for a second vertical beam relative to the CQI for the first vertical beam. In one embodiment, K may be smaller than L. In one embodiment, the UE may report the largest CQI with full bits (i.e., L bits), and report an offset for each of the other CQIs with K<L bits, to save overhead.

[0060] Assuming the largest CQI (e.g., CQI_V_1) is reported with full bits, then another CQI (e.g., CQI_V_K) can be represented as:

$$\text{CQI_V_k} = \text{CQI_V_1} - \text{offset}_k \quad (1), \text{ or}$$

$$\text{CQI_V_k} = \text{CQI_V_1} + \text{offset}_k \quad (2)$$

[0061] Since CQI_V_K is not larger than the CQI_V_1, the offset k can only take non-negative values in equation (1) or non-positive values in equation (2). Such characteristic may be utilized to further reduce the feedback overhead. For example, a set of non-negative values can be predefined, and the UE select an offset value from the set to report. An example of the set is shown in Table 3A. Comparing with defining a set with both non-negative and

negative values as shown in Table 3B, less bits (2 bits in the example of Table 3A) are required for the indication of the offset.

Table 3A. An example of CQI offset

Offset Indication	Offset level
0	0
1	1
2	2
3	≥ 3

[0062] In case, the reported CQI (e.g., CQI_V_1) with full bits is not the largest, then the CQI offset for other CQIs may be positive or negative, and thus another Table as shown in Table.3B may be used.

Table 3B. Another example of CQI offset

Offset Indication	Offset level
0	0
1	1
2	2
3	≥ 3
4	≤ -4
5	-3
6	-2
7	-1

[0063] In one embodiment, at block 203, the UE may report the CSI for the plurality of vertical beams in a physical uplink control channel (PUCCH). For example, the reported CSI for the plurality vertical beams may include multiple vertical precoding vectors and multiple CQIs in a compressed format. For example, the CSI may include PMI_V_1 (e.g., M bits), CQI_V_1 (e.g., 4 bits), PMI_V_2_offset (e.g., D bits, as shown in Table 1C) and CQI_V_2_offset (e.g., 2 bits as shown in Table 3A), where PMI_V_1 denotes the precoding matrix indicator for a first vertical precoding vector which may provide the largest capacity or SINR, CQI_V_1 denotes the CQI for a first vertical beam determined by PMI_V_1, PMI_V_2_offset denotes an offset of a second vertical precoding vector PMI_V_2 relative to the first PMI_V_1, and CQI_V_2_offset is an offset of the CQI_V_2 for a second vertical beam determined by PMI_V_2, relative to CQI_V_1. Due to capacity limitation of the PUCCH channel, the total payload of PMI_V_1, CQI_V_1, PMI_V_2_offset, and CQI_V_2_offset should not exceed a predefined number. In one embodiment, the predefined number can be 11 bits. It can be appreciated by those skilled in the art that embodiments of the disclosure are not

limited thereto, and the predefined number can be smaller or larger than 11 bits, depending on PUCCH types to be used in the future. Furthermore, it can be understood that CSI for more than two vertical beams may be reported in a PUCCH, though CSI for only two vertical beams are reported in this example.

5 [0064] In another embodiment, the reported CSI for the plurality vertical beams at block 203 in a PUCCH may include PMI_V_1_2, CQI_V_1 (e.g., 4 bits), and CQI_V_2_offset (e.g., 3 bits), where PMI_V_1_2 denotes the indication for a combination of {PMI_V_1, PMI_V_2}, while CQI_V_1 and CQI_V_2_offset denote same meaning as described above, but more bits (e.g., 3 bits as shown in Table 3B) for CQI_V_2 may be used.

10 [0065] In still another embodiment, the reported CSI for the plurality vertical beams at block 203 in a PUCCH may include only one vertical precoding vector and multiple CQIs explicitly. For example, the reported CSI may include PMI_V_1 (e.g., M bits), CQI_V_1 (e.g., 4 bits), CQI_V_2_offset (e.g., 2 bits) and CQI_V_3_offset (e.g., 2 bits), wherein CQI_V_3_offset denotes an offset value for a third CQI relative to CQI_V_1. In such a case, a
15 second and third vertical precoding vector (e.g., PMI_V_2 and PMI_V_3) may be derived based on PMI_V_1 and some predefinition. For example, PMI_V_2 and PMI_V_3 may be defined to be PMI_V_1+1 and PMI_V_1-1, respectively.

[0066] In one embodiment, the reported CQI for each of the plurality vertical beams may indicate a composite channel quality for a 3D channel, rather than for a vertical channel. Since
20 the 3D channel may have a rank higher than 1, transmission with two (or more) codewords may be supported. Therefore in the embodiment, for each vertical beam (determined by a vertical precoding vector), CQI for each of the two (or more) codewords may be reported at block 203. For example, the UE may report, for a first vertical beam, a CQI (e.g., 4 bits) for a first codeword, and an offset (e.g., 3 bits) relative to the CQI for the first codeword for a second
25 codeword. Regarding the other vertical beams, the UE may report for each of the two (or more) codewords, an offset (e.g., 2 bits) relative to the CQI for the first vertical beam. It should be noted that the number of bits described herein is just for exemplary purpose, and not for limitation.

[0067] In another embodiment, at block 203, the UE may report a CQI for a first vertical
30 beam of the plurality of vertical beams, in a first physical uplink control channel PUCCH, and report a CQI for a second vertical beam of the plurality of vertical beams, in a second PUCCH different from the first PUCCH; and wherein the CQI indicates channel quality of a three dimensional channel, and can be denoted as 3DCQI hereafter. For example, a 3DCQI for a first vertical beam (e.g., the strongest vertical beam) may be reported together with the

horizontal CSI (e.g., rank indicator for horizontal domain, precoding matrix indicator (PMI) for horizontal domain) in a first PUCCH, while 3DCQIs for other vertical beams may be reported, possibly together with the indications for vertical precoding vectors, in a second PUCCH separating from the first PUCCH.

5 [0068] In one embodiments, a new PUCCH type is designed for transmitting the CSI for the multiple vertical beams, where the CSI on PUCCH for the multiple vertical beams are transmitted in a compressed format.

