(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
11 April 2024 (11.04.2024)

WIPO | PCT

(10) **International Publication Number**
WO 2024/073997 A1

(51) **International Patent Classification:**
H04W 72/232 (2023.01)

(21) **International Application Number:**
PCT/CN2023/075863

(22) **International Filing Date:**
14 February 2023 (14.02.2023)

(25) **Filing Language:** English

(26) **Publication Language:** English

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(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST,

(54) **Title:** PUSCH TRANSMISSION WITH TWO CODEWORDS

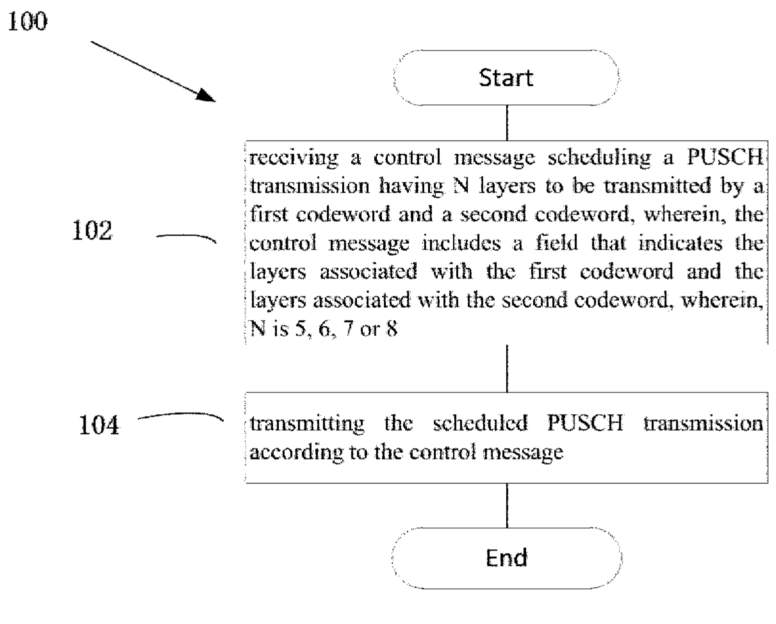

Figure 1

(57) **Abstract:** Methods and apparatuses for PUSCH transmission with two codewords are disclosed. In one embodiment, a UE comprises a transceiver; and a processor coupled to the transceiver, wherein the processor is configured to receive, via the transceiver, a control message scheduling a PUSCH transmission having N layers to be transmitted by a first codeword and a second codeword, wherein, the control message includes a field that indicates the layers associated with the first codeword and the layers associated with the second codeword, wherein, N is 5, 6, 7 or 8; and transmit, via the transceiver, the scheduled PUSCH transmission according to the control message.

WO 2024/073997 A1

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SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*
— *upon request of the applicant, before the expiration of the time limit referred to in Article 21(2)(a)*

PUSCH TRANSMISSION WITH TWO CODEWORDS

FIELD

[0001] The subject matter disclosed herein generally relates to wireless communications, and more particularly relates to methods and apparatuses for PUSCH transmission with two codewords.

BACKGROUND

[0002] The following abbreviations are herewith defined, at least some of which are referred to within the following description: New Radio (NR), Very Large Scale Integration (VLSI), Random Access Memory (RAM), Read-Only Memory (ROM), Erasable Programmable Read-Only Memory (EPROM or Flash Memory), Compact Disc Read-Only Memory (CD-ROM), Local Area Network (LAN), Wide Area Network (WAN), User Equipment (UE), Evolved Node B (eNB), Next Generation Node B (gNB), Uplink (UL), Downlink (DL), Central Processing Unit (CPU), Graphics Processing Unit (GPU), Field Programmable Gate Array (FPGA), Orthogonal Frequency Division Multiplexing (OFDM), Radio Resource Control (RRC), User Entity/Equipment (Mobile Terminal), Transmitter (TX), Receiver (RX), Physical Uplink Shared Channel (PUSCH), codeword (CW), codebook (CB), non-codebook (nCB), Sounding Reference Signal (SRS), Bandwidth part (BWP), Channel State Information Reference Signal (CSI-RS), Downlink Control Information (DCI), modulation and coding scheme (MCS), configured grant (CG), Transmit Precoding Matrix Indicator (TPMI), angle of departure (AOD), demodulation reference signal (DM-RS), Technical Specification (TS), Channel State Information (CSI), Orthogonal Complementary Code (OCC), Signal to Interference plus Noise Ratio (SINR), Signal to Noise Ratio (SNR), SRS Resource Indicator (SRI).

[0003] A UE with 8 TX ports can support a PUSCH transmission with more than 4 layers (e.g. 5 to 8 layers). With 8 TX ports, it is possible to transmit 5 to 8 layers in two codewords (CWs).

[0004] This invention targets PUSCH transmission with two codewords.

BRIEF SUMMARY

[0005] Methods and apparatuses for PUSCH transmission with two codewords are disclosed.

[0006] In one embodiment, a UE comprises a transceiver; and a processor coupled to the transceiver, wherein the processor is configured to receive, via the transceiver, a control message scheduling a PUSCH transmission having N layers to be transmitted by a first codeword and a second codeword, wherein, the control message includes a field that indicates the layers associated with the first codeword and the layers associated with the second codeword, wherein, N is 5, 6, 7 or 8; and transmit, via the transceiver, the scheduled PUSCH transmission according to the control message.

[0007] In some embodiment, the field is a transmission precoding matrix indicator (TPMI) field, and a sub-field of the TPMI field signals the precoder to use from a set of precoders in an N-layer codebook. Different precoders in the N-layer codebook may be different permutations of the same N transmission layers. If a co-phasing factor is applied to the two different polarizations of the same beam, the co-phasing factor is unchanged when the layers are permutated in different precoders. If an OCC code is applied to the two different polarizations of the same beam, the OCC code is unchanged as the layers are permutated in different precoders. Different pairs of layers transmitted by the same beam may be split between the first codeword and the second codeword in different precoders.

[0008] In some embodiment, the different permutations allocate the same N transmission layers into a first group and a second group, and the first group has $\lfloor N/2 \rfloor$ layers and the second group has $\lceil N/2 \rceil$ layers. If a beam is used to transmit two layers with two different orthogonal cover codes, the two layers may be in the same group. If a beam is used to transmit only one layer with orthogonal cover code (+1,+1), the beam may be always transmitted in the codeword having odd number of layers. In some embodiment, the first pair of layers transmitted by the same beam are always in the first group, and the other pairs of layers transmitted by the same beam are in the first group in different precoders, respectively.

[0009] In some embodiment, the field is a SRS resource indicator (SRI) field, and the SRI field indicates the SRS resources to use in the first codeword and the second codeword from a SRS resource set.

[0010] The SRI field may indicate the SRS resources to use in the first codeword and the SRS resources to use in the second codeword, respectively. In particular, the SRS resources to use in the first codeword and the SRS resources to use in the second codeword have no SRS resource in common. The SRI field may indicate the SRS resources to use in both the first codeword and the second codeword and the SRS resources to use in one of the first codeword and the second codeword, respectively. The SRI field may indicate, for each SRS resource in the SRS resource set, one of a first state in which the SRS resource is to use in the first codeword, a second state in which the SRS resource is to use in the second codeword, and a third state in which the SRS resource is not used.

[0011] In some embodiment, the processor is further configured to transmit SRS resources for non-codebook, and the SRS resource set is determined from the SRS resources in a SRS resource set for non-codebook.

[0012] In some embodiment, the control message is a DCI format 0_1 or 0_2 that schedule dynamically scheduled PUSCH or type 2 configured grant PUSCH. Alternatively, the control message is a RRC message that schedules type 1 configured grant PUSCH.

[0013] In another embodiment, a method performed at a UE comprises receiving a control message scheduling a PUSCH transmission having N layers to be transmitted by a first codeword and a second codeword, wherein, the control message includes a field that indicates the layers associated with the first codeword and the layers associated with the second codeword, wherein, N is 5, 6, 7 or 8; and transmitting the scheduled PUSCH transmission according to the control message.

[0014] In still another embodiment, a base unit comprises a transceiver; and a processor coupled to the transceiver, wherein the processor is configured to transmit, via the transceiver, a control message scheduling a PUSCH transmission having N layers to be transmitted by a first codeword and a second codeword, wherein, the control message includes a field that indicates the layers associated with the first codeword and the layers associated with the second codeword, wherein, N is 5, 6, 7 or 8; and receive, via the transceiver, the scheduled PUSCH transmission transmitted according to the control message.

[0015] In yet another embodiment, a method performed at a base unit comprises transmitting a control message scheduling a PUSCH transmission having N layers to be transmitted by a first codeword and a second codeword, wherein, the control message includes a field that indicates the layers associated with the first codeword and the layers associated with the second codeword, wherein, N is 5, 6, 7 or 8; and receiving the scheduled PUSCH transmission transmitted according to the control message.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] A more particular description of the embodiments briefly described above will be rendered by reference to specific embodiments that are illustrated in the appended drawings. Understanding that these drawings depict only some embodiments, and are not therefore to be considered to be limiting of scope, the embodiments will be described and explained with additional specificity and detail through the use of the accompanying drawings, in which:

[0017] Figure 1 is a schematic flow chart diagram illustrating an embodiment of a method;

[0018] Figure 2 is a schematic flow chart diagram illustrating an embodiment of another method; and

[0019] Figure 3 is a schematic block diagram illustrating apparatuses according to one embodiment.

[0020] DETAILED DESCRIPTION

[0021] As will be appreciated by one skilled in the art that certain aspects of the embodiments may be embodied as a system, apparatus, method, or program product. Accordingly, embodiments may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may generally all be referred to herein as a “circuit”, “module” or “system”. Furthermore, embodiments may take the form of a program product embodied in one or more computer readable storage devices storing machine-readable code, computer readable code, and/or program code, referred to hereafter as “code”. The storage devices may be tangible, non-transitory, and/or non-transmission. The storage devices may not embody signals. In a certain embodiment, the storage devices only employ signals for accessing code.

[0022] Certain functional units described in this specification may be labeled as “modules”, in order to more particularly emphasize their independent implementation. For example, a module may be implemented as a hardware circuit comprising custom very-large-scale integration (VLSI) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A module may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices or the like.

[0023] Modules may also be implemented in code and/or software for execution by various types of processors. An identified module of code may, for instance, include one or more physical or logical blocks of executable code which may, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified module need not be physically located together, but, may include disparate instructions stored in different locations which, when joined logically together, include the module and achieve the stated purpose for the module.

[0024] Indeed, a module of code may contain a single instruction, or many instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data may be identified and illustrated herein within modules and may be embodied in any suitable form and organized within any suitable type of data structure. This operational data may be collected as a single data set, or may be distributed over different locations including over different computer readable storage devices. Where a module or portions of a module are implemented in software, the software portions are stored on one or more computer readable storage devices.

[0025] Any combination of one or more computer readable medium may be utilized. The computer readable medium may be a computer readable storage medium. The computer readable storage medium may be a storage device storing code. The storage device may be, for example, but need not necessarily be, an electronic, magnetic, optical, electromagnetic, infrared, holographic, micromechanical, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing.

[0026] A non-exhaustive list of more specific examples of the storage device would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, random access memory (RAM), read-only memory (ROM), erasable programmable read-only memory (EPROM or Flash Memory), portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer-readable storage medium may be any tangible medium that can contain or store a program for use by or in connection with an instruction execution system, apparatus, or device.

[0027] Code for carrying out operations for embodiments may include any number of lines and may be written in any combination of one or more programming languages including an object-oriented programming language such as Python, Ruby, Java, Smalltalk, C++, or the like, and conventional procedural programming languages, such as the "C" programming language, or the like, and/or machine languages such as assembly languages. The code may be executed entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the very last scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

[0028] Reference throughout this specification to “one embodiment”, “an embodiment”, or similar language means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, appearances of the phrases “in one embodiment”, “in an embodiment”, and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment, but mean “one or more but not all embodiments” unless expressly specified otherwise. The terms “including”, “comprising”, “having”, and variations thereof mean “including but are not limited to”, unless otherwise expressly specified. An enumerated listing of items does not imply that any or all of the items are mutually exclusive, otherwise unless expressly specified. The terms “a”, “an”, and “the” also refer to “one or more” unless otherwise expressly specified.

