

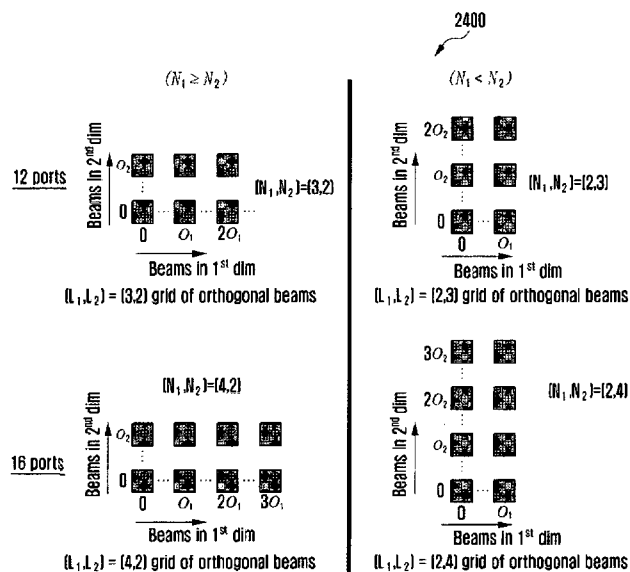


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[Continued on next page]

(54) Title: HIGHER RANK CODEBOOKS FOR ADVANCED WIRELESS COMMUNICATION SYSTEMS

[Figure 24]



(57) Abstract: A user equipment (UE) capable of communicating with a base station includes a plurality of antenna ports P, the UE includes a transceiver configured to receive downlink signals indicating precoder codebook parameters, the downlink signal including first and second quantities of antenna ports (N_1, N_2) indicating respective quantities of antenna ports in first and second dimensions, first and second oversampling factors (O_1, O_2) indicating respective oversampling factors for DFT beams in the first and second dimensions, and a codebook subset selection configuration among a plurality of codebook subset selection configurations, and a controller configured to determine first and second beam skip numbers (S_1, S_2) indicating respective differences of leading beam indices of two adjacent beam groups in the first and second dimensions, determine a plurality of precoding matrix indicators (PMIs) including a first PMI ($i_{1,1}, i_{1,2}$) and a second PMI i_2 , based on the received downlink signals and the skip numbers (S_1, S_2), and cause the transceiver to transmit uplink signals containing the plurality of PMIs to the base station.

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【DESCRIPTION】**【Invention Title】****HIGHER RANK CODEBOOKS FOR ADVANCED WIRELESS COMMUNICATION SYSTEMS****【Technical Field】**

[0001] The present disclosure relates generally to a codebook design and structure associated with a two dimensional transmit antenna array. Such two dimensional arrays are associated with a type of multiple-input-multiple-output (MIMO) system often termed “full-dimension” MIMO (FD-MIMO).

【Background Art】

[0002] Wireless communication has been one of the most successful innovations in modern history. Recently, the number of subscribers to wireless communication services exceeded five billion and continues to grow quickly. The demand of wireless data traffic is rapidly increasing due to the growing popularity among consumers and businesses of smart phones and other mobile data devices, such as tablets, “note pad” computers, net books, eBook readers, and machine type of devices. In order to meet the high growth in mobile data traffic and support new applications and deployments, improvements in radio interface efficiency and coverage is of paramount importance.

【Disclosure】**【Technical Problem】**

[0003] Therefore, an advanced codebook design for two dimensional transmit antenna array and transmission scheme using the two dimensional transmit antenna array are needed.

【Technical Solution】

[0004] The present disclosure relates to a pre-5th-Generation (5G) or 5G communication system to be provided for supporting higher data rates beyond 4th-Generation (4G) communication system such as Long Term Evolution (LTE).

[0005] In a first embodiment, a user equipment (UE) capable of communicating with a base station (BS) comprising a plurality of antenna ports P . The UE includes a transceiver configured to receive downlink signals indicating precoder codebook parameters, the downlink signal including

first and second quantities of antenna ports (N_1, N_2) indicating respective quantities of antenna ports in first and second dimensions, first and second oversampling factors (O_1, O_2) indicating respective oversampling factors for DFT beams in the first and second dimensions, and a codebook subset selection configuration among a plurality of codebook subset selection configurations, and a controller configured to determine first and second beam skip numbers (S_1, S_2) indicating respective differences of leading beam indices of two adjacent beam groups in the first and second dimensions, determine a plurality of precoding matrix indicators (PMIs) including a first PMI pair $(i_{1,1}, i_{1,2})$ and a second PMI i_2 , based on the received downlink signals and the skip numbers (S_1, S_2) , and cause the transceiver to transmit uplink signals containing the plurality of PMIs to the base station, wherein the skip numbers (S_1, S_2) for rank 3 and 4 are defined as: $(S_1, S_2) = (1, 1)$ when the codebook subset selection configuration is equal to 1; $(S_1, S_2) = \left(\frac{O_1}{2}, \frac{O_2}{2}\right)$ when the codebook subset selection configuration is equal to 2; $(S_1, S_2) = \left(O_1, \frac{O_2}{2}\right)$ when the codebook subset selection configuration is equal to 3; and $(S_1, S_2) = \left(O_1, \frac{O_2}{4}\right)$ for the codebook subset selection configuration being equal to 4, wherein the parameters (S_1, S_2) for rank 1 and 2 are defined as: $(S_1, S_2) = (1, 1)$ when the codebook subset selection configuration is equal to 1; and $(S_1, S_2) = (2, 2)$ when the codebook subset selection configuration is equal to 2, 3, and 4, wherein the parameters (S_1, S_2) for rank 5 to 8 are defined as: $(S_1, S_2) = (1, 1)$ when the codebook subset selection configuration is equal to 1; and $(S_1, S_2) = \left(\frac{O_1}{4}, \frac{O_2}{4}\right)$ when the codebook subset selection configuration is equal to 2, 3, and 4.

[0006] A base station (BS) comprising a plurality of antenna ports p , the BS includes a transmitter configured to transmit downlink signals indicating precoder codebook parameters, the downlink signal including first and second quantities of antenna ports (N_1, N_2) indicating respective quantities of antenna ports in first and second dimensions, first and second oversampling factors (O_1, O_2) indicating respective oversampling factors for DFT beams in the first and second dimensions, and a codebook subset selection configuration among a plurality of codebook subset

selection configurations, a receiver configured to receive a plurality of precoding matrix indicators (PMIs) including a first PMI pair $(i_{1,1}, i_{1,2})$ and a second PMI i_2 , determined based on the received downlink signals and skip numbers (S_1, S_2) , and a controller configured to determine a precoder to precoding a transmission signal based on the plurality of PMIs, wherein the skip numbers (S_1, S_2) for rank 3 and 4 are defined as: $(S_1, S_2) = (1, 1)$ when the codebook subset selection configuration is equal to 1; $(S_1, S_2) = \left(\frac{O_1}{2}, \frac{O_2}{2}\right)$ when the codebook subset selection configuration is equal to 2; $(S_1, S_2) = \left(O_1, \frac{O_2}{2}\right)$ when the codebook subset selection configuration is equal to 3; and $(S_1, S_2) = \left(O_1, \frac{O_2}{4}\right)$ for the codebook subset selection configuration being equal to 4, wherein the parameters (S_1, S_2) for rank 1 and 2 are defined as: $(S_1, S_2) = (1, 1)$ when the codebook subset selection configuration is equal to 1; and $(S_1, S_2) = (2, 2)$ when the codebook subset selection configuration is equal to 2, 3, and 4, wherein the parameters (S_1, S_2) for rank 5 to 8 are defined as: $(S_1, S_2) = (1, 1)$ when the codebook subset selection configuration is equal to 1; and

$(S_1, S_2) = \left(\frac{O_1}{4}, \frac{O_2}{4}\right)$ when the codebook subset selection configuration is equal to 2, 3, and 4.

【Advantageous Effects】

[0007] Embodiments of the present disclosure provide methods to provide an advanced codebook design for two dimensional transmit antenna array and enable efficient operations using two dimensional transmit antenna array.

【Description of Drawings】

[0008] For a more complete understanding of the present disclosure and its advantages, reference is now made to the following description taken in conjunction with the accompanying drawings, in which like reference numerals represent like parts:

[0009] FIGURE 1 illustrates an example wireless network according to this disclosure;

[0010] FIGURES 2A and 2B illustrate example wireless transmit and receive paths according to this disclosure;

[0011] FIGURE 3A illustrates an example user equipment according to this disclosure;

[0012] FIGURE 3B illustrates an example enhanced NodeB (eNB) according to this disclosure;

[0013] FIGURE 4 illustrates logical port to antenna port mapping 400 that may be employed within the wireless communication system according to some embodiments of the current disclosure;

[0014] FIGURE 5A illustrates a 4x4 dual-polarized antenna array 500 with antenna port (AP) indexing 1 and FIGURE 5B is the same 4x4 dual-polarized antenna array 510 with antenna port indexing (AP) indexing 2 according to embodiments of the present disclosure;

[0015] FIGURE 6 illustrates numbering of TX antenna elements (or TXRU) on a dual-polarized antenna array according to embodiments of the present disclosure;

[0016] Figure 7 illustrates beam grouping scheme, referred to as Scheme 1 according to embodiments of the present disclosure;

[0017] Figure 8 illustrates beam grouping scheme, referred to as Scheme 2 according to embodiments of the present disclosure;

[0018] Figure 9 illustrates beam grouping scheme, referred to as Scheme 3 according to embodiments of the present disclosure;

[0019] Figure 10 illustrates beam group type 1: co-phase orthogonality according to embodiments of the present disclosure;

[0020] Figure 11 illustrates an illustration of beam group type 2: horizontal beam orthogonality according to embodiments of the present disclosure;

[0021] Figure 12 illustrates an illustration of beam group type 3: vertical beam orthogonality according to embodiments of the present disclosure;

[0022] Figure 13 illustrates beam group type 4: both horizontal and vertical beam orthogonality;

[0023] Figure 14 illustrates subset restriction on rank-1 i_2 according to the embodiments of the present disclosure;

[0024] Figure 15 illustrates example beam indices in a beam group for the three beam grouping schemes 1500 according to the embodiments of the present disclosure;

[0025] Figure 16 illustrates different alternatives for remaining four rank 2 beam pairs for $(L_1, L_2) = (2, 2)$ according to the embodiments of the present disclosure;

[0026] Figure 17 illustrates total rank-2 beam pair combinations with 16 beams per layer according to embodiments of the present disclosure;

[0027] Figure 18 illustrates rank-2 beam pair combinations obtained with extension of Rel-10 8-Tx design to 2D according to embodiments of the present disclosure;

[0028] Figure 19 illustrates a method to construct rank-2 master codebook according to some embodiments of the present disclosure;

[0029] Figures 20A to 20D illustrates antenna configurations and antenna numbering according to some embodiments of the present disclosure;

[0030] Figure 21 illustrates that a precoder codebook construction according to some embodiments of the present disclosure;

[0031] Figure 22 illustrates an example 1D antenna configurations and antenna numbering – 16 port according to embodiments of the present disclosure;

[0032] Figure 23 illustrates an example 1D antenna configurations and antenna numbering– 12 port according to embodiments of the present disclosure;

[0033] Figure 24 illustrates the master beam group for 12 and 16 ports according to some embodiments of the present disclosure;

[0034] Figure 25 illustrates beam grouping schemes for rank 3-8 according to some embodiments of the present disclosure;

[0035] Figure 26 illustrates example beam grouping schemes for rank 3-4 according to some embodiments of the present disclosure;

[0036] Figure 27 illustrates example beam grouping schemes for rank 3-4 according to some embodiments of the present disclosure;

[0037] Figure 28 illustrates beam grouping schemes for rank 3-4 according to some embodiments of the present disclosure;

[0038] Figure 29 illustrates example rank 3-4 orthogonal beam pairs for 2 antenna ports in shorter dimension according to some embodiments of the present disclosure;

[0039] Figure 30 illustrates beam grouping schemes for rank 3-4: $N_1 \geq N_2$ case according to some embodiments of the present disclosure;

[0040] Figure 31 illustrates rank 3-4 orthogonal beam pairs for $N_2 \geq 4$ antenna ports in shorter dimension according to some embodiments of the present disclosure;

[0041] Figure 32 illustrates rank 5-8 orthogonal beam combinations for $(N_1, N_2) = (4, 2)$ according to some embodiments of the present disclosure;

[0042] Figure 33 illustrates rank 5-8 orthogonal beam combinations for $(N_1, N_2) = (3, 2)$ according to some embodiments of the present disclosure;

[0043] Figure 34 illustrates the rank 3-4 master codebook comprising W1 beam groups according to some embodiments of the present disclosure;

[0044] Figure 35 illustrates beam grouping schemes for rank 3-4 according to embodiments of the present disclosure;

[0045] Figures 36A and 36B illustrate beam grouping schemes for rank 3-4 according to embodiments of the present disclosure;

[0046] Figure 37 illustrates an alternate rank 3-8 codebook design 1 3700: $(L_1, L_2) = (4, 2)$ according to embodiments of the present disclosure;

[0047] Figure 38 illustrates an alternate rank 3-8 codebook design 2 3800: $(L_1, L_2) = (4, 1)$ according to embodiments of the present disclosure;

[0048] Figure 39 illustrates an alternate rank 3-8 codebook design 3 3900: $(L_1, L_2) = (2, 2)$ according to embodiments of the present disclosure;

[0049] Figure 40 illustrates an alternate rank 3-8 codebook design 4 4000 : $(L_1, L_2) = (2, 1)$ according to embodiments of the present disclosure;

[0050] Figure 41 illustrates example orthogonal beams for rank 3-4 when $k = 0$ according to some embodiments of the present disclosure;

[0051] Figure 42 illustrates alternate rank 5-6 orthogonal beam types 4200 according to embodiments of the present disclosure;

[0052] Figure 43 illustrates an alternate rank 7-8 orthogonal beam types according to embodiments of the present disclosure;

[0053] Figure 44 illustrates three example orthogonal-beam groups 4400, indexed by $k = 0, 1, 2$ for rank 3-4 according to some embodiments of the present disclosure;

[0054] Figure 45 illustrates example orthogonal beams 4500 for rank 3-4 when $k = 0$ according to some embodiments of the present disclosure;

[0055] Figure 46 illustrates orthogonal beam grouping 4600 for rank 5-8: 16 ports according to some embodiments of the present disclosure;

[0056] Figure 47 illustrates example orthogonal beam grouping for rank 5-8: 12 ports according to embodiments of the present disclosure;

[0057] Figure 48 illustrates example orthogonal beam grouping for rank 5-8: 8 ports according to embodiments of the present disclosure;

[0058] Figure 49 illustrates an example of orthogonal beam group for 1D port layout according to embodiments of the present disclosure;

[0059] Figure 50 illustrates an example of orthogonal beam group for 1D port layout according to embodiments of the present disclosure;

[0060] Figure 51 illustrates an example of orthogonal beam group 5100 for 1D port layout according to embodiments of the present disclosure;

[0061] Figure 52 illustrates an example of orthogonal beam group 5200 for 1D port layout according to embodiments of the present disclosure;

[0062] Figures 53A and 53B illustrate an alternate rank 3-8 codebook design 1: $(L_1, L_2) = (4, 2)$ according to embodiments of the present disclosure;

[0063] Figure 54 illustrates an alternate rank 3-8 codebook design 2: $(L_1, L_2) = (4, 1)$ according to embodiments of the present disclosure;

[0064] Figures 55A and 55B illustrate an alternate rank 3-8 codebook design 3: $(L_1, L_2) = (2, 2)$ according to embodiments of the present disclosure; and

[0065] Figures 56A and 56B illustrate an alternate rank 3-8 codebook design 4: $(L_1, L_2) = (2, 1)$ according to embodiments of the present disclosure.

[0066] Figure 57 illustrates Table 9.

[0067] Figure 58 illustrates Table 10.

[0068] Figure 59A illustrates Table 11-1, Figure 59B illustrates Table 11-2, and Figure 59C illustrates Table 11-3.

[0069] Figure 60A illustrates Table 12-1, Figure 60B illustrates Table 12-2, Figure 60C illustrates Table 12-3, and Figure 60D illustrates Table 12-4.

[0070] Figure 61A illustrates Table 13-1, Figure 61B illustrates Table 13-2, Figure 61C illustrates Table 13-3, and Figure 61D illustrates Table 13-4.

[0071] Figure 62A illustrates Table 14-1.

[0072] Figure 62B illustrates Table 14-2.

[0073] Figure 62C illustrates Table 14-3.

[0074] Figure 62D illustrates Table 14-4.

[0075] Figure 63A illustrates Table 15-1, Figure 63B illustrates Table 15-2, Figure 63C illustrates Table 15-3, and Figure 63D illustrates Table 15-4.

[0076] Figures 64A, 64B and 64C illustrate Table 19.

[0077] Figures 65A and 65B illustrate Table 20.

[0078] Figure 66 illustrates Table 21.

[0079] Figure 67 illustrates Table 25.

[0080] Figures 68A and 68B illustrate Table 29.

- [0081] Figure 69 illustrates Table 32.
- [0082] Figure 70 illustrates Table 35.
- [0083] Figure 71 illustrates Table 36.
- [0084] Figure 72 illustrates Table 43.
- [0085] Figure 73 illustrates Table 44.
- [0086] Figure 74 illustrates Table 48.
- [0087] Figure 75 illustrates Table 49.
- [0088] Figure 76 illustrates Table 56.
- [0089] Figure 77 illustrates Table 57.
- [0090] Figure 78 illustrates Table 59.
- [0091] Figure 79 illustrates Table 60.
- [0092] Figure 80 illustrates Table 62.
- [0093] Figure 81 illustrates Table 63.
- [0094] Figure 82 illustrates Table 66.
- [0095] Figure 83 illustrates Table 67.
- [0096] Figures 84A and 84B illustrate Table 77
- [0097] Figure 85 illustrates Table 79.
- [0098] Figure 86 illustrates Table 80.
- [0099] Figure 87A illustrates Table 87-1.
- [0100] Figure 87B illustrates Table 87-2.
- [0101] Figure 87C illustrates Table 87-3.
- [0102] Figure 87D illustrates Table 87-4.
- [0103] Figure 88A illustrates Table 88-1.
- [0104] Figure 88B illustrates Table 88-2.
- [0105] Figure 88C illustrates Table 88-3.
- [0106] Figure 88D illustrates Table 88-4.
- [0107] Figure 89A illustrates Table 89-1
- [0108] Figure 89B illustrates Table 89-2.
- [0109] Figure 89C illustrates Table 89-3.
- [0110] Figure 89D illustrates Table 89-4.
- [0111] Figure 89E illustrates Table 89-5.
- [0112] Figure 90A illustrates Table 90-1.
- [0113] Figure 90B illustrates Table 90-2.

- [0114] Figure 90C illustrates Table 90-3.
- [0115] Figure 90D illustrates Table 90-4.
- [0116] Figure 90E illustrates Table 90-5.
- [0117] Figure 90F illustrates Table 90-6.
- [0118] Figure 91A illustrates Table 91-1.
- [0119] Figure 91B illustrates Table 91-2.
- [0120] Figure 91C illustrates Table 91-3.
- [0121] Figure 91D illustrates Table 91-4.
- [0122] Figure 92A illustrates Table 92-1.
- [0123] Figure 92B illustrates Table 92-2.
- [0124] Figure 92C illustrates Table 92-3.
- [0125] Figure 92D illustrates Table 92-4.
- [0126] Figure 93A illustrates Table 93-1.
- [0127] Figure 93B illustrates Table 93-2.
- [0128] Figure 93C illustrates Table 93-3.
- [0129] Figure 93D illustrates Table 93-4.
- [0130] Figure 93E illustrates Table 93-5.
- [0131] Figure 94A illustrates Table 94-1.
- [0132] Figure 94B illustrates Table 94-2.
- [0133] Figure 94C illustrates Table 94-3.
- [0134] Figure 94D illustrates Table 94-4.
- [0135] Figure 94E illustrates Table 94-5.
- [0136] Figure 95A illustrates Table 95-1.
- [0137] Figure 95B illustrates Table 95-2.
- [0138] Figure 95C illustrates Table 95-2.
- [0139] Figure 95D illustrates Table 95-3.
- [0140] Figure 96A illustrates Table 96-1.
- [0141] Figure 96B illustrates Table 96-2.
- [0142] Figure 96C illustrates Table 96-3.
- [0143] Figure 96D illustrates Table 96-4.
- [0144] Figure 97A illustrates Table 97-1.
- [0145] Figure 97B illustrates Table 97-2.
- [0146] Figure 97C illustrates Table 97-3.

[0147] Figures 97D, 97E and 97F illustrate Table 97-4.

[0148] Figure 98A illustrates Table 98-1.

[0149] Figure 98B illustrates Table 98-2.

[0150] Figure 98C illustrates Table 98-3.

[0151] Figures 98D, 98E and 98F illustrate Table 98-4.

[0152] Figures 99A and 99B illustrate Table 99.

[0153] Figures 100A and 100B illustrate Table 100.

[0154] Figures 101A, 101B, 101C and 101D illustrate Table 101.

[0155] Figures 102A, 102B, 102C and 102D illustrate Table 102.

【Mode for Invention】

[0156] Figures 1 through 56, discussed below, and the various embodiments used to describe the principles of the present disclosure in this patent document are by way of illustration only and should not be construed in any way to limit the scope of the disclosure. Those skilled in the art will understand that the principles of the present disclosure may be implemented in any suitably arranged wireless communication system.

[0157] The following documents and standards descriptions are hereby incorporated by reference into the present disclosure as if fully set forth herein: (1) 3rd generation partnership project 3GPP TS 36.211, “E-UTRA, Physical channels and modulation”, Release-12; (2) 3GPP TS 36.212, “E-UTRA, Multiplexing and channel coding”, Release-12; and (3) 3GPP TS 36.213, “E-UTRA, Physical layer procedures”, Release-12.

[0158] To meet the demand for wireless data traffic having increased since deployment of 4G communication systems, efforts have been made to develop an improved 5G or pre-5G communication system. Therefore, the 5G or pre-5G communication system is also called a ‘Beyond 4G Network’ or a ‘Post LTE System’.

[0159] The 5G communication system is considered to be implemented in higher frequency (mmWave) bands, e.g., 60GHz bands, so as to accomplish higher data rates. To decrease propagation loss of the radio waves and increase the transmission distance, the beamforming, massive multiple-input multiple-output (MIMO), Full Dimensional MIMO (FD-MIMO), array antenna, an analog beam forming, large scale antenna techniques are discussed in 5G communication systems.

[0160] In addition, in 5G communication systems, development for system network improvement is under way based on advanced small cells, cloud Radio Access Networks (RANs), ultra-dense networks, device-to-device (D2D) communication, wireless backhaul, moving network, cooperative communication, Coordinated Multi-Points (CoMP), reception-end interference cancellation and the like.

[0161] In the 5G system, Hybrid FSK and QAM Modulation (FQAM) and sliding window superposition coding (SWSC) as an advanced coding modulation (ACM), and filter bank multi carrier(FBMC), non-orthogonal multiple access(NOMA), and sparse code multiple access (SCMA) as an advanced access technology have been developed.

[0162] FIGURE 1 illustrates an example wireless network 100 according to this disclosure. The embodiment of the wireless network 100 shown in FIGURE 1 is for illustration only. Other embodiments of the wireless network 100 could be used without departing from the scope of this disclosure.

[0163] The wireless network 100 includes an eNodeB (eNB) 101, an eNB 102, and an eNB 103. The eNB 101 communicates with the eNB 102 and the eNB 103. The eNB 101 also communicates with at least one Internet Protocol (IP) network 130, such as the Internet, a proprietary IP network, or other data network.

[0164] Depending on the network type, other well-known terms may be used instead of “eNodeB” or “eNB,” such as “base station” or “access point.” For the sake of convenience, the terms “eNodeB” and “eNB” are used in this patent document to refer to network infrastructure components that provide wireless access to remote terminals. Also, depending on the network type, other well-known terms may be used instead of “user equipment” or “UE,” such as “mobile station,” “subscriber station,” “remote terminal,” “wireless terminal,” or “user device.” For the sake of convenience, the terms “user equipment” and “UE” are used in this patent document to refer to remote wireless equipment that wirelessly accesses an eNB, whether the UE is a mobile device (such as a mobile telephone or smartphone) or is normally considered a stationary device (such as a desktop computer or vending machine).

[0165] The eNB 102 provides wireless broadband access to the network 130 for a first plurality of user equipments (UEs) within a coverage area 120 of the eNB 102. The first plurality of UEs includes a UE 111, which may be located in a small business (SB); a UE 112, which may be located in an enterprise (E); a UE 113, which may be located in a WiFi hotspot (HS); a UE 114, which may be located in a first residence (R); a UE 115, which may be located in a second residence (R); and a UE 116, which may be a mobile device (M) like a cell phone, a wireless laptop,

a wireless PDA, or the like. The eNB 103 provides wireless broadband access to the network 130 for a second plurality of UEs within a coverage area 125 of the eNB 103. The second plurality of UEs includes the UE 115 and the UE 116. In some embodiments, one or more of the eNBs 101-103 may communicate with each other and with the UEs 111-116 using 5G, long-term evolution (LTE), LTE-A, WiMAX, or other advanced wireless communication techniques.