[0069] In Figs. 3B-3D, some exemplary procedures between an eNB and UE related to the CSI feedback for multiple vertical beams are schematically illustrated. In the example shown
10 in Fig. 3B, the eNB may configure and transmit horizontal CSI-RS set, and the UE may measure the CSI-RS set and feedback horizontal CSI (denoted as H_CSI). The feedback may be based on legacy codebooks and legacy feedback schemes, for example, UE may feedback horizontal rank indicator (RI_H), horizontal precoding matrix indicator (PMI_H) and horizontal CQI (CQI_H). The eNB also configure and transmit vertical CSI-RS set, and based on which, the
15 UE may measure and feedback vertical CSI for multiple vertical beams (denoted as V_CSI). In this example, the UE may report PMI_V_1, CQI_V_1 for the first vertical beam, PMI_V_2, CQI_V_2 for the second vertical beams, and so on. The feedback may be, for example, based on DFT codebooks and wideband feedback. It should be noted that embodiments of the disclosure are not limited thereto. The CSI for the multiple vertical beams are transmitted in a
20 compressed format. For example, the reported PMI_V_2 and/or CQI_V_2 may be in a form of an offset, rather than absolute values. Based on feedback (including H_CSI and V_CSI) from the UE, the eNB may determine proper 3D precoder and 3D modulation and coding schemes (MCs) to be used for downlink transmission to the UE.

[0070] Fig. 3C shows another example, where the eNB configures and transmits CSI-RS,
25 and the UE measures and feedbacks 3D CSI. The 3D CSI contains channel state information of multiple vertical beams. In this example, the UE reports horizontal CSI (H_CSI), e.g., horizontal rank indicator (RI_H), horizontal PMI (PMI_H) and 3D CQI for the first vertical beam (3DCQI_V_1) together. The feedback may be based on legacy codebooks and legacy feedback schemes, e.g., using a legacy PUCCH type. The UE can report PMI for multiple
30 vertical beams and CQI for other vertical beams than the first vertical beam in another PUCCH. This feedback may be based on DFT codebooks. The CSI feedback for the multiple vertical beams in the other PUCCH may be transmitted in a compressed format, as described above with reference to Fig. 2, block 3. In one embodiment, the feedback may be performed using a new

PUCCH type. Based on the feedback from the UE, the eNB may calculate 3D precoder and 3D MCs for downlink transmission to this UE.

[0071] Another example is shown in Fig. 3D, where the eNB configures and transmit long term cell-specific non-precoded CSI-RS, and based on which, the UE measures and feedback vertical CSI for multiple vertical beams. The feedback may be based on legacy codebooks and legacy feedback schemes (e.g., legacy PUCCH type). As shown in Fig. 3D, the UE may report PMI_V_1 and/or CQI_V_1 for the first vertical beam, PMI_V_2 and CQI_V_2_offset for the second vertical beam, and so on. The transmission can be in a compressed format as described with reference to Fig. 2, block 203, and the transmission may be based on a new PUCCH type.

Based on the feedback from the UE, the eNB may choose a proper vertical beam, and then configure and transmit short term UE specific precoded CSI_RS based on its choice. Then UE can measure and feedback 3D CSI, e.g, RI, PMI_H, and 3D CQI. This feedback may be performed using legacy feedback scheme, e.g., based on a legacy PUCCH type. Based on the feedback, the eNB can calculate 3D precoder and 3D MCs for downlink transmission to this UE.

[0072] It should be noted that though some details are described with reference to Figs. 3B-3D, it should be noted that they are presented just for illustrative purpose, and embodiments are not limited thereto. That is, embodiments of the disclosure may be embodied without some of the details.

[0073] Reference is now made to Fig. 4, which illustrate a flow chart of a method 400 in a wireless system with 3D-MIMO according to an embodiment of the disclosure. The method can be implemented by a base station, e.g., eNB 101 shown in Fig. 1, or any suitable devices which may need CSI for scheduling.

[0074] As shown in Fig. 4, the method 400 comprises transmitting a reference signal to a device (e.g., one of the UE 103-107 shown in Fig. 1) at block 401, and receiving CSIs for a plurality of vertical beams from the device at block 402; wherein the channel state information is estimated by the device based on the reference signal transmitted at block 401 and then compressed when being transmitted by the device (e.g., at block 203 of the method 200) based on correlation of the plurality of vertical beams.

[0075] The reference signal transmitted to the device at block 401 may be the reference signal received at block 201 of method 200, and thus there can be various schemes for the reference signal transmission as described with reference to Fig. 2. For example, the reference signal may be CSI-RS, and at block 401 the CSI-RS may be transmitted from each antenna element of an AAS as shown in Fig. 3A to facilitate 3D channel estimation. In another

embodiment, the reference signal may be CSI-RS, and at block 401, the CSI-RS may be transmitted from a column of antenna elements of an AAS to facilitate vertical channel estimation. In still another embodiment of the disclosure, at block 401, a base station may transmit reference signal (which may be denoted as V_CSI) for vertical CSI estimation and reference signal (which may be denoted as H_CSI) for horizontal CSI estimation, respectively. Note that embodiments of the disclosure are not limited to any reference signal transmission scheme, as long as the transmitted reference signal is suitable for vertical channel estimation or 3D channel estimation.

[0076] The CSI for a plurality of vertical beams received at block 402 can be the CSI reported in a compressed format at block 203 of method 200. Therefore, details regarding the CSI described with reference to Fig. 2 and method 200 also apply here.

[0077] In one embodiment, at block 402, the base station may receive a M-bits indicator for a first vertical precoding vector of a plurality of vertical precoding vectors, and receive a D-bits indicator for a second vertical precoding vector of the plurality of vertical precoding vectors, the D-bits indicator indicates an offset of the second vertical precoding vector relative to the first vertical precoding vector. In one embodiment, D may be smaller than M. Some examples for the D-bits indicator have been described with reference to method 200 and Table 1A to 1C, and thus will not be repeated here. It can be appreciated that the D bits can be used to indicate any suitable offset levels, and are not limited to those shown in the Tables.

[0078] Alternatively, at block 402, the base station may receive an index (or an indicator) indicating a combination of multiple vertical precoding vectors in a predefined set of combinations. One example of the predefined set of combinations can be, but not limited to, that shown in Table 2.

[0079] In one embodiment, at block 402, the base station may receive an indicator which indicates a first vertical precoding vector of a plurality of vertical precoding vectors explicitly and indicates a second vertical precoding vector of the plurality of vertical precoding vectors implicitly. For example, the base station may receive a vertical precoding vector PMI_V_1 (which may correspond to the strongest vertical beam) of M bits only. Based on some predefined criterion, the PMI_V_1 also indicate implicitly other vertical precoding vectors, e.g., it may indicate PMI_V_2 and PMI_V_3 as PMI_V_1+1, and PMI_V_1-1, respectively. That is to say, the base station may receive only part of a plurality of vertical precoding vectors explicitly, and then derive other vertical precoding vectors implicitly based on correlation between the vertical precoding vectors.