[0029] Furthermore, described features, structures, or characteristics of various embodiments may be combined in any suitable manner. In the following description, numerous specific details are provided, such as examples of programming, software modules, user selections, network transactions, database queries, database structures, hardware modules, hardware circuits, hardware chips, etc., to provide a thorough understanding of embodiments. One skilled in the relevant art will recognize, however, that embodiments may be practiced without one or more of the specific details, or with other methods, components, materials, and so forth. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid any obscuring of aspects of an embodiment.

[0030] Aspects of different embodiments are described below with reference to schematic flowchart diagrams and/or schematic block diagrams of methods, apparatuses, systems, and program products according to embodiments. It will be understood that each block of the schematic flowchart diagrams and/or schematic block diagrams, and combinations of blocks in the schematic flowchart diagrams and/or schematic block diagrams, can be implemented by code. This code may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which are executed via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions specified in the schematic flowchart diagrams and/or schematic block diagrams for the block or blocks.

[0031] The code may also be stored in a storage device that can direct a computer, other programmable data processing apparatus, or other devices, to function in a particular manner, such that the instructions stored in the storage device produce an article of manufacture including instructions which implement the function specified in the schematic flowchart diagrams and/or schematic block diagrams block or blocks.

[0032] The code may also be loaded onto a computer, other programmable data processing apparatus, or other devices, to cause a series of operational steps to be performed on the computer, other programmable apparatus or other devices to produce a computer implemented process such that the code executed on the computer or other programmable apparatus provides processes for implementing the functions specified in the flowchart and/or block diagram block or blocks.

[0033] The schematic flowchart diagrams and/or schematic block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of apparatuses, systems, methods and program products according to various embodiments. In this regard, each block in the schematic flowchart diagrams and/or schematic block diagrams may represent a module, segment, or portion of code, which includes one or more executable instructions of the code for implementing the specified logical function(s).

[0034] It should also be noted that in some alternative implementations, the functions noted in the block may occur out of the order noted in the Figures. For example, two blocks shown in succession may substantially be executed concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. Other steps and methods may be conceived that are equivalent in function, logic, or effect to one or more blocks, or portions thereof, to the illustrated Figures.

[0035] Although various arrow types and line types may be employed in the flowchart and/or block diagrams, they are understood not to limit the scope of the corresponding embodiments. Indeed, some arrows or other connectors may be used to indicate only the logical flow of the depicted embodiment. For instance, an arrow may indicate a waiting or monitoring period of unspecified duration between enumerated steps of the depicted embodiment. It will also be noted that each block of the block diagrams and/or flowchart diagrams, and combinations of blocks in the block diagrams and/or flowchart diagrams, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and code.

[0036] The description of elements in each Figure may refer to elements of proceeding figures. Like numbers refer to like elements in all figures, including alternate embodiments of like elements.

[0037] The UE can be configured in two different modes for PUSCH multi-antenna precoding, referred as codebook (CB) based transmission and non-codebook (nCB) based transmission, respectively. When the UE is configured with codebook based PUSCH transmission, one SRS resource set used for codebook can be configured in a BWP of a cell for the UE. When the UE is configured with non-codebook based PUSCH transmission, one SRS resource set used for non-codebook can be configured in a BWP of a cell for the UE.

[0038] To enable codebook based PUSCH transmission, the UE shall be configured to transmit one or more SRS resources used for codebook for uplink channel measurement. Based on the measurements on the configured SRS resources transmitted by the UE, the gNB determines a suitable rank and the precoding matrix (i.e., precoder) from a pre-defined codebook, which includes a set of precoding matrices with different ranks, and sends the information to the UE when scheduling a PUSCH transmission.

[0039] For non-codebook based PUSCH transmission, the UE is required to measure a CSI-RS to obtain the uplink channel information based on channel reciprocity. In this case, a CSI-RS resource, which is a DL reference signaling transmitted by the gNB for DL channel measurement, is associated with the SRS resource set used for non-codebook. The UE selects what it believes is a suitable uplink precoder and applies the selected precoder to a set of configured SRS resources with one SRS resource transmitted on each layer defined by the precoder. Based on the received SRS resources, the gNB decides to modify the UE-selected precoder for the scheduled PUSCH transmission.

[0040] For ranks 1 to 4, all the layers of a PUSCH transmission are transmitted in a single codeword. For ranks 5 to 8, all the layers of a PUSCH transmission are transmitted in two codewords (e.g., a first codeword and a second codeword). The first half of layers are transmitted in the first codeword, and the last half of layers are transmitted in the second codeword. In particular, the number of layers in the two codewords for rank = 5 to 8 are as follows in Table 0:

Transmission rank	number of layers in the first codeword (k_1)	number of layers in the second codeword (k_2)
5	2	3

6	3	3
7	3	4
8	4	4

Table 0

[0041] Each codeword has its own MCS. Since a single MCS is assigned to a codeword, it is best that the SNRs (or SINRs) of the layers transmitted in the codeword match the MCS assigned to the codeword. In the following description, to make simplification, SNR or SINR of the layers is abbreviated as SNR of the layers.

[0042] When a UE is equipped with 8 antenna ports (e.g., PUSCH or SRS antenna ports), the base unit (e.g., gNB) may send to the UE a DCI (e.g., DCI with format 0_1 or DCI with format 0_2) scheduling dynamically scheduled PUSCH or type 2 configured-grant PUSCH with up to 8 layers (i.e., PUSCH layers) or a RRC message (e.g., configuredGrantConfig) to configure type 1 configured-grant PUSCH with up to 8 layers. Incidentally, a brief summary of CG PUSCH is as follows. CG (configured grant) PUSCH is used for semi-static UL traffic, which can be transmitted without dedicated scheduling DCI. Two types of CG PUSCH are specified in NR Release 15. For type 1 CG PUSCH, all the information used for the PUSCH transmission are configured by RRC signaling and the CG PUSCH can be periodically transmitted according to the configured period. For type 2 CG PUSCH, part of information used for the PUSCH transmission is configured by RRC signaling, while the other information is indicated by an activation DCI. Type 2 CG PUSCH can only be periodically transmitted upon receiving the activation DCI. When the UE receives a deactivation DCI to deactivate type 2 CG PUSCH, the corresponding PUSCH shall not be transmitted. Both type 1 CG PUSCH and type 2 CG PUSCH are configured by configured grant PUSCH configuration (i.e., by higher layer parameter *configuredGrantConfig* IE) and each *configuredGrantConfig* has an ID.

[0043] In codebook based PUSCH transmission, UE needs to transmit the PUSCH transmission (e.g., dynamically scheduled PUSCH transmission by DCI, type 1 configured-grant PUSCH transmission configured by RRC signaling and triggered by DCI, type 2 configured-grant PUSCH transmission configured by RRC signaling and activated by DCI) using the precoder indicated by TPMI sent from the gNB, where the TPMI is contained in a TPMI field in the DCI or the RRC signaling. It means that only the gNB can permute the layers and allocate the proper physical transmission layers into the two codewords if necessary.

[0044] The single panel Type 1 codebook in NR Release 15 was designed to utilize 3 or 4 distinct physical beams (i.e., angle of departures (AODs)) with two polarizations to achieve ranks 5 to 8. There is no relative strength of these beams in the codebook. Because the type 1 codebook only has co-phase information and does not have amplitude information, there is no way for the UE to know the relative strength of the layers. Given a TPMI, the UE does not have the flexibility to determine which physical layer is transmitted using which DM-RS port.

[0045] In non-codebook based PUSCH transmission, the UE needs to transmit the PUSCH transmission (e.g., dynamically scheduled PUSCH transmission by DCI, type 1 configured-grant PUSCH transmission configured by RRC signaling and triggered by DCI, type 2 configured-grant PUSCH transmission configured by RRC signaling and activated by DCI) using the precoder indicated by the SRI field in the DCI or the RRC signaling. Because there is no amplitude information in the SRI (nor in the SRS resources for non-codebook), different SRS resources will have different strengths. Based on these SRS resources, different layers of the PUSCH transmission will have different SNRs. There is no way for the UE to know the SNRs of these layers based on the SRI.

[0046] On the other hand, for both codebook based PUSCH transmission and non-codebook based PUSCH transmission, the gNB may acquire the relative strength of the layers from SRS signals transmitted from the UE. However, in legacy, there is no way for the gNB to signal the UE to adjust the relative transmission powers among the layers. As a consequence, the UE can only transmit all the signaled layers with equal power. From information theory, this is not optimal to achieve the channel capacity. On the other hand, the layers are mapped into two codewords, where each codeword can have its own MCS. To maximize the transmission capacity, it is desirable that the different beams (different layers) in the same codeword have SNRs that are relatively uniform.

[0047] To maximize the transmission capacity of the two codewords, it is desirable to allocate those layers with similar SNRs in a same codeword, which means that it is desirable to group the beams with similar strengths in the same codeword. Incidentally, the above analysis only applies to ranks 5 to 8, in which the layers are transmitted in two codewords, since for ranks 1 to 4, all the layers are transmitted in a single codeword.

[0048] This disclosure proposes solutions to solve the above problem, for both codebook based PUSCH transmission and non-codebook based PUSCH transmission.

[0049] A first embodiment relates to solutions for codebook based PUSCH transmission.

[0050] The first embodiment proposes to introduce new precoders and an additional subfield (i_3) in the 8TX full coherent codebook to enhance the NR Release 15 single panel type-1 codebook for transmission ranks 5 to 8, so that the set of beams grouped into each codeword can be adjusted to better match the MCS, which would lead to increasing the capacity.

[0051] A first sub-embodiment of the first embodiment relates to enhancement to Rank 5 codebook.

[0052] The number of columns of the precoding matrix (i.e., precoder) is equal the number of layers (i.e., the rank) of a PUSCH transmission for which the precoding matrix can be applied. So, precoding matrix (precoder) can be further described as rank *R* (e.g., *R* can be from 1 to 8) precoding matrix (precoder). Rank *R* precoding matrix (precoder) can be also denoted as *R*-layer precoding matrix (precoder). A collection of rank *R* precoders can be referred to as rank R codebook.

[0053] Table 5.2.2.2.1-9 in section 5.2.2.2.1 of TS 38.214 gives the legacy codebook for 5-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$ as follows:

codebookMode = 1-2				
	$i_{1,1}$	$i_{1,2}$	i_2	
$N_2 > 1$	$0,\dots,N_1O_1-1$	$0,\dots,N_2O_2-1$	$0,1$	$W^{(5)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 = 1$	$0,\dots,N_1O_1-1$	0	$0,1$	$W^{(5)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,0,0,0,i_2}$
where $W^{(5)}_{l,l',l'',m,m',m'',n} = \frac{1}{\sqrt{5P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} \end{bmatrix}$.				

[0054] A beam is defined by the parameter $\boldsymbol{i_1}$, taking the form $(\boldsymbol{l},\boldsymbol{m})$. In particular,

$$i_1 = \begin{cases} \begin{bmatrix} i_{1,1} & i_{1,2} \end{bmatrix} & \upsilon \in \{2,3,4\} \\ \begin{bmatrix} i_{1,1} & i_{1,2} & i_{1,3} \end{bmatrix} & \upsilon \in \{2,3,4\} \end{cases}$$

where, $\boldsymbol{v}$ and $\boldsymbol{\varphi_n}$ as well as N_1, N_2, O_1, O_2, $i_{1,1}$, $i_{1,2}$, $i_{1,3}$, etc, are defined in section 5.2.2.2.1 of TS 38.214. $\boldsymbol{i_2}$ is co-phasing parameters. OCC codes are ((1, 1), (1,-1)) in the codebook.