[0166] Dotted lines show the approximate extents of the coverage areas 120 and 125, which are shown as approximately circular for the purposes of illustration and explanation only. It should be clearly understood that the coverage areas associated with eNBs, such as the coverage areas 120 and 125, may have other shapes, including irregular shapes, depending upon the configuration of the eNBs and variations in the radio environment associated with natural and man-made obstructions.

[0167] As described in more detail below, one or more of BS 101, BS 102 and BS 103 include 2D antenna arrays as described in embodiments of the present disclosure. In some embodiments, one or more of BS 101, BS 102 and BS 103 support the codebook design and structure for systems having 2D antenna arrays.

[0168] Although FIGURE 1 illustrates one example of a wireless network 100, various changes may be made to FIGURE 1. For example, the wireless network 100 could include any number of eNBs and any number of UEs in any suitable arrangement. Also, the eNB 101 could communicate directly with any number of UEs and provide those UEs with wireless broadband access to the network 130. Similarly, each eNB 102-103 could communicate directly with the network 130 and provide UEs with direct wireless broadband access to the network 130. Further, the eNB 101, 102, and/or 103 could provide access to other or additional external networks, such as external telephone networks or other types of data networks.

[0169] FIGURES 2A and 2B illustrate example wireless transmit and receive paths according to this disclosure. In the following description, a transmit path 200 may be described as being implemented in an eNB (such as eNB 102), while a receive path 250 may be described as being implemented in a UE (such as UE 116). However, it will be understood that the receive path 250 could be implemented in an eNB and that the transmit path 200 could be implemented in a UE. In some embodiments, the receive path 250 is configured to support the codebook design and structure for systems having 2D antenna arrays as described in embodiments of the present disclosure.

[0170] The transmit path 200 includes a channel coding and modulation block 205, a serial-to-parallel (S-to-P) block 210, a size N Inverse Fast Fourier Transform (IFFT) block 215, a

parallel-to-serial (P-to-S) block 220, an add cyclic prefix block 225, and an up-converter (UC) 230. The receive path 250 includes a down-converter (DC) 255, a remove cyclic prefix block 260, a serial-to-parallel (S-to-P) block 265, a size N Fast Fourier Transform (FFT) block 270, a parallel-to-serial (P-to-S) block 275, and a channel decoding and demodulation block 280.

[0171] In the transmit path 200, the channel coding and modulation block 205 receives a set of information bits, applies coding (such as a low-density parity check (LDPC) coding), and modulates the input bits (such as with Quadrature Phase Shift Keying (QPSK) or Quadrature Amplitude Modulation (QAM)) to generate a sequence of frequency-domain modulation symbols. The serial-to-parallel block 210 converts (such as de-multiplexes) the serial modulated symbols to parallel data in order to generate N parallel symbol streams, where N is the IFFT/FFT size used in the eNB 102 and the UE 116. The size N IFFT block 215 performs an IFFT operation on the N parallel symbol streams to generate time-domain output signals. The parallel-to-serial block 220 converts (such as multiplexes) the parallel time-domain output symbols from the size N IFFT block 215 in order to generate a serial time-domain signal. The add cyclic prefix block 225 inserts a cyclic prefix to the time-domain signal. The up-converter 230 modulates (such as up-converts) the output of the add cyclic prefix block 225 to an RF frequency for transmission via a wireless channel. The signal may also be filtered at baseband before conversion to the RF frequency.

[0172] A transmitted RF signal from the eNB 102 arrives at the UE 116 after passing through the wireless channel, and reverse operations to those at the eNB 102 are performed at the UE 116. The down-converter 255 down-converts the received signal to a baseband frequency, and the remove cyclic prefix block 260 removes the cyclic prefix to generate a serial time-domain baseband signal. The serial-to-parallel block 265 converts the time-domain baseband signal to parallel time domain signals. The size N FFT block 270 performs an FFT algorithm to generate N parallel frequency-domain signals. The parallel-to-serial block 275 converts the parallel frequency-domain signals to a sequence of modulated data symbols. The channel decoding and demodulation block 280 demodulates and decodes the modulated symbols to recover the original input data stream.

[0173] Each of the eNBs 101-103 may implement a transmit path 200 that is analogous to transmitting in the downlink to UEs 111-116 and may implement a receive path 250 that is analogous to receiving in the uplink from UEs 111-116. Similarly, each of UEs 111-116 may implement a transmit path 200 for transmitting in the uplink to eNBs 101-103 and may implement a receive path 250 for receiving in the downlink from eNBs 101-103.

[0174] Each of the components in FIGURES 2A and 2B can be implemented using only hardware or using a combination of hardware and software/firmware. As a particular example, at least some

of the components in FIGURES 2A and 2B may be implemented in software, while other components may be implemented by configurable hardware or a mixture of software and configurable hardware. For instance, the FFT block 270 and the IFFT block 215 may be implemented as configurable software algorithms, where the value of size N may be modified according to the implementation.

[0175] Furthermore, although described as using FFT and IFFT, this is by way of illustration only and should not be construed to limit the scope of this disclosure. Other types of transforms, such as Discrete Fourier Transform (DFT) and Inverse Discrete Fourier Transform (IDFT) functions, could be used. It will be appreciated that the value of the variable N may be any integer number (such as 1, 2, 3, 4, or the like) for DFT and IDFT functions, while the value of the variable N may be any integer number that is a power of two (such as 1, 2, 4, 8, 16, or the like) for FFT and IFFT functions.

[0176] Although FIGURES 2A and 2B illustrate examples of wireless transmit and receive paths, various changes may be made to FIGURES 2A and 2B. For example, various components in FIGURES 2A and 2B could be combined, further subdivided, or omitted and additional components could be added according to particular needs. Also, FIGURES 2A and 2B are meant to illustrate examples of the types of transmit and receive paths that could be used in a wireless network. Any other suitable architectures could be used to support wireless communications in a wireless network.

[0177] FIGURE 3A illustrates an example UE 116 according to this disclosure. The embodiment of the UE 116 illustrated in FIGURE 3A is for illustration only, and the UEs 111-115 of FIGURE 1 could have the same or similar configuration. However, UEs come in a wide variety of configurations, and FIGURE 3A does not limit the scope of this disclosure to any particular implementation of a UE.

[0178] The UE 116 includes an antenna 305, a radio frequency (RF) transceiver 310, transmit (TX) processing circuitry 315, a microphone 320, and receive (RX) processing circuitry 325. The UE 116 also includes a speaker 330, a main processor 340, an input/output (I/O) interface (IF) 345, a keypad 350, a display 355, and a memory 360. The memory 360 includes a basic operating system (OS) program 361 and one or more applications 362.

[0179] The RF transceiver 310 receives, from the antenna 305, an incoming RF signal transmitted by an eNB of the network 100. The RF transceiver 310 down-converts the incoming RF signal to generate an intermediate frequency (IF) or baseband signal. The IF or baseband signal is sent to the RX processing circuitry 325, which generates a processed baseband signal by filtering, decoding,

and/or digitizing the baseband or IF signal. The RX processing circuitry 325 transmits the processed baseband signal to the speaker 330 (such as for voice data) or to the main processor 340 for further processing (such as for web browsing data).

[0180] The TX processing circuitry 315 receives analog or digital voice data from the microphone 320 or other outgoing baseband data (such as web data, e-mail, or interactive video game data) from the main processor 340. The TX processing circuitry 315 encodes, multiplexes, and/or digitizes the outgoing baseband data to generate a processed baseband or IF signal. The RF transceiver 310 receives the outgoing processed baseband or IF signal from the TX processing circuitry 315 and up-converts the baseband or IF signal to an RF signal that is transmitted via the antenna 305.

[0181] The main processor 340 can include one or more processors or other processing devices and execute the basic OS program 361 stored in the memory 360 in order to control the overall operation of the UE 116. For example, the main processor 340 could control the reception of forward channel signals and the transmission of reverse channel signals by the RF transceiver 310, the RX processing circuitry 325, and the TX processing circuitry 315 in accordance with well-known principles. In some embodiments, the main processor 340 includes at least one microprocessor or microcontroller.

[0182] The main processor 340 is also capable of executing other processes and programs resident in the memory 360, such as operations for channel quality measurement and reporting for systems having 2D antenna arrays as described in embodiments of the present disclosure as described in embodiments of the present disclosure. The main processor 340 can move data into or out of the memory 360 as required by an executing process. In some embodiments, the main processor 340 is configured to execute the applications 362 based on the OS program 361 or in response to signals received from eNBs or an operator. The main processor 340 is also coupled to the I/O interface 345, which provides the UE 116 with the ability to connect to other devices such as laptop computers and handheld computers. The I/O interface 345 is the communication path between these accessories and the main controller 340.

[0183] The main processor 340 is also coupled to the keypad 350 and the display unit 355. The operator of the UE 116 can use the keypad 350 to enter data into the UE 116. The display 355 may be a liquid crystal display or other display capable of rendering text and/or at least limited graphics, such as from web sites.

[0184] The memory 360 is coupled to the main processor 340. Part of the memory 360 could include a random access memory (RAM), and another part of the memory 360 could include a Flash memory or other read-only memory (ROM).

[0185] Although FIGURE 3A illustrates one example of UE 116, various changes may be made to FIGURE 3A. For example, various components in FIGURE 3A could be combined, further subdivided, or omitted and additional components could be added according to particular needs. As a particular example, the main processor 340 could be divided into multiple processors, such as one or more central processing units (CPUs) and one or more graphics processing units (GPUs). Also, while FIGURE 3A illustrates the UE 116 configured as a mobile telephone or smartphone, UEs could be configured to operate as other types of mobile or stationary devices.

[0186] FIGURE 3B illustrates an example eNB 102 according to this disclosure. The embodiment of the eNB 102 shown in FIGURE 3B is for illustration only, and other eNBs of FIGURE 1 could have the same or similar configuration. However, eNBs come in a wide variety of configurations, and FIGURE 3B does not limit the scope of this disclosure to any particular implementation of an eNB. It is noted that eNB 101 and eNB 103 can include the same or similar structure as eNB 102.

[0187] As shown in FIGURE 3B, the eNB 102 includes multiple antennas 370a-370n, multiple RF transceivers 372a-372n, transmit (TX) processing circuitry 374, and receive (RX) processing circuitry 376. In certain embodiments, one or more of the multiple antennas 370a-370n include 2D antenna arrays. The eNB 102 also includes a controller/processor 378, a memory 380, and a backhaul or network interface 382.

[0188] The RF transceivers 372a-372n receive, from the antennas 370a-370n, incoming RF signals, such as signals transmitted by UEs or other eNBs. The RF transceivers 372a-372n down-convert the incoming RF signals to generate IF or baseband signals. The IF or baseband signals are sent to the RX processing circuitry 376, which generates processed baseband signals by filtering, decoding, and/or digitizing the baseband or IF signals. The RX processing circuitry 376 transmits the processed baseband signals to the controller/processor 378 for further processing.

[0189] The TX processing circuitry 374 receives analog or digital data (such as voice data, web data, e-mail, or interactive video game data) from the controller/processor 378. The TX processing circuitry 374 encodes, multiplexes, and/or digitizes the outgoing baseband data to generate processed baseband or IF signals. The RF transceivers 372a-372n receive the outgoing processed baseband or IF signals from the TX processing circuitry 374 and up-converts the baseband or IF signals to RF signals that are transmitted via the antennas 370a-370n.

[0190] The controller/processor 378 can include one or more processors or other processing devices that control the overall operation of the eNB 102. For example, the controller/processor 378 could control the reception of forward channel signals and the transmission of reverse channel signals by the RF transceivers 372a-372n, the RX processing circuitry 376, and the TX processing circuitry 374 in accordance with well-known principles. The controller/processor 378 could support additional functions as well, such as more advanced wireless communication functions. For instance, the controller/processor 378 can perform the blind interference sensing (BIS) process, such as performed by a BIS algorithm, and decodes the received signal subtracted by the interfering signals. Any of a wide variety of other functions could be supported in the eNB 102 by the controller/processor 378. In some embodiments, the controller/processor 378 includes at least one microprocessor or microcontroller.

[0191] The controller/processor 378 is also capable of executing programs and other processes resident in the memory 380, such as a basic OS. The controller/processor 378 is also capable of supporting channel quality measurement and reporting for systems having 2D antenna arrays as described in embodiments of the present disclosure. In some embodiments, the controller/processor 378 supports communications between entities, such as web RTC. The controller/processor 378 can move data into or out of the memory 380 as required by an executing process.

[0192] The controller/processor 378 is also coupled to the backhaul or network interface 382. The backhaul or network interface 382 allows the eNB 102 to communicate with other devices or systems over a backhaul connection or over a network. The interface 382 could support communications over any suitable wired or wireless connection(s). For example, when the eNB 102 is implemented as part of a cellular communication system (such as one supporting 5G, LTE, or LTE-A), the interface 382 could allow the eNB 102 to communicate with other eNBs over a wired or wireless backhaul connection. When the eNB 102 is implemented as an access point, the interface 382 could allow the eNB 102 to communicate over a wired or wireless local area network or over a wired or wireless connection to a larger network (such as the Internet). The interface 382 includes any suitable structure supporting communications over a wired or wireless connection, such as an Ethernet or RF transceiver.

[0193] The memory 380 is coupled to the controller/processor 378. Part of the memory 380 could include a RAM, and another part of the memory 380 could include a Flash memory or other ROM. In certain embodiments, a plurality of instructions, such as a BIS algorithm is stored in memory. The plurality of instructions are configured to cause the controller/processor 378 to perform the

BIS process and to decode a received signal after subtracting out at least one interfering signal determined by the BIS algorithm.

[0194] As described in more detail below, the transmit and receive paths of the eNB 102 (implemented using the RF transceivers 372a-372n, TX processing circuitry 374, and/or RX processing circuitry 376) support communication with aggregation of FDD cells and TDD cells.

[0195] Although FIGURE 3B illustrates one example of an eNB 102, various changes may be made to FIGURE 3B. For example, the eNB 102 could include any number of each component shown in FIGURE 3. As a particular example, an access point could include a number of interfaces 382, and the controller/processor 378 could support routing functions to route data between different network addresses. As another particular example, while shown as including a single instance of TX processing circuitry 374 and a single instance of RX processing circuitry 376, the eNB 102 could include multiple instances of each (such as one per RF transceiver).

[0196] Logical Port To Antenna Port Mapping

[0197] FIGURE 4 illustrates logical port to antenna port mapping 400 that may be employed within the wireless communication system according to some embodiments of the current disclosure. The embodiment of the port mapping illustrated in FIGURE 4 is for illustration only. However, port mappings come in a wide variety of configurations, and FIGURE 4 does not limit the scope of this disclosure to any particular implementation of a port mapping.

[0198] FIGURE 4 illustrates logical port to antenna port mapping 400, according to some embodiments of the current disclosure. In the figure, Tx signals on each logical port is fed into an antenna virtualization matrix (e.g., of a size $M \times 1$), output signals of which are fed into a set of M physical antenna ports. In some embodiments, M corresponds to a total number or quantity of antenna elements on a substantially vertical axis. In some embodiments, M corresponds to a ratio of a total number or quantity of antenna elements to S , on a substantially vertical axis, wherein M and S are chosen to be a positive integer.

[0199] FIGURE 5A illustrates a 4x4 dual-polarized antenna array 500 with antenna port (AP) indexing 1 and FIGURE 5B is the same 4x4 dual-polarized antenna array 510 with antenna port indexing (AP) indexing 2.

[0200] In certain embodiments, each labelled antenna element is logically mapped onto a single antenna port. In general, one antenna port can correspond to multiple antenna elements (physical antennas) combined via a virtualization. This 4x4 dual polarized array can then be viewed as $16 \times 2 = 32$ -element array of elements. The vertical dimension (consisting of 4 rows) facilitates elevation beamforming in addition to the azimuthal beamforming across the horizontal dimension

(consisting of 4 columns of dual polarized antennas). MIMO precoding in Rel.12 LTE standardization (per TS36.211 sections 6.3.4.2 and 6.3.4.4; and TS36.213 section 7.2.4) was largely designed to offer a precoding gain for one-dimensional antenna array. While fixed beamforming (i.e. antenna virtualization) can be implemented across the elevation dimension, it is unable to reap the potential gain offered by the spatial and frequency selective nature of the channel.

[0201] FIGURE 6 illustrates another numbering of TX antenna elements (or TXRU) on a dual-polarized antenna array 600 according to embodiments of the present disclosure. The embodiment shown in FIGURE 6 is for illustration only. Other embodiments could be used without departing from the scope of the present disclosure.

[0202] In certain embodiments, eNB is equipped with 2D rectangular antenna array (or TXRUs), comprising M rows and N columns with $P=2$ polarized, wherein each element (or TXRU) is indexed with (m, n, p) , and $m = 0, \dots, M-1, n = 0, \dots, N-1, p = 0, \dots, P-1$, as illustrated in FIGURE 6 with $M=N=4$. When the example shown in FIGURE 6 represents a TXRU array, a TXRU can be associated with multiple antenna elements. In one example (1-dimensional (1D) subarray partition), an antenna array comprising a column with a same polarization of a 2D rectangular array is partitioned into M groups of consecutive elements, and the M groups correspond to the M TXRUs in a column with a same polarization in the TXRU array in FIGURE 6. In later embodiments, (M, N) is sometimes denoted as (N_H, N_V) or (N_1, N_2) .

[0203] In some embodiments, a UE is configured with a CSI-RS resource comprising $Q=MNP$ number of CSI-RS ports, wherein the CSI-RS resource is associated with MNP number of resource elements (REs) in a pair of PRBs in a subframe.

[0204] A UE is configured with a CSI-RS configuration via higher layer, configuring Q antenna ports – antenna ports A(1) through A(Q). The UE is further configured with CSI reporting configuration via higher layer in association with the CSI-RS configuration. The CSI reporting configuration includes information element (IE) indicating the CSI-RS decomposition information (or component PMI port configuration). The information element may comprise at least two integers, say N_1 and N_2 , which respectively indicates a first number of antenna ports for a first dimension, and a second number of antenna ports for a second dimension, wherein $Q = N_1 \cdot N_2$.

[0205] When the UE is configured with (N_1, N_2) , the UE calculates CQI with a composite precoder constructed with two-component codebooks, N_1 -Tx codebook (codebook 1) and N_2 -Tx codebook (codebook 2). When W_1 and W_2 are respectively are precoders of codebook 1 and codebook 2, the composite precoder (of size $P \times (\text{rank})$) is the (columnwise) Kronecker product of the two,

$W = W_1 \otimes W_2$. If PMI reporting is configured, the UE will report at least two component PMI corresponding to selected pair of W_1 and W_2 .

[0206] In one method, either W_1 or W_2 is further decomposed according to the double codebook structure. For example, W_1 is further decomposed into:

$$W_1(n, m) = \frac{1}{p_1} \begin{bmatrix} v_m \\ \phi_n v_m \end{bmatrix} \text{ if rank 1; and } W_1(n, m, m') = \frac{1}{p_2} \begin{bmatrix} v_m & v_{m'} \\ \phi_n v_m & -\phi_n v_{m'} \end{bmatrix} \text{ if rank 2,}$$

wherein p_1 and p_2 are normalization factors to make total transmission power 1, v_m is an m -th DFT vector out of a $(N_1/2)$ -Tx DFT codebook with oversampling factor o_1 , and ϕ_n is a co-phase. Furthermore, the index m, m', n determines the precoder W_1 .

[0207] If the transmission rank is one (or number of transmission layers is one), then CQI will be derived with $W = W_1 \otimes W_2 = \frac{1}{p_1} \begin{bmatrix} v_m \otimes W_2 \\ \phi_n v_m \otimes W_2 \end{bmatrix}$; and if the transmission rank is two, then CQI will be

$$\text{derived with } W = W_1 \otimes W_2 \big|_{\text{columnwise KP}} = \frac{1}{p_2} \begin{bmatrix} v_m \otimes W_2 & v_{m'} \otimes W_2 \\ \phi_n v_m \otimes W_2 & -\phi_n v_{m'} \otimes W_2 \end{bmatrix}.$$

[0208] In one example of this method, $N_1 = 8$ and $N_2 = 4$, and the TXRUs (or the antenna ports) are numbered according to Figure 5(b). In this case, W_1 is further decomposed into:

$$W_1(n, m) = \frac{1}{p_1} \begin{bmatrix} v_m \\ \phi_n v_m \end{bmatrix} \text{ if rank 1; and } W_1(n, m, m') = \frac{1}{p_2} \begin{bmatrix} v_m & v_{m'} \\ \phi_n v_m & -\phi_n v_{m'} \end{bmatrix} \text{ if rank 2,}$$

wherein v_m is an m -th DFT vector out of a 4-Tx DFT codebook with oversampling factor 8; and $\phi_n = e^{j \frac{2\pi n}{2}}$. Furthermore, with one transmission layer, CQI will be derived with precoder

$$W = W_1 \otimes W_2 = \frac{1}{\sqrt{8}} \begin{bmatrix} v_m \otimes W_2 \\ \phi_n v_m \otimes W_2 \end{bmatrix}; \text{ and with two transmission layer, CQI will be derived with}$$

$$\text{precoder } W = W_1 \otimes W_2 \big|_{\text{columnwise KP}} = \frac{1}{4} \begin{bmatrix} v_m \otimes W_2 & v_{m'} \otimes W_2 \\ \phi_n v_m \otimes W_2 & -\phi_n v_{m'} \otimes W_2 \end{bmatrix}.$$

[0209] In another method, both W_1 and W_2 are further decomposed according to the double codebook structure with two stages. The first stage codebook is used to represent WB and long-term channel, and the second stage codebook is used to represent SB and short-term channel. For example, W_1 and W_2 can be decomposed as $W_1 = U_1 V_1$ and $W_2 = U_2 V_2$, respectively, where:

- U_1 and U_2 belong to the first stage codebooks $C_1^{(1)}$ and $C_2^{(1)}$; V_1 and V_2 belong to the second stage codebooks $C_1^{(2)}$ and $C_2^{(2)}$;
- The double codebook $C_1 = C_1^{(1)}C_1^{(2)}$ comprises of DFT vectors out of a $(N_1/2)$ -Tx DFT codebook with oversampling factor o_1 , where the first stage codebook $C_1^{(1)}$ corresponds to a set of fixed number L_1 of uniformly-spaced beams, and the second stage codebook $C_1^{(2)}$ corresponds to selecting one beam out of L_1 beams and applying a cross-polco-phase ϕ_n ; and
- The $C_2 = C_2^{(1)}C_2^{(2)}$ comprises of DFT vectors out of a (N_2) -Tx DFT codebook with oversampling factor o_2 , where the first stage codebook $C_2^{(1)}$ corresponds to a set of fixed number L_2 of uniformly-spaced beams, and the second stage codebook $C_2^{(2)}$ corresponds to selecting one beam out of L_2 beams;

[0210] In a special case, uniformly-spaced beams are consecutively-spaced beams.

[0211] A beam grouping scheme is defined in terms of two groups of parameters, one group per dimension d . A group of parameters for dimension d comprises at least one of the following parameters:

- a number of antenna ports N_d ;
- an oversampling factor o_d ;
- a skip number s_d ; (for the first stage codebook $C_d^{(1)}$)
- a beam offset number f_d ;
- a beam spacing number p_d ; (for the second stage codebook $C_d^{(2)}$) and
- a number of beams L_d .

[0212] A beam group indicated by a first PMI $i_{1,d}$ of dimension d (corresponding to $C_d^{(1)}$), is determined based upon these six parameters. The total number of beams is $N_d \cdot o_d$; and the beams are indexed by an integer m_d , wherein beam m_d , v_{m_d} , corresponds to a precoding vector

$$v_{m_d} = \begin{bmatrix} 1 & e^{j\frac{2\pi m_d}{o_d N_d}} & \dots & e^{j\frac{2\pi m_d (N_d-1)}{o_d N_d}} \end{bmatrix}^t, m_d = 0, \dots, N_d \cdot o_d / k_d - 1, \text{ where } k_1 = 2 \text{ and } k_2 = 1, \text{ if cross-pol is considered in the first dimension, or } k_1 = 1 \text{ and } k_2 = 2, \text{ if cross-pol is considered in the second dimension.}$$

[0213] The first PMI $i_{1,d}$ of dimension d , where $i_{1,d} = 0, \dots, N_d \cdot o_d / s_d - 1$, can indicate any of L_d beams indexed by:

$$m_d = f_d + s_d \cdot i_{1,d}, f_d + s_d \cdot i_{1,d} + p_d, \dots, f_d + s_d \cdot i_{1,d} + (L_d - 1) p_d.$$

These L_d beams are referred to as a beam group.