[0080] In another embodiment, the base station may receive a CQI for each of the plurality of vertical beams, wherein the channel quality indicator indicates channel quality of a vertical channel or channel quality of a three dimensional channel. In one embodiment, the base station may receive a L-bits CQI for a first vertical beam of the plurality of vertical beams, and receive a K-bits offset of a CQI for a second vertical beam relative to the CQI for the first vertical beam. In one embodiment, K may be smaller than L. In another embodiment, the offset values can be restricted to non-negative values, to reduce the required bits (i.e., K) for the offset indication.

[0081] The CSI for the plurality of vertical beams may be received in a physical uplink control channel (PUCCH) in some embodiment. The CSI received in the PUCCH may include information related to multiple vertical precoding vectors and multiple CQIs. Alternatively, the CSI may include an indication for a combination of multiple vertical precoding vectors and information related to multiple CQIs. As described above, the CSI may include only one vertical precoding vector, and multiple CQIs, and in such case, other vertical precoding vectors may be derived implicitly by the base station.

[0082] In another embodiment, the base station may receive a channel quality indicator for a first vertical beam of the plurality of vertical beams, in a first PUCCH, and receive a channel quality indicator for a second vertical beam of the plurality of vertical beams, in a second PUCCH different from the first PUCCH; and wherein the channel quality indicator indicates channel quality of a three dimensional channel. As described with reference to method 200, the CSI contained in one PUCCH may include a 3DCQI for a first vertical beam (e.g., the strongest vertical beam) together with the horizontal CSI (e.g., rank indicator for horizontal domain, precoding matrix indicator (PMI) for horizontal domain), while the CSI contained in another PUCCH may include 3DCQIs for other vertical beams, possibly together with the indications for one or more vertical precoding vectors.

[0083] By receiving the CSI for the plurality of vertical beams with the method 400, the base station obtains more flexibility in scheduling. For example, the base station may choose, from the plurality of beams, a beam which causes less interference to other cells or UEs, or choose a beam which provides the largest throughput for a specific UE, depending on the requirement. In this way, inter-cell interference can be reduced and total system performance can be improved. Meanwhile, since the CSI is report in a compressed format, the overhead can be kept low.

[0084] Note that operations described with reference to the blocks of any method herein do not have to be performed in the exact order disclosed, unless explicitly stated. That is, operations at the blocks may also be performed reversely to the order as shown or concurrently.

[0085] Reference is now made to Fig. 5, which illustrates a schematic block diagram of an apparatus 500 in a wireless system with 3D-MIMO according to an embodiment of the present disclosure. In one embodiment, the apparatus 500 may be implemented as a mobile device or UE, or a part thereof. Alternatively or additionally, the apparatus 500 may be implemented as any other suitable network element in the wireless communication system. The apparatus 500 is operable to carry out the example method 200 described with reference to Fig. 2, and possibly any other processes or methods. It is also to be understood that the method 200 is not necessarily carried out by the apparatus 500. At least some blocks of the method 200 can be performed by one or more other entities.

[0086] As illustrated in Fig. 5, the apparatus 500 comprises a receiver 501, configured to receive a reference signal from a base station, an estimator 502, configured to estimate channel state information for a plurality of vertical beams, based on the received reference signal, and a transmitter 503, configured to report the channel state information for the plurality of vertical beams, in a compressed format, based on correlation of the plurality of vertical beams.

[0087] In one embodiment, the receiver 501, the estimator 502, and the transmitter 503 can be configured to perform the operations described with reference to block 201, 202, and 203 of the method 200, respectively, and thus, some detailed descriptions for 501-503 may be omitted here.

[0088] In one embodiment, the transmitter 503 may be configured to report a M-bits indicator for a first vertical precoding vector of a plurality of vertical precoding vectors, and report a D-bits indicator for a second vertical precoding vector of the plurality of vertical precoding vectors; the D-bits indicator indicates an offset of the second vertical precoding vector relative to the first vertical precoding vector. In one embodiment, D may be smaller than M.

[0089] In another embodiment, the transmitter 503 may be configured to report an index of a combination of multiple vertical precoding vectors in a predefined set of combinations. One example of the predefined set of combinations is shown in Table 2, but embodiments of the disclosure are not limited to this.

[0090] In still another embodiment, the transmitter 503 can be configured to report only a first vertical precoding vector of a plurality of vertical precoding vectors explicitly and report

other vertical precoding vectors implicitly. In such case, a predefined relationship between the first vertical precoding vector and the other vertical precoding vectors is assumed.

[0091] Alternatively or additionally, the transmitter 503 may be configured to report a CQI for each of the plurality of vertical beams, in a compressed format, based on the correlation of the plurality of vertical beams. The CQI may indicate channel quality of a vertical channel or channel quality of a composite three dimensional channel.

[0092] In one embodiment, the transmitter 503 may be configured to report a L-bits CQI for a first vertical beam of the plurality of vertical beams, and report a K-bits offset of a CQI for a second vertical beam relative to the CQI for the first vertical beam. In one embodiment, K may be smaller than L. The K-bits offset may be selected from a set of non-negative values or a set of non-positive values, in one embodiment. Such limitation enables further overhead reduction.

[0093] It can be appreciated that the transmitter 503 may be configured to report more than two CQIs, by reporting part of the CQIs with absolute values while reporting each of the other CQIs with an offset to save signaling overhead.

[0094] In one embodiment, the transmitter 503 may be configured to report the CSI for the plurality of vertical beams in a PUCCH. In another embodiment, the transmitter 503 may be configured to report a CQI for a first vertical beam of the plurality of vertical beams, in a first PUCCH, and report a CQI for a second vertical beam of the plurality of vertical beams, in a second PUCCH different from the first PUCCH. The CQI may, for example, indicate channel quality of a composite 3D channel. As an example, the first PUCCH may contain a 3DCQI for the first vertical beam (e.g., the strongest vertical beam) together with horizontal CSIs (e.g., rank indicator for horizontal domain, precoding matrix indicator (PMI) for horizontal domain), while the second PUCCH may include 3DCQIs for other vertical beams, possibly together with indications for one or more vertical precoding vectors.

[0095] Reference is now made to Fig. 6, which illustrate a schematic block diagram of an apparatus 600 in communication with the apparatus 500 in a wireless system with 3D MIMO, according to an embodiment of the present disclosure. In one embodiment, the apparatus 600 may be implemented as base station or a part thereof. Alternatively or additionally, the apparatus 600 may be implemented as any other suitable devices in the wireless communication system. The apparatus 600 is operable to carry out the example method 400 described with reference to FIG. 4 and possibly any other processes or methods. It is also to be understood that the method 400 is not necessarily carried out by the apparatus 600. At least some steps of the method 400 can be performed by one or more other entities.