[0055] For rank 5, three beams, represented by three beam directions $\left((\boldsymbol{l},\boldsymbol{m}),(\boldsymbol{l'},\boldsymbol{m'}),(\boldsymbol{l''},\boldsymbol{m''})\right)$, are used, where each of the first beam $(\boldsymbol{l},\boldsymbol{m})$ and the second beam $(\boldsymbol{l'},\boldsymbol{m'})$ is used to transmit two layers utilizing the two polarization directions (with OCC (+1, +1) and (+1, -1)), while the last beam $(\boldsymbol{l''},\boldsymbol{m''})$ is used to transmit a single data layer using OCC (+1, +1).

[0056] For rank 5, 2 layers are transmitted in the first codeword and 3 layers are transmitted in the second codeword. The 2 layers transmitted in the first codeword are indicated by the first two columns of the precoder (e.g., $\boldsymbol{W}^{(5)}_{l,l',l'',m,m'.m'',n}$) and the 3 layers transmitted in the second codeword are indicated by the last three columns of the precoder. Based on the legacy codebook in table 5.2.2.2.1-9, the only one precoder $\boldsymbol{W}^{(5)}_{l,l',l'',m,m'.m'',n}$ indicates that the first codeword contains the two layers transmitted by $(\boldsymbol{l},\boldsymbol{m})$, and the second codeword contains the two layers transmitted by $(\boldsymbol{l}',\boldsymbol{m}')$ and the single layer transmitted by $(\boldsymbol{l}'',\boldsymbol{m}'')$. This works well when the signal strength or the SNR of the three layers in the second codeword are similar, e.g., when the SNR of the two layers transmitted by $(\boldsymbol{l},\boldsymbol{m})$ are closer to the SNR of the two layers transmitted by $(\boldsymbol{l}',\boldsymbol{m}')$ than to the SNR of the single layer transmitted by $(\boldsymbol{l}'',\boldsymbol{m}'')$.

[0057] However, it is possible that the SNR of the two layers transmitted by $(\boldsymbol{l},\boldsymbol{m})$ are closer to the SNR of the single layer transmitted by $(\boldsymbol{l}'',\boldsymbol{m}'')$ than to the SNR of the two layers transmitted by $(\boldsymbol{l}',\boldsymbol{m}')$. It means that the two layers transmitted by $(\boldsymbol{l},\boldsymbol{m})$ and the single layer transmitted by $(\boldsymbol{l}'',\boldsymbol{m}'')$ should be assigned to the second codeword.

[0058] In view of the above, this disclosure proposes a new precoder for rank 5:

[0059] $$W^{(5,\mathbf{1})}_{l,l',l'',m,m'.m'',n} = \frac{1}{\sqrt{5P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l',m'} & v_{l',m'} & v_{l,m} & v_{l,m} & v_{l'',m''} \\ v_{l',m'} & -v_{l',m'} & \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l'',m''} \end{bmatrix}.$$

[0060] Based on the new precoder, the first codeword includes the two layers transmitted by $(\boldsymbol{l}',\boldsymbol{m}')$, and the second codeword includes the two layers transmitted by $(\boldsymbol{l},\boldsymbol{m})$ and the single layer transmitted by $(\boldsymbol{l}'',\boldsymbol{m}'')$. To achieve flexibility, both the legacy precoder for rank 5 and the new precoder for rank 5 are necessary. So, a new subfield $\boldsymbol{i}_3$ of 1 bit with value ‘0’ or ‘1’ is added to signal to the UE which precoder for rank 5 is to use. As a whole, the codebook for rank 5 is enhanced as in Table 1.

codebookMode = 1-2					
	$i_{1,1}$	$i_{1,2}$	i_2	i_3	
$N_2 > 1$	$0,\dots,N_1O_1-1$	$0,\dots,N_2O_2-1$	$0,1$	$0,1$	$W^{(5,i_3)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 = 1$	$0,\dots,N_1O_1-1$	0	$0,1$	$0,1$	$W^{(5,i_3)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,0,0,0,i_2}$
Where $W^{(5,0)}_{l,l',l'',m,m'.m'',n} = \frac{1}{\sqrt{5P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} \end{bmatrix}$, $W^{(5,1)}_{l,l',l'',m,m'.m'',n} = \frac{1}{\sqrt{5P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l',m'} & v_{l',m'} & v_{l,m} & v_{l,m} & v_{l'',m''} \\ v_{l',m'} & -v_{l',m'} & \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l'',m''} \end{bmatrix}$.					

Table 1

[0061] Based on the value '0' or '1' of the subfield $\boldsymbol{i}_3$, $W^{(5,0)}_{l,l',l'',m,m'.m'',n}$ or $W^{(5,1)}_{l,l',l'',m,m'.m'',n}$ is signaled as the precoder. For example, if the subfield $\boldsymbol{i}_3$ indicates '0', the precoder $\boldsymbol{W}^{(5,0)}_{l,l',l'',m,m'.m'',n} = \frac{1}{\sqrt{5P_{\text{CSI-RS}}}}\begin{bmatrix} \boldsymbol{v}_{l,m} & \boldsymbol{v}_{l,m} & \boldsymbol{v}_{l',m'} & \boldsymbol{v}_{l',m'} & \boldsymbol{v}_{l'',m''} \\ \boldsymbol{\varphi}_n\boldsymbol{v}_{l,m} & -\boldsymbol{\varphi}_n\boldsymbol{v}_{l,m} & \boldsymbol{v}_{l',m'} & -\boldsymbol{v}_{l',m'} & \boldsymbol{v}_{l'',m''} \end{bmatrix}$ is applied, which indicates that the 2 layers transmitted in the first codeword indicated by the first two columns of the precoder are transmitted by the first beam $(\boldsymbol{l},\boldsymbol{m})$, and the 3 layers transmitted in the second codeword indicated by the last three columns of the precoder are transmitted by the second beam $(\boldsymbol{l}',\boldsymbol{m}')$ and the third beam $(\boldsymbol{l}'',\boldsymbol{m}'')$. On the other hand, if the subfield $\boldsymbol{i}_3$ indicates '1', the precoder $\boldsymbol{W}^{(5,1)}_{l,l',l'',m,m'.m'',n} = \frac{1}{\sqrt{5P_{\text{CSI-RS}}}}\begin{bmatrix} \boldsymbol{v}_{l',m'} & \boldsymbol{v}_{l',m'} & \boldsymbol{v}_{l,m} & \boldsymbol{v}_{l,m} & \boldsymbol{v}_{l'',m''} \\ \boldsymbol{v}_{l',m'} & -\boldsymbol{v}_{l',m'} & \boldsymbol{\varphi}_n\boldsymbol{v}_{l,m} & -\boldsymbol{\varphi}_n\boldsymbol{v}_{l,m} & \boldsymbol{v}_{l'',m''} \end{bmatrix}$ is applied, which indicates that the 2 layers transmitted in the first codeword indicated by the first two columns of the precoder are transmitted by the second beam $(\boldsymbol{l}',\boldsymbol{m}')$, and the 3 layers transmitted in the second codeword indicated by the last three columns of the precoder are transmitted by the first beam $(\boldsymbol{l},\boldsymbol{m})$ and the third beam $(\boldsymbol{l}'',\boldsymbol{m}'')$.

[0062] A second sub-embodiment of the first embodiment relates to enhancement to Rank 6 codebook.

[0063] Table 5.2.2.2.1-10 in section 5.2.2.2.1 of TS 38.214 gives the codebook for 6-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$ as follows:

codebookMode = 1-2				
	$i_{1,1}$	$i_{1,2}$	i_2	
$N_2 > 1$	$0,\ldots,N_1O_1-1$	$0,\ldots,N_2O_2-1$	$0,1$	$W^{(6)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 = 1$	$0,\ldots,N_1O_1-1$	0	$0,1$	$W^{(6)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,0,0,0,i_2}$
where $W^{(6)}_{l,l',l'',m,m',m'',n} = \frac{1}{\sqrt{6P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} & v_{l'',m''} & -v_{l'',m''} \end{bmatrix}$.				

[0064] For rank 6, three beams $\left((\boldsymbol{l},\boldsymbol{m}),(\boldsymbol{l}',\boldsymbol{m}'),(\boldsymbol{l}'',\boldsymbol{m}'')\right)$ are used, where each beam is used to transmit two data layers utilizing the two polarization directions (with OCC (+1, +1) and (+1, -1)).

[0065] For rank 6, 3 layers are transmitted in the first codeword and 3 layers are transmitted in the second codeword. The 3 layers transmitted in the first codeword are indicated by the first three columns of the precoder (e.g., $\boldsymbol{W}^{(6)}_{l,l',l'',m,m'.m'',n}$) and the 3 layers transmitted in the second codeword are indicated by the last three columns of the precoder. Based on the legacy codebook in table 5.2.2.2.1-10, the only one precoder $W^{(6)}_{l,l',l'',m,m',m'',n}$ indicates that the first codeword contains the two layers transmitted by beam (l, m) with OCC (+1, +1) and (+1, -1), and the first layer transmitted by (l', m') with OCC (+1, +1), and the second codeword contains the second layer transmitted by (l', m') with OCC (+1, -1), and the two layers transmitted by beam (l'', m'') with OCC (+1, +1) and (+1, -1). This works best when the SNR of the two layers transmitted by (l', m') are between the SNR of the two layers transmitted by (l, m) and the SNR of the two layers transmitted by (l'', m'').

[0066] However, it is possible that the SNR of the two layers transmitted by (l, m), or the SNR of the two layers transmitted by (l'', m'') is in the middle. It means that it is possible that the SNR of the two layers transmitted by (l, m) are between the SNR of the two layers transmitted by (l', m') and the SNR of the two layers transmitted by (l'', m''), and that it is also possible that the SNR of the two layers transmitted by (l'', m'') are between the SNR of the two layers transmitted by (l, m) and the SNR of the two layers transmitted by (l', m').

[0067] In view of the above, this disclosure proposes two new precoders for rank 6:

[0068] $W^{(6,1)}_{l,l',l'',m,m',m'',n} = \frac{1}{\sqrt{6P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l',m'} & v_{l',m'} & v_{l,m} & v_{l,m} & v_{l'',m''} & v_{l'',m''} \\ \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} & \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l'',m''} & -v_{l'',m''} \end{bmatrix}$, for the situation that the SNR of the two layers transmitted by (l, m) is in the middle; and

[0069] $W^{(6,2)}_{l,l',l'',m,m',m'',n} = \frac{1}{\sqrt{6P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l'',m''} & v_{l'',m''} & v_{l',m'} & v_{l',m'} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l'',m''} & -v_{l'',m''} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} \end{bmatrix}$, for the situation that the SNR of the two layers transmitted by (l'', m'') is in the middle.

[0070] To distinguish three precoders for rank 6 (legacy precoder in Table 5.2.2.2.1-10 in section 5.2.2.2.1, two new precoders for rank 6), a new subfield i_3 of 2 bits with value '00' or '01' or '10' (i.e., 0, 1, 2) is added to signal to the UE which precoder for rank 6 is to use. As a whole, the codebook for rank 6 is enhanced as in Table 2.

codebookMode = 1-2					
	$i_{1,1}$	$i_{1,2}$	i_2	i_3	
$N_2 > 1$	$0,\dots,N_1O_1-1$	$0,\dots,N_2O_2-1$	$0,1$	$0,1,2$	$W^{(6,i_3)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 = 1$	$0,\dots,N_1O_1-1$	0	$0,1$	$0,1,2$	$W^{(6,i_3)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,0,0,0,i_2}$
where $W^{(6,0)}_{l,l',l'',m,m'.m'',n} = \frac{1}{\sqrt{6P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} & v_{l'',m''} & -v_{l'',m''} \end{bmatrix}$, $W^{(6,1)}_{l,l',l'',m,m'.m'',n} = \frac{1}{\sqrt{6P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l',m'} & v_{l',m'} & v_{l,m} & v_{l,m} & v_{l'',m''} & v_{l'',m''} \\ \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} & \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l'',m''} & -v_{l'',m''} \end{bmatrix}$, $W^{(6,2)}_{l,l',l'',m,m'.m'',n} = \frac{1}{\sqrt{6P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l'',m''} & v_{l'',m''} & v_{l',m'} & v_{l',m'} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l'',m''} & -v_{l'',m''} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} \end{bmatrix}$.					