[0214] Later in this disclosure, the dimension $d = \{1, 2\}$ and $d = \{H, V\}$ are used interchangeably for simplicity.

[0215] In one example, $N_1 = 8$ and $N_2 = 4$, and the TXRUs (or the antenna ports) are numbered according to Figure 5B.

[0216] Figure 7 illustrates beam grouping scheme 700, referred to as Scheme 1 according to embodiments of the present disclosure.

[0217] Figure 8 illustrates beam grouping scheme 800, referred to as Scheme 2 according to embodiments of the present disclosure.

[0218] Figure 9 illustrates beam grouping scheme 900, referred to as Scheme 3 according to embodiments of the present disclosure.

[0219] The related parameters for each beam scheme are listed in Table 1.

[0220] Table 1 Parameters for three example beam grouping schemes

	A first oversampling factor o_1 for the first dimension	A first beam spacing p_1 for the first dimension	A first number of beams L_1 for the first dimension	A second oversampling factor o_2 for the second dimension	A second beam spacing p_2 for the second dimension	A second number of beams L_2 for the second dimension
Scheme 1	8	1	4	4	1	1
Scheme 2	8	1	1	4	1	4
Scheme 3	8	1	2	4	1	2

[0221] In these schemes, an oversampling factor $o_1 = 8$ is considered for $C_1^{(1)}$ codebook and an oversampling factor $o_2 = 4$ is considered for $C_2^{(1)}$ codebook. Hence, total number of beams for $C_1^{(1)}$ codebook is $\frac{N_1 o_1}{2} = 32$, and total number of beams for $C_2^{(1)}$ codebook is $N_2 o_2 = 16$.

[0222] Figure 7, Figure 8 and Figure 9 illustrate these 16×32 3D beams constructed by Kronecker product of each beam vector in $C_1^{(1)}$ codebook and each beam vector in $C_2^{(1)}$ codebook as a 16×32 grid, wherein each square correspond to a beam.

[0223] In some embodiments: the UE is configured with a parameterized KP codebook corresponding to the codebook parameters $(N_d, o_d, s_d, f_d, p_d, L_d)$ where $d=1,2$ from a *master codebook* by applying *codebook subset restriction*. The master codebook is a large codebook with default codebook parameters.

[0224] In one method, the master codebook may be unique. In another method, there may be multiple master codebooks and the UE may be configured with at least one master codebook from the multiple master codebooks. An example of multiple master codebooks may be based on beam offset numbers f_1 and f_2 as shown in the table below. In this example, a 1-bit indication may be used to indicate the master codebook via higher layer such as RRC.

[0225] Table 2 offset numbers f_1 and f_2

	f_1	f_2
Master codebook 0	0	0
Master codebook 1	$0, 1, \dots, s_1-1$	$0, 1, \dots, s_2-1$

[0226] For simplicity, it is assumed that $f_1 = f_2 = 0$ (Master codebook 0) in the rest of the disclosure. However, the disclosure is applicable to other values of f_1 and f_2 .

[0227] Two examples of master codebook parameters for $Q = 12, 16$, and 32 antenna ports are tabulated in Table 3 and Table 4. Note that $Q = N_1 N_2$ in Table 3 and $Q = MNP$ in Table 4.

[0228] Table 3: Master codebook parameters for $Q = 12, 16$, and 32 antenna ports

Q	N_1	N_2	o_1	o_2	L_1	L_2	p_1	p_2	s_1	s_2
12	4	3	8	4	4	4	1,2	1,2	1,2,4	1,2,4
12	6	2	8	4	4	4	1,2	1,2	1,2,4	1,2,4
16	4	4	8	4	4	4	1,2	1,2	1,2,4	1,2,4
16	8	2	8	4	4	4	1,2	1,2	1,2,4	1,2,4
32	8	4	8	4	4	4	1,2	1,2	1,2,4	1,2,4
32	4	8	8	4	4	4	1,2	1,2	1,2,4	1,2,4

[0229] Table 4: Master codebook parameters for $Q = 12, 16$, and 32 antenna ports

Q	M	N	P	o_1	o_2	L_1	L_2	p_1	p_2	s_1	s_2
12	3	2	2	8	4	4	4	1,2	1,2	1,2,4	1,2,4
12	2	3	2	8	4	4	4	1,2	1,2	1,2,4	1,2,4
16	4	2	2	8	4	4	4	1,2	1,2	1,2,4	1,2,4
16	2	4	2	8	4	4	4	1,2	1,2	1,2,4	1,2,4
32	4	4	2	8	4	4	4	1,2	1,2	1,2,4	1,2,4
32	8	2	2	8	4	4	4	1,2	1,2	1,2,4	1,2,4

[0230] The focus of this disclosure is on the details of rank > 1 KP codebook design based on the codebook parameters: $(N_d, o_d, s_d, f_d, p_d, L_d)$ where $d=1,2$.

[0231] Let r be the number of transmission layers (rank), where $r = 1,2,3,4$, for example. The KP pre-coding matrix of rank r is given by:

$$P = \frac{1}{\sqrt{Qr}} [c_{m_1} \otimes u_{i_1} \otimes v_{j_1}, c_{m_2} \otimes u_{i_2} \otimes v_{j_2}, \dots, c_{m_r} \otimes u_{i_r} \otimes v_{j_r}],$$

where

- $c_{m_1}, c_{m_2}, \dots, c_{m_r}$ are 2×1 QPSK co-phase vectors from $\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & j & -1 & -j \end{bmatrix}$;
- $u_{i_1}, u_{i_2}, \dots, u_{i_r}$ are $(N_1/2) \times 1$ DFT vectors, where i_k is the index of k th DFT vector belonging to a beam group in the first dimension codebook $C_1^{(1)}$; and
- $v_{j_1}, v_{j_2}, \dots, v_{j_r}$ are $N_2 \times 1$ DFT vectors, where j_k is the index of k th DFT vector belonging to a beam group in the second dimension codebook $C_2^{(1)}$.
- Orthogonality condition for rank $r > 1$:

[0232] In order to ensure orthogonality between pre-coding vectors corresponding to multiple layers, any two columns, k and l , of the pre-coding matrix P must satisfy $p_k^* p_l = 0$ where $p_k \stackrel{\text{def}}{=} c_{m_k} \otimes u_{i_k} \otimes v_{j_k}$ is the k th column of the pre-coding matrix P . Because of the specific KP structure of the pre-coding matrix, we have that the condition $p_k^* p_l = 0$ is satisfied if any one of the following condition is satisfied:

1. Co-phase orthogonality: $c_{m_k}^* c_{m_l} = 0$,
2. Azimuth beam orthogonality: $u_{i_k}^* u_{i_l} = 0$, and
3. Elevation beam orthogonality: $v_{i_k}^* v_{i_l} = 0$.

[0233] In the first condition, the orthogonality is achieved utilizing the cross-pol antenna configuration by choosing orthogonal co-phase vectors, and in the second and the third conditions, it is achieved relying on the spacing between the beams in two dimensions.

[0234] Figure 10 illustrates beam group type 1 1000: co-phase orthogonality according to embodiments of the present disclosure.

[0235] Figure 11 illustrates an illustration of beam group type 2 1200: horizontal beam orthogonality according to embodiments of the present disclosure.

[0236] Figure 12 illustrates an illustration of beam group type 3 1300: vertical beam orthogonality according to embodiments of the present disclosure.

[0237] Figure 13 illustrates beam group type 4: both horizontal and vertical beam orthogonality

[0238] The number of beam group hypotheses depends on the beam group type.

[0239] In some embodiments, the beam groups in the first stage codebook C_1 is based upon the orthogonality condition. For instance, the beam groups may be according to at least one of the following four types:

[0240] Type 1: Adjacent beams (for co-phase orthogonality): In this type, a beam group consists of adjacent beams in both horizontal and vertical dimensions. An example of type 1 beam group is shown in Figure 10 for $N_1 = 8$, $N_2 = 2$, $o_1 = o_2 = 4$. In this example, a beam group consists of 2 adjacent beams in the horizontal dimension and 2 adjacent beams in vertical dimension. For example, beam group 0 consists of beams $\{0,1\}$ in the horizontal dimension and beams $\{0,1\}$ in the vertical dimension.

[0241] Type 2: 1D orthogonal beams in horizontal: In this type, a beam group consists of adjacent beams in vertical dimension and orthogonal beams in horizontal dimension. An example of type 2 beam group is shown in Figure 11 for $N_1 = 8$, $N_2 = 2$, $o_1 = o_2 = 4$. In this example, a beam group consists of 2 adjacent beams in the vertical dimension and 2 orthogonal beam pairs in horizontal dimension. For example, beam group 0 consists of beams $\{0,1,8,9\}$ in the horizontal dimension and beams $\{0,1\}$ in the vertical dimension.

[0242] Type 3: 1D orthogonal beams in vertical: In this type, a beam group consists of adjacent beams in horizontal dimension and orthogonal beams in vertical dimension. An example of type 2 beam group is shown in Figure 12 for $N_1 = 8$, $N_2 = 2$, $o_1 = o_2 = 4$. In this example, a beam group consists of 2 adjacent beams in the horizontal dimension and 2 orthogonal beam pairs in vertical dimension. For example, beam group 0 consists of beams $\{0,1\}$ in the horizontal dimension and beams $\{0,1,4,5\}$ in the vertical dimension.

[0243] Type 4: 2D orthogonal beams in both horizontal and vertical: In this type, a beam group consists of orthogonal beams in both horizontal and vertical dimensions. An example of type 2 beam group is shown in Figure 13 for $N_1 = 8$, $N_2 = 2$, $o_1 = o_2 = 4$. In this example, a beam group consists of 2 orthogonal beam pairs in the horizontal dimension and 2 orthogonal beam pairs in vertical dimension. For example, beam group 0 consists of beams $\{0,1,8,9\}$ in the horizontal dimension and beams $\{0,1,4,5\}$ in the vertical dimension.

[0244] For beam group types 2 – 4, there are two alternatives depending on the spacing between the two orthogonal beams in the same dimension:

- Alt 1: the spacing between the two orthogonal beams is the maximum
- Alt 2: the spacing between the two orthogonal beams is the minimum

[0245] In some embodiments, the two alternatives, Alt 1 and Alt 2, of beam group types are treated together in a single codebook or they are treated separately in two codebooks.

[0246] For example, in Figure 11, there are four sets of orthogonal beams in horizontal dimension: $\{0,4,8,12\}$, $\{1,5,9,13\}$, $\{2,6,10,14\}$, and $\{3,7,11,15\}$. In Alt 1, beams group 0 consists of beams $\{0,1,8,9\}$ in horizontal dimension where beam pairs $\{0,8\}$ and $\{1,9\}$ correspond to orthogonal beams with maximum spacing of 8 between them. Similarly, in Alt 2, beams group 0 consists of beams $\{0,1,4,5\}$ in horizontal dimension where beam pairs $\{0,4\}$ and $\{1,5\}$ correspond to orthogonal beams with minimum spacing of 4 between them. Note that here spacing between two beam indices b_1 and b_2 is defined as:

$$\min\{[(b_1 + b_2) + 16] \bmod 16, [(b_1 - b_2) + 16] \bmod 16\}.$$

[0247] Table 5 shows the number of beam group hypotheses according to the beam groupings in Figure 10 – Figure 13.

[0248] Table 5: Number of beam group hypotheses

Beam group type	Number of beam group hypotheses
Type 1 (co-phase orthogonality)	$8 * 4 = 32$
Type 2 (horizontal beam orthogonality)	$4 * 4 = 16$ (For each of Alt 1 and Alt 2)
Type 3 (vertical beam orthogonality)	$8 * 2 = 16$ (For each of Alt 1 and Alt 2)
Type 4 (2D-beam orthogonality)	$8 * 2 = 16$ (For each of Alt 1 and Alt 2)

[0249] The abovementioned examples of the different beam group types for illustrations only. All embodiments in the disclosure are applicable to other beam group types. Furthermore, the beam

group of size (2,2) in horizontal and vertical dimensions is also for illustrations only. The scope of this disclosure includes any other beam group sizes such as (4,1), (1,4), (4,4) etc.

[0250] One codebook table:

[0251] In some embodiments, a single rank $r > 1$ double codebook is designed based upon one of the above-mentioned orthogonality conditions or beam group types. In this case, we have as single table of rank $r > 1$.

[0252] In one example method, the first stage codebook C_1 indices consist of the beam group type 1. Therefore, indices of the codewords in C_1 correspond to $i_1 = 0, 1, \dots, 31$ according to Table 5, where $i_1 = 0-7$ indicates $i_{1H} = 0-7$ and $i_{1V} = 0$; $i_1 = 8-15$ indicates $i_{1H} = 0-7$ and $i_{1V} = 1$; $i_1 = 16-23$ indicates $i_{1H} = 0-7$ and $i_{1V} = 2$; and $i_1 = 24-31$ indicates $i_{1H} = 0-7$ and $i_{1V} = 3$.

[0253] In some embodiments, a single rank $r > 1$ double codebook is designed based upon more than one of the above-mentioned orthogonality conditions or beam group types. In this case, we have as single table of rank $r > 1$.

[0254] In one example method, the first stage codebook C_1 indices consist of the beam group type 1 and the beam group type 4 (Alt 1 and Alt 2). Therefore, indices of the codewords in C_1 correspond to $i_1 = 0, 1, \dots, 63$ according to Table 5. The indices $i_1 = 0, 1, \dots, 31$ are for the beam group type 1; the indices $i_1 = 32, 33, \dots, 47$ are for the beam group type 4 Alt 1; and the indices $i_1 = 48, 49, \dots, 63$ are for the beam group type 4 Alt 2. The breakdown of i_1 indices into (i_{1H}, i_{1V}) indices can be constructed similar to the previous embodiment.

[0255] Multiple codebook table:

[0256] In some embodiments, multiple rank $r > 1$ double codebooks are designed based upon a combination of the orthogonality conditions or beam group types. In this case, we have multiple tables of rank $r > 1$, one table for each beam group type.

[0257] In one example method, there are two codebooks (or tables), one for the beam group type 1 and another for the beam group type 4 (Alt 1 and Alt 2). Therefore, indices of the codewords in C_1 of the first table correspond to $i_1 = 0, 1, \dots, 31$ and that of the second table correspond to $i_1 = 0, 1, \dots, 31$ according to Table 5 where $i_1 = 0, 1, \dots, 15$ are for the beam group type 4 Alt 1 and $i_1 = 16, 17, \dots, 31$ are for the beam group type 4 Alt 2. The breakdown of i_1 indices into (i_{1H}, i_{1V}) indices can be constructed similar to the previous embodiment.

[0258] In some embodiments, 2-bit indication is used to configure single or multiple tables.

[0259] Table 6: Codebook type configuration table

Indicator	Codebook type
00	Single table consisting of one beam group type
01	Single table consisting of multiple group types
10	Multiple tables, one for each beam group type
11	reserved

[0260] Beam group type determination/configuration:

[0261] The specific beam group type depends on the channel condition between the eNB and the UE. For example, for some UEs, beam group may be of type 1; for some UEs, it may be of type 4; and for some other UEs, it may be of both type 1 and type 4. Therefore, the beam group type may be included as an important CSI parameter, which is determined/configured according to one of the following methods.

[0262] In some embodiments, the beam group type for rank $r > 1$ is pre-configured, i.e., it is fixed in the standards specification. For example: only Type 1 and Type 4 Alt 1 are supported.

[0263] In some embodiments, beam group type for rank $r > 1$ can be configured to the UE or reported by the UE. Alt 1: eNB detects the change in the beam group type and indicates the beam group type to the UE using an RRC information element comprising a CSI configuration. The UE is configured in the higher-layer of the beam group type. Alt 2: UE detects the change beam group type and reports an indication of the beam group type to eNB, e.g., in its CSI report.

[0264] In some embodiments, multiple beam group types for rank $r > 1$ are configured. In this case, an indication of beam group type is included in the CSI report.

[0265] In one method, eNB configures multiple beam group types for rank $r > 1$ to the UE. UE selects one beam group type and feeds back to the eNB. In one alternative, it is indicated jointly with the RI in the RI reporting instances. In another alternative, it is reported separately.

[0266] In another method, UE selects multiple beam group types and communicates them to the eNB, which uses them to configure a beam group type to the UE.

[0267] In some embodiments, 2-bit indication is used to configure one of the beam group type determination methods according to Table 7 below.

[0268] Table 7: Beam group type determination method

Method indicator	Method
00	Pre-configured or fixed
01	Beam group type change is detected

10	Multiple beam group types are configured
11	Reserved

[0269] Example rank 2 types codebooks:

[0270] In some embodiments, the rank 2 codebook consists of a single table of beam group type 1, where the beam groups consist of 2 adjacent beams in horizontal dimension and 2 adjacent beams in vertical dimension, for example as shown in Figure 10. Two beams p_k and p_l are selected out of the four beams; and two co-phase values are considered to obtain orthogonal beams $\begin{bmatrix} p_k & p_l \\ p_k & -p_l \end{bmatrix}$ and $\begin{bmatrix} p_k & p_l \\ jp_k & -jp_l \end{bmatrix}$ based on co-phase orthogonality.

[0271] In one example (Example 1), the two beams p_k and p_l are identical. In another example (Example 2), the two beams are either identical or different in either horizontal or vertical dimensions. The rank 2 beam indices for Example 1 and Example 2 for a given beam group with index $i_1 = (i_{1,H}, i_{1,V})$ are shown in Table 8.

[0272] Table 8: Rank 2 beam indices for a given $i_1 = (i_{1,H}, i_{1,V})$

	(H,V) beam indices for beam 1	(H,V) beam indices for beam 2
	1	2
Beam 1 = Beam 2	$(i_{1,H}, i_{1,V}) + (0,0)$	$(i_{1,H}, i_{1,V}) + (0,0)$
	$(i_{1,H}, i_{1,V}) + (0,1)$	$(i_{1,H}, i_{1,V}) + (0,1)$
	$(i_{1,H}, i_{1,V}) + (1,0)$	$(i_{1,H}, i_{1,V}) + (1,0)$
	$(i_{1,H}, i_{1,V}) + (1,1)$	$(i_{1,H}, i_{1,V}) + (1,1)$
Beam 1 $\neq$ Beam 2 (either horizontal or vertical beams are different)	$(i_{1,H}, i_{1,V}) + (0,0)$	$(i_{1,H}, i_{1,V}) + (0,1)$
	$(i_{1,H}, i_{1,V}) + (0,0)$	$(i_{1,H}, i_{1,V}) + (1,0)$
	$(i_{1,H}, i_{1,V}) + (1,1)$	$(i_{1,H}, i_{1,V}) + (0,1)$
	$(i_{1,H}, i_{1,V}) + (1,1)$	$(i_{1,H}, i_{1,V}) + (1,0)$

[0273] The rank 2 codebook table for Example 1 is shown in Table 9 for $N_1 = 8$, $N_2 = 2$, $\alpha_1 = \alpha_2 = 4$. Similar table can be constructed for Example 2.

[0274] Please see the below Table Section for Table 9.

[0275] In some embodiments, the rank 2 codebook consists of a single table of beam group type 1 and beam group type 4 with Alt 1, where the beam group type 1 comprises of beam groups of 2 adjacent beams in horizontal dimension and 2 adjacent beams in vertical dimension (Figure 10),

and the beam group type 4 comprises of beam groups of 4 pairs of orthogonal beams that are maximally separated in both horizontal and vertical dimensions (Alt 1 in Figure 13).

[0276] For the beam group type 1, one beam ($p_k = p_l$) out of the four beams is selected; and for the beam group type 4, a pair (p_k, p_l) of beams out the four pairs of orthogonal beams is selected.

Two co-phase values are considered to obtain orthogonal beams $\begin{bmatrix} p_k & p_l \\ p_k & -p_l \end{bmatrix}$ and $\begin{bmatrix} p_k & p_l \\ jp_k & -jp_l \end{bmatrix}$.

[0277] An example rank 2 codebook table is shown in Table 10 for $N_1 = 8, N_2 = 2, o_1 = o_2 = 4$.

[0278] Please see the below Table Section for Table 10.

[0279] In some embodiments, Table 9 of the rank 2 codebook consists of two subtables, a first subtable for a first beam group (type 1) and a second subtable for a second beam group (type 4 with Alt 1), where the details of the two codebook tables are similar to the previous embodiment of single table.

[0280] An example rank 2 codebook table is shown in Table 11 for $N_1 = 8, N_2 = 2, o_1 = o_2 = 4$. Two alternative methods are considered for the construction of the table.

[0281] In one method (denoted by Method 1), the selected beam group type is explicitly configured to a UE (or reported by the UE). When the UE is configured with (or reports) the first beam group, the UE is configured to report PMI according to Table 8-1, in which $i_1 = 0 - 31$; on the other hand when the UE is configured with the second beam group, the UE is configured report PMI according to Table 8, in which $i_1 = 0 - 15$. In this case, depending on which beam group type is configured, the number of reported bits for i_1 also changes. When the first beam group type is configured, 5 bit information is reported for $i_1 = 0 - 31$; when the second group type is configured, 4 bit information is reported for $i_1 = 0 - 15$.

[0282] In another method (denoted by Method 2), the selected beam group type is configured to a UE (or reported by the UE) by means of codebook subset restriction. In this case, the first PMI i_1 has a total range of 0 - 47. When the UE is configured (or has reported) with the first beam group type, the UE is configured to restrict the PMI range to 0 - 31; when the UE is configured (or has reported) with the second beam group type, the UE is configured to restrict the PMI range to 32 - 47.

[0283] Table 8 also illustrates i_1 to (i_{1H}, i_{1V}) mapping. With Method 2, the first PMI i_1 has a total range of 0 - 47. With Method 1, the first PMI i_1 has a range of either 0 - 31 or 0 - 15. According to the table, $i_{1H} = 0-7$ and $i_{1V} = 0$ are indicated by $i_1 = 32 - 39$ with Method 2; and by $i_1 = 0 - 7$ with Method 1.

[0284] Please see the below Table Section for Tables 11-1 to 11-2.

[0285] In some embodiments, the rank 2 codebook consists of three tables, Table 12-1 for a first beam group (type 1), Table 12-2 for a second beam group (type 4 with Alt 1), and Table 12-3 for a third beam group (type 4 with Alt 2), where the details of the three codebook tables are similar to the previous embodiments.

[0286] An example rank 2 codebook table is shown in Table 12 for $N_1 = 8$, $N_2 = 2$, $\alpha_1 = \alpha_2 = 4$. Two alternative methods are considered for the construction of the table.

[0287] In one method (denoted by Method 1), the selected beam group type is explicitly configured to a UE (or reported by the UE). When the UE is configured with (or reports) the first beam group, the UE is configured to report PMI according to Table 12-1, in which $i_1 = 0 - 31$; on the other hand when the UE is configured with the second beam group, the UE is configured report PMI according to Table 12-2, in which $i_1 = 0 - 15$; and when the UE is configured with the third beam group, the UE is configured report PMI according to Table 12-3, in which $i_1 = 0 - 15$. In this case, depending on which beam group type is configured, the number of reported bits for i_1 also changes. When the first beam group type is configured, 5 bit information is reported for $i_1 = 0 - 31$; when the second or the third group type is configured, 4 bit information is reported for $i_1 = 0 - 15$.

[0288] In another method (denoted by Method 2), the selected beam group type is configured to a UE (or reported by the UE) by means of codebook subset restriction. In this case, the first PMI i_1 has a total range of $0 - 63$. When the UE is configured (or has reported) with the first beam group type, the UE is configured to restrict the PMI range to $0 - 31$; when the UE is configured (or has reported) with the second beam group type, the UE is configured to restrict the PMI range to $32 - 47$; and when the UE is configured (or has reported) with the third beam group type, the UE is configured to restrict the PMI range to $48 - 63$.

[0289] Table 12-4 illustrates i_1 to (i_{1H}, i_{1V}) mapping. With Method 2, the first PMI i_1 has a total range of $0 - 63$. With Method 1, the first PMI i_1 has a range of either $0 - 31$ or $0 - 15$. According to the table, $i_{1H} = 0-7$ and $i_{1V} = 0$ are indicated by $i_1 = 32 - 39$ with Method 2; and by $i_1 = 0 - 7$ with Method 1. Similarly, $i_{1H} = 0-7$ and $i_{1V} = 0$ are indicated by $i_1 = 48 - 55$ with Method 2; and by $i_1 = 0 - 7$ with Method 1.

[0290] Please see the below Table Section for Tables 12-1 to 12-4.

[0291] In some embodiments, the rank 2 codebook consists of three tables, Table 13-1 for a first beam group (type 1), Table 13-2 for a second beam group (type 2 with Alt 1), and Table 13-3 for a third beam group (type 4 with Alt 1), where the details of the three codebook tables are similar to the previous embodiments.