[0096] As shown in Fig. 6, the apparatus 600 comprises a transmitter 601, configured to transmit a reference signal to a device (e.g., UE 102 shown in Fig. 1), and a receiver 602, configured to receive channel state information for a plurality of vertical beams from the device, wherein the channel state information is estimated by the device based on the reference signal and then compressed when being transmitted by the device based on correlation of the plurality of vertical beams. In one embodiment, the transmitter 601 and the receiver 602 may be configured to perform the operations of block 401 and 402 of method 400 described with reference to Fig. 4.

[0097] In one embodiment, the transmitter 601 may be configured to transmit CSI-RS from each antenna element of an AAS shown in Fig. 3A, to facilitate 3D channel estimation. In another example, the transmitter 601 may be configured to transmit the CSI-RS from a column of antenna elements of the AAS, to facilitate vertical channel estimation. Embodiments of the disclosure are not limited to any reference signal transmission schemes, as long as the reference signal is suitable for vertical channel estimation or 3D channel estimation.

[0098] In another embodiment, the receiver 602 may be configured to receive a M-bits indicator for a first vertical precoding vector of a plurality of vertical precoding vectors, and a D-bits indicator for a second vertical precoding vector of the plurality of vertical precoding vectors, which indicates an offset of the second vertical precoding vector relative to the first vertical precoding vector. In one embodiment D may be smaller than M. Examples for the D-bits indicator can be found in Table 1A-1C.

[0099]

[00100] Alternatively, the receiver 602 may be configured to receive an index indicating a combination of multiple vertical precoding vectors in a predefined set of combinations. In another embodiment, the receiver 602 may be configured to receive an indicator which indicates a first vertical precoding vector of a plurality of vertical precoding vectors explicitly and indicates a second vertical precoding vector of the plurality of vertical precoding vectors implicitly.

[00101] Additionally or alternatively, the receiver 602 may be configured to receive a CQI for each of the plurality of vertical beams. The CQI may indicate channel quality of a vertical channel or channel quality of a three dimensional channel.

[00102] In one embodiment, the receiver 602 may be configured to receive a L-bits CQI for a first vertical beam of the plurality of vertical beams, and a K-bits offset of a CQI for a second vertical beam relative to the CQI for the first vertical beam. In one embodiment, K may be smaller than L. In another embodiment, the offset may be restricted to be non-negative or

non-positive values, to further reduce overhead. For example, the K-bits offset may be selected from a set of non-negative values or a set of non-positive values.

[00103] In some embodiments, the receiver 602 can be configured to receive the CSI for the plurality of vertical beams in a PUCCH. In some other embodiments, the receiver 602 may be configured to receive a CQI for a first vertical beam of the plurality of vertical beams, in a first PUCCH, and receive a CQI for a second vertical beam of the plurality of vertical beams, in a second PUCCH different from the first PUCCH. The CQI may indicate channel quality of a three dimensional channel, for example.

[00104] Fig. 7 illustrates a simplified block diagram of an apparatus 710, and an apparatus 720 that are suitable for use in practicing the embodiments of the present disclosure. The apparatus 710 may be a base station; the apparatus 720 may be a UE.

[00105] The apparatus 710 comprises at least one processor 711, such as a data processor (DP) 711 and at least one memory (MEM) 712 coupled to the processor 711. The apparatus may further comprise a suitable RF transmitter TX and receiver RX 713 (which may be implemented in a single component or separate components) coupled to the processor 711. The MEM 712 stores a program (PROG) 714. The PROG 714 may include instructions that, when executed on the associated processor 711, enable the apparatus 710 to operate in accordance with the embodiments of the present disclosure, for example to perform the method 400. The TX/RX 713 may be used for bidirectional radio communication with other apparatuses or devices in the network, e.g., the apparatus 720. Note that the TX/RX 713 may have multiple antennas (e.g., an AAS) to facilitate the communication. A combination of the at least one processor 711 and the at least one MEM 712 may form processing means 715 adapted to implement various embodiments of the present disclosure.

[00106] The apparatus 720 comprises at least one processor 721, such as a DP, at least one MEM 722 coupled to the processor 721. The apparatus 720 may further comprise a suitable RF TX/ RX 723 (which may be implemented in a single component or separate components) coupled to the processor 721. The MEM 722 stores a PROG 724. The PROG 724 may include instructions that, when executed on the associated processor 721, enable the apparatus 720 to operate in accordance with the embodiments of the present disclosure, for example to perform the method 200. The TX/RX 723 is for bidirectional radio communications with other apparatuses or devices in the network, e.g., the apparatus 710. Note that the TX/RX 723 may have multiple antennas to facilitate the communication. A combination of the at least one processor 721 and the at least one MEM 722 may form processing means 725 adapted to implement various embodiments of the present disclosure.

[00107] Various embodiments of the present disclosure may be implemented by computer program executable by one or more of the processor 711, 721 in software, firmware, hardware or in a combination thereof.

[00108] The MEMs 712, 722 may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory, as non-limiting examples. While only one MEM is shown in the apparatuses 710, 720, there may be several physically distinct memory units in them.

[00109] The processors 711, 721 may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on multicore processor architecture, as non-limiting examples. Each of the apparatuses 710, 720 may have multiple processors, such as an application specific integrated circuit (ASIC) chip that is slaved in time to a clock which synchronizes the main processor.

[00110] Although the above description is made in the context of LTE 3D-MIMO, it should not be construed as limiting the spirit and scope of the present disclosure. The idea and concept of the present disclosure can be generalized to also cover other wireless networks with the feature of 3D-MIMO including non-cellular network, e.g., ad-hoc network.

[00111] In addition, the present disclosure provides a carrier containing the computer program as mentioned above, wherein the carrier is one of an electronic signal, optical signal, radio signal, or computer readable storage medium. The computer readable storage medium can be, for example, an optical compact disk or an electronic memory device like a RAM (random access memory), a ROM (read only memory), Flash memory, magnetic tape, CD-ROM, DVD, Blue-ray disc and the like.

[00112] The techniques described herein may be implemented by various means so that an apparatus implementing one or more functions of a corresponding apparatus described with an embodiment comprises not only prior art means, but also means for implementing the one or more functions of a corresponding apparatus described with an embodiment and it may comprise separate means for each separate function, or means may be configured to perform two or more functions. For example, these techniques may be implemented in hardware (one or more apparatuses), firmware (one or more apparatuses), software (one or more modules), or combinations thereof. For a firmware or software, implementation may be made through modules (e.g., procedures, functions, and so on) that perform the functions described herein.

[00113] Exemplary embodiments herein have been described above with reference to block diagrams and flowchart illustrations of methods, apparatuses, i.e. systems. It will be understood that each block of the block diagrams and flowchart illustrations, and combinations of blocks in the block diagrams and flowchart illustrations, respectively, can be implemented by various means including computer program instructions. These computer program instructions may be loaded onto a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions which execute on the computer or other programmable data processing apparatus create means for implementing the functions specified in the flowchart block or blocks.