Table 2

[0071] Based on the value '00' or '01' or '10' of the subfield i_3, $W^{(6,0)}_{l,l',l'',m,m'.m'',n}$ or $W^{(6,1)}_{l,l',l'',m,m'.m'',n}$ or $W^{(6,2)}_{l,l',l'',m,m'.m'',n}$ is signaled as the precoder.

[0072] A third sub-embodiment of the first embodiment relates to enhancement to Rank 7 codebook.

[0073] Table 5.2.2.2.1-11 in section 5.2.2.2.1 of TS 38.214 gives the codebook for 7-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$ as follows:

codebookMode = 1-2				
	$i_{1,1}$	$i_{1,2}$	i_2	
$N_1 = 4, N_2 = 1$	$0,\dots,\frac{N_1O_1}{2}-1$	0	$0,1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,i_{1,1}+3O_1,0,0,0,0,i_2}$
$N_1 > 4, N_2 = 1$	$0,\dots,N_1O_1-1$	0	$0,1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,i_{1,1}+3O_1,0,0,0,0,i_2}$
$N_1 = 2, N_2 = 2$	$0,\dots,N_1O_1-1$	$0,\dots,N_2O_2-1$	$0,1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 = 2$	$0,\dots,N_1O_1-1$	$0,\dots,\frac{N_2O_2}{2}-1$	$0,1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 > 2$	$0,\dots,N_1O_1-1$	$0,\dots,N_2O_2-1$	$0,1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2,i_2}$
where $W^{(7)}_{l,l',l'',l''',m,m'.m'',m''',n} = \frac{1}{\sqrt{7P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} & v_{l''',m'''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & \varphi_n v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} & -v_{l''',m'''} \end{bmatrix}$.				

[0074] For rank 7, four beams $((l,m),(l',m'),(l'',m''),(l''',m'''))$ are used, where each of three beams $(l,m),(l'',m''),(l''',m''')$ is used to transmit two layers utilizing the two polarization directions (with OCC (+1, +1) and (+1, -1)), while the beam (l',m') is used to transmit a single layer with OCC (+1, +1).

[0075] For rank 7, 3 layers are transmitted in the first codeword and 4 layers are transmitted in the second codeword. The 3 layers transmitted in the first codeword are indicated by the first three columns of the precoder (e.g., $\boldsymbol{W}^{(7)}_{l,l',l'',l''',m,m'.m'',m''',n}$) and the 4 layers transmitted in the second codeword are indicated by the last four columns of the precoder. Based on the legacy codebook in table 5.2.2.2.1-11, the only one precoder $\boldsymbol{W}^{(7)}_{l,l',l'',l''',m,m'.m'',m''',n}$ indicates that the first codeword contains the two layers transmitted by beam $(\boldsymbol{l},\boldsymbol{m})$ with OCC (+1, +1) and (+1, -1), and the single layer transmitted by beam $(\boldsymbol{l'},\boldsymbol{m'})$ with OCC (+1, +1), and the second codeword contains the two layers transmitted by beam $(\boldsymbol{l''},\boldsymbol{m''})$ with OCC (+1, +1) and (+1, -1) and the two layers transmitted by beam $(\boldsymbol{l'''},\boldsymbol{m'''})$ with OCC (+1, +1) and (+1, -1).

[0076] Similar to the enhancement to rank 5 codebook, two new precoders are proposed for rank 7:

[0077] $W^{(7,1)}_{l,l',l'',l''',m,m'.m'',m''',n} = \frac{1}{\sqrt{7P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l'',m''} & v_{l'',m''} & v_{l',m'} & v_{l,m} & v_{l,m} & v_{l''',m'''} & v_{l''',m'''} \\ v_{l'',m''} & -v_{l'',m''} & \varphi_n v_{l',m'} & \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l''',m'''} & -v_{l''',m'''} \end{bmatrix}$, in which the beam $(\boldsymbol{l''},\boldsymbol{m''})$ is allocated to be with the beam $(\boldsymbol{l'},\boldsymbol{m'})$ in the first codeword while the beam $(\boldsymbol{l},\boldsymbol{m})$ and the beam $(\boldsymbol{l'''},\boldsymbol{m'''})$ are in the second codeword; and

[0078] $W^{(7,2)}_{l,l',l'',l''',m,m'.m'',m''',n} = \frac{1}{\sqrt{7P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l''',m'''} & v_{l''',m'''} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l,m} & v_{l,m} \\ v_{l''',m'''} & -v_{l''',m'''} & \varphi_n v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & \varphi_n v_{l,m} & -\varphi_n v_{l,m} \end{bmatrix}$, in which the beam $(\boldsymbol{l'''},\boldsymbol{m'''})$ is allocated to be with the beam $(\boldsymbol{l'},\boldsymbol{m'})$ in the first codeword while the beam $(\boldsymbol{l''},\boldsymbol{m''})$ and the beam $(\boldsymbol{l},\boldsymbol{m})$ are in the second codeword.

[0079] To distinguish three precoders for rank 7 (legacy precoder in Table 5.2.2.2.1-11 in section 5.2.2.2.1, two new precoders for rank 7), a new subfield $\boldsymbol{i_3}$ of 2 bits with value '00' or '01' or '10' (i.e., 0, 1, 2) is added to signal to the UE which precoder for rank 7 is to use. As a whole, the codebook for rank 7 is enhanced as in Table 3.

codebookMode = 1-2					
	$i_{1,1}$	$i_{1,2}$	i_2	i_3	
$N_1 = 4, N_2 = 1$	$0, \ldots, \frac{N_1 O_1}{2} - 1$	0	$0, 1$	$0, 1, 2$	$W^{(7,\ i_3)}_{i_{1,1}, i_{1,1}+O_1, i_{1,1}+2O_1, i_{1,1}+3O_1, 0,0,0,0, i_2}$
$N_1 > 4, N_2 = 1$	$0, \ldots, N_1 O_1 - 1$	0	$0, 1$	$0, 1, 2$	$W^{(7,\ i_3)}_{i_{1,1}, i_{1,1}+O_1, i_{1,1}+2O_1, i_{1,1}+3O_1, 0,0,0,0, i_2}$
$N_1 = 2, N_2 = 2$	$0, \ldots, N_1 O_1 - 1$	$0, \ldots, N_2 O_2 - 1$	$0, 1$	$0, 1, 2$	$W^{(7,\ i_3)}_{i_{1,1}, i_{1,1}+O_1, i_{1,1}, i_{1,1}+O_1, i_{1,2}, i_{1,2}, i_{1,2}+O_2, i_{1,2}+O_2, i_2}$
$N_1 > 2, N_2 = 2$	$0, \ldots, N_1 O_1 - 1$	$0, \ldots, \frac{N_2 O_2}{2} - 1$	$0, 1$	$0, 1, 2$	$W^{(7,\ i_3)}_{i_{1,1}, i_{1,1}+O_1, i_{1,1}, i_{1,1}+O_1, i_{1,2}, i_{1,2}, i_{1,2}+O_2, i_{1,2}+O_2, i_2}$
$N_1 > 2, N_2 > 2$	$0, \ldots, N_1 O_1 - 1$	$0, \ldots, N_2 O_2 - 1$	$0, 1$	$0, 1, 2$	$W^{(7,\ i_3)}_{i_{1,1}, i_{1,1}+O_1, i_{1,1}, i_{1,1}+O_1, i_{1,2}, i_{1,2}, i_{1,2}+O_2, i_{1,2}+O_2, i_2}$

Where

$$W^{(7,\ 0)}_{l,l',l'',l''',m,m'.m'',m''',n} = \frac{1}{\sqrt{7P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} & v_{l''',m'''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & \varphi_n v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} & -v_{l''',m'''} \end{bmatrix}$$

$$W^{(7,1)}_{l,l',l'',l''',m,m'.m'',m''',n} = \frac{1}{\sqrt{7P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l'',m''} & v_{l'',m''} & v_{l',m'} & v_{l,m} & v_{l,m} & v_{l''',m'''} & v_{l''',m'''} \\ v_{l'',m''} & -v_{l'',m''} & \varphi_n v_{l',m'} & \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l''',m'''} & -v_{l''',m'''} \end{bmatrix}$$

$$W^{(7,2)}_{l,l',l'',l''',m,m'.m'',m''',n} = \frac{1}{\sqrt{7P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l''',m'''} & v_{l''',m'''} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l,m} & v_{l,m} \\ v_{l''',m'''} & -v_{l''',m'''} & \varphi_n v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & \varphi_n v_{l,m} & -\varphi_n v_{l,m} \end{bmatrix}$$

Table 3

[0080] Based on the value ‘00’ or ‘01’ or ‘10’ of the subfield $\boldsymbol{i_3}$, $W^{(7,\ 0)}_{l,l',l'',l''',m,m'.m'',m''',n}$ or $W^{(7,1)}_{l,l',l'',l''',m,m'.m'',m''',n}$ or $W^{(7,2)}_{l,l',l'',l''',m,m'.m'',m''',n}$ is signaled as the precoder.

[0081] A fourth sub-embodiment of the first embodiment relates to enhancement to Rank 8 codebook.

[0082] Table 5.2.2.2.1-12 in section 5.2.2.2.1 of TS 38.214 gives the codebook for 8-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$ as follows:

codebookMode = 1-2				
	$i_{1,1}$	$i_{1,2}$	i_2	
$N_1 = 4, N_2 = 1$	$0, \ldots, \frac{N_1 O_1}{2} - 1$	0	$0, 1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,i_{1,1}+3O_1,0,0,0,0,i_2}$
$N_1 > 4, N_2 = 1$	$0, \ldots, N_1 O_1 - 1$	0	$0, 1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,i_{1,1}+3O_1,0,0,0,0,i_2}$
$N_1 = 2, N_2 = 2$	$0, \ldots, N_1 O_1 - 1$	$0, \ldots, N_2 O_2 - 1$	$0, 1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 = 2$	$0, \ldots, N_1 O_1 - 1$	$0, \ldots, \frac{N_2 O_2}{2} - 1$	$0, 1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 > 2$	$0, \ldots, N_1 O_1 - 1$	$0, \ldots, N_2 O_2 - 1$	$0, 1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2,i_2}$
where $W^{(8)}_{l,l',l'',l''',m,m'.m'',m''',n} = \frac{1}{\sqrt{8P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} & v_{l''',m'''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} & -v_{l''',m'''} \end{bmatrix}$.				

[0083] For rank 8, four beams ($(\boldsymbol{l}, \boldsymbol{m}), (\boldsymbol{l}', \boldsymbol{m}'), (\boldsymbol{l}'', \boldsymbol{m}''), (\boldsymbol{l}''', \boldsymbol{m}''')$) are used, where each beam is used to transmit two layers utilizing the two polarization directions (with OCC (+1, +1) and (+1, -1)).

[0084] For rank 8, 4 layers are transmitted in the first codeword and 4 layers are transmitted in the second codeword. The 4 layers transmitted in the first codeword are indicated by the first four columns of the precoder (e.g.,$W^{(8)}_{l,l',l'',l''',m,m'.m'',m''',n}$) and the 4 layers transmitted in the second codeword are indicated by the last four columns of the precoder. Based on the legacy codebook in table 5.2.2.2.1-12, the only one precoder $\boldsymbol{W}^{(8)}_{l,l',l'',l''',m,m'.m'',m''',n}$ indicates that the first codeword contains the two layers transmitted by beam $(\boldsymbol{l}, \boldsymbol{m})$ with OCC (+1, +1) and (+1, -1) and the two layers transmitted by beam $(\boldsymbol{l'}, \boldsymbol{m'})$ with OCC (+1, +1) and (+1, -1), and the second codeword contains the two layers transmitted by beam $(\boldsymbol{l}'', \boldsymbol{m}'')$ with OCC (+1, +1) and (+1, -1) and the two layers transmitted by beam $(\boldsymbol{l}''', \boldsymbol{m}''')$ with OCC (+1, +1) and (+1, -1).