[0292] An example rank 2 codebook table is shown in Tables 13-1 to 13-4 for $N_1 = 8$, $N_2 = 2$, $\nu_1 = \nu_2 = 4$. Two alternative methods are considered for the construction of the table.

[0293] In one method (denoted by Method 1), the selected beam group type is explicitly configured to a UE (or reported by the UE). When the UE is configured with (or reports) the first beam group, the UE is configured to report PMI according to Table 13-1, in which $i_1 = 0 - 31$; on the other hand when the UE is configured with the second beam group, the UE is configured report PMI according to Table 13-2, in which $i_1 = 0 - 15$; and when the UE is configured with the third beam group, the UE is configured report PMI according to Table 13-3, in which $i_1 = 0 - 15$. In this case, depending on which beam group type is configured, the number of reported bits for i_1 also changes. When the first beam group type is configured, 5 bit information is reported for $i_1 = 0 - 31$; when the second or the third group type is configured, 4 bit information is reported for $i_1 = 0 - 15$.

[0294] In another method (denoted by Method 2), the selected beam group type is configured to a UE (or reported by the UE) by means of codebook subset restriction. In this case, the first PMI i_1 has a total range of $0 - 63$. When the UE is configured (or has reported) with the first beam group type, the UE is configured to restrict the PMI range to $0 - 31$; when the UE is configured (or has reported) with the second beam group type, the UE is configured to restrict the PMI range to $32 - 47$; and when the UE is configured (or has reported) with the third beam group type, the UE is configured to restrict the PMI range to $48 - 63$.

[0295] Table 13-4 illustrates i_1 to (i_{1H}, i_{1V}) mapping. With Method 2, the first PMI i_1 has a total range of $0 - 63$. With Method 1, the first PMI i_1 has a range of either $0 - 31$ or $0 - 15$. According to the table, $i_{1H} = 0-3$ and $i_{1V} = 0$ are indicated by $i_1 = 32 - 35$ with Method 2; and by $i_1 = 0 - 3$ with Method 1. Similarly, $i_{1H} = 0-7$ and $i_{1V} = 0$ are indicated by $i_1 = 48 - 55$ with Method 2; and by $i_1 = 0 - 7$ with Method 1.

[0296] Please see the below Table Section for Tables 13-1 to 13-4.

[0297] Another example rank 2 codebook table is shown in Tables 14-1 to 14-4 for $N_1 = 8$, $N_2 = 2$, $\nu_1 = \nu_2 = 4$. Two alternative methods, Method 1 and Method 2, are considered for the construction of the table. Details of the methods are skipped because it is similar to the previous embodiments.

[0298] Please see the below Table Section for Tables 14-1 to 14-4.

[0299] In some embodiments, the rank 2 codebook consists of three tables, Table 15-1 for a first beam group (type 1), Table 15-2 for a second beam group (type 2 with Alt 1), and Table 15-3 for beam group (type 3 with Alt 1), where the details of the three codebook tables are similar to the previous embodiments.

[0300] Another example rank 2 codebook table is shown in Table 15 for $N_1 = 8$, $N_2 = 2$, $\alpha_1 = \alpha_2 = 4$. Two alternative methods, Method 1 and Method 2, are considered for the construction of the table. Details of the methods are skipped because it is similar to the previous embodiments.

[0301] Please see the below Table Section for Tables 15-1 to 15-4.

[0302] Although the above rank 2 codebooks are for $N_1 = 8$ and $N_2 = 2$, the rank 2 codebooks for other values of N_1 and N_2 such as $(N_1, N_2) = (4, 4)$, $(2, 6)$, and $(4, 3)$ can be similarly constructed.

[0303] Also, the idea of the disclosure is applicable to construct codebooks of rank more than 2.

[0304] Figure 14 illustrates subset restriction 1400 on rank-1 i_2 according to the embodiments of the present disclosure.

[0305] Depending on the values of parameters L_1 and L_2 , indicating the numbers of beams in a beam group on the first and the second dimensions, subset restriction on rank-1 i_2 indices can be differently applied. Figure 14 illustrates codebook subset restriction on rank-1 i_2 indices in terms of parameters L_1 and L_2 , with an assumption that the master codebook has rank-1 i_2 indices corresponding to 1410: $(L_1, L_2) = (4, 4)$. In this case, the master codebook for i_2 comprises 16 beams, spanned by 4x4 beams in the first and the second dimensions. In some embodiments, the index h and v in the figure corresponds to $i_{2,1}$ and $i_{2,2}$. The shaded squares represent the rank-1 i_2 (or $i_{2,1}$ and $i_{2,2}$) indices that are obtained after subset restriction and the white squares represent the indices that are not included. In the figure, 1410, 1420, 1430, 1440, 1450 and 1460 respectively correspond to a codebook subset when $(L_1, L_2) = (4, 4)$, $(2, 4)$, $(4, 2)$, $(1, 4)$, $(4, 1)$ and $(2, 2)$ are configured. For example, 1450 shows that the beam group selected after the codebook subset restriction comprises four beams in the h dimension: ($v = i_{2,2} = 0$ and $h = i_{2,1} = 0, 1, 2, 3$).

[0306] Table 16 illustrates the codebook subset restriction table according to some embodiments of the present disclosure. Depending on the configured values of L_1 and L_2 , the subset of rank-1 i_2 indices can be obtained from a row of the table. Note that $L_1 = L_2 = 4$ corresponds to no subset restriction. In these embodiments it is assumed that $(i_{1,1}, i_{1,2}) = (i_{1,H}, i_{1,V})$, but the same design can apply even if $(i_{1,1}, i_{1,2}) = (i_{1,V}, i_{1,H})$.

[0307] Table 16: An illustration of subset restriction on rank-1 i_2

(L_1, L_2)	Corresponding case in Figure 14	Number of i_2 indices
$(4, 1)$	1450	16 (=4 beams x 4 co-phases)
$(1, 4)$	1440	16
$(2, 2)$	1460	16

(4,2)	1430	32 (=8 beams x 4 co-phases)
(2,4)	1420	32
(4,4)	1410	64 (=16 beams x 4 co-phases)

[0308] In some embodiments, UE is configured with the 2 layer (or rank 2) codebook with the same codebook parameters as 1 layer codebook. In particular, rank 2 pre-coders are obtained out of those beams in the same beam groups. In other words, two beams p_k and p_l comprising a rank-2 precoder are selected from a beam group; and two co-phase values construct two orthogonal matrices corresponding to two different rank-2 precoding matrix: $\begin{bmatrix} p_k & p_l \\ p_k & -p_l \end{bmatrix}$ and $\begin{bmatrix} p_k & p_l \\ jp_k & -jp_l \end{bmatrix}$.

[0309] In some embodiments, UE is configured with (L_1, L_2) chosen from the set $\{(1,4),(2,2),(4,1)\}$ – which respectively correspond to 1440, 1450 and 1460; then a beam group comprises 4 beams. The 4 beams comprising a beam group in each of 1440, 1450 and 1460 can be indexed as 0, 1, 2, and 3.

[0310] Figure 15 illustrates example beam indices in a beam group for the three beam grouping schemes 1500 according to the embodiments of the present disclosure. In the Figure 15, the four selected beams are sequentially indexed into 0, 1, 2, and 3. 1510, 1520 and 1530 respectively illustrates the beam indexing for those beam groups of 1440, 1450 and 1460. These indexing are for illustration only, and embodiments in the disclosures are applicable to any other type of beam indexing.

[0311] If indices of the two rank-2 beams, k and l , are the same ($k = l$), then there are 4 possible rank 2 pairs, and if they are different $k \neq l$ then there are $\binom{4}{2} = 6$ possible rank-2 pairs. So, there are 10 rank-2 beam pairs in total.

[0312] Table 17 shows an example construction of rank 2 beam pairs $(k, l) \in \{0, 1, 2, 3\}$, according to some embodiments of the present disclosure. In some embodiments, the beam indices 0,1,2,3 here correspond to the beam indices shown in Figure 15. Note that the beam pair indices 0 – 7 correspond to Rel. 12 based rank 2 beam pairs. As shown in Table 17, the beam pair indices 8 and 9 are the rest of beam pairs that have not been represented in Rel-12 codebook.

[0313] Table 17: Rank 2 Beam Pair Index Table

Beam pair index	Beam Pairs (k, l)	Comments
0	(0,0)	Same beam construction

1	(1,1)	
2	(2,2)	
3	(3,3)	
4	(0,1)	Different beam construction – Rel12
5	(1,2)	
6	(0,3)	
7	(1,3)	
8	(0,2)	Different beam construction – non-Rel12
9	(2,3)	

[0314] In some embodiments, for each of $(L_1, L_2) \in \{(1,4), (4,1)\}$ corresponding to 1510 and 1520, beam pair indices 0 – 7 in Table 17 are selected to construct a rank-2 precoding matrix codebook. On the other hand, for $(L_1, L_2) = (2,2)$ corresponding to 1530, beam pair indices 0 – 3 (same beam construction) in Table 17 and an additional set of beam pair indices are selected to construct a rank-2 precoding matrix codebook.

[0315] The additional set of beam pair indices should be selected in such a way that the codebook represents more frequently selected rank-2 precoder matrices in the two dimensional beam space. Such a selection can be system-specific, or UE specific, depending on the channel condition and deployment scenario. Hence, it is proposed that the additional set is configured either UE specifically or system-wide.

[0316] Examples of the additional set of beam pair indices for $(L_1, L_2) = (2,2)$ corresponding to 1530 are:

- Scheme 0: The set comprises beam pairs corresponding to beam pair indices 4 – 7, which correspond to different beam construction according to Rel-12.
- Scheme 1: The set comprises beam pairs which have one dimensional beam variability;
- Scheme 2: The set comprises the 3 beam pairs including beam 0, and an additional beam pair of (1,3).
- Scheme 3: The set comprises a set of 4 beam pairs selected from beam pair indices 4 – 9 in Table 17.

[0317] Figure 16 illustrates Scheme 1 1610 and Scheme 2 1620 according to the embodiments of the present disclosure.

[0318] Table 18 illustrates a rank-2 codebook construction schemes for $(L_1, L_2) = (2, 2)$ according to some embodiments of the present disclosure. A scheme can be configured to a UE in higher layer (RRC, by eNB); or it can be pre-configured at the UE.

[0319] Table 178: Alternatives for remaining 4 beam pairs for rank 2

Scheme for $(L_1, L_2) = (2, 2)$	Configured beam pair indices (Table 17)
0	0 – 7
1	0 – 6, 9
2	0 – 4, 6 – 8
3	0 – 3, and 4 indices out of 4 – 9

[0320] Figure 16 illustrates different alternatives for remaining four rank 2 beam pairs for 1530 $(L_1, L_2) = (2, 2)$ according to the embodiments of the present disclosure.

[0321] In these embodiments, the total number of precoding matrix for each selected $(L_1, L_2) \in \{(1, 4), (4, 1), (2, 2)\}$ in the codebook is 16, and they are constructed according to the selected values of (k, l) corresponding to selected beam pair indices in Table 17 and two choices of co-phases:

$$\begin{bmatrix} p_k & p_l \\ p_k & -p_l \end{bmatrix} \text{ and } \begin{bmatrix} p_k & p_l \\ jp_k & -jp_l \end{bmatrix}.$$

[0322] There are two options to construct the master rank-2 codebook:

- Option 1: All the 10 beam pairs in Table 17 are included in the rank-2 master codebook for all the pairs of (L_1, L_2) .
- Option 2: All the beam pairs in Table 17 excluding non-Rel12 different beam pairs (i.e., beam pair index 8 and 9) are included in the rank-2 master codebook for all the pairs of (L_1, L_2) .

[0323] In some embodiments, Table 19 is used as a rank-2 (2 layer) master codebook, which is constructed according to Option 1, that can be used for any of $Q = 12, 16$ and 32 antenna configurations, wherein the corresponding rank 2 precoder is

$$W_{m_1, m_2, m_1', m_1', n}^{(2)} = \frac{1}{\sqrt{2Q}} \begin{bmatrix} v_{m_1} \otimes v_{m_2} & v_{m_1'} \otimes v_{m_2'} \\ \varphi_n v_{m_1} \otimes v_{m_2} & -\varphi_n v_{m_1'} \otimes v_{m_2'} \end{bmatrix}.$$

[0324] In this rank-2 master codebook table, the 2nd dimension beam index $m_2 (m'_2)$ increases first as i_2 increases. Similar table can be constructed for the case in which the 1st dimension beam index $m_1 (m'_1)$ increases first as i_2 increases.

[0325] This master codebook includes rank-2 precoders that are used for both Schemes 1 and 2, 1610 and 1620.

[0326] The master codebook comprises the following rank-2 precoders:

- Set 1: The two layers are with the same beam in both dimensions (indices 0 – 3 in Table 17), which maps to $i_2 = 0 – 31$;
- Set 2a: The two layers are with a first beam in the first dimension, and are with Rel12 based two different beams in the second dimension (indices 4 – 7 in Table 17), which maps to $i_2 = 32 – 39$;
- Set 2b (used for Option 1): The two layers are with a first beam in the first dimension, and are with non-Rel12 based two different beams in the second dimension (indices 8 – 9 in Table 17), which maps to $i_2 = 40 – 43$;
- Set 3: Same construction as those for $i_2 = 32 – 43$, with replacing the first beam with a second, a third and a fourth beam in the first dimension, which maps to $i_2 = 44 – 79$.
- Set 4: Same construction as those for $i_2 = 32 – 79$, with swapping the role of the first and the second dimension, which maps to $i_2 = 80 – 127$.
- Set 5 (used for Scheme 2 only): The closest diagonal beam pairs in the +45 degree direction, which maps to $i_2 = 128 – 159$.
- Set 6 (used for Scheme 2 only): The closest diagonal beam pairs in the -45 degree direction, which maps to $i_2 = 160 – 191$.

[0327] The master codebook for Option 2 and Scheme 2 (1620) can be similarly constructed, by selecting only those components (sets) that correspond to Option 2:

- Set 1: The two layers are with the same beam in both dimensions (indices 0 – 3 in Table 17) ... 32 precoders;
- Set 2a: The two layers are with a first beam in the first dimension, and are with Rel12 based two different beams in the second dimension (indices 4 – 7 in Table 17) ... 8 precoders;
- Set 3: Same construction as Set 2, with replacing the first beam with a second, a third and a fourth beam in the first dimension ... 24(=8x3) precoders.
- Set 4: Same construction as Set 2 and Set 3, with swapping the role of the first and the second dimension ... 32 precoders

- Set 5 (used for scheme 2 only): The closest diagonal beam pairs in the +45 degree direction ... (32 precoders)
- Set 6 (used for scheme 2 only): The closest diagonal beam pairs in the -45 degree direction ... (32 precoders)

[0328] The PMI indices (i_2) can be correspondingly mapped to those 160 (=32x5) precoders.

[0329] In some embodiments, a rank-2 master codebook is defined, and the UE is configured with a rank-2 codebook which is a subset of the rank-2 master codebook. The selected subset is configured for the UE in the higher layer, by means of a plurality of codebook subset restriction parameters, e.g., (L_1, L_2), scheme index in Table 18, etc.

[0330] For example, if the UE is configured with (L_1, L_2) = (1, 4), then Set 1 corresponding to (L_1, L_2) = (1, 4) comprising 8 precoders and Set 2a comprising 8 precoders, are selected as valid rank-2 precoders for PMI reporting. In this case, the total number of rank-2 precoders after the CSR is 16, which can be reported by a 4-bit field. It is noted that other cases with (L_1, L_2) = (4, 1) and (2, 2) can also be similarly constructed, and a 4-bit field can convey the selected rank-2 precoder after CSR in these cases as well.

[0331] For example, if the UE is configured with Scheme 1 (1610) with Option 2 with $L_1 = L_2 = 2$, then Set 1, Set 2a, Set 3 and Set 4 corresponding to $L_1 = L_2 = 2$ are selected as valid rank-2 precoders for PMI reporting. In this case, Set 1 has 8 precoders (4x2 same-beam precoders, including two different co-phases), Set 2a and Set 3 have 4 precoders (2x2 different-beam precoders in the 1st dimension), and Set 4 has 4 precoders (2x2 different-beam precoders in the 2nd dimension). The total number of rank-2 precoders after the CSR is 16, which can be reported by a 4-bit field.

[0332] For example, if the UE is configured with Scheme 2 (1620) with Option 2 with $L_1 = L_2 = 2$, then Set 1, Set 2a, Set 4, Set 5 and Set 6 corresponding to $L_1 = L_2 = 2$ and Scheme 2 (1620) are selected as valid rank-2 precoders for PMI reporting. In this case, Set 1 has 8 precoders (4x2 same-beam precoders), Set 2a and Set 4 have 4 precoders (2 different-beam precoders respectively in the 1st and the 2nd dimensions), and Set 5 and Set 6 have 4 precoders (2 diagonal beam pairs respectively in the +45 and -45 degree directions). The total number of rank-2 precoders after the CSR is 16, which can be reported by a 4-bit field.

[0333] In some embodiments, the UE reports $i_{2,1} (i'_{2,1})$, $i_{2,2} (i'_{2,2})$ and n in place of i_2 , in which case m_1, m'_1, m_2 , and m'_2 are determined as:

$$m_1 = s_1 i_{1,1} + p_1 i_{2,1}, \quad m'_1 = s_1 i'_{1,1} + p_1 i'_{2,1}, \quad m_2 = s_2 i_{1,2} + p_2 i_{2,2}, \quad \text{and} \quad m'_2 = s_2 i'_{1,2} + p_2 i'_{2,2}.$$

[0334] In those embodiments related to Table 19, and other related embodiments, the parameters s_1 , s_2 , p_1 , and p_2 in this table can be selected, e.g., according to Table 3, and it is assumed that $L_1 = L_2 = 4$. Also $i_{1,H} = 0, 1, \dots, \frac{N_1 o_1}{P s_1} - 1$ and $i_{1,V} = 0, 1, \dots, \frac{N_2 o_2}{s_2} - 1$.

[0335] Please see the below Table Section for Table 19.

[0336] Note that if (L_1, L_2) is restricted to $\{(4,1), (1,4), (2,2)\}$, then some codewords in Table 19 can never be selected. Hence, we alternatively propose to reduce the size of master codebook and define the codebook subset restriction in terms of (L_1, L_2) accordingly.

[0337] In some embodiments, a rank-2 master codebook is defined, and the UE is configured with a rank-2 codebook which is a subset of the rank-2 master codebook. The selected subset is configured for the UE in the higher layer, by means of a plurality of codebook subset restriction parameters, e.g., (L_1, L_2) , scheme index in Table 18, and the like.

[0338] An example rank-2 master codebook construction can be found in Table 20 assuming $s_1 = s_2 = 2$ and $p_1 = p_2 = 1$. The master codebook can be used for any of $Q = 12, 16$ and 32 antenna configurations, wherein the corresponding rank 2 precoding matrix is:

$$W_{m_1, m_2, m_1, m_1, n}^{(2)} = \frac{1}{\sqrt{2Q}} \begin{bmatrix} v_{m_1} \otimes v_{m_2} & v_{m_1} \otimes v_{m_2} \\ \phi_n v_{m_1} \otimes v_{m_2} & -\phi_n v_{m_1} \otimes v_{m_2} \end{bmatrix}.$$

[0339] In this table, the 2nd dimension beam index m_2 increases first as i_2 increases. Similar table can be constructed for the case in which the 1st dimension beam index m_1 increases first as i_2 increases. The codebook comprises all the same beam pairs corresponding to the three beam groups $(L_1, L_2) = (4,1), (1,4)$ and $(2,2)$ (indices 0 – 3 in Table 17), different beam pairs – Rel12 (indices 4 – 7 in Table 177) corresponding to the beam groups $(L_1, L_2) = (4,1)$ and $(1,4)$, and different beam pairs – non-Rel12 (indices 8 – 9 in Table 17) corresponding to the beam groups $(L_1, L_2) = (2,2)$.

[0340] In this case, the codebook subset restriction can be constructed as in Table 21 for 1140, 1150 and 1160.

[0341] In some embodiments, the beam spacing p_1 for the first dimension is selected such that a narrowly spaced beams in the first dimension comprise a beam group, and the beam spacing p_2 for the second dimension is selected such that a widely spaced beams in the second dimension comprise the beam group. For example, for $Q = 16$, $N_1 = 8$, $N_2 = 2$, $o_1 = o_2 = 8$, p_1 and p_2 can be chosen as: $p_1 = 1$, $p_2 = 8$, i.e., a beam group in the first dimension comprises of narrowly spaced

adjacent beams and a beam group in the second dimension comprises of widely spaced orthogonal beams.

[0342] Please see the below Table Section for Tables 20 and 21.

[0343] In some embodiments, v_{m_1} , $v_{m_1'}$, v_{m_2} , and $v_{m_2'}$ to comprise a precoding matrix

$$W_{m_1, m_2, m_1', m_2', n}^{(2)} = \frac{1}{\sqrt{2Q}} \begin{bmatrix} v_{m_1} \otimes v_{m_2} & v_{m_1'} \otimes v_{m_2'} \\ \phi_n v_{m_1} \otimes v_{m_2} & -\phi_n v_{m_1'} \otimes v_{m_2'} \end{bmatrix}, \text{ are differently configured depending on}$$

whether beamformed CSI-RS, or non-precoded CSI-RS or both are configured. In one such example with $Q = 16$ and $N_1 = 8$ and $N_2 = 2$:

- When the UE is configured with only non-precoded CSI-RS or both types of CSI-RS, the UE is further configured to use:

$$v_{m_1} = \begin{bmatrix} 1 & e^{j\frac{2\pi m_1}{32}} & e^{j\frac{4\pi m_1}{32}} & e^{j\frac{6\pi m_1}{32}} \end{bmatrix}^t, v_{m_2} = \begin{bmatrix} 1 & e^{j\frac{2\pi m_2}{32}} \end{bmatrix}^t,$$

$$v_{m_1'} = \begin{bmatrix} 1 & e^{j\frac{2\pi m_1'}{32}} & e^{j\frac{4\pi m_1'}{32}} & e^{j\frac{6\pi m_1'}{32}} \end{bmatrix}^t \text{ and } v_{m_2'} = \begin{bmatrix} 1 & e^{j\frac{2\pi m_2'}{32}} \end{bmatrix}^t;$$

- When the UE is configured with only beamformed CSI-RS, the UE is further configured to use:

$$v_{m_1} = \mathbf{e}_{m_1}^{(4 \times 1)}, v_{m_2} = \mathbf{e}_{m_2}^{(2 \times 1)},$$

$$v_{m_1'} = \mathbf{e}_{m_1'}^{(4 \times 1)}, \text{ and } v_{m_2'} = \mathbf{e}_{m_2'}^{(2 \times 1)};$$

Herein $\mathbf{e}_m^{(N \times 1)}$, $m = 0, 1, \dots, N-1$, is an $N \times 1$ column vector comprising with $(N-1)$ elements with zero value and one element with value of one. The one element with value of one is on $(m+1)$ -th row. For example, $\mathbf{e}_1^{(4 \times 1)} = [0 \ 1 \ 0 \ 0]^t$; and $\mathbf{e}_2^{(4 \times 1)} = [0 \ 0 \ 1 \ 0]^t$. In this case, the UE is further configured to use $i_{1,1} = i_{1,2} = 0$ in the table entries, and the UE is configured to report only i_2 as PMI, and not to report $i_{1,1}$ and $i_{1,2}$.

[0344] In these embodiments, the UE can identify that a configured CSI-RS resource is beamformed or non-precoded by:

- Alt 1. Explicit RRC indication: The UE is configured with a higher-layer parameter for the configured CSI-RS resource, indicating whether the configured CSI-RS resource is beamformed or non-precoded.
- Alt 2. Implicit indication: The UE is configured with a different set of CSI-RS port numbers for beamformed CSI-RS than the non-precoded CSI-RS. In one example, the

ex																
(V, H)	(0, 0)	(0, 1)	(0, 2)	(0, 3)	(1, 0)	(1, 1)	(1, 2)	(1, 3)	(2, 0)	(2, 1)	(2, 2)	(2, 3)	(3, 0)	(3, 1)	(3, 2)	(3, 3)

[0350] One potential way to construct a master codebook with a reasonable size is to reuse the Rel-10 8-Tx beam pair combinations for both dimensions as illustrated in Figure 18. In this case, the number of beam pair combinations per dimension per beam group is 8: $\{(0,0),(1,1),(2,2),(3,3),(0,1),(1,2),(0,3),(1,3)\}$. In this case, the total number of beam pair combinations for the 2 dimensions per beam group is $8 \times 8 = 64$. With applying the two co-phase matrices, the total number of rank-2 precoding matrices per beam group constructed in this way becomes $64 \times 2 = 128$. When compared with the total 64 number of rank-1 precoding matrices per beam group, this master rank-2 codebook still has twice large number as the rank-1 precoding matrix in the master codebook.