[00114] While this specification contains many specific implementation details, these should not be construed as limitations on the scope of any implementation or of what may be claimed, but rather as descriptions of features that may be specific to particular embodiments of particular implementations. Certain features that are described in this specification in the context of separate embodiments can also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment can also be implemented in multiple embodiments separately or in any suitable sub-combination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a sub-combination or variation of a sub-combination.

[00115] It should also be noted that the above described embodiments are given for describing rather than limiting the disclosure, and it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the disclosure as those skilled in the art readily understand. Such modifications and variations are considered to be associated with the scope of the disclosure and the appended claims. The protection scope of the disclosure is defined by the accompanying claims.

WHAT IS CLAIMED IS:

- 5 1. A method in a wireless system with three dimensional multiple input multiple output, comprising:
- receiving a reference signal from a base station,
- estimating channel state information for a plurality of vertical beams, based on the received reference signal, and
- 10 reporting the channel state information for the plurality of vertical beams, in a compressed format, based on correlation of the plurality of vertical beams.
2. The method of Claim 1, wherein reporting the channel state information for the plurality of vertical beams, in a compressed format, based on correlation of the plurality of
- 15 vertical beams comprises:
- reporting a M-bits indicator for a first vertical precoding vector of a plurality of vertical precoding vectors, and
- reporting a D-bits indicator for a second vertical precoding vector of the plurality of vertical precoding vectors, which indicates an offset of the second vertical precoding vector
- 20 relative to the first vertical precoding vector.
3. The method of Claim 1, wherein reporting the channel state information for the plurality of vertical beams, in a compressed format, based on correlation of the plurality of vertical beams comprises:
- 25 reporting an index of a combination of multiple vertical precoding vectors in a predefined set of combinations.
4. The method of Claim 1, wherein reporting the channel state information for the plurality of vertical beams, in a compressed format, based on correlation of the plurality of
- 30 vertical beams comprises:
- reporting a plurality of vertical precoding vectors, by reporting only a first vertical precoding vector of the plurality of vertical precoding vectors explicitly and reporting other vertical precoding vectors implicitly.

5. The method of any of Claims 1-4, wherein reporting the channel state information for the plurality of vertical beams, in a compressed format, based on correlation of the plurality of vertical beams comprises:

reporting a channel quality indicator for each of the plurality of vertical beams, in a compressed format, based on the correlation of the plurality of vertical beams, and

wherein the channel quality indicator indicates channel quality of a vertical channel or channel quality of a three dimensional channel.

6. The method of Claim 5, wherein reporting a channel quality indicator for each of the plurality of vertical beams, in a compressed format, based on the correlation of the plurality of vertical beams comprises:

reporting a L-bits channel quality indicator for a first vertical beam of the plurality of vertical beams, and

reporting a K-bits offset of an channel quality indicator for a second vertical beam relative to the channel quality indicator for the first vertical beam.

7. The method of Claim 6, wherein the K-bits offset is selected from a set of non-negative values or a set of non-positive values.

8. The method of Claim 1, wherein reporting the channel state information for the plurality of vertical beams, in a compressed format, based on correlation of the plurality of vertical beams comprises:

reporting the channel state information for the plurality of vertical beams in a physical uplink control channel PUCCH.

9. The method of 5, wherein reporting a channel quality indicator for each of the plurality of vertical beams comprises:

reporting a channel quality indicator for a first vertical beam of the plurality of vertical beams, in a first physical uplink control channel PUCCH, and

reporting a channel quality indicator for a second vertical beam of the plurality of vertical beams, in a second PUCCH different from the first PUCCH; and

wherein the channel quality indicator indicates channel quality of a three dimensional channel.

10. A method in a wireless system with three dimensional multiple input multiple output, comprising:

transmitting a reference signal to a device,

receiving channel state information for a plurality of vertical beams from the device, and

5 wherein the channel state information is estimated by the device based on the reference signal and then compressed when being transmitted by the device based on correlation of the plurality of vertical beams.

11. The method of Claim 10, wherein receiving the channel state information for a plurality of vertical beams comprises:

receiving a M-bits indicator for a first vertical precoding vector of a plurality of vertical precoding vectors, and

receiving a D-bits indicator for a second vertical precoding vector of the plurality of vertical precoding vectors, which indicates an offset of the second vertical precoding vector relative to the first vertical precoding vector.

12. The method of Claim 10, wherein receiving the channel state information for a plurality of vertical beams comprises:

receiving an index indicating a combination of multiple vertical precoding vectors in a predefined set of combinations.

13. The method of Claim 10, wherein receiving the channel state information for a plurality of vertical beams comprises:

receiving an indicator which indicates a first vertical precoding vector of a plurality of vertical precoding vectors explicitly and indicates a second vertical precoding vector of the plurality of vertical precoding vectors implicitly.

14. The method of any of Claims 10-13, wherein receiving the channel state information for a plurality of vertical beams comprises:

receiving a channel quality indicator for each of the plurality of vertical beams, wherein the channel quality indicator indicates channel quality of a vertical channel or channel quality of a three dimensional channel.

15. The method of Claim 14, wherein receiving a channel quality indicator for each of the plurality of vertical beams comprises:

receiving a L-bits channel quality indicator for a first vertical beam of the plurality of vertical beams, and

5 receiving a K-bits offset of a channel quality indicator for a second vertical beam relative to the channel quality indicator for the first vertical beam.

16. The method of Claim 15, wherein the K-bits offset is selected from a set of non-negative values or a set of non-positive values.

10

17. The method of Claim 10, wherein receiving channel state information for a plurality of vertical beams comprises:

receiving the channel state information for the plurality of vertical beams in a physical uplink control channel PUCCH.

15

18. The method of 14, wherein receiving a channel quality indicator for each of the plurality of vertical beams comprises:

receiving a channel quality indicator for a first vertical beam of the plurality of vertical beams, in a first physical uplink control channel PUCCH, and

20 receiving a channel quality indicator for a second vertical beam of the plurality of vertical beams, in a second PUCCH different from the first PUCCH; and

wherein the channel quality indicator indicates channel quality of a three dimensional channel.

25 19. An apparatus in a wireless system with three dimensional multiple input multiple output, comprising:

a receiver, configured to receive a reference signal from a base station,

an estimator, configured to estimate channel state information for a plurality of vertical beams, based on the received reference signal, and

30 a transmitter, configured to report the channel state information for the plurality of vertical beams, in a compressed format, based on correlation of the plurality of vertical beams.

20. The apparatus of Claim 19, wherein the transmitter is configured to:
report a M-bits indicator for a first vertical precoding vector of a plurality of vertical precoding vectors, and
report a D-bits indicator for a second vertical precoding vector of the plurality of vertical precoding vectors, which indicates an offset of the second vertical precoding vector relative to the first vertical precoding vector.