[0085] Similar to the enhancement to rank 6 codebook, two new precoders are proposed for rank 8:

[0086] $W^{(8,1)}_{l,l',l'',l''',m,m'.m'',m''',n} =$

$$\frac{1}{\sqrt{8P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l'',m''} & v_{l'',m''} & v_{l',m'} & v_{l',m'} & v_{l''',m'''} & v_{l''',m'''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l'',m''} & -v_{l'',m''} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} & v_{l''',m'''} & -v_{l''',m'''} \end{bmatrix},$$

in which the beam $(\boldsymbol{l}, \boldsymbol{m})$ are the beam $(\boldsymbol{l}'', \boldsymbol{m}'')$ are in the first codeword while the beam $(\boldsymbol{l'}, \boldsymbol{m'})$ and the beam $(\boldsymbol{l}''', \boldsymbol{m}''')$ are in the second codeword; and

[0087] $W^{(8,2)}_{l,l',l'',l''',m,m'.m'',m''',n} =$

$$\frac{1}{\sqrt{8P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l''',m'''} & v_{l''',m'''} & v_{l'',m''} & v_{l'',m''} & v_{l',m'} & v_{l',m'} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l''',m'''} & -v_{l''',m'''} & v_{l'',m''} & -v_{l'',m''} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} \end{bmatrix}$$ in which

the beam $(\boldsymbol{l}, \boldsymbol{m})$ and the beam $(\boldsymbol{l}''', \boldsymbol{m}''')$ are in the first codeword while the beam $(\boldsymbol{l}'', \boldsymbol{m}'')$ and the beam $(\boldsymbol{l}', \boldsymbol{m}')$ are in the second codeword.

[0088] To distinguish three precoders for rank 8 (legacy precoder in Table 5.2.2.2.1-12 in section 5.2.2.2.1, two new precoders for rank 8), a new subfield $\boldsymbol{i_3}$ of 2 bits with value '00' or '01' or '10' (i.e., 0, 1, 2) is added to signal to the UE which precoder for rank 8 is to use. As a whole, the codebook for rank 8 is enhanced as in Table 4.

codebookMode = 1-2					
	$i_{1,1}$	$i_{1,2}$	i_2	i_3	
$N_1 = 4, N_2 = 1$	$0, \ldots, \frac{N_1 O_1}{2} - 1$	0	$0, 1$	$0, 1, 2$	$W^{(8,i_3)}_{i_{1,1}, i_{1,1}+O_1, i_{1,1}+2O_1, i_{1,1}+3O_1, 0,0,0,0, i_2}$
$N_1 > 4, N_2 = 1$	$0, \ldots, N_1 O_1 - 1$	0	$0, 1$	$0, 1, 2$	$W^{(8,i_3)}_{i_{1,1}, i_{1,1}+O_1, i_{1,1}+2O_1, i_{1,1}+3O_1, 0,0,0,0, i_2}$
$N_1 = 2, N_2 = 2$	$0, \ldots, N_1 O_1 - 1$	$0, \ldots, N_2 O_2 - 1$	$0, 1$	$0, 1, 2$	$W^{(8,i_3)}_{i_{1,1}, i_{1,1}+O_1, i_{1,1}, i_{1,1}+O_1, i_{1,2}, i_{1,2}, i_{1,2}+O_2, i_{1,2}+O_2, i_2}$
$N_1 > 2, N_2 = 2$	$0, \ldots, N_1 O_1 - 1$	$0, \ldots, \frac{N_2 O_2}{2} - 1$	$0, 1$	$0, 1, 2$	$W^{(8,i_3)}_{i_{1,1}, i_{1,1}+O_1, i_{1,1}, i_{1,1}+O_1, i_{1,2}, i_{1,2}, i_{1,2}+O_2, i_{1,2}+O_2, i_2}$
$N_1 > 2, N_2 > 2$	$0, \ldots, N_1 O_1 - 1$	$0, \ldots, N_2 O_2 - 1$	$0, 1$	$0, 1, 2$	$W^{(8,i_3)}_{i_{1,1}, i_{1,1}+O_1, i_{1,1}, i_{1,1}+O_1, i_{1,2}, i_{1,2}, i_{1,2}+O_2, i_{1,2}+O_2, i_2}$

where

$$W^{(8,0)}_{l,l',l'',l''',m,m'.m'',m''',n} = \frac{1}{\sqrt{8P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} & v_{l''',m'''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} & -v_{l''',m'''} \end{bmatrix}$$

$$W^{(8,1)}_{l,l',l'',l''',m,m'.m'',m''',n} = \frac{1}{\sqrt{8P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l'',m''} & v_{l'',m''} & v_{l',m'} & v_{l',m'} & v_{l''',m'''} & v_{l''',m'''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l'',m''} & -v_{l'',m''} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} & v_{l''',m'''} & -v_{l''',m'''} \end{bmatrix}$$

$$\boldsymbol{W}^{(8,2)}_{l,l',l'',l''',m,m'.m'',m''',n} = \frac{1}{\sqrt{8P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l''',m'''} & v_{l''',m'''} & v_{l'',m''} & v_{l'',m''} & v_{l',m'} & v_{l',m'} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l''',m'''} & -v_{l''',m'''} & v_{l'',m''} & -v_{l'',m''} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} \end{bmatrix}$$

Table 4

[0089] Based on the value '00' or '01' or '10' of the subfield $\boldsymbol{i_3}$, $W^{(8,0)}_{l,l',l'',l''',m,m'.m'',m''',n}$ or $W^{(8,1)}_{l,l',l'',l''',m,m'.m'',m''',n}$ or $\boldsymbol{W}^{(8,2)}_{l,l',l'',l''',m,m'.m'',m''',n}$ is signaled as the precoder.

[0090] As a whole, according to the first embodiment related to codebook based PUSCH transmission, new precoders are added to each of the codebooks for ranks 5 to 8, and a new subfield $\boldsymbol{i_3}$ is further added in the codebook to indicate which precoder is applied. When a different precoder is applied, the layers transmitted in the first codeword and the layers transmitted in the second codeword can be dynamically configured.

[0091] In the first embodiment, different precoders are different permutations of the same set of *N* (*N* is 5 to 8) transmission layers. For example, for two precoders for Rank 5 (i.e., $N = 5$) in Table 1, both precoders are for the same 5 layers (i.e., two layers transmitted by beam $(\boldsymbol{l}, \boldsymbol{m})$, two layers transmitted by beam $(\boldsymbol{l}', \boldsymbol{m}')$ and one layer transmitted by beam $(\boldsymbol{l}'', \boldsymbol{m}'')$). The difference of the two precoders lies in that, when $\boldsymbol{W}^{(5,0)}_{l,l',l'',m,m',m'',n}$ is indicated, the two layers transmitted by beam $(\boldsymbol{l}, \boldsymbol{m})$ is in the first codeword; and the two layers transmitted by beam $(\boldsymbol{l}', \boldsymbol{m}')$ and one layer transmitted by beam $(\boldsymbol{l}'', \boldsymbol{m}'')$ are in the second codeword, while the $\boldsymbol{W}^{(5,1)}_{l,l',l'',m,m',m'',n}$ is indicated, the two layers transmitted by beam $(\boldsymbol{l}', \boldsymbol{m}')$ is in the first codeword; and the two layers transmitted by beam $(\boldsymbol{l}, \boldsymbol{m})$ and one layer transmitted by beam $(\boldsymbol{l}'', \boldsymbol{m}'')$ are in the second codeword.

[0092] According to the first embodiment, different permutations allocate the same *N* (*N* is 5 to 8) transmission layers into two groups, where a first group has $\lfloor N/2 \rfloor$ layers and a second group has $\lceil N/2 \rceil$ layers. For example, for two precoders for Rank 5 in Table 1, the first group has $\lfloor N/2 \rfloor = \lfloor 5/2 \rfloor = 2$ layers; and the second group has $\lceil N/2 \rceil = \lceil 5/2 \rceil = 3$ layers. Incidentally, $\lceil x \rceil$ means the smallest integer that is equal to or larger than *x*; while $\lfloor x \rfloor$ means the largest integer that is equal to or smaller than *x*.

[0093] For ranks 5, 7 and 8, if a beam is used to transmit two layers with two different OCCs on two polarization directions, these two layers are in the same group. For example, for rank 5, for the permutation of $\boldsymbol{W}^{(5,0)}_{l,l',l'',m,m',m'',n}$, the two layers transmitted by $(\boldsymbol{l}, \boldsymbol{m})$ are in the first group; and the two layers transmitted by $(\boldsymbol{l}', \boldsymbol{m}')$ are in the second group; while for the permutation of $\boldsymbol{W}^{(5,1)}_{l,l',l'',m,m',m'',n}$, the two layers transmitted by $(\boldsymbol{l}, \boldsymbol{m})$ are in the second group; and the two layers transmitted by $(\boldsymbol{l}', \boldsymbol{m}')$ are in the first group.

[0094] For each of ranks 5 and 7, there is a beam used to transmit only one layer with orthogonal cover code (+1, +1), that is, beam $(\boldsymbol{l}'', \boldsymbol{m}'')$ for rank 5 and beam $(\boldsymbol{l}', \boldsymbol{m}')$ for rank 7. The beam used to transmit only one layer with orthogonal cover code (+1, +1) is always transmitted in the codeword with odd number of layers. The beam $(\boldsymbol{l}'', \boldsymbol{m}'')$ for rank 5 is always in the second group (i.e., transmitted in the second codeword which has 3 layers); and the beam $(\boldsymbol{l}', \boldsymbol{m}')$ for rank 7 is always in the first group (i.e., transmitted in the first codeword which has 3 layers).

[0095] For each of ranks 5 to 8, if a co-phasing factor (i.e., i_2 in each of codebooks in Tables 1 to 4) is applied to the two different polarizations of the same beam, the co-phasing factor is unchanged as the layers are permutated in different precoders. As an example, for rank 5, $W^{(5,0)}_{l,l',l'',m,m',m'',n} = \frac{1}{\sqrt{5P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} \end{bmatrix}$, $W^{(5,1)}_{l,l',l'',m,m',m'',n} = \frac{1}{\sqrt{5P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l',m'} & v_{l',m'} & v_{l,m} & v_{l,m} & v_{l'',m''} \\ v_{l',m'} & -v_{l',m'} & \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l'',m''} \end{bmatrix}$; the parameter φ_n is unchanged as the first 2 layers in $W^{(5,0)}_{l,l',l'',m,m',m'',n}$ moved to layers 3 and 4 in $W^{(5,1)}_{l,l',l'',m,m',m'',n}$.

[0096] For each of ranks 5 to 8, if an OCC code (e.g., (+1, +1) or (+1, -1)) is applied to the two different polarizations of the same beam, the OCC code is unchanged as the layers are permutated in different precoders. For example, for two precoders for Rank 5 in Table 1, in each of the permutation of $W^{(5,0)}_{l,l',l'',m,m',m'',n}$ and the permutation of $W^{(5,1)}_{l,l',l'',m,m',m'',n}$, the OCC code (+1, +1) is always applied to the first layer transmitted by beam (l, m), the first layer transmitted by beam (l', m') and the single layer transmitted by beam (l'', m''); and the OCC code (+1, -1) is always applied to the second layer transmitted by beam (l, m) and the second layer transmitted by beam (l', m').

[0097] For rank 6, different pairs of layers transmitted by the same beam are split between different codewords (i.e., between the first codeword and the second codeword). For example, for the precoder $W^{(6,0)}_{l,l',l'',m,m',m'',n} = \frac{1}{\sqrt{6P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} & v_{l'',m''} & -v_{l'',m''} \end{bmatrix}$, the pair of layers transmitted by beam (l', m') are split between the first codeword and the second codeword; for the precoder $W^{(6,1)}_{l,l',l'',m,m',m'',n} = \frac{1}{\sqrt{6P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l',m'} & v_{l',m'} & v_{l,m} & v_{l,m} & v_{l'',m''} & v_{l'',m''} \\ \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} & \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l'',m''} & -v_{l'',m''} \end{bmatrix}$, the pair of layers transmitted by beam (l, m) are split between the first codeword and the second codeword; and for the precoder $W^{(6,2)}_{l,l',l'',m,m',m'',n} = \frac{1}{\sqrt{6P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l'',m''} & v_{l'',m''} & v_{l',m'} & v_{l',m'} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l'',m''} & -v_{l'',m''} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} \end{bmatrix}$, the pair of layers transmitted by beam (l'', m'') are split between the first codeword and the second codeword.