[0351] Figure 18 illustrates Rank-2 beam pair combinations 1800 obtained with extension of Rel-10 8-Tx design to 2D according to embodiments of the present disclosure.

[0352] Alternative master codebook Design

[0353] Table 23 Beam index mapping for $(L_1, L_2) = (4, 4)$

Beam pair index	0	1	2	3	4	5	6	7
(first layer, second layer)	(0,0)	(1,1)	(2,2)	(3,3)	(0,1)	(1,2)	(0,3)	(1,3)

[0354] Figure 19 and Table 23 illustrate a method to construct rank-2 master codebook 1900 according to some embodiments of the present disclosure. Utilizing the 8 beam pairs in Table 23 for each dimension, an 8×8 grid can be considered for the two dimensions as shown in Figure 19. When beam pair indices (x, y) is selected for the 1st and 2nd dimensions, corresponding beam pairs are selected for the two dimensions, according to Table 23.

[0355] For example, applying Table 23 to each of x and y , with $x = 1$ the selected beam pair for the first dimension is (1,1) and with $y = 2$, the selected beam pair for the second dimension is (2,2). Then, the corresponding rank-2 precoding matrix is:

$$W_{m_1, m_2, m_1', m_2'}^{(2)} = \frac{1}{\sqrt{2Q}} \begin{bmatrix} v_{m_1} \otimes v_{m_2} & v_{m_1'} \otimes v_{m_2'} \\ \varphi_n v_{m_1} \otimes v_{m_2} & -\varphi_n v_{m_1'} \otimes v_{m_2'} \end{bmatrix}, \text{ where}$$

- $m_1 = m_1' = s_1 \cdot i_{1,1} + p_1$; and
- $m_2 = m_2' = s_2 \cdot i_{1,2} + 2p_2$.

[0356] In general, when the selected beam pair for the first dimension is (a_0, a_1) and the selected beam pair for the second dimension is (b_0, b_1) , the beam indices m_1, m_1', m_2, m_2' are selected as

- $m_1 = s_1 \cdot i_{1,1} + a_0 \cdot p_1$;
- $m_1' = s_1 \cdot i_{1,1} + a_1 \cdot p_1$;
- $m_2 = s_2 \cdot i_{1,2} + b_0 \cdot 2p_2$; and
- $m_2' = s_2 \cdot i_{1,2} + b_1 \cdot 2p_2$.

[0357] As total number of pairs for (x, y) in Figure 19 is 64, with applying the two co-phases of $\{1, j\}$ for φ_n , total number of codewords becomes 128. In order to keep the number of codewords to 64, one possible alternative is to keep type 1 and type 2-3 codewords. In this case, $(x, y) \in \{(x, y) : x \in \{0, 1, 2, 3\}, y \in \{0, 1, 2, 3\}\} \cup \{(x, y) : x \in \{4, 5, 6, 7\}, y \in \{4, 5, 6, 7\}\}$.

[0358] Figures 20A to 20D illustrates antenna configurations and antenna numbering 2001, 2002, 2003 and 2004 respectively considered in some embodiments of the present disclosure. In all the four antenna configurations of Figures 20A to 20D, cross pol (or Cross-pol) antenna array is considered, in which a pair of antenna elements in a same physical location are polarized in two distinct angles, e.g., +45 degrees and -45 degrees.

[0359] Figures 20A and 20B are antenna configurations with 16 CSI-RS ports, comprising 8 pairs of cross-pol antenna elements placed in a 2D antenna panel. The 8 pairs can be placed in 2x4 (Figure 20A) or 4x2 manner (Figure 20B) on horizontal and vertical dimensions.

[0360] Figures 20C and 20D are antenna configurations with 12 CSI-RS ports, comprising 6 pairs of cross-pol antenna elements placed in a 2D antenna panel. The 8 pairs can be placed in 2x3 (Figure 20C) or 3x2 manner (Figure 20D) on horizontal and vertical dimensions.

[0361] Antenna number assignment in Figures 20A to 20D

[0362] In Figures 20A to 20D, antennas are indexed with integer numbers, 0, 1, ..., 15 for 16-port configurations (Figures 20A and 20B), and 0, ..., 11 for 12-port configurations (Figures 20C and 20D).

[0363] In wide arrays (such as 12-port config A and 16-port config A), antenna numbers are assigned such that

- Consecutive numbers are assigned for all the antenna elements for a first polarization, and

proceed to a second polarization.

- For a given polarization,
 - Numbering scheme 1: consecutive numbers are assigned for a first row with progressing one edge to another edge, and proceed to a second row.
 - Numbering scheme 2: consecutive numbers are assigned for a first column with progressing one edge to another edge, and proceed to a second column.

[0364] For example, in Figure 20A, antenna numbers 0-7 are assigned for a first polarization, and 8-15 are assigned for a second polarization; and antenna numbers 0-3 are assigned for a first row and 4-7 are assigned for a second row.

[0365] Antenna numbers in tall arrays (such as 12-port config B and 16-port config B) are obtained by simply rotating the wide antenna arrays (such as 12-port config A and 16-port config A) by 90 degrees.

[0366] PMI feedback precoder generation according to the antenna numbering in Figures 20A to 20D

[0367] In some embodiments, when a UE is configured with 12 or 16 port CSI-RS for a CSI-RS resource, the UE is configured to report a PMI feedback precoder according to the antenna numbers in Figures 2A to 2D. A rank-1 precoder, $W_{m,n,p}$, which is an $N_{CSIRS} \times 1$ vector, to be reported by the UE has the following form:

$$W_{m,n,p} = [w_0 \quad w_1 \quad \dots \quad w_{N_{CSIRS}-1}] = \frac{1}{\sqrt{N_{CSIRS}}} \begin{bmatrix} v_m \otimes u_n \\ \phi_p(v_m \otimes u_n) \end{bmatrix},$$

wherein:

- N_{CSIRS} = number of configured CSI-RS ports in the CSI-RS resource, e.g., 12, 16, etc.
- u_n is a $N \times 1$ oversampled DFT vector for a first dimension, whose oversampling factor is O_2 .
- v_m is a $M \times 1$ oversampled DFT vector for a second dimension, whose oversampling factor is O_1 .
- The dimension assignment can be done with $N \geq M$ according to numbering scheme 1 in Figures 20A to 20D, with $(N,M) \in \{(4,2), (4,3), (2,2)\}$; alternatively, the dimension assignment can be done with $N \leq M$ with swapping the role of columns and rows, with $(N,M) \in \{(2,4), (3,4), (2,2)\}$ according to numbering scheme 2 in Figures 20A to 20D.

- φ_p is a co-phase, e.g., in a form of $e^{j\frac{2\pi p}{4}}$, $p=0,1,2,3$.

[0368] Here, example set of oversampling factors that can be configured for S_1 and S_2 are 4 and 8; and $m, m' \in \{0,1,\dots, O_1 M\}$, and $n, n' \in \{0,1,\dots, O_2 N\}$. In a special case, $m = m'$ and $n = n'$.

[0369] Figure 21 illustrates a precoding weight application 2100 to antenna configurations of Figures 20A to 20D according to some embodiments of the present disclosure.

[0370] When any of 16-port config A and B is used at the eNB with configuring $N_{CSIRS}=16$ to the UE, a submatrix $v_m \otimes u_n$ of $W_{m,n,p}$ corresponds to a precoder applied on 8 co-pol elements, whose antenna numbers are 0 through 7. Given the antenna configuration, $M=2$ and $N=4$ should be configured for v_m and u_n . If 16-port config A is used, u_n is a 4x1 vector representing a horizontal DFT beam and v_m is a 2x1 vector representing a vertical DFT beam. If 16-port config B is used, u_n is a 4x1 vector representing a vertical DFT beam and v_m is a 2x1 vector representing a horizontal DFT beam.

[0371] With 12 or 16-port configurations, v_m can be written as $v_m = \begin{bmatrix} 1 & e^{j\frac{2\pi m}{M'}} \end{bmatrix}^t = \begin{bmatrix} 1 & e^{j\frac{2\pi m}{Mo_1}} \end{bmatrix}^t$.

[0372] With 16-port configurations, u_n can be written as:

$$\bullet \quad u_n = \begin{bmatrix} 1 & e^{j\frac{2\pi n}{N'}} & e^{j\frac{4\pi n}{N'}} & e^{j\frac{6\pi n}{N'}} \end{bmatrix}^t = \begin{bmatrix} 1 & e^{j\frac{2\pi n}{No_2}} & e^{j\frac{4\pi n}{No_2}} & e^{j\frac{6\pi n}{No_2}} \end{bmatrix}^t.$$

[0373] With 12-port configurations, u_n can be written as:

$$\bullet \quad u_n = \begin{bmatrix} 1 & e^{j\frac{2\pi n}{N'}} & e^{j\frac{4\pi n}{N'}} \end{bmatrix}^t = \begin{bmatrix} 1 & e^{j\frac{2\pi n}{No_2}} & e^{j\frac{4\pi n}{No_2}} \end{bmatrix}^t.$$

[0374] Precoding weights to be applied to antenna port numbers 0 through 3 are u_n , and the

precoding weights to be applied to antenna ports 4 through 7 are $u_n e^{j\frac{2\pi n}{Mo_1}} = u_n e^{j\frac{2\pi n}{M'}}$ with an appropriate power normalization factor. Similarly, precoding weights to be applied to antenna port numbers 8 through 11 are $u_{n'}$, and the precoding weights to be applied to antenna ports 12 through

15 are $u_n e^{j \frac{2\pi m'}{M\alpha_1}}$ with an appropriate power normalization factor. This method of precoding weight application is illustrated in Figure 21.

[0375] It is noted that the precoding weight assignment on the antennas can be similarly illustrated for 12-port config A and B, to the case of 16-port config A and B.

[0376] For CQI derivation purpose, UE needs to assume that PDSCH signals on antenna ports $\{7, \dots, 6 + \nu\}$ for ν layers would result in signals equivalent to corresponding symbols transmitted

on antenna numbers $\{0, 1, \dots, N_{CSIRS} - 1\}$, as given by
$$\begin{bmatrix} y^{(0)}(i) \\ \vdots \\ y^{(N_{CSIRS}-1)}(i) \end{bmatrix} = W_{m,n,p}(i) \begin{bmatrix} x^{(0)}(i) \\ \vdots \\ x^{(\nu-1)}(i) \end{bmatrix},$$

where $x(i) = [x^{(0)}(i) \dots x^{(\nu-1)}(i)]^T$ is a vector of symbols from the layer mapping in subclause 6.3.3.2 of 3GPP TS 36.211, where $W_{m,n,p}(i)$ is the precoding matrix corresponding to the reported PMI applicable to $x(i)$.

[0377] Parameter configuration for oversampled DFT codebooks v_m and u_n :

[0378] Figure 21 illustrates that a precoder codebook construction 2100 according to some embodiments of the present disclosure.

[0379] $W_{m,n,p} = [w_0 \ w_1 \ \dots \ w_{N_{CSIRS}-1}] = \frac{1}{\sqrt{N_{CSIRS}}} \begin{bmatrix} v_m \otimes u_n \\ \phi_p(v_m \otimes u_n) \end{bmatrix}$ can be flexibly used for both

wide and tall 2D arrays, with appropriately configuring parameters M and N .

[0380] On the other hand, it is also sometimes desired to allocate a smaller DFT oversampling factor for the vertical dimension than for the horizontal dimension, maybe due to different angle/spread distribution. Hence, configurability of parameters to change the oversampled codebooks, v_m and u_n , is desired for that purpose. This motivates the following method.

[0381] In some embodiments, a UE is configured to report PMI, which are generated according to a precoding matrix, comprising at least those two oversampled DFT vectors: v_m and u_n . For the generation of the PMI, the UE is further configured to select a codebook for v_m and a codebook for u_n , wherein each codebook for v_m and u_n is selected from multiple codebook choices. For this purpose, the UE may be configured with a set of parameters by higher layers.

[0382] Some example parameters are:

- M' and N' : to determine the denominator of the exponents for the oversampled DFT vectors

v_m and u_n :

$$\begin{aligned} \circ \quad v_m &= \begin{bmatrix} 1 & e^{j\frac{2\pi m}{M'}} \end{bmatrix}^t; \text{ and} \\ \circ \quad u_n &= \begin{bmatrix} 1 & e^{j\frac{2\pi n}{N'}} & e^{j\frac{4\pi n}{N'}} & e^{j\frac{6\pi n}{N'}} \end{bmatrix}^t \text{ or } u_n = \begin{bmatrix} 1 & e^{j\frac{2\pi n}{N'}} & e^{j\frac{4\pi n}{N'}} \end{bmatrix}^t. \end{aligned}$$

- P_M : to select a codebook out of multiple (e.g., 2) codebooks corresponding to v_m and similarly; and P_N : for u_n .

[0383] In one method, M' and N' are directly configured by two higher layer parameters respectively defined for M' and N' .

- In one such example, $M' \in \{16, 32\}$ and $N' \in \{16, 32\}$.
- In another such example, $M' \in \{8, 16, 32\}$ and $N' \in \{8, 16, 32\}$.

[0384] In another method, a pair M' and N' is configured by a higher layer parameter, namely *newParameterToIndicateDenominator*. Although this method is less flexible than the previous one, it has a benefit of being able to limit the UE complexity increase.

[0385] In one such example:

<i>newParameterToIndicateDenominator</i>	(M', N')
A first value	(32, 16)
A second value	(16, 32)

[0386] In another method, P_M and P_N correspond to oversampling factors α_1 and α_2 which is allowed to have a value of either 2, 4 or 8.

[0387] In some embodiments, to facilitate the UE CSI reporting operation according to some embodiments of the present disclosure, a CSI resource configuration, i.e., CSI-RS-ConfigNZP comprises an additional field, e.g., *newParameterToIndicateDenominator*, to indicate DFT oversampling factor as illustrated in the following:

CSI-RS-ConfigNZP-r11 ::= SEQUENCE {
 csi-RS-ConfigNZPId-r11 CSI-RS-ConfigNZPId-r11,
 antennaPortsCount-r11 ENUMERATED {an1, an2, an4, an8, an12, an16},
 newParameterToIndicateDenominator ENUMERATED {a first value, a second value, ...},

...

}

[0388] Figure 22 illustrates an example 1D antenna configurations and antenna numbering 2200 – 16 port according to embodiments of the present disclosure.

[0389] Figure 23 illustrates an example 1D antenna configurations and antenna numbering 2300 – 12 port according to embodiments of the present disclosure.

[0390] Figure 22 and Figure 23 show an 1D antenna configuration and application of the precoding matrix 2200 and 2300 constructed for 16 and 12 port CSI-RS respectively according to some embodiments of the present disclosure.

[0391] For this antenna configuration, a rank-1 precoding matrix $W_{n,p}$ can be constructed as:

$$W_{n,p} = \begin{bmatrix} w_0 & w_1 & \dots & w_{N_{CSIRS}-1} \end{bmatrix} = \frac{1}{\sqrt{N_{CSIRS}}} \begin{bmatrix} u_n \\ \phi_p u_n \end{bmatrix},$$

wherein:

- u_n is a $N \times 1$ oversampled DFT vector, whose oversampling factor is S_N :

$$u_n = \begin{bmatrix} 1 & e^{j\frac{2\pi n}{N'}} & e^{j\frac{4\pi n}{N'}} & e^{j\frac{6\pi n}{N'}} & e^{j\frac{8\pi n}{N'}} & e^{j\frac{10\pi n}{N'}} & e^{j\frac{12\pi n}{N'}} & e^{j\frac{14\pi n}{N'}} \end{bmatrix}^t \text{ for 16 port CSI-RS; and}$$

$$u_n = \begin{bmatrix} 1 & e^{j\frac{2\pi n}{N'}} & e^{j\frac{4\pi n}{N'}} & e^{j\frac{6\pi n}{N'}} & e^{j\frac{8\pi n}{N'}} & e^{j\frac{10\pi n}{N'}} \end{bmatrix}^t \text{ for 12 port CSI-RS;}$$

- $N = 8$ (for Figure 22, i.e., for 16 port CSI-RS) or 6 (for Figure 23, i.e., for 12 port CSI-RS) number of columns
- $N' = N \cdot S_N$.

[0392] It is noted that the rank-1 precoding matrix $W_{m,n,p}$ constructed for the 2D antenna array of Figure 2 of the following form:

$$W_{m,n,p} = \begin{bmatrix} w_0 & w_1 & \dots & w_{N_{CSIRS}-1} \end{bmatrix} = \frac{1}{\sqrt{N_{CSIRS}}} \begin{bmatrix} v_m \otimes u'_n \\ \phi_p (v_m \otimes u'_n) \end{bmatrix} = \frac{1}{\sqrt{N_{CSIRS}}} \begin{bmatrix} u'_n \\ e^{j\frac{2\pi m}{M'}} u'_n \\ \phi_p u'_n \\ \phi_p e^{j\frac{2\pi m}{M'}} u'_n \end{bmatrix};$$

where u'_n is an oversampled DFT vector of length $N/2$, can be used for constructing the rank-1 precoding matrix $W_{n,p}$ constructed for the 1D antenna array, with some changes: $v_m \otimes u'_n$, the

single-pol component of $W_{m,n,p}$, should be the same as u_n so that it can be used for 1D array. We can see that u_n can be written as:

$$u_n = \begin{bmatrix} u'_n & e^{j\frac{2\pi n}{N'} \frac{N}{2}} u'_n \end{bmatrix}^t = \begin{bmatrix} 1 \\ e^{j\frac{2\pi n}{N'} \frac{N}{2}} \end{bmatrix} \otimes u'_n;$$

and hence, we need to have $v_m = \begin{bmatrix} 1 \\ e^{j\frac{2\pi m}{M'}} \end{bmatrix}$ should be equal to $\begin{bmatrix} 1 \\ e^{j\frac{2\pi n}{N'} \frac{N}{2}} \end{bmatrix}$, in order to use the 2D

precoding matrix to 1D antenna array. With equating the exponents, we obtain:

$$m = \frac{M'n}{N'} \cdot \frac{N}{2} = \frac{M'n}{2\alpha_2}.$$

[0393] With 16-port CSI-RS case illustrated in Figure 22, $N/2 = 4$; in this case,

$$u'_n = \begin{bmatrix} 1 & e^{j\frac{2\pi n}{N'}} & e^{j\frac{4\pi n}{N'}} & e^{j\frac{6\pi n}{N'}} \end{bmatrix}^t \text{ and } m = \frac{4M'n}{N'} \text{ (or } v_m = \begin{bmatrix} 1 \\ e^{j\frac{8\pi m}{N'}} \end{bmatrix} \text{). Furthermore, if } M' = N', \text{ we need}$$

$m = 4n$ (or $v_m = \begin{bmatrix} 1 \\ e^{j\frac{8\pi m}{M'}} \end{bmatrix}$), to use the 2D precoding matrix to 1D antenna array. If $M' = N'/2$, we need

$m = 2n$ (or $v_m = \begin{bmatrix} 1 \\ e^{j\frac{4\pi m}{M'}} \end{bmatrix}$), to use the 2D precoding matrix to 1D antenna array.

[0394] With 12-port CSI-RS case illustrated in Figure 23, $N/2 = 3$; in this case,

$$u'_n = \begin{bmatrix} 1 & e^{j\frac{2\pi n}{N'}} & e^{j\frac{4\pi n}{N'}} \end{bmatrix}^t \text{ and } m = \frac{3M'n}{N'} \text{ (or } v_m = \begin{bmatrix} 1 \\ e^{j\frac{6\pi m}{N'}} \end{bmatrix} \text{). Furthermore, if } M' = N', \text{ we need } m = 3n,$$

to use the 2D precoding matrix to 1D antenna array. If $M' = N'/2$, we need $m = 3n/2$ (or

$v_m = \begin{bmatrix} 1 \\ e^{j\frac{3\pi m}{N'}} \end{bmatrix}$), to use the 2D precoding matrix to 1D antenna array.

[0395] Dimension-restricted PMI

[0396] Hence, in some embodiments, for rank-1 reporting, a UE can be configured to report PMI corresponding to a precoding matrix $W_{m,n,p}$, in the 2D codebook, wherein the first index m , is determined as a deterministic function of the second index n and the number of CSI-RS ports. The UE is configured this way when eNB wants to use the 2D codebook constructed for the 2D array of Figure 2 for supporting 1D array of Figure 22 and Figure 23. The UE is configured to report PMI in such a way when the UE is configured to report *dimension restricted PMI* by higher-layer signaling (RRC). Some examples are as in the following.

[0397] In the below examples, the UE is configured to report information only on n and p .

- Ex 1) When the number of CSI-RS ports is 16 and $M' = N'$, the UE is configured to report

$W_{m=4n,n,p}$. Here $m = 4n$ and $v_m = \begin{bmatrix} 1 \\ e^{j\frac{8\pi m}{M'}} \end{bmatrix}$ is assumed for CQI derivation and precoding matrix construction.

- Ex 2) When the number of CSI-RS ports is 12 and $M' = N'$, the UE is configured to report

$W_{m=3n,n,p}$. Here $m = 3n$ and $v_m = \begin{bmatrix} 1 \\ e^{j\frac{6\pi m}{M'}} \end{bmatrix}$ is assumed for CQI derivation and precoding matrix construction.

- Ex 3) When the number of CSI-RS ports is 16 and $M' = N'/2$, the UE is configured to report

$W_{m=2n,n,p}$. Here $m = 2n$ and $v_m = \begin{bmatrix} 1 \\ e^{j\frac{4\pi m}{M'}} \end{bmatrix}$ is assumed for CQI derivation and precoding matrix construction.

- Ex 4) When the number of CSI-RS ports is 12 and $M' = N'/2$, the UE is configured to report

$W_{m=3n/2,n,p}$. Here $m = 3n/2$ and $v_m = \begin{bmatrix} 1 \\ e^{j\frac{3\pi m}{M'}} \end{bmatrix}$ is assumed for CQI derivation and precoding matrix construction.

[0398] For rank-2 reporting, a UE can be configured to report PMI corresponding to a precoding matrix $W_{m,n,m',n',p}^{(2)}$, in the 2D codebook, wherein the first indices m and m' are respectively determined as deterministic functions of the second index n , n' and the number of CSI-RS ports. The UE is configured to report PMI in such a way when the UE is configured to report *dimension restricted PMI* by higher-layer signaling (RRC).

[0399] Here, $W_{m_1,m_2,m'_1,m'_1,n}^{(2)} = \frac{1}{\sqrt{2Q}} \begin{bmatrix} v_{m_1} \otimes u_{m_2} & v_{m'_1} \otimes u_{m'_2} \\ \varphi_n v_{m_1} \otimes u_{m_2} & -\varphi_n v_{m'_1} \otimes u_{m'_2} \end{bmatrix}$.

- Ex 1) When the number of CSI-RS ports is 16 and $M' = N'$, the UE is configured to report

$W_{m=4n,n,m'=4n',n',p}$.

- Ex 2) When the number of CSI-RS ports is 12 and $M' = N'$, the UE is configured to report

$W_{m=3n,n,m'=3n',n',p}$.

- Ex 3) When the number of CSI-RS ports is 16 and $M' = N'/2$, the UE is configured to report

$$W_{m=2n, n, m'=2n', n', p}$$

- Ex 4) When the number of CSI-RS ports is 12 and $M' = N/2$, the UE is configured to report

$$W_{m=3n/2, n, m'=3n'/2, n', p}$$

[0400] The dimension restriction can apply in a similar manner for other rank cases as well.

[0401] In this case, only the first dimension PMI's (i.e., m and p) are reported, and the second dimension PMI's (i.e., n) are determined as a function of m and not reported, i.e., the PMI is *dimension-restricted*.

[0402] In some alternative embodiments, a UE is configured to report PMI according to a rank-specific codebook table.