21. The apparatus of Claim 19, wherein the transmitter is configured to:
report an index of a combination of multiple vertical precoding vectors in a predefined set of combinations.

22. The apparatus of Claim 19, wherein the transmitter is configured to:
report a plurality of vertical precoding vectors, by reporting only a first vertical precoding vector of a plurality of vertical precoding vectors explicitly and reporting other vertical precoding vectors implicitly.

23. The apparatus of any of Claims 19-22, wherein the transmitter is configured to:
report a channel quality indicator for each of the plurality of vertical beams, in a compressed format, based on the correlation of the plurality of vertical beams, and
wherein the channel quality indicator indicates channel quality of a vertical channel or channel quality of a three dimensional channel.

24. The apparatus of Claim 23, wherein the transmitter is configured to:
report a L-bits channel quality indicator for a first vertical beam of the plurality of vertical beams, and
report a K-bits offset of an channel quality indicator for a second vertical beam relative to the channel quality indicator for the first vertical beam.

25. The apparatus of Claim 24, wherein the K-bits offset is selected from a set of non-negative values or a set of non-positive values.

26. The apparatus of Claim 19, wherein the transmitter is configured to:

report the channel state information for the plurality of vertical beams in a physical uplink control channel PUCCH.

27. The apparatus of 23, wherein the transmitter is configured to:

5 report a channel quality indicator for a first vertical beam of the plurality of vertical beams, in a first physical uplink control channel PUCCH, and

report a channel quality indicator for a second vertical beam of the plurality of vertical beams, in a second PUCCH different from the first PUCCH; and

10 wherein the channel quality indicator indicates channel quality of a three dimensional channel.

28. An apparatus in a wireless system with three dimensional multiple input multiple output, comprising:

a transmitter, configured to transmit a reference signal to a device, and

15 a receiver, configured to receive channel state information for a plurality of vertical beams from the device,

wherein the channel state information is estimated by the device based on the reference signal and then compressed when being transmitted by the device based on correlation of the plurality of vertical beams.

20

29. The apparatus of Claim 28, wherein the receiver is configured to:

receive a M-bits indicator for a first vertical precoding vector of a plurality of vertical precoding vectors, and

25 receive a D-bits indicator for a second vertical precoding vector of the plurality of vertical precoding vectors, which indicates an offset of the second vertical precoding vector relative to the first vertical precoding vector.

30. The apparatus of Claim 28, wherein the receiver is configured to:

30 receive an index indicating a combination of multiple vertical precoding vectors in a predefined set of combinations.

31. The apparatus of Claim 28, wherein the receiver is configured to:

receive an indicator which indicates a first vertical precoding vector of a plurality of vertical precoding vectors explicitly and indicates a second vertical precoding vector of the plurality of vertical precoding vectors implicitly.

5 32. The apparatus of any of Claims 28-31, wherein the receiver is configured to:
receive a channel quality indicator for each of the plurality of vertical beams, wherein
the channel quality indicator indicates channel quality of a vertical channel or channel quality of
a three dimensional channel.

10 33. The apparatus of Claim 32, wherein receiver is configured to:
receive a L-bits channel quality indicator for a first vertical beam of the plurality of
vertical beams, and
receive a K-bits offset of a channel quality indicator for a second vertical beam relative
to the channel quality indicator for the first vertical beam.

15 34. The apparatus of Claim 33, wherein the K-bits offset is selected from a set of
positive values or a set of negative values.

 35. The apparatus of Claim 28, wherein the receiver is configured to:
20 receive the channel state information for the plurality of vertical beams in a physical
uplink control channel PUCCH.

 36. The apparatus of 32, wherein the receiver is configured to:
receive a channel quality indicator for a first vertical beam of the plurality of vertical
25 beams, in a first physical uplink control channel PUCCH, and
receive a channel quality indicator for a second vertical beam of the plurality of vertical
beams, in a second PUCCH different from the first PUCCH; and
wherein the channel quality indicator indicates channel quality of a three dimensional
channel.

30 37. An apparatus in a wireless system with three dimensional multiple input
multiple output, comprising a processor and a memory, said memory containing instructions
executable by said processor whereby said apparatus is operative to perform the method of any
of Claims 1-9.

38. An apparatus in a wireless system with three dimensional multiple input multiple output, comprising a processor and a memory, said memory containing instructions executable by said processor whereby said apparatus is operative to perform the method of any
5 of Claims 10-16.