[0098] For rank 8, the first pair of layers transmitted by the same beam (i.e., the pair of layers transmitted by (l, m)) are always in the first group (i.e., in the first codeword), and the other pairs of layers transmitted by the same beam (i.e., the pair of layers transmitted by $(\boldsymbol{l'}, \boldsymbol{m'})$, the pair of layers transmitted by $(\boldsymbol{l''}, \boldsymbol{m''})$, and the pair of layers transmitted by $(\boldsymbol{l'''}, \boldsymbol{m'''})$) are in the first group (i.e., in the first codeword) in different precoders, respectively. That is, for the precoder

$$W^{(8,0)}_{l,l',l'',l''',m,m',m'',m''',n} = \frac{1}{\sqrt{8P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} & v_{l''',m'''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} & -v_{l''',m'''} \end{bmatrix},$$

the pair of layers transmitted by $(\boldsymbol{l}, \boldsymbol{m})$ and the pair of layers transmitted by $(\boldsymbol{l'}, \boldsymbol{m'})$ are in the first group (in the first codeword); for the precoder

$$W^{(8,1)}_{l,l',l'',l''',m,m',m'',m''',n} = \frac{1}{\sqrt{8P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l'',m''} & v_{l'',m''} & v_{l',m'} & v_{l',m'} & v_{l''',m'''} & v_{l''',m'''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l'',m''} & -v_{l'',m''} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} & v_{l''',m'''} & -v_{l''',m'''} \end{bmatrix},$$

the pair of layers transmitted by $(\boldsymbol{l}, \boldsymbol{m})$ and the pair of layers transmitted by $(\boldsymbol{l''}, \boldsymbol{m''})$ are in the first group (in the first codeword); for the precoder

$$\boldsymbol{W}^{(8,2)}_{l,l',l'',l''',m,m',m'',m''',n} = \frac{1}{\sqrt{8P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l''',m'''} & v_{l''',m'''} & v_{l'',m''} & v_{l'',m''} & v_{l',m'} & v_{l',m'} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l''',m'''} & -v_{l''',m'''} & v_{l'',m''} & -v_{l'',m''} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} \end{bmatrix},$$

the pair of layers transmitted by $(\boldsymbol{l}, \boldsymbol{m})$ and the pair of layers transmitted by $(\boldsymbol{l''}, \boldsymbol{m''})$ are in the first group (in the first codeword).

[0099] A second embodiment relates to solutions for non-codebook based PUSCH transmission.

[00100] The second embodiment proposes a new SRS resource indication scheme for ranks 5 to 8 to allow the gNB to direct the layers into the two codewords, so that layers of similar strengths are in a same codeword to allow a MCS better matched with their effective SNRs. This can be done by designing new SRI for non-codebook based PUSCH for UE with 8 TX antenna ports.

[00101] In particular, when the maximal possible rank is more than 4 ($L_u = \min\{L_{max}, N_{SRS}\} \geq 5$), the SRI field indicates not only the subset of k SRS resources out of N_{SRS} SRS resources in the SRS resource set, but also which SRS resources to use in each of the codewords for ranks 5 to 8. L_{max} is the maximal number of layers for the PUSCH transmission.

[00102] Different methods are proposed to indicate the SRS resources to use in the PUSCH transmission for each of the two codewords. Because the number of layers used in the two codewords are different for different ranks, the number of possible combinations (and their formula) for each rank is also different.

[00103] A first sub-embodiment of the second embodiment relates to a first method.

[00104] According to the first method, to signal which SRS resources to use in each of the two codewords, the SRI can include two parts (may be referred to as two subfields): SRI_1 and SRI_2. SRI_1 indicates a set of k_1 SRS resources out of N_{SRS} SRS resources to use in the first codeword, and SRI_2 indicates a set of k_2 SRS resources out of $N_{SRS} - k_1$ SRS resources to use in the second codeword. It implies that the SRS resources used in the first codeword are different from the SRS resources used in the second codeword, that is, a first subset of SRS resources used in the first codeword and a second subset of SRS resources used in the second codeword have no elements in common. The total transmission rank is $k = k_1 + k_2$.

[00105] Incidentally, SRI_1 and SRI_2 may be regarded as two separate fields, e.g., in DCI or in RRC signaling, instead of being two subfields in SRI field.

[00106] For example, when the SRS resource set contains $N_{SRS} = 8$ SRS resources $\{S_0, S_1, S_2, S_3, S_4, S_5, S_6, S_7\}$, $SRI_1 = \{S_0, S_1\}$, $SRI_2 = \{S_4, S_5, S_6\}$. The total rank is 5. In particular, the first codeword contains SRS resources $\{S_0, S_1\}$ and the second codeword contains SRS resources $\{S_4, S_5, S_6\}$.

[00107] When the maximal number of layers is $L_u = \min\{L_{max}, N_{SRS}\}$=5, the total number of states (codepoints in the SRI field) indicated by SRI_1 and SRI_2 are: $N_5 = \sum_{k=1}^{4}\binom{N_{SRS}}{k} + \binom{N_{SRS}}{2}\binom{N_{SRS}-2}{3}$. If $N_{SRS} = 8$, $N_5 = \sum_{k=1}^{4}\binom{8}{k} + \binom{8}{2}\binom{8-2}{3} = \binom{8}{1} + \binom{8}{2} + \binom{8}{3} + \binom{8}{4} + \binom{8}{2}\binom{8-2}{3} = 8 + 28 + 56 + 70 + 28\times20 = 722$.

[00108] When the maximal number of layers is $L_u = \min\{L_{max}, N_{SRS}\}$=6, the total number of states indicated by SRI_1 and SRI_2 are: $N_6 = \sum_{k=1}^{4}\binom{N_{SRS}}{k} + \binom{N_{SRS}}{2}\binom{N_{SRS}-2}{3} + \binom{N_{SRS}}{3}\binom{N_{SRS}-3}{3}$. If $N_{SRS} = 8$, $N_6 = \sum_{k=1}^{4}\binom{8}{k} + \binom{8}{2}\binom{8-2}{3} + \binom{8}{3}\binom{8-3}{3} = 8 + 28 + 56 + 70 + 28\times20 + 56\times10 = 1282$.

[00109] When the maximal number of layers is $L_u = \min\{L_{max}, N_{SRS}\}$=7, the total number of states indicated by SRI_1 and SRI_2 are: $N_7 = \sum_{k=1}^{4}\binom{N_{SRS}}{k} + \binom{N_{SRS}}{2}\binom{N_{SRS}-2}{3} +$

$\binom{N_{SRS}}{3}\binom{N_{SRS}-3}{3}+\binom{N_{SRS}}{3}\binom{N_{SRS}-3}{4}$. If $N_{SRS}=8$, $N_7=\sum_{k=1}^{4}\binom{8}{k}+\binom{8}{2}\binom{8-2}{3}+\binom{8}{3}\binom{8-3}{3}+\binom{8}{3}\binom{8-3}{4}$ = 8 + 28 + 56 + 70 + 28×20 + 56×10 + 56×5 = 1562.

[00110] When the maximal number of layers is $L_u=\min\{L_{max},N_{SRS}\}$=8, the total number of states indicated by SRI_1 and SRI_2 are: $N_8=\sum_{k=1}^{4}\binom{N_{SRS}}{k}+\binom{N_{SRS}}{2}\binom{N_{SRS}-2}{3}+\binom{N_{SRS}}{3}\binom{N_{SRS}-3}{3}+\binom{N_{SRS}}{3}\binom{N_{SRS}-3}{4}+\binom{N_{SRS}}{4}\binom{N_{SRS}-4}{4}$. If $N_{SRS}=8$, $N_8=\sum_{k=1}^{4}\binom{8}{k}+\binom{8}{2}\binom{8-2}{3}+\binom{8}{3}\binom{8-3}{3}+\binom{8}{3}\binom{8-3}{4}+\binom{8}{4}\binom{8-4}{4}$ = 8 + 28 + 56 + 70 + 28×20 + 56×10 + 56×5 + 70×1 = 1632.

[00111] To summarize, the number of states (SRI codepoints) required for rank $5\le L\le 8$ is given by $N_L=\sum_{k=1}^{4}\binom{N_{SRS}}{k}+\sum_{l=5}^{L}\binom{N_{SRS}}{\lfloor l/2\rfloor}\binom{N_{SRS}-\lfloor l/2\rfloor}{l-\lfloor l/2\rfloor}$.

[00112] The number of bits required for the SRI field is $\lceil log_2(N_L)\rceil$. If $N_{SRS}=8$, the number of bits for L = 5 to 8 are $\lceil log_2(722)\rceil$ (=10), $\lceil log_2(1282)\rceil$ (=10), $\lceil log_2(1562)\rceil$ (=10), $\lceil log_2(1632)\rceil$ (=11), respectively.

[00113] A second sub-embodiment of the second embodiment relates to a second method.

[00114] According to the second method, to signal which SRS resources to use in each of the two codewords, the SRI can include two parts (may be referred to as two subfields): SRI_a and SRI_1. SRI_a first indicates a set of k SRS resources out of N_{SRS} SRS resources to use in both codewords, and SRI_1 indicates a set of k_1 SRS resources out of the k SRS resources signalled in SRI_a to use in the first codeword. Obviously, SRI_1 may be replaced by SRI_2 indicating a set of k_2 SRS resources out of the k SRS resources signalled in SRI_a to use in the second codeword. It means that a third subset of SRS resources used in both the first codeword and the second codeword, and a fourth subset of SRS resources used in either the first codeword or the second codeword are indicated in the SRI. Incidentally, SRI_a and SRI_1 (or SRI_a and SRI_2) may be regarded as two separate fields, e.g., in DCI or in RRC signaling, instead of being two subfields in SRI field.

[00115] For example, when the SRS resource set contains $N_{SRS}=8$ SRS resources {S_0, S_1, S_2, S_3, S_4, S_5, S_6, S_7}, SRI_a = {S_0, S_1 , S_4, S_5, S_6}, SRI_1 = {S_0, S_1} (or SRI_2 = {S_4, S_5, S_6}). The total rank is 5. In particular, the first codeword contains SRS resources {S_0, S_1} and the second codeword contains SRS resources {S_4, S_5, S_6}.

[00116] According to the second method, when the maximal number of layers is $L_u = \min\{L_{max}, N_{SRS}\}$ =5, the total number of states indicated by SRI_a and SRI_l are: $N_5 = \sum_{k=1}^{4}\binom{N_{SRS}}{k} + \binom{N_{SRS}}{5}\binom{5}{2}$. If $N_{SRS} = 8$, $N_5 = \sum_{k=1}^{4}\binom{8}{k} + \binom{8}{5}\binom{5}{2}$ = 8 + 28 + 56 + 70 + 56 ×10 = 722.

[00117] When the maximal number of layers is $L_u = \min\{L_{max}, N_{SRS}\}$ =6, the total number of states indicated by SRI_1 and SRI_2 are: $N_6 = \sum_{k=1}^{4}\binom{N_{SRS}}{k} + \binom{N_{SRS}}{5}\binom{5}{2} + \binom{N_{SRS}}{6}\binom{6}{3}$. If $N_{SRS} = 8$, $N_6 = \sum_{k=1}^{4}\binom{8}{k} + \binom{8}{5}\binom{5}{2} + \binom{8}{6}\binom{6}{3}$ = 8 + 28 + 56 + 70 + 56 ×10 + 28×20 = 1282.

[00118] When the maximal number of layers is $L_u = \min\{L_{max}, N_{SRS}\}$ =7, the total number of states indicated by SRI_1 and SRI_2 are: $N_7 = \sum_{k=1}^{4}\binom{N_{SRS}}{k} + \binom{N_{SRS}}{5}\binom{5}{2} + \binom{N_{SRS}}{6}\binom{6}{3} + \binom{N_{SRS}}{7}\binom{7}{3}$. If $N_{SRS} = 8$, $N_7 = \sum_{k=1}^{4}\binom{8}{k} + \binom{8}{5}\binom{5}{2} + \binom{8}{6}\binom{6}{3} + \binom{8}{7}\binom{7}{3}$ = 8 + 28 + 56 + 70 + 56 ×10 + 28×20 + 8×35 = 1562.