[0403] An example table for RI = 1 is shown in Table 24, wherein:

- $W_{m_1, m_2, n}^{(1)} = \frac{1}{\sqrt{Q}} \begin{bmatrix} v_{m_1} \otimes u_{m_2} \\ \phi_n v_{m_1} \otimes u_{m_2} \end{bmatrix}$, Q is number of configured NZP CSI-RS ports

[0404] Table 24 Master codebook for 1 layer CSI reporting for $(L_1, L_2) = (4, 2)$

i_2	0	1	2	3
Precoder	$W_{s_1 i_{1,1}, s_2 i_{1,2}, 0}^{(1)}$	$W_{s_1 i_{1,1}, s_2 i_{1,2}, 1}^{(1)}$	$W_{s_1 i_{1,1}, s_2 i_{1,2}, 2}^{(1)}$	$W_{s_1 i_{1,1}, s_2 i_{1,2}, 3}^{(1)}$
i_2	4	5	6	7
Precoder	$W_{s_1 i_{1,1} + p_1, s_2 i_{1,2}, 0}^{(1)}$	$W_{s_1 i_{1,1} + p_1, s_2 i_{1,2}, 1}^{(1)}$	$W_{s_1 i_{1,1} + p_1, s_2 i_{1,2}, 2}^{(1)}$	$W_{s_1 i_{1,1} + p_1, s_2 i_{1,2}, 3}^{(1)}$
i_2	8	9	10	11
Precoder	$W_{s_1 i_{1,1} + 2p_1, s_2 i_{1,2}, 0}^{(1)}$	$W_{s_1 i_{1,1} + 2p_1, s_2 i_{1,2}, 1}^{(1)}$	$W_{s_1 i_{1,1} + 2p_1, s_2 i_{1,2}, 2}^{(1)}$	$W_{s_1 i_{1,1} + 2p_1, s_2 i_{1,2}, 3}^{(1)}$
i_2	12	13	14	15
Precoder	$W_{s_1 i_{1,1} + 3p_1, s_2 i_{1,2}, 0}^{(1)}$	$W_{s_1 i_{1,1} + 3p_1, s_2 i_{1,2}, 1}^{(1)}$	$W_{s_1 i_{1,1} + 3p_1, s_2 i_{1,2}, 2}^{(1)}$	$W_{s_1 i_{1,1} + 3p_1, s_2 i_{1,2}, 3}^{(1)}$
i_2	16 – 31			
Precoder	Entries 16-31 constructed with replacing the second subscript $s_2 i_{1,2}$ with $s_2 i_{1,2} + p_2$ in entries 0 – 15.			

[0405] An example table for RI = 2 is shown in Table 25, wherein:

$$\bullet \quad W_{m_1, m_2, m'_1, m'_1, n}^{(2)} = \frac{1}{\sqrt{2Q}} \begin{bmatrix} v_{m_1} \otimes u_{m_2} & v_{m'_1} \otimes u_{m'_2} \\ \varphi_n v_{m_1} \otimes u_{m_2} & -\varphi_n v_{m'_1} \otimes u_{m'_2} \end{bmatrix}$$

[0406] Please see the below Table Section for Table 25.

[0407] When the UE is configured to report *dimension restricted PMI* by higher-layer signaling (RRC), the UE is configured to force $i_{1,2} = 0$, and report only $i_{1,1}$ and i_2 according to Table 24. In addition the UE is further configured to select a subset of $\{i_2 : i_2 \in \{0,1,\dots,15\}\}$ in the codebook which corresponds to the 1D beam group, and report i_2 values selected from the subset only.

[0408] The same dimension restriction can apply for other rank cases as well.

[0409] Dimension restricted PMI configuration

[0410] In one method, the UE is configured to report the dimension-restricted PMI if a parameter configured in the higher-layer indicates “1D” configuration; the UE is configured to use the 2D PMI $W_{m,n,p}$ if the parameter indicates “2D” configuration.

[0411] In another method, the UE is configured to report the dimension-restricted PMI if a parameter(s) configured in the higher-layer indicates that at least one of M and N is 1; the UE is configured to use the 2D PMI $W_{m,n,p}$ otherwise.

[0412] In another method, the UE is configured to report the dimension-restricted PMI if a parameter, say *PmiDimensionRestriction* is configured in the higher-layer; the UE is configured to use the 2D PMI $W_{m,n,p}$ if the parameter is not configured.

[0413] In some embodiments, the UE is configured with a set of codebook subset selection parameters (including the PMI dimension restriction as well), according to the configured antenna dimension parameters, i.e., M and/or N .

[0414] Parameterized codebook / Codebook subset selection

[0415] U.S. Provisional Patent Application No. 14/995,126 filed on January 23, 2016 discloses a parameterized codebook, and is hereby incorporated by reference in their entirety. Some embodiments in that disclosure are reproduced below.

[0416] A group of parameters for dimension d comprises at least one of the following parameters:

- a number of antenna ports N_d ;
- an oversampling factor o_d ;
- a beam group spacing s_d , (for W1)
- a beam offset number f_d ;

- a beam spacing number p_d ; (for W2) and
- a number of beams L_d .

[0417] A beam group indicated by a first PMI $i_{1,d}$ of dimension d (corresponding to $W_d^{(1)}$), is determined based upon these six parameters.

- The total number of beams is $N_d \cdot o_d$; and the beams are indexed by an integer m_d , wherein beam m_d , v_{m_d} , corresponds to a precoding vector.

$$v_{m_d} = \begin{bmatrix} 1 & e^{j \frac{2\pi m_d}{o_d N_d}} & \dots & e^{j \frac{2\pi m_d (N_d - 1)}{o_d N_d}} \end{bmatrix}^T, m_d = 0, \dots, N_d \cdot o_d - 1.$$

- The first PMI of dimension d , namely $i_{1,d} = 0, \dots, N_d \cdot o_d / s_d - 1$, can indicate any of L_d beams indexed by:

$$m_d = f_d + s_d \cdot i_{1,d}, f_d + s_d \cdot i_{1,d} + p_d, \dots, f_d + s_d \cdot i_{1,d} + (L_d - 1) p_d.$$

- These L_d beams are referred to as a beam group.

[0418] In some embodiments: the UE is configured with a parameterized KP codebook corresponding to the codebook parameters $(N_d, o_d, s_d, f_d, p_d, L_d)$ where $d=1,2$ from a (master) codebook by applying *codebook subset selection*. The master codebook is a large codebook with default codebook parameters.

[0419] In some embodiments: the UE is configured with at least one of those codebook parameters $(N_d, o_d, s_d, f_d, p_d, L_d)$ and/or PMI dimension restriction for each dimension, when the UE is configured with a set of parameters related to the antenna dimension information, e.g., Q, M and N .

[0420] The focus of this disclosure is on an alternate design of rank 3-8 codebooks.

[0421] In some embodiments, the master rank 3-8 codebook parameters for $Q = 8, 12, 16$, and 32 antenna ports and $(L_1, L_2) = (4, 2)$ are according to Table 26, where multiple oversampling factors in two dimension are supported. The remaining codebook parameters may be fixed, for example, $s_1 = s_2 = 1$ or 2, and $p_1 = 1, 2$, or O_1 and $p_2 = 1, 2$, or O_2 . Note that $Q = PN_1N_2$ in Table 26.

[0422] Table 26: Master rank 3-8 codebook parameters for $Q = 8, 12, 16$, and 32 antenna ports and $(L_1, L_2) = (4, 2)$

Q	N_1	N_2	P	O_1	O_2	L_1	L_2
8	2	2	2	2,4,8	2,4,8	4	2
12	3	2	2	2,4,8	2,4,8	4	2
12	2	3	2	2,4,8	2,4,8	4	2

16	4	2	2	2,4,8	2,4,8	4	2
16	2	4	2	2,4,8	2,4,8	4	2
32	4	4	2	2,4,8	2,4,8	4	2
32	8	2	2	2,4,8	2,4,8	4	2

[0423] The oversampling factor in one or both dimensions is configurable according to the below table.

Oversampling factor O_d in dimension d where $d = 1, 2$	2,4,8
---	-------

[0424] In some embodiments, the master codebook parameters for $Q = 8, 12, 16$, and 32 antenna ports and $(L_1, L_2) = (4, 2)$ are according to Table 27, where single oversampling factors in two dimension are supported. The remaining codebook parameters may be fixed, for example, $s_1 = s_2 = 2$, and $p_1 = p_2 = 8$.

[0425] Table 27: Master rank 3-8 codebook parameters for $Q = 8, 12, 16$, and 32 antenna ports and $(L_1, L_2) = (4, 2)$

Q	N_1	N_2	P	O_1	O_2	L_1	L_2
8	2	2	2	8	8	4	2
12	3	2	2	8	8	4	2
12	2	3	2	8	8	4	2
16	4	2	2	8	8	4	2
16	2	4	2	8	8	4	2
32	4	4	2	8	8	4	2
32	8	2	2	8	8	4	2

[0426] In some embodiments, the master codebook parameters are rank-agnostic and hence are the same for all ranks, e.g. 1-8.

[0427] In some embodiments, the master codebook parameters are rank-specific and hence are different for different ranks, e.g. 1-8. In one example, the rank 1-2 master codebook parameters are specified a first set of values, the rank 3-4 master codebook parameters are specified a second set of values, and the rank 5-8 master codebook parameters are specified a third set of values. An example of rank-specific master codebook parameters is shown in Table 28.

[0428] Table 28: Rank-specific master codebook parameters

Q	(N_1, N_2)	P	(O_1, O_2)	(L_1, L_2)	(s_1, s_2)			(p_1, p_2)		
					Rank 1-2	Rank 3-4	Rank 5-8	Rank 1-2	Rank 3-4	Rank 5-8
8	(2,2)	2	(8,8)	(4,2)	(2,2)	(8,4)	(2,2)	(1,1)	(2,2)	(1,1)
12	(3,2)									
16	(4,2)									
32	(4,4),(8,2)									

[0429] Rank 3-8 master beam group

[0430] Figure 24 illustrates the master beam group 2400 of for 12 and 16 ports according to some embodiments of the present disclosure.

[0431] In some embodiments, the rank 3-8 master codebook consists of W1 orthogonal beam groups as shown in Figure 24. Two orthogonal beam group configurations, depending on the configured (N_1, N_2) are:

- If $N_1 \geq N_2$, then the orthogonal beam group size is (3,2) and (4,2) for 12 and 16 ports, respectively; and
- If $N_1 < N_2$, then the orthogonal beam group size is (2,3) and (2,4) for 12 and 16 ports, respectively.

[0432] For 12 ports, two orthogonal beam groups are:

- For $N_1 \geq N_2$, the beam group consists of 6 “closest” orthogonal beams in 2D, where 3 orthogonal beams with indices $\{0, O_1, 2O_1\}$ are for the 1st or longer dimension and 2 orthogonal beams with indices $\{0, O_2\}$ are for the 2nd or shorter dimension; and
- For $N_1 < N_2$, the beam group consists of 6 “closest” orthogonal beams in 2D, where 2 orthogonal beams with indices $\{0, O_1\}$ are for the 1st or shorter dimension and 3 orthogonal beams with indices $\{0, O_2, 2O_2\}$ are for the 2nd or longer dimension.

[0433] For 16 ports, two orthogonal beam groups are:

- For $N_1 \geq N_2$, the beam group consists of 8 “closest” orthogonal beams in 2D, where 4 orthogonal beams with indices $\{0, O_1, 2O_1, 3O_1\}$ are for the 1st or longer dimension and 2 orthogonal beams with indices $\{0, O_2\}$ are for the 2nd or shorter dimension; and

- For $N_1 < N_2$, the beam group consists of 8 “closest” orthogonal beams in 2D, where 2 orthogonal beams with indices $\{0, O_1\}$ are for the 1st or shorter dimension and 4 orthogonal beams with indices $\{0, O_2, 2O_2, 3O_2\}$ are for the 2nd or longer dimension.

[0434] Unless otherwise specified, 16 ports with $N_1 \geq N_2$ is assumed in the rest of the disclosure. All embodiments in this disclosure, however, are applicable to $N_1 < N_2$ configuration, and also 12 ports.

[0435] Rank 3-8 beam grouping schemes from the master beam group

[0436] In some embodiments, a UE is configured with a beam group consisting of beams which are a subset of beams in the master beam group. In one method, the configuration is via RRC signaling.

[0437] Figure 25 illustrates beam group schemes 2500 for rank 3-8 according to some embodiments of the present disclosure. The 1st dim and the 2nd dim in the figure correspond to beams in the first dimension and in the second dimension. The shaded (black) squares represent the beams that form a beam group and are obtained after beam selection and the white squares represent the beams that are not included in the beam group.

[0438] In Figure 25:

- Beam Group 0 corresponds to a beam group when $(L_1, L_2) = (4, 1)$ is configured and the selected beam combination comprises of 4 orthogonal beams located at $\{(x, 0)\}$ where $x = \{0, O_1, 2O_1, 3O_1\}$;
- Beam Group 1 corresponds to a beam group when $(L_1, L_2) = (2, 2)$ - *square pattern* is configured and the selected beam combination comprises of 4 orthogonal beams located at $\{(0, 0), (0, O_1), (O_1, O_2), (O_1, 0)\}$; and
- Beam Group 2 corresponds to a beam group when $(L_1, L_2) = (2, 2)$ - *checker board pattern* is configured and the selected beam combination comprises of 4 orthogonal beams located at $\{(0, 0), (O_1, O_2), (2O_1, 0), (3O_1, O_2)\}$.

[0439] In some embodiments, a UE is configured with a beam group by means of codebook subset selection (CSS) or codebook subsampling on rank 3-8 i'_2 indices, with an assumption that the master codebook has rank 3-8 i'_2 indices corresponding to $(L_1, L_2) = (4, 2)$ as shown in Figure 24.

[0440] In one method, the CSS configuration is in terms of parameters L_1 and L_2 .

[0441] In one method, the CSS configuration is explicit for Beam Group 0, Beam Group 1, and Beam Group 2 (Figure 25).

[0442] In another method, the CSS configuration is in terms of a bitmap of length 8 (equal to number of beams in master beam group), where the number of 1's in the bitmap is 4.

[0443] In another method, the CSS configuration is in terms of a bitmap of length equal to the number of i'_2 indices in the master codebook, where the number of 1's in the bitmap is fixed.

[0444] In some embodiments, the 1st dim and the 2nd dim in the figure correspond to $i_{2,1}$ and $i_{2,2}$.

[0445] In some embodiments, the shaded (black) squares represent the rank 3-8 i_2 (or $i_{2,1}$ and $i_{2,2}$) indices that form a beam group and are obtained after subset selection and the white squares represent the indices that are not included in the beam group.

[0446] In some embodiments, $Q = 2N_1 * N_2$.

[0447] In some embodiments, the UE reports $i_{2,1}$, $i_{2,2}$ and n in place of i_2 , in which case m_1 and m_2 are determined as:

$$m_1 = s_1 i_{1,1} + p_1 i_{2,1} \text{ and } m_2 = s_2 i_{1,2} + p_2 i_{2,2}.$$

[0448] In those embodiments, $p_1 = O_1$ and $p_2 = O_2$. So, $m_1 = s_1 i_{1,1} + O_1 i_{2,1}$ and $m_2 = s_2 i_{1,2} + O_2 i_{2,2}$.

[0449] In those embodiments, $i_{1,1} = 0, 1, \dots, \frac{N_1 O_1}{s_1} - 1$ and $i_{1,2} = 0, 1, \dots, \frac{N_2 O_2}{s_2} - 1$.

[0450] Rank 3 codebook

[0451] In some embodiments, Table 29 is used as a rank-3 (3 layer) master codebook that can be used for any of $Q = 8, 12, 16$, and 32 antenna port configurations, wherein the corresponding rank

$$3 \text{ precoder is either } W_{m_1, m'_1, m_2, m'_2}^{(3)} = \frac{1}{\sqrt{3Q}} \begin{bmatrix} v_{m_1} \otimes u_{m_2} & v_{m_1} \otimes u_{m_2} & v_{m'_1} \otimes u_{m'_2} \\ v_{m_1} \otimes u_{m_2} & -v_{m_1} \otimes u_{m_2} & -v_{m'_1} \otimes u_{m'_2} \end{bmatrix}$$

$$\text{or } W_{m_1, m'_1, m_2, m'_2}^{(3)} = \frac{1}{\sqrt{3Q}} \begin{bmatrix} v_{m_1} \otimes u_{m_2} & v_{m_1} \otimes u_{m_2} & v_{m'_1} \otimes u_{m'_2} \\ v_{m_1} \otimes u_{m_2} & -v_{m_1} \otimes u_{m_2} & -v_{m'_1} \otimes u_{m'_2} \end{bmatrix}.$$

[0452] Please see the below Table Section for Table 29.

[0453] Table 30 shows i'_2 indices to orthogonal beam pairs mapping that are considered to derive rank-3 precoders $W_{m_1, m'_1, m_2, m'_2}^{(3)}$ and $\tilde{W}_{m_1, m'_1, m_2, m'_2}^{(3)}$ in Table 29.

[0454] Table 30: i'_2 indices to orthogonal beam pairs mapping (in Table 29)

i'_2 indices	Orthogonal beam pairs
----------------	-----------------------

0 - 3	(0,0), (O ₁ ,0)
4 - 7	(O ₁ ,0), (2O ₁ ,0)
8 - 11	(2O ₁ ,0), (3O ₁ ,0)
12 - 15	(3O ₁ ,0), (0,0)
16 - 19	(0,O ₂), (O ₁ ,O ₂)
20 - 23	(0,0), (0,O ₂)
24 - 27	(O ₁ ,0), (O ₁ ,O ₂)
28 - 31	(0,0), (O ₁ ,O ₂)
32 - 35	(O ₁ ,O ₂), (2O ₁ ,0)
36 - 39	(2O ₁ ,0), (3O ₁ ,O ₂)
40 - 43	(3O ₁ ,O ₂), (0,0)

[0455] Depending on the configured beam group, a UE selects a subset of i'_2 indices in Table 29 in order to derive the codebook for PMI calculation. Table 31 shows selected rank-3 i'_2 indices determined dependent upon a selected beam group. Beam group 0, Beam group 1, and Beam group 2 are constructed according to Figure 25.

[0456] Table 31: Selected i'_2 indices for rank-3 CSI reporting (in Table 29)

Beam Group	Selected i'_2 indices
0	0 - 15
1	0 - 3, 16 - 27
2	28 - 43

[0457] Rank 4 codebook

[0458] In some embodiments, Table 32 is used as a rank-4 (4 layer) master codebook that can be used for any of Q = 8, 12, 16, and 32 antenna port configurations, wherein the corresponding rank

$$4 \text{ precoder is } W_{m_1, m'_1, m_2, m'_2, n}^{(4)} = \frac{1}{\sqrt{4Q}} \begin{bmatrix} v_{m_1} \otimes u_{m_2} & v_{m'_1} \otimes u_{m_2} & v_{m_1} \otimes u_{m_2} & v_{m'_1} \otimes u_{m_2} \\ \phi_n v_{m_1} \otimes u_{m_2} & \phi_n v_{m'_1} \otimes u_{m_2} & -\phi_n v_{m_1} \otimes u_{m_2} & -\phi_n v_{m'_1} \otimes u_{m_2} \end{bmatrix}$$

[0459] Please see the below Table Section for Table 32.

[0460] Table 33 shows i'_2 indices to orthogonal beam pairs mapping that are considered to derive rank-4 precoders $W_{m_1, m'_1, m_2, m'_2, n}^{(4)}$ in Table 32.

[0461] Table 33: i'_2 indices to orthogonal beam pairs mapping (in Table 32)

i'_2 indices	Orthogonal beam pairs
0 - 1	(0,0), (0 ₁ ,0)
2 - 3	(0 ₁ ,0), (20 ₁ ,0)
4 - 5	(20 ₁ ,0), (30 ₁ ,0)
6 - 7	(30 ₁ ,0), (0,0)
8 - 9	(0,0 ₂), (0 ₁ ,0 ₂)
10 - 11	(0,0), (0,0 ₂)
12 - 13	(0 ₁ ,0), (0 ₁ ,0 ₂)
14 - 15	(0,0), (0 ₁ ,0 ₂)
16 - 17	(0 ₁ ,0 ₂), (20 ₁ ,0)
18 - 19	(20 ₁ ,0), (30 ₁ ,0 ₂)
20 - 21	(30 ₁ ,0 ₂), (0,0)

[0462] Depending on the configured beam group, a UE selects a subset of i'_2 indices in Table 32 in order to derive the codebook for PMI calculation. Table 34 shows selected rank-4 i'_2 indices determined dependent upon a selected beam group. Beam group 0, Beam group 1, and Beam group 2 are constructed according to Figure 25.

[0463] Table 34: Selected i'_2 indices for rank-4 CSI reporting (in Table 32)

Beam Group	Selected i'_2 indices
0	0 - 7
1	0 - 1, 8 - 13
2	14 - 21

[0464] Rank 5-6 master codebook

[0465] In some embodiments, Table 35 is used as a rank-5 (5 layer) master codebook that can be used for any of Q = 8, 12, 16, and 32 antenna port configurations, wherein the corresponding rank

$$5 \text{ precoder is } W_{m_1, m_1', m_1'', m_2, m_2', m_2''}^{(5)} = \frac{1}{\sqrt{5Q}} \begin{bmatrix} v_{m_1} \otimes u_{m_2} & v_{m_1} \otimes u_{m_2} & v_{m_1'} \otimes u_{m_2'} & v_{m_1'} \otimes u_{m_2'} & v_{m_1''} \otimes u_{m_2''} \\ v_{m_1} \otimes u_{m_2} & -v_{m_1} \otimes u_{m_2} & v_{m_1'} \otimes u_{m_2'} & -v_{m_1'} \otimes u_{m_2'} & v_{m_1''} \otimes u_{m_2''} \end{bmatrix}.$$

[0466] Please see the below Table Section for Table 35.

[0467] In some embodiments, Table 36 is used as a rank-6 (6 layer) master codebook that can be used for any of Q = 8, 12, 16, and 32 antenna port configurations, wherein the corresponding rank 6 precoder is

$$W_{m_1, m_1', m_1'', m_2, m_2', m_2''}^{(6)} = \frac{1}{\sqrt{6Q}} \begin{bmatrix} v_{m_1} \otimes u_{m_2} & v_{m_1} \otimes u_{m_2} & v_{m_1'} \otimes u_{m_2'} & v_{m_1'} \otimes u_{m_2'} & v_{m_1''} \otimes u_{m_2''} & v_{m_1''} \otimes u_{m_2''} \\ v_{m_1} \otimes u_{m_2} & -v_{m_1} \otimes u_{m_2} & v_{m_1'} \otimes u_{m_2'} & -v_{m_1'} \otimes u_{m_2'} & v_{m_1''} \otimes u_{m_2''} & -v_{m_1''} \otimes u_{m_2''} \end{bmatrix}$$

[0468] Please see the below Table Section for Table 36.

[0469] Table 37 shows i_2' indices to orthogonal beam triples mapping that are considered to derive rank-5 precoders $W_{m_1, m_1', m_1'', m_2, m_2', m_2''}^{(5)}$ in Table 35, and rank-6 precoders $W_{m_1, m_1', m_1'', m_2, m_2', m_2''}^{(6)}$ in Table 36.

[0470] Table 37: i_2' indices to orthogonal beam triples mapping for rank 5-6 (in Table 35 and Table 36)

i_2' indices	Orthogonal beam pairs
0	(0,0), (O ₁ ,0), (2O ₁ ,0)
1	(O ₁ ,0), (2O ₁ ,0), (3O ₁ ,0)
2	(2O ₁ ,0), (3O ₁ ,0), (0,0)
3	(3O ₁ ,0), (0,0), (2O ₁ ,0)
4	(0,0), (O ₁ ,0), (O ₁ ,O ₂)
5	(O ₁ ,0), (O ₁ ,O ₂), (0,O ₂)
6	(O ₁ ,O ₂), (0,O ₂), (0,0)
7	(0,O ₂), (0,0), (O ₁ ,0)
8	(0,0), (O ₁ ,O ₂), (2O ₁ ,0)
9	(O ₁ ,O ₂), (2O ₁ ,0), (3O ₁ ,O ₂)
10	(2O ₁ ,0), (3O ₁ ,O ₂), (0,0)
11	(3O ₁ ,O ₂), (0,0), (O ₁ ,O ₂)

[0471] Depending on the configured beam group, a UE selects a subset of i_2' indices in Table 35 (rank-5) and Table 36 (rank-6) in order to derive the codebook for PMI calculation. Table 38

shows selected rank-5 and rank-6 i'_2 indices determined dependent upon a selected beam group. Beam group 0, Beam group 1, and Beam group 2 are constructed according to Figure 25.

[0472] Table 38: Selected i'_2 indices for rank-5 and rank-6 CSI reporting (in Table 35 and Table 36 오류! 참조 원본을 찾을 수 없습니다.)