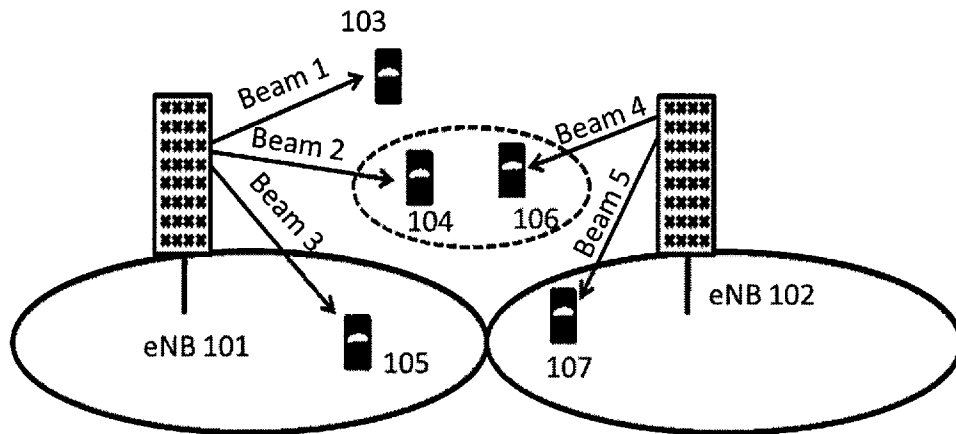


Fig. 1

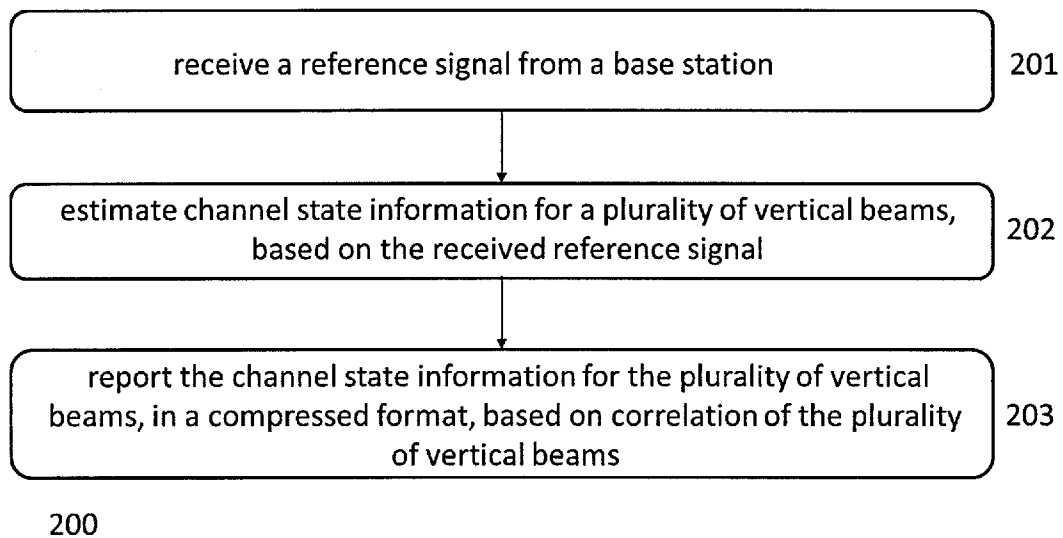


Fig. 2

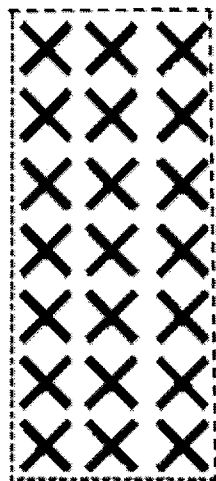


Fig. 3A

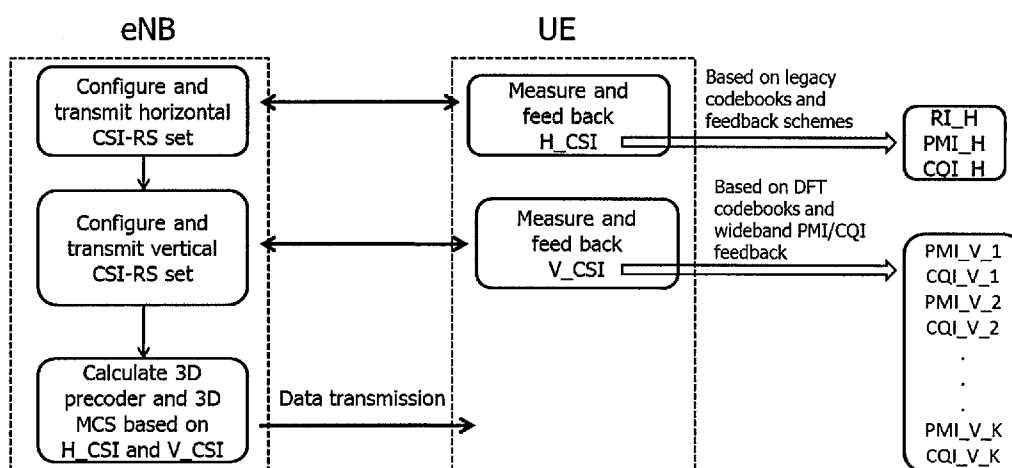


Fig. 3B

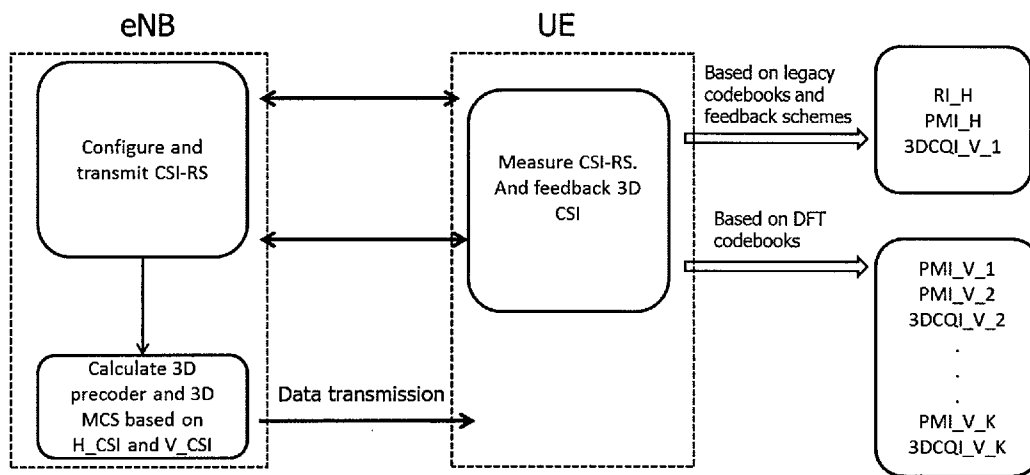


Fig. 3C

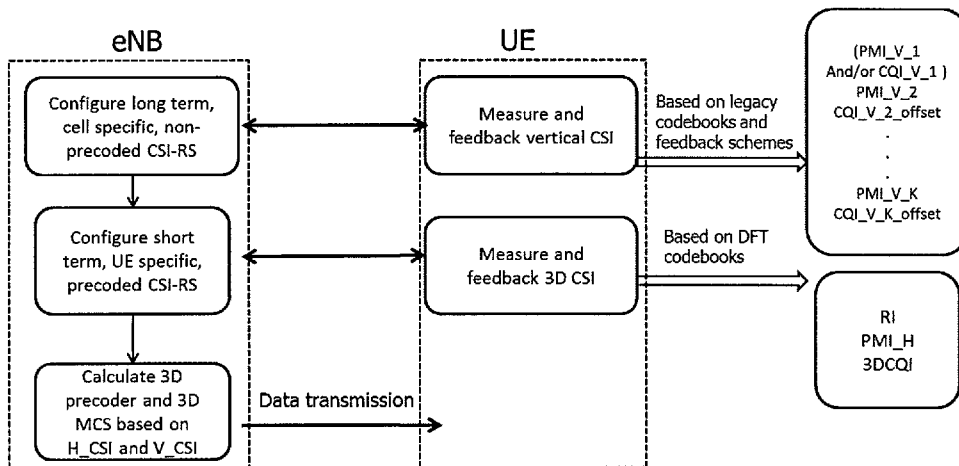


Fig. 3D

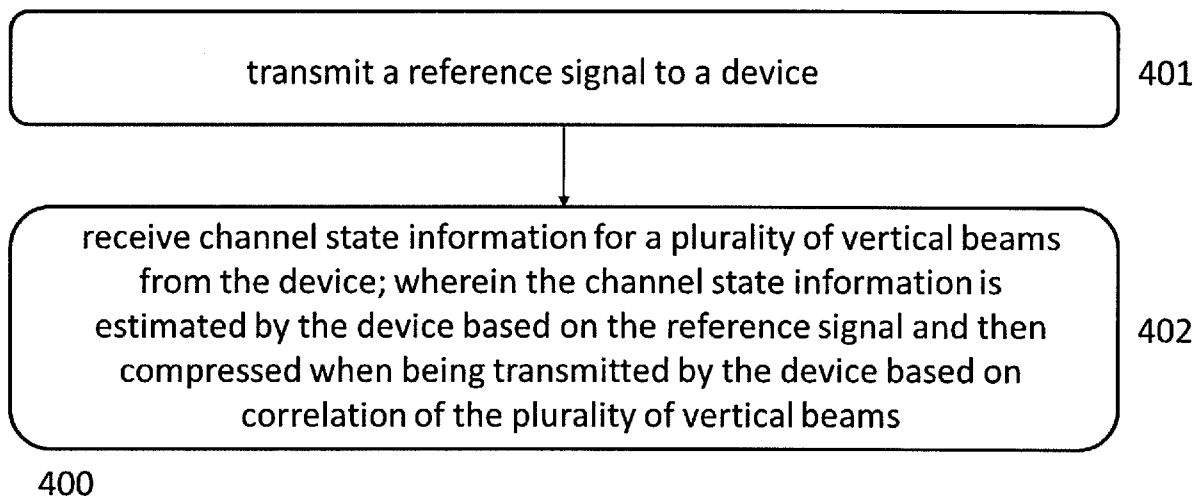


Fig.4

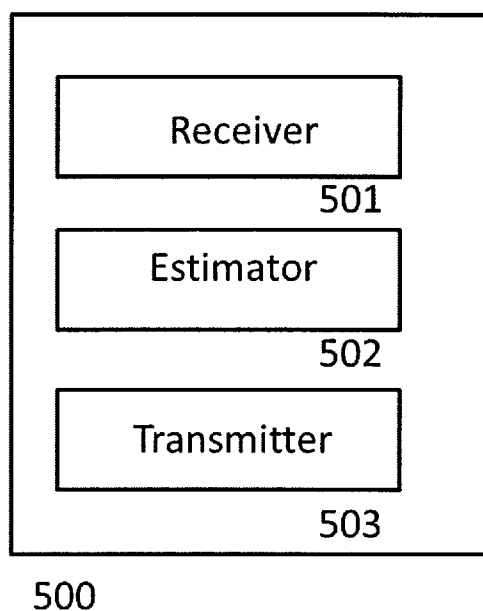


Fig.5

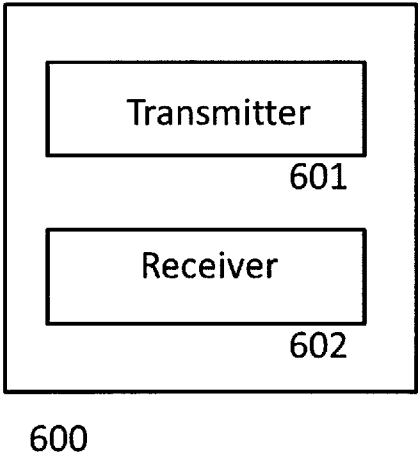


Fig. 6

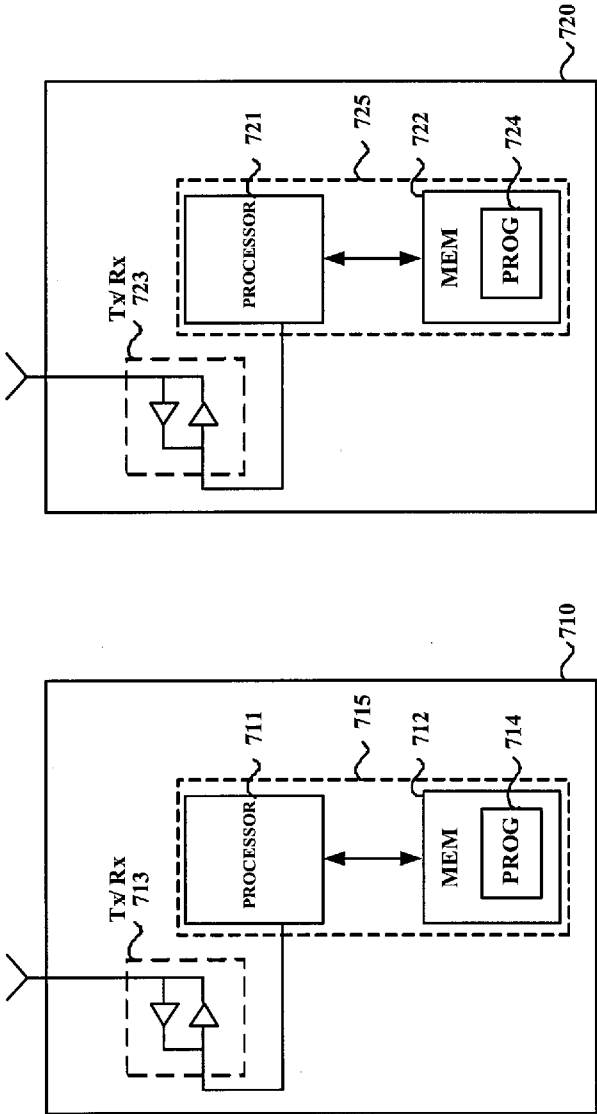


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2015/078791

A. CLASSIFICATION OF SUBJECT MATTER

H04W 24/10(2009.01)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)

H04L; H04W; H04Q

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)

WPI, EPODOC, CNPAT, CNKI: MIMO, reference, signal, vertical, beam, channel, state, information, CSI, RS, full, three, dimensional

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 104604277 A (NTT DOCOMO, INC.) 06 May 2015 (2015-05-06) description, paragraphs [0063]-[0073], figure 9	1-38
X	CN 104604170 A (NTT DOCOMO, INC.) 06 May 2015 (2015-05-06) description, paragraphs [0101]-[0105]	1-38
A	CN 103825664 A (ACADEMY OF TELECOM TECHNOLOGY) 28 May 2014 (2014-05-28) the whole document	1-38



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“E” earlier application or patent but published on or after the international filing date

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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

29 January 2016

Date of mailing of the international search report

18 February 2016

Name and mailing address of the ISA/CN

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2015/078791

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
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				US	2015222340	A1	06 August 2015
				WO	2014038321	A1	13 March 2014
CN	104604170	A	06 May 2015	WO	2014038347	A1	13 March 2014
				EP	2894801	A1	15 July 2015
				JP	2014053812	A	20 March 2014
CN	103825664	A	28 May 2014	TW	201534077	A	01 September 2015
				WO	2015124072	A1	27 August 2015