[00119] When the maximal number of layers is $L_u = \min\{L_{max}, N_{SRS}\}$ =8, the total number of states indicated by SRI_1 and SRI_2 are: $N_8 = \sum_{k=1}^{4}\binom{N_{SRS}}{k} + \binom{N_{SRS}}{5}\binom{5}{2} + \binom{N_{SRS}}{6}\binom{6}{3} + \binom{N_{SRS}}{7}\binom{7}{3} + \binom{N_{SRS}}{8}\binom{8}{4}$. If $N_{SRS} = 8$, $N_8 = \sum_{k=1}^{4}\binom{8}{k} + \binom{8}{5}\binom{5}{2} + \binom{8}{6}\binom{6}{3} + \binom{8}{7}\binom{7}{3} + \binom{8}{8}\binom{8}{4}$ = 8 + 28 + 56 + 70 + 56 ×10 + 28×20 + 8×35 + 1× 70 = 1632.

[00120] To summarize, the number of states (SRI codepoints) required for rank $5 \leq L \leq 8$ is given by $N_L = \sum_{k=1}^{4}\binom{N_{SRS}}{k} + \sum_{l=5}^{L}\binom{N_{SRS}}{l}\binom{l}{\lfloor l/2 \rfloor}$.

[00121] The number of bits required for the SRI field is $\lceil log_2(N_L) \rceil$. If $N_{SRS} = 8$, the number of bits for L = 5 to 8 are $\lceil log_2(722) \rceil$ (=10), $\lceil log_2(1282) \rceil$ (=10), $\lceil log_2(1562) \rceil$ (=10), $\lceil log_2(1632) \rceil$ (=11), respectively.

[00122] It can be proven that the number of states, or the total number of bits required for the first method and for the second method are the same.

[00123] A third sub-embodiment of the second embodiment relates to a third method:

[00124] According to the third method, each SRS resource in the SRS resource set is assigned to one of three states, i.e., a first state: it is used to transmit in the first codeword; a second state: it is used to transmit in the second codeword; and a third state, it is not used to transmit. For a SRS resource set with 8 SRS resources, the total number of states is 3^8 =6561,

which requires $\lceil log_2(6561) \rceil = 13$ bits. That is, for N_{SRS}>4 (e.g., N_{SRS} = 5 to 8), the number of states is $3^{N_{SRS}}$ and the number of bits required is $\lceil log_2(3^{N_{SRS}}) \rceil$.

[00125] For N_{SRS} ≤4 (e.g., N_{SRS} = 1 to 4), because there is only 1 codeword with maximal rank of 4, an SRS resource has only 2 states, i.e., a first state: it is used in the PUSCH transmission; and a second state: it is not used in the PUSCH transmission. The total number of states is $2^{N_{SRS}}$, which requires N_{SRS} bits. An implementation is to use a bit map to signal whether each SRS resource is used or not in the PUSCH transmission.

[00126] As a whole, according to the second embodiment related to non-codebook based PUSCH transmission, the SRI indication is enhanced to indicate not only the SRS resources for ranks 5 to 8, but also which SRS resources are to be transmitted in the first codeword and which SRS resources are to be transmitted in the second codeword.

[00127] According to the first embodiment, the indication of the layers associated with the first codeword and the layers associated with the second codeword is implemented in the TPMI (i.e., enhanced TPMI), while according to the second embodiment, the indication of the layers associated with the first codeword and the layers associated with the second codeword is implemented in SRI (i.e., enhanced SRI).

[00128] The enhanced TPMI can be included in TPMI field; and the enhanced SRI can be included in the SRI field. The TPMI field or the SRI field can be used in DCI format 0_1 or 0_2 to schedule dynamically scheduled PUSCH or type 2 configured-grant PUSCH, or in RRC message (configuredGrantConfig) to configure type 1 configured-grant PUSCH.

[00129] Figure 1 is a schematic flow chart diagram illustrating an embodiment of a method 100 according to the present application. In some embodiments, the method 100 is performed by an apparatus, such as a remote unit (e.g. UE). In certain embodiments, the method 100 may be performed by a processor executing program code, for example, a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[00130] The method 100 is a method performed at a UE, comprising: 102 receiving a control message scheduling a PUSCH transmission having N layers to be transmitted by a first codeword and a second codeword, wherein, the control message includes a field that indicates the layers associated with the first codeword and the layers associated with the second codeword, wherein, N is 5, 6, 7 or 8; and 104 transmitting the scheduled PUSCH transmission according to the control message.

[00131] In some embodiment, the field is a transmission precoding matrix indicator (TPMI) field, and a sub-field of the TPMI field signals the precoder to use from a set of precoders in a N-layer codebook. Different precoders in the N-layer codebook may be different permutations of the same N transmission layers. If a co-phasing factor is applied to the two different polarizations of the same beam, the co-phasing factor is unchanged when the layers are permutated in different precoders. If an OCC code is applied to the two different polarizations of the same beam, the OCC code is unchanged as the layers are permutated in different precoders. Different pairs of layers transmitted by the same beam may be split between the first codeword and the second codeword in different precoders.

[00132] In some embodiment, the different permutations allocate the same N transmission layers into a first group and a second group, and the first group has $\lfloor N/2 \rfloor$ layers and the second group has $\lceil N/2 \rceil$ layers. If a beam is used to transmit two layers with two different orthogonal cover codes, the two layers may be in the same group. If a beam is used to transmit only one layer with orthogonal cover code (+1,+1), the beam may be always transmitted in the codeword having odd number of layers. In some embodiment, the first pair of layers transmitted by the same beam are always in the first group, and the other pairs of layers transmitted by the same beam are in the first group in different precoders, respectively.

[00133] In some embodiment, the field is a SRS resource indicator (SRI) field, and the SRI field indicates the SRS resources to use in the first codeword and the second codeword from a SRS resource set.

[00134] The SRI field may indicate the SRS resources to use in the first codeword and the SRS resources to use in the second codeword, respectively. In particular, the SRS resources to use in the first codeword and the SRS resources to use in the second codeword have no SRS resource in common. The SRI field may indicate the SRS resources to use in both the first codeword and the second codeword and the SRS resources to use in one of the first codeword and the second codeword, respectively. The SRI field may indicate, for each SRS resource in the SRS resource set, one of a first state in which the SRS resource is to use in the first codeword, a second state in which the SRS resource is to use in the second codeword, and a third state in which the SRS resource is not used.

[00135] In some embodiment, the method further comprises transmitting SRS resources for non-codebook, and the SRS resource set is determined from the SRS resources in a SRS resource set for non-codebook.

[00136] In some embodiment, the control message is a DCI format 0_1 or 0_2 that schedule dynamically scheduled PUSCH or type 2 configured grant PUSCH. Alternatively, the control message is a RRC message that schedules type 1 configured grant PUSCH.

[00137] Figure 2 is a schematic flow chart diagram illustrating an embodiment of a method 200 according to the present application. In some embodiments, the method 200 is performed by an apparatus, such as a base unit. In certain embodiments, the method 200 may be performed by a processor executing program code, for example, a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[00138] The method 200 may comprise 202 transmitting a control message scheduling a PUSCH transmission having N layers to be transmitted by a first codeword and a second codeword, wherein, the control message includes a field that indicates the layers associated with the first codeword and the layers associated with the second codeword, wherein, N is 5, 6, 7 or 8; and 204 receiving the scheduled PUSCH transmission transmitted according to the control message.

[00139] Figure 3 is a schematic block diagram illustrating apparatuses according to one embodiment.

[00140] Referring to Figure 3, the UE (i.e. the remote unit) includes a processor, a memory, and a transceiver. The processor implements a function, a process, and/or a method which are proposed in Figure 1.

[00141] The UE comprises a transceiver; and a processor coupled to the transceiver, wherein the processor is configured to receive, via the transceiver, a control message scheduling a PUSCH transmission having N layers to be transmitted by a first codeword and a second codeword, wherein, the control message includes a field that indicates the layers associated with the first codeword and the layers associated with the second codeword, wherein, N is 5, 6, 7 or 8; and transmit, via the transceiver, the scheduled PUSCH transmission according to the control message.

[00142] The gNB (i.e. the base unit) includes a processor, a memory, and a transceiver. The processor implements a function, a process, and/or a method which are proposed in Figure 2.

[00143] The base unit comprises a transceiver; and a processor coupled to the transceiver, wherein the processor is configured to transmit, via the transceiver, a control message scheduling a PUSCH transmission having N layers to be transmitted by a first codeword and a second codeword, wherein, the control message includes a field that indicates the layers associated with

the first codeword and the layers associated with the second codeword, wherein, N is 5, 6, 7 or 8; and receive, via the transceiver, the scheduled PUSCH transmission transmitted according to the control message.

[00144] Layers of a radio interface protocol may be implemented by the processors. The memories are connected with the processors to store various pieces of information for driving the processors. The transceivers are connected with the processors to transmit and/or receive a radio signal. Needless to say, the transceiver may be implemented as a transmitter to transmit the radio signal and a receiver to receive the radio signal.

[00145] The memories may be positioned inside or outside the processors and connected with the processors by various well-known means.

[00146] In the embodiments described above, the components and the features of the embodiments are combined in a predetermined form. Each component or feature should be considered as an option unless otherwise expressly stated. Each component or feature may be implemented not to be associated with other components or features. Further, the embodiment may be configured by associating some components and/or features. The order of the operations described in the embodiments may be changed. Some components or features of any embodiment may be included in another embodiment or replaced with the component and the feature corresponding to another embodiment. It is apparent that the claims that are not expressly cited in the claims are combined to form an embodiment or be included in a new claim.

[00147] The embodiments may be implemented by hardware, firmware, software, or combinations thereof. In the case of implementation by hardware, according to hardware implementation, the exemplary embodiment described herein may be implemented by using one or more application-specific integrated circuits (ASICs), digital signal processors (DSPs), digital signal processing devices (DSPDs), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), processors, controllers, micro-controllers, microprocessors, and the like.

[00148] Embodiments may be practiced in other specific forms. The described embodiments are to be considered in all respects to be only illustrative and not restrictive. The scope of the invention is, therefore, indicated in the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

CLAIMS

1. A user equipment (UE), comprising:
a transceiver; and
a processor coupled to the transceiver, wherein the processor is configured to
receive, via the transceiver, a control message scheduling a PUSCH transmission having N layers to be transmitted by a first codeword and a second codeword, wherein, the control message includes a field that indicates the layers associated with the first codeword and the layers associated with the second codeword, wherein, N is 5, 6, 7 or 8; and
transmit, via the transceiver, the scheduled PUSCH transmission according to the control message.

2. The UE of claim 1, wherein,
the field is a transmission precoding matrix indicator (TPMI) field, and
a sub-field of the TPMI field signals the precoder to use from a set of precoders in a N-layer codebook.

3. The UE of claim 2, wherein,
different precoders in the N-layer codebook are different permutations of the same *N* transmission layers.

4. The UE of claim 3, wherein,
the different permutations allocate the same *N* transmission layers into a first group and a second group, and
the first group has $\lfloor N/2 \rfloor$ layers and the second group has $\lceil N/2 \rceil$ layers.

5. The UE of claim 4, wherein,
if a beam is used to transmit two layers with two different orthogonal cover codes, the two layers are in the same group.

6. The UE of claim 4, wherein,
if a beam is used to transmit only one layer with orthogonal cover code (+1,+1), the beam is always transmitted in the codeword having odd number of layers.

7. The UE of claim 3, wherein,
if a co-phasing factor is applied to the two different polarizations of the same beam, the co-phasing factor is unchanged when the layers are permutated in different precoders.

8. The UE of claim 3, wherein,
if an OCC code is applied to the two different polarizations of the same beam, the OCC code is unchanged as the layers are permutated in different precoders.