Beam Group	Selected i'_2 indices
0	0 - 3
1	4 - 7
2	8 - 11

[0473] Rank 7-8 master codebook

[0474] In some embodiments, Table 39 is used as a rank-7 (7 layer) master codebook that can be used for any of $Q = 8, 12, 16$, and 32 antenna port configurations, wherein the corresponding rank 7 precoder is

$$W_{m_1, m_1', m_1'', m_1''', m_2, m_2', m_2'', m_2'''}^{(7)} = \frac{1}{\sqrt{7Q}} \begin{bmatrix} v_{m_1} \otimes u_{m_2} & v_{m_1} \otimes u_{m_2} & v_{m_1'} \otimes u_{m_2} & v_{m_1'} \otimes u_{m_2} & v_{m_1''} \otimes u_{m_2} & v_{m_1''} \otimes u_{m_2} & v_{m_1'''} \otimes u_{m_2} & v_{m_1'''} \otimes u_{m_2} \\ v_{m_1} \otimes u_{m_2} & -v_{m_1} \otimes u_{m_2} & v_{m_1'} \otimes u_{m_2} & -v_{m_1'} \otimes u_{m_2} & v_{m_1''} \otimes u_{m_2} & -v_{m_1''} \otimes u_{m_2} & v_{m_1'''} \otimes u_{m_2} & -v_{m_1'''} \otimes u_{m_2} \end{bmatrix}$$

[0475] Table 39: Master codebook for 7 layer CSI reporting for $(N_1, N_2) = (4, 2)$ and $(L_1, L_2) = (4, 2)$

i'_2	0
Precoder	$W_{s_1 i_{1,1}, s_1 i_{1,1} + O_1, s_1 i_{1,1} + 2O_1, s_1 i_{1,1} + 3O_1, s_2 i_{1,2}, s_2 i_{1,2}, s_2 i_{1,2}, s_2 i_{1,2}}^{(7)}$
i'_2	1
Precoder	$W_{s_1 i_{1,1}, s_1 i_{1,1} + O_1, s_1 i_{1,1} + O_1, s_1 i_{1,1}, s_2 i_{1,2}, s_2 i_{1,2}, s_2 i_{1,2} + O_2, s_2 i_{1,2} + O_2}^{(7)}$
i'_2	2
Precoder	$W_{s_1 i_{1,1}, s_1 i_{1,1} + O_1, s_1 i_{1,1} + 2O_1, s_1 i_{1,1} + 3O_1, s_2 i_{1,2}, s_2 i_{1,2} + O_2, s_2 i_{1,2}, s_2 i_{1,2} + O_2}^{(7)}$

[0476] In some embodiments, Table 40 is used as a rank-8 (8 layer) master codebook that can be used for any of $Q = 8, 12, 16$, and 32 antenna port configurations, wherein the corresponding rank 8 precoder is

$$W_{m_1, m_1', m_1'', m_1''', m_2, m_2', m_2'', m_2'''}^{(8)} = \frac{1}{\sqrt{8Q}} \begin{bmatrix} v_{m_1} \otimes u_{m_2} & v_{m_1} \otimes u_{m_2} & v_{m_1'} \otimes u_{m_2'} & v_{m_1'} \otimes u_{m_2'} & v_{m_1''} \otimes u_{m_2''} & v_{m_1''} \otimes u_{m_2''} & v_{m_1'''} \otimes u_{m_2'''} & v_{m_1'''} \otimes u_{m_2'''} \\ v_{m_1} \otimes u_{m_2} & -v_{m_1} \otimes u_{m_2} & v_{m_1'} \otimes u_{m_2'} & -v_{m_1'} \otimes u_{m_2'} & v_{m_1''} \otimes u_{m_2''} & -v_{m_1''} \otimes u_{m_2''} & v_{m_1'''} \otimes u_{m_2'''} & -v_{m_1'''} \otimes u_{m_2'''} \end{bmatrix}$$

[0477] Table 40: Master codebook for 8 layer CSI reporting for $(N_1, N_2) = (4, 2)$ and $(L_1, L_2) = (4, 2)$

i_2'	0
Precoder	$W_{s_{1i_{1,1}}, s_{1i_{1,1}} + O_1, s_{1i_{1,1}} + 2O_1, s_{1i_{1,1}} + 3O_1, s_{2i_{1,2}}, s_{2i_{1,2}}, s_{2i_{1,2}}, s_{2i_{1,2}}}^{(8)}$
i_2'	1
Precoder	$W_{s_{1i_{1,1}}, s_{1i_{1,1}} + O_1, s_{1i_{1,1}} + O_1, s_{1i_{1,1}} + s_{2i_{1,2}}, s_{2i_{1,2}}, s_{2i_{1,2}} + O_2, s_{2i_{1,2}} + O_2}^{(8)}$
i_2'	2
Precoder	$W_{s_{1i_{1,1}}, s_{1i_{1,1}} + O_1, s_{1i_{1,1}} + 2O_1, s_{1i_{1,1}} + 3O_1, s_{2i_{1,2}}, s_{2i_{1,2}} + O_2, s_{2i_{1,2}}, s_{2i_{1,2}} + O_2}^{(8)}$

[0478] Table 41 shows i_2' indices to orthogonal beam quadruples mapping that are considered to derive rank-7 precoders $W_{m_1, m_1', m_1'', m_1''', m_2, m_2', m_2'', m_2'''}^{(7)}$ in Table 39, and rank-8 precoders

$W_{m_1, m_1', m_1'', m_1''', m_2, m_2', m_2'', m_2'''}^{(8)}$ in Table 40.

[0479] Table 41: i_2' indices to orthogonal beam triples mapping for rank 7-8 (in Table 39 and Table 40)

i_2' indices	Orthogonal beam pairs
0	(0,0), (0 ₁ ,0), (20 ₁ ,0), (30 ₁ ,0)
1	(0,0), (0 ₁ ,0), (0 ₁ ,02), (0,02)
2	(0,0), (0 ₁ ,02), (20 ₁ ,0), (30 ₁ ,02)

[0480] Depending on the configured beam group, a UE selects a subset of i'_2 indices in Table 39 (rank-7) and Table 40 (rank-8) in order to derive the codebook for PMI calculation. Table 42 shows selected rank-7 and rank-8 i'_2 indices determined dependent upon a selected beam group. Beam group 0, Beam group 1, and Beam group 2 are constructed according to Figure 25.

[0481] Table 42: Selected i'_2 indices for rank-7 and rank-8 CSI reporting (in Table 39 and Table 40)

Beam Group	Selected i'_2 indices
0	0
1	1
2	2

[0482] Alternate rank3-4 codebook designs

[0483] Figure 26 illustrates example beam grouping schemes 2600 for rank 3-4 according to some embodiments of the present disclosure.

[0484] In some embodiments, the rank 3-4 master codebook consists of W1 beam groups of $(L_1, L_2) = (2, 2)$ beams as shown in Figure 26. The beam group consists of 4 “closest” orthogonal beams in 2D, where 4 orthogonal beams with indices $\{0, O_1\}$ are for the 1st or longer dimension and 2 orthogonal beams with indices $\{0, O_2\}$ are for the 2nd or shorter dimension.

[0485] In some embodiments, Figure 26 illustrates rank 3-4 beam groups according to some embodiments of the present disclosure. The 1st dim and the 2nd dim in the figure correspond to beams in the first dimension and in the second dimension. The shaded (black) squares represent the beams that form a beam group and are obtained after beam selection and the white squares represent the beams that are not included in the beam group.

[0486] In the figure, Beam Group 0 corresponds to a beam group when $(L_1, L_2) = (1, 2)$ is configured and the selected orthogonal beam pair is vertical (or in 2nd dim) and is located at $\{(0, x)\}$ where $x = \{0, O_2\}$; Beam Group 1 corresponds to a beam group when $(L_1, L_2) = (2, 1)$ is configured and the selected orthogonal beam pair is horizontal (in 1st dim) and is located at $\{(x, 0)\}$ where $x = \{0, O_1\}$; Beam Group 2 corresponds to a beam group when $(L_1, L_2) = (1, 1)$ is configured and the selected orthogonal beam pair is in -45 degree direction and is located at $(O_1, 0)$ and $(0, O_2)$; and Beam Group 3 corresponds to a beam group when $(L_1, L_2) = (1, 1)$ is configured and the selected orthogonal beam pair is in +45 degree direction and is located at $(0, 0)$ and (O_1, O_2) .

[0487] In some embodiments, Table 43 and Table 44 are used as a rank-3 (3 layers) and rank-4 (4 layers) master codebook that can be used for any of $Q = 8, 12, 16$, and 32 antenna port configurations.

[0488] Please see the Table Section for Tables 43 and 44.

[0489] Table 45 shows i'_2 indices to orthogonal beam pairs mapping that are considered to derive rank-3 precoders $\tilde{W}_{m_1, m_1, m_2, m_2}^{(3)}$ and $\tilde{W}_{m_1, m_1, m_2, m_2}^{(3)}$ in Table 43. Depending on the configured beam group, a UE selects a subset of i'_2 indices in Table 45 in order to derive the codebook for PMI calculation. Table also shows selected rank-3 i'_2 indices determined dependent upon a selected beam group. Beam group 0, Beam group 1, and Beam group 2 are constructed according to Figure 26. The corresponding mapping for rank-4 pre-coders in Table 44 is also shown in Table 45.

[0490] Table 45: i'_2 indices to orthogonal beam pairs mapping (in Table 43)

Beam Group	Rank-3 i'_2 indices	Rank-3 i'_2 indices	Rank-4 i'_2 indices	Rank-4 i'_2 indices	Orthogonal beam pairs
0	0 - 3	4 (2 bits)	0 - 1	2 (1 bit)	(0,0), (0, O_2)
1	4 - 7		2 - 3		(0,0), (O_1 ,0)
2	8 - 11		4 - 5		(0, O_2), (O_1 ,0)
3	12 - 15		6 - 7		(0,0), (O_1 , O_2)

[0491] In some embodiments, a beam group is configured with a beam group which is a subset of the four beam group set $S = \{\text{Beam Group 0, Beam Group 1, Beam Group 2, and Beam Group 3}\}$, where beam groups are according to Figure 26. Depending on the configured subset of S , the UE derives rank 3-4 i'_2 indices from Table 45.

[0492] In one example, the configured beam group is a singleton subset of S , for example $S_0 = \{\text{Beam Group 1}\}$.

[0493] In one example, the configured beam group is a non- singleton, strict subset of S , for example $S_1 = \{\text{Beam Group 0, Beam Group 1}\}$, and $S_2 = \{\text{Beam Group 1, Beam Group 3}\}$.

[0494] In one example, the configured beam group is the full set $S_3 = S$.

[0495] For these example sets $S_0 - S_3$, the selected rank 3-4 i'_2 indices and their mapping to i_2 indices and the corresponding number of feedback bits are tabulated in Table 46. Note that this table is for illustration only. Similar table can be constructed for other beam groups according to some embodiments of this disclosure.

[0496] Table 46: i'_2 indices to i_2 indices mapping for example beam groups

Configured beam group	Rank-3 i'_2 indices	Rank-3 i_2 indices (number of bits)	Rank-4 i'_2 indices	Rank-4 i_2 indices (number of bits)
S0	4 - 7	0 - 3 (2 bits)	2 - 3	0 - 1 (1 bit)
S1	0 - 7	0 - 7 (3 bits)	0 - 3	0 - 3 (2 bits)
S2	4 - 7, 12 - 15	0 - 7 (3 bits)	2 - 3, 6 - 7	0 - 3 (2 bits)
S3	0 - 15	0 - 7 (4 bits)	0 - 7	0 - 7 (3 bits)

[0497] Figure 27 illustrates example beam grouping schemes 2700 for rank 3-4 according to some embodiments of the present disclosure.

[0498] In some embodiments, the rank 3-4 master codebook consists of W_1 beam groups of $(L_1, L_2) = (8, 2)$ beams as shown in Figure 27, where it is assumed that O_1 belongs to $\{4, 8, 16, \dots\}$. The beam group consists of 4 quadruple of orthogonal beams, which are shown as black and three pattern squares, where each quadruple comprises of 4 “closest” orthogonal beams in 2D. For example, the quadruple shown in black comprises of 4 orthogonal beams $\{0, 4, 8, 12\}$. Note that beams are numbered according to the numbering scheme shown to the right-hand-side of the $(8, 2)$ grid in the figure. The same numbering scheme will be used in the embodiments below. The 4 orthogonal beams for the other three quadruples shown as three patterns can be determined similarly.

[0499] In some embodiments, Figure 27 illustrates rank 3-4 beam groups according to some embodiments of the present disclosure. The 1st dim and the 2nd dim in the figure correspond to beams in the first dimension and in the second dimension. The black and three pattern squares represent the beams that form a beam group and are obtained after beam selection and the white squares represent the beams that are not included in the beam group.

[0500] In the Figure 27:

- Beam Group 0 corresponds to a beam group when $(L_1, L_2) = (8, 1)$ is configured and the selected orthogonal beam pairs are along horizontal (or 1st dim) and are located at $\{(0, 4), (1, 5), (2, 6), (3, 7)\}$;

- Beam Group 1 corresponds to a beam group when $(L_1, L_2) = (4, 2)$ is configured and the selected orthogonal beam pairs are located at $\{(0, 4), (1, 5)\}$ in the first row and at $\{(2, 6), (3, 7)\}$ in the second row;
- Beam Group 2 corresponds to a beam group when $(L_1, L_2) = (4, 2)$ is configured and the selected orthogonal beam pairs are located at $\{(0, 4), (1, 5)\}$ in the first row, $(0, 8)$ in the first column, and $(0, 9)$ along the +45 direction;
- Beam Group 3 corresponds to a beam group when $(L_1, L_2) = (2, 2)$ is configured and the selected orthogonal beam pairs are located at $\{(0, 8), (1, 9)\}$ in the first and the second columns, $(0, 9)$ along the +45 direction, and $(1, 8)$ along the -45 direction ; and
- Beam Group 4 corresponds to a beam group when $(L_1, L_2) = (2, 2)$ - *checker pattern* is configured and the selected orthogonal beam pairs are located at $\{(0, 9), (9, 2), (2, 11), (11, 0)\}$ which form a checker pattern.

[0501] In some embodiments, similar to Table 43 and Table 44, rank-3 (3 layers) and rank-4 (4 layers) master codebooks can be constructed by considering union of all orthogonal beam pairs according to Beam Group 0 - Beam Group 4 in Figure 27, that can be used for any of $Q = 8, 12, 16$, and 32 antenna port configurations.

[0502] In some embodiments, a UE is configured with at least one beam group out of Beam Group 0 - Beam Group 4 in Figure 27 according to some embodiments of this disclosure. Depending on the configured beam group, the UE either selects the beams from $(8, 2)$ beam grid in Figure 27 or i'_2 indices from the associated rank 3-4 codebook tables, and maps them sequentially to i_2 indices 0 - A, according to some embodiments of this disclosure, where A+1 is the number of selected i'_2 indices.

[0503] Figure 28 illustrates beam grouping schemes 2800 for rank 3-4 according to some embodiments of the present disclosure.

[0504] In some embodiments, the rank 3-4 master codebook consists of W_1 beam groups of $(L_1, L_2) = (4, 2)$ beams as shown in Figure 28, where it is assumed that O_1 belongs to $\{2, 4, 8, 16, \dots\}$. The beam group consists of 2 quadruple of orthogonal beams, which are shown as black and dotted pattern squares, where each quadruple comprises of 4 "closest" orthogonal beams in 2D. For example, the quadruple shown in black comprises of 4 orthogonal beams $\{0, 2, 4, 6\}$. Note that beams are numbered according to the numbering scheme shown to the right-hand-side of the $(4, 2)$ grid in the figure. The same numbering scheme will be used in the embodiments below. The 4 orthogonal beams for the other quadruple shown as dotted patterns is $\{1, 3, 5, 7\}$.

[0505] Figure 28 illustrates rank 3-4 beam groups according to some embodiments of the current invention, the illustrations of different beam groups is similar to those in Figure 27.

[0506] In some embodiments, similar to Table 43 and Table 44, rank-3 (3 layers) and rank-4 (4 layers) master codebooks can be constructed by considering union of all orthogonal beam pairs according to Beam Group 0 - Beam Group 4 in Figure 28, that can be used for any of $Q = 8, 12, 16$, and 32 antenna port configurations.

[0507] In some embodiments, a UE is configured with at least one beam group out of Beam Group 0 - Beam Group 4 in Figure 28 according to some embodiments of this disclosure. Depending on the configured beam group, the UE either selects the beams from (4,2) beam grid in Figure 28 or i'_2 indices from the associated rank 3-4 codebook tables, and maps them sequentially to i_2 indices 0 - A, according to some embodiments of this disclosure, where A+1 is the number of selected i'_2 indices.

[0508] Rank 3-4 codebook based on orthogonal pair type

[0509] Figure 29 illustrates example rank 3-4 orthogonal beam pairs 2900 for 2 antenna ports in shorter dimension according to some embodiments of the present disclosure.

[0510] In some embodiments, starting from the master leading beam group of size $(L_1, L_2) = (4, 2)$ for $N_1 \geq N_2$ and $(2, 4)$ for $N_1 < N_2$, the rank-3 and rank-4 orthogonal beam pairs are constructed based upon the orthogonal pair type. An illustration of example orthogonal pair types, for 2 antenna ports in the shorter dimension, is shown in Figure 29. The top of the figure shows the master beam group which comprises of the leading beams $\{b_0\}$ of the group of orthogonal beam pairs $\{(b_0, b_1)\}$, where

- $b_0 \in B_0^A \equiv \{(x, y) : x \in \{0, p_1, 2p_1, 3p_1\} \text{ and } y \in \{0, p_2\}\}$ for $N_1 \geq N_2$, and
- $b_0 \in B_0^B \equiv \{(x, y) : x \in \{0, p_1\} \text{ and } y \in \{0, p_2, 2p_2, 3p_2\}\}$ for $N_1 < N_2$.

[0511] The orthogonal beams $\{b_1\}$ of the orthogonal pairs are determined dependent upon the orthogonal pair type.

[0512] Two example orthogonal beam types are:

- Orthogonal beam type 0: This pair is constructed by considering beams that are orthogonal to the leading beams in the *longer dimension only*. According to this construction, the orthogonal beams are
 - $b_1 \in B_1^A \equiv \{(O_1 + x, y) : (x, y) \in B_0^A\}$ for $N_1 \geq N_2$, and
 - $b_1 \in B_1^B \equiv \{(x, O_2 + y) : (x, y) \in B_0^B\}$ for $N_1 < N_2$; and

- Orthogonal beam type 1: This pair is constructed by considering beams that are orthogonal to the leading beams in *both longer and shorter dimensions*. According to this construction, the orthogonal beams are

- $b_1 \in B_1^{(A)} \equiv \{(O_1 + x, O_2 + y) : (x, y) \in B_0^A\}$ for $N_1 \geq N_2$, and
- $b_1 \in B_1^{(B)} \equiv \{(O_1 + x, O_2 + y) : (x, y) \in B_0^B\}$ for $N_1 < N_2$.

[0513] In general, for $N_1 \geq N_2$,

- Orthogonal beam type 0: $b_1 \in B_1^{(A)} \equiv \{(n_1 O_1 + x, y) : (x, y) \in B_0^A\}$; and
- Orthogonal beam type 1: $b_1 \in B_1^{(A)} \equiv \{(n_1 O_1 + x, n_2 O_2 + y) : (x, y) \in B_0^A\}$.

[0514] Here, $n_1 \in \{1, \dots, N_1 - 1\}$ and $n_2 \in \{1, \dots, N_2 - 1\}$. For $N_1 < N_2$, the general orthogonal beam types can be defined similarly.

[0515] In one method, n_1, n_2 are fixed in the specification. In another method, n_1, n_2 is either configured by higher-layer signaling (RRC) or reported by the UE.

[0516] In some embodiments, separate rank 3-4 codebooks are constructed for each of the orthogonal beam pair types. For example, for Orthogonal pairs 0 and Orthogonal pair 1 in Figure 29, two separate rank 3-4 tables are constructed similar to some embodiments of this disclosure.

[0517] In some embodiments, a single rank 3-4 codebooks are constructed for each of the orthogonal beam pair types. For example, for Orthogonal pairs 0 and Orthogonal pair 1 in Figure 29, a single rank 3-4 tables is constructed.

[0518] For $N_1 \geq N_2$, Table 48 and Table 49 show the example of single master rank 3-4 codebook tables that can be used for any of $Q = 8, 12, 16$, and 32 antenna port configurations, wherein δ_1, δ_2 are according to Table 47. For $N_1 < N_2$, the codebook tables can be constructed similarly.

[0519] In one method, $s_1 = O_1$, and $s_2 = O_2$. In this case $i_{1,2}=0$ and $i_{1,2}=1$ result in the same precoding matrix.

- If $(N_1, N_2) = (4, 2)$, then $i_{1,1} \in \{0, 1, \dots, N_1 - 1\}$ and $i_{1,2}=0$. In this case $i_{1,2}$ is not reported by the UE. Then, the number of bits for indicating $(i_{1,1}, i_{1,2})$ pair is correspondingly determined with counting only the $i_{1,1}$ component.
- If $(N_1, N_2) = (3, 2)$, then $i_{1,1} \in \{0, 1, \dots, N_1 - 1\}$ and $i_{1,2}=0$; and hence $i_{1,2}$ is not reported by the UE. Then, the number of bits for indicating $(i_{1,1}, i_{1,2})$ pair is correspondingly determined, with counting only the $i_{1,1}$ component.

[0520] In one method, $s_1 = O_1$, and $s_2 = O_2/2$. In this case $i_{1,2}=0$ and $i_{1,2}=1$ result in the difference precoding matrices.

- If $(N_1, N_2) = (4, 2)$, then $i_{1,1} \in \{0, 1, 2, 3\}$ and $i_{1,2} \in \{0, 1\}$. Then, the number of bits for indicating $(i_{1,1}, i_{1,2})$ pair is $(2+1 = 3)$ bits.
- If $(N_1, N_2) = (3, 2)$, then $i_{1,1} \in \{0, 1, 2\}$ and $i_{1,2} \in \{0, 1\}$. Then, the number of bits for indicating $(i_{1,1}, i_{1,2})$ pair is $(2+1 = 3)$ bits.

[0521] Table 47: Orthogonal beam type to (δ_1, δ_2) mapping

Type	Configuration	δ_1	δ_2
Orthogonal beam type 0	$N_1 \geq N_2$	O_1	0
	$N_1 < N_2$	0	O_2
Orthogonal beam type 1	Both	O_1	O_2

[0522] Please see the Table Section for Tables 48 and 49.

[0523] In some embodiments, the rank 3-4 orthogonal beam pair type is pre-determined, for example Orthogonal beam type 0.

[0524] In some embodiments, a UE is configured with a rank 3-4 orthogonal pair type e.g., selected from Orthogonal beam type 0 and Orthogonal beam type 1, by the eNB via RRC.

[0525] In some embodiments, a UE reports a rank 3-4 orthogonal pair type selected from Orthogonal beam type 0 and Orthogonal beam type 1, to the eNB.

[0526] In one method, this indication is SB and short-term. In this case, the UE reports orthogonal pair type per subband, and i_2 can indicate this information as well as other information such as beam selection and co-phase.

[0527] In another method, it is WB and long-term. In this case the UE reports one orthogonal pair type for whole set S subbands in case of PUSCH reporting. In case of PUCCH reporting, this information is reported together with i_1 (i_{11} and i_{12}).

[0528] Figure 30 illustrates beam grouping schemes 3000 for rank 3-4: $N_1 \geq N_2$ case according to some embodiments of the present disclosure.

[0529] In some embodiments, for $N_1 \geq N_2$, Figure 30 illustrates rank 3-4 beam groups BG0, BG1, and BG2. For $N_1 < N_2$, the beam groups are obtained by 90 degree rotation of those in Figure 30. The shaded (gray) and pattern squares represent the beams that form a beam group and are obtained after beam selection and the white squares represent the beams that are not included in the beam group.

[0530] In Figure 30:

- Beam Group 0 corresponds to a beam group when $(L_1, L_2) = (4, 1)$ is configured and the selected beams are in the 1st dimension only;
- Beam Group 1 corresponds to a beam group when $(L_1, L_2) = (2, 2)$ - *square* is configured and the selected beams form a square; and
- Beam Group 2 corresponds to a beam group when $(L_1, L_2) = (2, 2)$ - *checker board* is configured and the selected beams form a checker board.

[0531] In some embodiments, a UE is configured with a beam group from BG0, BG1, and BG2 according to some embodiments of the present disclosure. Depending on the configured BG, UE constructs the rank 3-4 codebook for the PMI calculation.

[0532] Depending on the configured beam group, a UE selects a subset of i'_2 indices in Table 48 and Table 49 in order to derive the rank 3 & 4 codebook for PMI calculation. In one method, the UE sequentially maps the selected i'_2 indices to 0-4 to obtain the corresponding i_2 indices, where $A+1$ is the number of selected i'_2 indices.

[0533] Table 50 and Table 51 respectively show selected rank-3 & 4 i'_2 indices determined dependent upon a selected beam group. Beam group 0, Beam group 1, and Beam group 2 are constructed according to Figure 30.

[0534] Table 50: Selected i'_2 indices for rank-3 CSI reporting (in Table 48)

Beam Group	Selected i'_2 indices
0	0 – 15
1	0 - 7, 16 - 23
2	0 – 3, 8 – 11, 20 – 23, 28 – 31

Table 51: Selected i'_2 indices for rank-4 CSI reporting (in Table 47)

Beam Group	Selected i'_2 indices
0	0 – 7
1	0 - 3, 8 – 11
2	0 – 1, 4 – 5, 10 – 11, 14 – 15

[0535] In one method, a UE is configured with a beam group type indicator and an orthogonal beam type indicator by higher layer.