9. The UE of claim 3, wherein,
different pairs of layers transmitted by the same beam are split between the first codeword and the second codeword in different precoders.

10. The UE of claim 4, wherein,
the first pair of layers transmitted by the same beam are always in the first group, and the other pairs of layers transmitted by the same beam are in the first group in different precoders, respectively.

11. The UE of claim 1, wherein,
the field is a SRS resource indicator (SRI) field, and
the SRI field indicates the SRS resources to use in the first codeword and the second codeword from a SRS resource set.

12. The UE of claim 11, wherein,
the SRI field indicates the SRS resources to use in the first codeword and the SRS resources to use in the second codeword, respectively.

13. The UE of claim 12, wherein,
the SRS resources to use in the first codeword and the SRS resources to use in the second codeword have no SRS resource in common.

14. The UE of claim 11, wherein,
the SRI field indicates the SRS resources to use in both the first codeword and the second codeword and the SRS resources to use in one of the first codeword and the second codeword, respectively.

15. The UE of claim 11, wherein,
the SRI field indicates, for each SRS resource in the SRS resource set, one of a first state in which the SRS resource is to use in the first codeword, a second state in which the SRS resource is to use in the second codeword, and a third state in which the SRS resource is not used.

16. The UE of claim 11, wherein,
the processor is further configured to transmit, via the transceiver, SRS resources for non-codebook, and
the SRS resource set is determined from the SRS resources in a SRS resource set for non-codebook.

17. The UE of claim 1, wherein,
the control message is a DCI format 0_1 or 0_2 that schedule dynamically scheduled PUSCH or type 2 configured grant PUSCH.

18. The UE of claim 1, wherein,
the control message is a RRC message that schedules type 1 configured grant PUSCH.

19. A method performed at a user equipment (UE), comprising:
receiving a control message scheduling a PUSCH transmission having N layers to be transmitted by a first codeword and a second codeword, wherein, the control

message includes a field that indicates the layers associated with the first codeword and the layers associated with the second codeword, wherein, N is 5, 6, 7 or 8; and

transmitting the scheduled PUSCH transmission according to the control message.

20. A base unit, comprising:

a transceiver; and

a processor coupled to the transceiver, wherein the processor is configured to

transmit, via the transceiver, a control message scheduling a PUSCH transmission having N layers to be transmitted by a first codeword and a second codeword, wherein, the control message includes a field that indicates the layers associated with the first codeword and the layers associated with the second codeword, wherein, N is 5, 6, 7 or 8; and

receive, via the transceiver, the scheduled PUSCH transmission transmitted according to the control message.

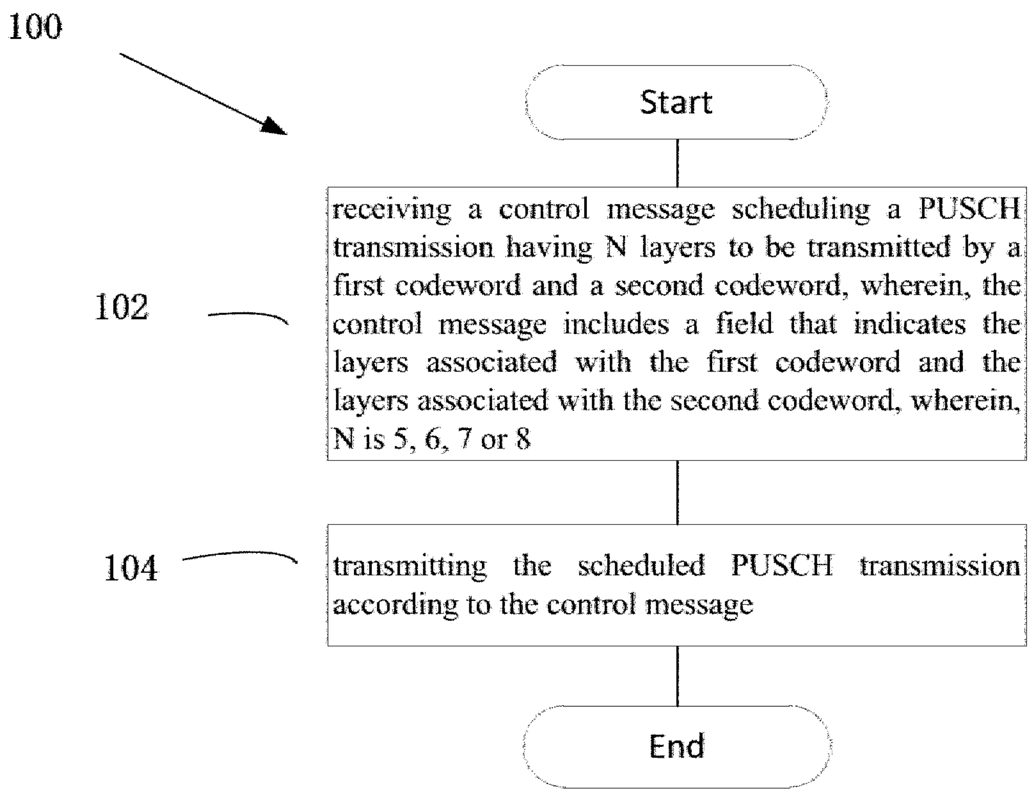
100
Start
102
receiving a control message scheduling a PUSCH transmission having N layers to be transmitted by a first codeword and a second codeword, wherein, the control message includes a field that indicates the layers associated with the first codeword and the layers associated with the second codeword, wherein, N is 5, 6, 7 or 8
104
transmitting the scheduled PUSCH transmission according to the control message
End

Figure 1

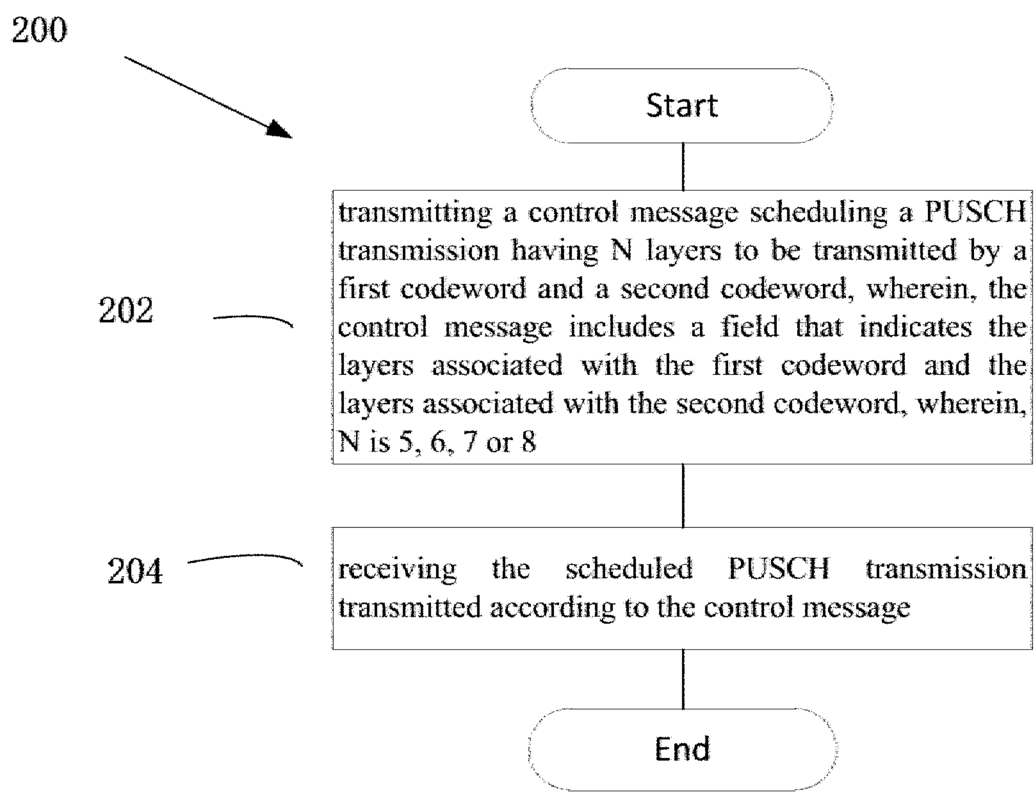

Figure 2

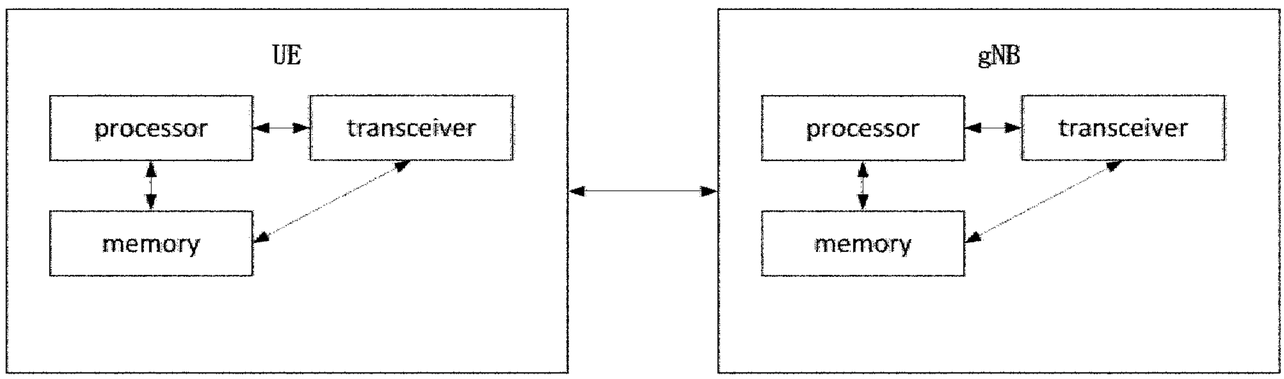

Figure 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/075863

A. CLASSIFICATION OF SUBJECT MATTER

H04W72/232(2023.01)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)

IPC: 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)

3GPP,CNTXT,ENTXT,DWPI,WPABS:pusch,first,second,codeword,associate,layer,schedule,sri,tpmi

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2023004062 A1 (INTEL CORPORATION) 26 January 2023 (2023-01-26) description, page 22 line 14 to page 32 line 27	1-20
X	CN 115191095 A (QUALCOMM INCORPORATED) 14 October 2022 (2022-10-14) description, paragraphs [0048]-[0099]	1-20
X	US 2023035992 A1 (APPLE INC.) 02 February 2023 (2023-02-02) description, paragraphs [0045]-[0079]	1-20
A	US 2020136867 A1 (HUAWEI TECHNOLOGIES CO., LTD.) 30 April 2020 (2020-04-30) the whole document	1-20
A	CN 110754058 A (IDAC HOLDINGS, INC.) 04 February 2020 (2020-02-04) the whole document	1-20
A	Nokia et al. "R1-1705952, On the number of codewords in NR" *3GPP TSG RAN WG1#88 bis*, 07 April 2017 (2017-04-07), the whole document	1-20

☐ 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
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 August 2023	**27 September 2023**

Name and mailing address of the ISA/CN	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2023/075863

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
WO	2023004062	A1	26 January 2023	None			
CN	115191095	A	14 October 2022	WO	2021184336	A1	23 September 2021
				EP	4122138	A1	25 January 2023
US	2023035992	A1	02 February 2023	WO	2023004646	A1	02 February 2023
				CN	116018761	A	25 April 2023
US	2020136867	A1	30 April 2020	EP	3697161	A1	19 August 2020
				WO	2019095334	A1	23 May 2019
				BR	112020009761	A2	03 November 2020
				WO	2019095478	A1	23 May 2019
				JP	2021503838	A	12 February 2021
				CA	3084547	A1	23 May 2019
				CN	111212480	A	29 May 2020
				CN	111212481	A	29 May 2020
CN	110754058	A	04 February 2020	EP	3639449	A1	22 April 2020
				RU	2020100055	A	09 July 2021
				US	2023188292	A1	15 June 2023
				WO	2018231626	A1	20 December 2018
				EP	4213433	A1	19 July 2023
				TW	201906383	A	01 February 2019
				JP	2020523909	A	06 August 2020
				US	2020213057	A1	02 July 2020