[0536] In another method, a UE is configured with a beam group type indicator by higher layer, and configured to report an orthogonal beam type indicator together with either i_1 or i_2 .

[0537] Figure 31 illustrates Rank 3-4 orthogonal beam pairs 3100 for $N_2 \geq 4$ antenna ports in shorter dimension according to some embodiments of the present disclosure.

[0538] In some embodiments, for $N_2 \geq 4$ antenna ports in the shorter dimension, as shown in Figure 31, three orthogonal pair types are considered for rank 3-4 orthogonal beam pair construction, where Orthogonal pair 0 and 1 are the same as explained above. Orthogonal pair 2 is constructed by considering beams that are orthogonal to the leading beams in both longer and shorter dimensions, and that are going shown as shown in the figure. According to this construction, the orthogonal beams are:

$$b_1 \in \{(O_1 + x, (N_2 - 1)O_2 + y) : x \in \{0, p_1, 2p_1, 3p_1\} \text{ and } y \in \{0, p_2\}\}.$$

[0539] The rank 3-4 codebook tables in this case can be constructed according to some embodiments of this disclosure.

[0540] Rank 5-8 codebook based on orthogonal pair type: 16 ports

[0541] Figure 32 illustrates rank 5-8 orthogonal beam combinations 3200 for $(N_1, N_2) = (4, 2)$ according to some embodiments of the present disclosure.

[0542] In some embodiments, for $(N_1, N_2) = (4, 2)$, starting from the 8 orthogonal beams, as illustrated in Figure 32, orthogonal beam combinations for rank 5-8 precoding matrices are constructed based upon the orthogonal beam types. An illustration of example orthogonal beam types is also shown in Figure 32. The top of the figure shows the 8 orthogonal beams which comprises of the orthogonal beams (b_0, b_1) , where $(b_0, b_1) \in \{(x, y) : x \in \{0, O_1, 2O_1, 3O_1\} \text{ and } y \in \{0, O_2\}\}$.

[0543] Three orthogonal beam types that is likely to show up in practice according to the propagation channel characteristics are:

- Orthogonal beam type 0: This pair is constructed by considering 4 beams that are orthogonal in *the first (longer) dimension only*. According to this construction, the orthogonal beams are $(b_0, b_1) \in \{(x, 0) : x \in \{0, O_1, 2O_1, 3O_1\}\}$;
- Orthogonal beam type 1: This pair is constructed by considering 4 beams that are orthogonal in *both first (longer) and second (shorter) dimensions* and that form a checker pattern. According to this construction, the orthogonal beams are $(b_0, b_1) \in \{(0, 0), (0, O_2), (O_1, 0), (O_1, O_2)\}$; and

- Orthogonal beam type 2: This pair is constructed by considering 4 beams that are orthogonal in *both first (longer) and second (shorter) dimensions* and that form a square. According to this construction, the orthogonal beams are $(b_0, b_1) \in \{(x, y) : x \in \{0, O_1\} \text{ and } y \in \{0, O_2\}\}$.

[0544] For $(N_1, N_2) = (2, 4)$ configuration, the orthogonal beam type construction is similar (90 degree rotation of orthogonal beam types in Figure 32).

[0545] In some embodiments, the rank 5-8 orthogonal beam type is pre-determined, for example Orthogonal beam type 0.

[0546] In some embodiments, a UE is configured with a rank 5-8 orthogonal beam type by the eNB via RRC.

[0547] In some embodiments, a UE reports a rank 5-8 orthogonal beam type to the eNB.

[0548] In one method, the candidate orthogonal beam type comprises only types 0 and 1.

[0549] In one method, this indication is SB and short-term. In this case, the UE reports orthogonal beam type per subband, and i_2 can indicate this information as well as other information such as beam selection and co-phase.

[0550] In another method, it is WB and long-term. In this case the UE reports one orthogonal beam type for whole (set S) subbands in case of PUSCH reporting. In case of PUCCH reporting, this information is reported together with i_1 (i_{11} and i_{12}).

[0551] Table 52: Orthogonal beam type to (δ) mapping: 16 ports

Type	Configuration	$\delta_{1,1}$	$\delta_{2,1}$	$\delta_{1,2}$	$\delta_{2,2}$	$\delta_{1,3}$	$\delta_{2,3}$
Orthogonal beam type 0	$N_1 \geq N_2$	O_1	0	$2O_1$	0	$3O_1$	0
	$N_1 < N_2$	0	O_2	0	$2O_2$	0	$3O_2$
Orthogonal beam type 1	$N_1 \geq N_2$	O_1	O_2	$2O_1$	0	$3O_1$	O_2
	$N_1 < N_2$	O_1	O_2	0	$2O_2$	0	$3O_2$
Orthogonal beam type 2	Both	O_1	0	O_1	O_2	0	O_2

[0552] In one method, $s_1 = 2$, and $s_2 = 2$.

- $i_{1,1} \in \{0, \dots, O_1/2-1\}$ and $i_{1,2} \in \{0, \dots, O_2/2-1\}$. Then, the number of bits for indicating $(i_{1,1}, i_{1,2})$ pair is corresponding correspondingly determined. This is valid for both cases of $(N_1, N_2) = (4, 2)$ and $(3, 2)$.

[0553] In some embodiments, δ_1, δ_2 for rank 3-4 and $\delta_{1,1}, \delta_{1,2}, \delta_{1,3}, \delta_{2,1}, \delta_{2,2}, \delta_{2,3}$ for rank 5-8 are respectively configured with two separate orthogonal beam type configurations according to Table 47 and Table 52.

[0554] In some embodiments, δ_1, δ_2 for rank 3-4 and $\delta_{1,1}, \delta_{1,2}, \delta_{1,3}, \delta_{2,1}, \delta_{2,2}, \delta_{2,3}$ for rank 5-8 are configured with a common orthogonal beam type configuration according to Table 47 and Table 52. For example, if orthogonal beam type 0 is configured, type 0 is configured for rank 3-8 and the delta values are selected as in the following:

	δ_1		δ_2			
Orthogonal beam type 0	O_1		0			
	$\delta_{1,1}$	$\delta_{2,1}$	$\delta_{1,2}$	$\delta_{2,2}$	$\delta_{1,3}$	$\delta_{2,3}$
Orthogonal beam type 0	O_1	0	$2O_1$	0	$3O_1$	0

[0555] In some embodiments, δ_1, δ_2 for rank 3-4 and $\delta_{1,1}, \delta_{1,2}, \delta_{1,3}, \delta_{2,1}, \delta_{2,2}, \delta_{2,3}$ for rank 5-8 are configured according to Table 53, wherein δ_1, δ_2 for rank 3-4 is mapped to $\delta_{1,1}, \delta_{2,1}$ in the table.

[0556] Table 53: Alternate delta table for rank 3-8 codebook

	δ	k			
		0	1	2	3
If $N_2 = 1$	$\delta_{1,k}$	0	O_1	$2O_1$	$3O_1$
	$\delta_{2,k}$	0	0	0	0
If $N_1 > 1$ and $N_2 > 1$	$\delta_{1,k}$	0	O_1	0	O_1
	$\delta_{2,k}$	0	0	O_2	O_2
If $N_1 = 1$	$\delta_{1,k}$	0	0	0	0
	$\delta_{2,k}$	0	O_2	$2O_2$	$3O_2$

[0557] Rank 5-8 codebook based on orthogonal pair type: 12 ports

[0558] Figure 33 illustrates rank 5-8 orthogonal beam combinations 3300 for $(N_1, N_2) = (3, 2)$ according to some embodiments of the present disclosure.

[0559] In some embodiments, for $(N_1, N_2) = (3, 2)$, starting from the 6 orthogonal beams, as illustrated in Figure 33, orthogonal beam combinations for rank 5-8 precoding matrices are constructed based upon the orthogonal beam types. An illustration of example orthogonal beam types is also shown in Figure 33. The top of the figure shows the 6 orthogonal beams which comprises of the orthogonal beams (b_0, b_1) , where $(b_0, b_1) \in \{(x, y) : x \in \{0, O_1, 2O_1\} \text{ and } y \in \{0, O_2\}\}$.

[0560] Three orthogonal beam types that is likely to show up in practice according to the propagation channel characteristics are:

- Orthogonal beam type 0: This pair is constructed by considering 3 beams that are orthogonal in *the longer dimension and 1 beam in the shorter dimension*. According to this construction, the orthogonal beams are $(b_0, b_1) \in \{(x, 0) : x \in \{0, O_1, 2O_1\}\} \cup \{(0, O_2)\}$;
- Orthogonal beam type 1: This pair is constructed by considering 3 beams that are orthogonal in *the longer dimension and 1 beam in the shorter dimension*. According to this construction, the orthogonal beams are $(b_0, b_1) \in \{(x, 0) : x \in \{0, O_1, 2O_1\}\} \cup \{(O_1, O_2)\}$; and
- Orthogonal beam type 2: This pair is constructed by considering 4 beams that are orthogonal in *both first (longer) and second (shorter) dimensions* and that form a square. According to this construction, the orthogonal beams are $(b_0, b_1) \in \{(x, y) : x \in \{0, O_1\} \text{ and } y \in \{0, O_2\}\}$.

[0561] In some embodiments, similar to 16 ports case, a UE is configured with one orthogonal beam type in Figure 33 according to some embodiments of this disclosure.

[0562] In some embodiments, similar to 16 ports case, a UE reports one orthogonal beam type in Figure 33 according to some embodiments of this disclosure.

[0563] For rank 5, 6, 7, 8, the precoding matrices are determined according to the configured orthogonal beam type as in Table 54.

[0564] Table 54 Orthogonal beam type to (δ) mapping: 12 ports

Type	Configuration	$\delta_{1,1}$	$\delta_{2,1}$	$\delta_{1,2}$	$\delta_{2,2}$	$\delta_{1,3}$	$\delta_{2,3}$
Orthogonal beam type 0	$N_1 \geq N_2$	O_1	0	$2O_1$	0	0	O_2
	$N_1 < N_2$	0	O_2	0	$2O_2$	O_1	0
Orthogonal beam type 1	$N_1 \geq N_2$	O_1	0	$2O_1$	0	O_1	O_2
	$N_1 < N_2$	0	O_2	0	$2O_2$	O_1	O_2
Orthogonal beam type 2	Both	O_1	0	O_1	O_2	0	O_2

[0565] Alternate rank 3-4 codebook designs on orthogonal pair type

[0566] Figure 34 illustrates an illustration of beam grouping schemes 3400 for rank 3-4 according to some embodiments of the present disclosure.

[0567] Table 55 Orthogonal beam type to (δ) mapping for rank 3-4 codebook

Type	Orthogonal beam type (k)	$\delta_{1,0}^{(k)}$	$\delta_{2,0}^{(k)}$	$\delta_{1,1}^{(k)}$	$\delta_{2,1}^{(k)}$
Option 0	0	0	0	0	O_1
	1	0	O_1	O_1	O_2
	2	O_1	O_2	0	O_2
	3	0	O_2	0	0
Option 1	0	0	0	0	O_1
	1	0	0	O_1	O_2
	2	O_1	O_2	0	O_2
	3	0	O_2	0	0
Option 2	0	0	0	0	O_1
	1	0	0	O_1	O_2
	2	O_1	O_2	0	O_2
	3	0	O_2	0	O_1

[0568] Figure 34 illustrates the rank 3-4 master codebook 3400 comprising W1 beam groups according to some embodiments of the present disclosure. The beam group consists of 4 “closest” orthogonal beams in 2D, where 4 orthogonal beams with indices $\{0, O_1\}$ are for the 1st dimension and 2 orthogonal beams with indices $\{0, O_2\}$ are for the 2nd dimension.

[0569] Starting from these 4 orthogonal beams, 4 orthogonal beam pair types are constructed that are included in the rank 3-4 master codebook.

[0570] There are multiple options to construct 4 orthogonal pairs. Out of which, three important options, Option 0, Option1, and Option 2 are shown in Figure 34.

- Option 0: In this option, 4 orthogonal beam pairs correspond to 2 horizontal pairs (Orthogonal beam type 0, Orthogonal beam type 2) and 2 vertical pairs (Orthogonal beam type 1, Orthogonal beam type 3).

- Option 1: In this option, 4 orthogonal beam pairs correspond to 2 horizontal pairs (Orthogonal beam type 0, Orthogonal beam type 2), 1 vertical pair (Orthogonal beam type 3), and 1 diagonal up pair (Orthogonal beam type 1).
- Option 2: In this option, 4 orthogonal beam pairs correspond to 1 horizontal pair (Orthogonal beam type 0), 1 vertical pair (Orthogonal beam type 3), 1 diagonal up pair (Orthogonal beam type 1), and 1 diagonal down pair (Orthogonal beam type 2).

[0571] The rank-3 and rank-4 codebooks according to this orthogonal beam pair construction is shown in Table 56 and Table 57, respectively, where Table 55 is used for $\delta_{1,0}^{(k)}$, $\delta_{2,0}^{(k)}$, $\delta_{1,1}^{(k)}$, and $\delta_{2,1}^{(k)}$ values for each of the considered codebook option, where the superscript $k = 0, 1, 2$, and 3 are used for Orthogonal beam type 0, Orthogonal beam type 1, Orthogonal beam type 2, and Orthogonal beam type 3, respectively. Note that the codebooks can be used for any of $Q = 8, 12, 16$, and 32 antenna port configurations with at least 2 ports in the shorter dimension.

[0572] Please see the below Table Section for Table 56 and 57.

[0573] In some embodiments, a UE is configured with one of Option 0, Option 1, and Option 2 for rank 3-4 codebooks.

[0574] In some embodiments, the rank 3-4 codebook option is pre-determined, for example Option 1.

[0575] In some embodiments, a UE is configured with one orthogonal beam type from Orthogonal beam type 0, Orthogonal beam type 1, Orthogonal beam type 2, and Orthogonal beam type 3 in Figure 34 according to some embodiments of this disclosure.

[0576] In some embodiments, a UE reports one orthogonal beam type from Orthogonal beam type 0, Orthogonal beam type 1, Orthogonal beam type 2, and Orthogonal beam type 3 in Figure 34 according to some embodiments of this disclosure.

[0577] Embodiments on rank 3-4 codebooks with 2, 3, or 4 orthogonal beam types (without SB beam selection)

[0578] Figure 35 illustrates beam grouping schemes 3500 for rank 3-4 according to embodiments of the present disclosure.

[0579] Table 58: Number of orthogonal beam type to (δ) mapping for rank 3-4 codebook

Number of orthogonal beam types (K)	Orthogonal beam type (k)	$\delta_{1,0}^{(k)}$	$\delta_{2,0}^{(k)}$	$\delta_{1,1}^{(k)}$	$\delta_{2,1}^{(k)}$

2,3,4	0	0	0	O_1	0
	1	0	0	O_1	O_2
3,4	2	0	0	0	O_2
4	3	0	O_2	O_1	O_2

[0580] In some embodiments, as shown in Figure 35, the rank 3-4 master beam group consists of 4 “closest” orthogonal beams in 2D, where 4 orthogonal beams with indices $\{0, O_1\}$ are for the 1st dimension and 2 orthogonal beams with indices $\{0, O_2\}$ are for the 2nd dimension, and 2, 3, or 4 orthogonal beam types are considered to construct the rank 3-4 codebooks. The 4 orthogonal beam types are as follows:

- Orthogonal beam type 0 corresponds to the orthogonal beam pair $\{(0,0),(O_1,0)\}$.
- Orthogonal beam type 1 corresponds to the orthogonal beam pair $\{(0,0),(O_1,O_2)\}$.
- Orthogonal beam type 2 corresponds to the orthogonal beam pair $\{(0,0),(0,O_2)\}$.
- Orthogonal beam type 3 corresponds to the orthogonal beam pair $\{(0, O_2),(O_1,O_2)\}$.

[0581] Depending on the number of orthogonal beam types considered to construct the rank 3-4 codebooks, the orthogonal beam types are selected as follows:

- If the number of orthogonal beam types = 2, then Orthogonal beam type 0 and Orthogonal beam type 1 are selected.
- If the number of orthogonal beam types = 3, then Orthogonal beam type 0, Orthogonal beam type 1, and Orthogonal beam type 2 are selected.
- If the number of orthogonal beam types = 4, then Orthogonal beam type 0, Orthogonal beam type 1, Orthogonal beam type 2, and Orthogonal beam type 3 are selected.

[0582] Please see the below Table Section for Table 59 and 60.

[0583] The rank-3 and rank-4 codebooks according to this orthogonal beam pair construction is shown in Table 59 and Table 60, respectively, where Table 58 is used for $\delta_{1,0}^{(k)}$, $\delta_{2,0}^{(k)}$, $\delta_{1,1}^{(k)}$, and $\delta_{2,1}^{(k)}$ values for each of $K = 2, 3$, or 4 , where the superscript $k = 0, 1, 2$, and 3 are used for Orthogonal beam type 0, Orthogonal beam type 1, Orthogonal beam type 2, and Orthogonal beam type 3, respectively. Note that the codebooks can be used for any of $Q = 8, 12, 16$, and 32 antenna port configurations with at least 2 ports in the shorter dimension.

[0584] The number of bits to report rank 3-4 PMI (i_2) is shown in Table 61 for both SB and WB reporting of orthogonal beam type. Note that in case SB reporting of orthogonal beam type, $K = 2$

requires 1 bit and $K = 3, 4$ requires 2 bits in each SB. For WB reporting, 1 bit ($K = 1$) and 2 bits ($K = 3, 4$) are reported for the whole WB.

[0585] Table 61: Number of rank 3-4 i_2 bits

K	SB reporting of orthogonal beam type		WB reporting of orthogonal beam type	
	Number of i_2 bits in each SB (Rank 3)	Number of i_2 bits in each SB (Rank 4)	Number of i_2 bits in each SB (Rank 3)	Number of i_2 bits in each SB (Rank 4)
2	$2+1 = 3$	$1+1 = 2$	2	1
3	$2+2 = 4$	$1+2 = 3$		
4	$2+2 = 4$	$1+2 = 3$		

[0586] In some embodiments, a UE is configured with one of $K = 2, 3$, or 4 for rank 3-4 codebooks.

[0587] In some embodiments, the rank 3-4 codebook is pre-determined with a fixed K value, for example $K = 4$.

[0588] In some embodiments, a UE is configured with one orthogonal beam type depending on the configured value of K according to some embodiments of this disclosure.

[0589] In some embodiments, a UE reports one orthogonal beam type from K orthogonal beam types depending on the configured value of K according to some embodiments of this disclosure.

[0590] In one method, the configured value of $K = 4$.

[0591] In one method, this reporting is SB and short-term. In this case, the UE reports orthogonal beam type per subband, and i_2 can indicate this information as well as other information such as beam selection and co-phase.

[0592] In another method, it is WB and long-term. In this case the UE reports one orthogonal beam type for whole (set S) subbands in case of PUSCH reporting. In case of PUCCH reporting, this information is reported together with i_1 (i_{11} and i_{12}).

[0593] Embodiments on rank 3-4 codebooks with 2, 3, or 4 orthogonal beam types (with SB beam selection)

[0594] Figure 36 illustrates beam grouping schemes 3600 for rank 3-4 according to embodiments of the present disclosure.

[0595] In some embodiments, as shown in Figure 36, the rank 3-4 master beam group consists of 4 "closest" orthogonal beam groups of size $(L_1, L_2) = (4, 2)$ in 2D for $N_1 \geq N_2$ configuration, where 4 orthogonal beam groups are located at $\{0, O_1\}$ for the 1st dimension and $\{0, O_2\}$ are for the 2nd

dimension. The 4 orthogonal beam types are the same as in Figure 35 except that each type corresponds to a pair of orthogonal beam groups. Depending on the number of orthogonal beam types (K) considered to construct the rank 3-4 codebooks, the orthogonal beam types are selected as follows:

- Orthogonal beam type 0 corresponds to the orthogonal beam group pair located at $\{(0,0),(O_1,0)\}$.
- Orthogonal beam type 1 corresponds to the orthogonal beam group pair located at $\{(0,0),(O_1,O_2)\}$.
- Orthogonal beam type 2 corresponds to the orthogonal beam group pair located at $\{(0,0),(0,O_2)\}$.
- Orthogonal beam type 3 corresponds to the orthogonal beam group pair located at $\{(0,O_2),(O_1,O_2)\}$.

[0596] Please see the below Table Section for Tables 62 and 63.

[0597] The rank-3 and rank-4 codebooks according to this orthogonal beam group pair construction is shown in Table 62 and Table 63, respectively, where Table 48 is used for $\delta_{1,0}^{(k)}$, $\delta_{2,0}^{(k)}$, $\delta_{1,1}^{(k)}$, and $\delta_{2,1}^{(k)}$ values for each of $K = 2, 3$, or 4 , where the superscript $k = 0, 1, 2$, and 3 are used for Orthogonal beam type 0, Orthogonal beam type 1, Orthogonal beam type 2, and Orthogonal beam type 3, respectively. Note that the codebooks can be used for any of $Q = 8, 12, 16$, and 32 antenna port configurations with at least 2 ports in the shorter dimension.

[0598] Some of the embodiments of this disclosure on configuration or reporting of K , orthogonal beam type, and delta values are applicable to this embodiment.

[0599] It is straightforward for the skilled-in-the-art to recognize that the this embodiment is applicable to other orthogonal beam group sizes including size $(L_1, L_2) = (4,1), (2,2), (2,1)$, and $(1,1)$.

[0600] Embodiments on delta reporting with i_1 ($i_{1,1}$ and $i_{1,2}$)

[0601] In some embodiments, a UE reports δ_1, δ_2 (or $\delta_{1,0}^{(0)}, \delta_{2,0}^{(0)}, \delta_{1,1}^{(0)}$, and $\delta_{2,1}^{(0)}$) for rank 3-4 codebooks and $\delta_{1,1}, \delta_{1,2}, \delta_{1,3}, \delta_{2,1}, \delta_{2,2}, \delta_{2,3}$ for rank 5-8 codebooks, according to some embodiments of this disclosure, jointly with i_1 (or $i_{1,1}$ or $i_{1,2}$).

[0602] In one alternative, the UE reports $i_1' = (i_1, j)$ where i_1 corresponds to the W1 beam group reporting and j corresponds to the orthogonal beam type (δ_1, δ_2 or $\delta_{1,0}^{(0)}, \delta_{2,0}^{(0)}, \delta_{1,1}^{(0)}$, and $\delta_{2,1}^{(0)}$) reporting for rank 3-4. For example, for rank 3-4 codebook tables in Table 62 and Table 637, the

UE reports i'_1 using a 4-bit indication, where the 2 bits are used to indicate i_1 and 2 bits are used indicate j .

[0603] In one method, the two most significant bits (MSB) corresponds to the orthogonal beam type (j) and the 2 two least significant bits (LSB) corresponds to i_1 . Table 64 shows an example of such i'_1 reporting.

[0604] Table 64: i'_1 to (i_1, j) mapping for rank 3-4 codebooks (Table 62 and Table 63)

$b_3b_2b_1b_0$		j	b_1b_0	i_1
0000	00	Orthogonal beam type 0	00	0
0001			01	1
0010			10	2
0011			11	3
0100-0111	01	Orthogonal beam type 1	00,01,10,11	0-3
1000-1011	10	Orthogonal beam type 2	00,01,10,11	0-3
1100-1111	11	Orthogonal beam type 3	00,01,10,11	0-3

[0605] In another method, the two most significant bits (MSB) corresponds to i_1 and the 2 two least significant bits (LSB) corresponds to the orthogonal beam type (j).

[0606] In another alternative, the UE reports $i'_{1,1} = (i_{1,1}, j)$ where $i_{1,1}$ corresponds to the W1 beam group reporting in the 1st dimension and j corresponds to the orthogonal beam type (δ_1, δ_2 or $\delta_{1,0}^{(0)}, \delta_{2,0}^{(0)}, \delta_{1,1}^{(0)},$ and $\delta_{2,1}^{(0)}$) reporting for rank 3-4. For example, for rank 3-4 codebook tables in Table 62 and Table 63 the UE reports $i'_{1,1}$ using a 4-bit indication, where the 2 bits are used to indicate $i_{1,1}$ and 2 bits are used indicate j . Similar to the first alternative, 2 bits to indicate j may either be 2 LSBs or 2 MSBs of the 4-bit indication.

[0607] In yet another alternative, the UE reports $i'_{1,2} = (i_{1,2}, j)$ where $i_{1,2}$ corresponds to the W1 beam group reporting in the 2nd dimension and j corresponds to the orthogonal beam type (δ_1, δ_2 or $\delta_{1,0}^{(0)}, \delta_{2,0}^{(0)}, \delta_{1,1}^{(0)},$ and $\delta_{2,1}^{(0)}$) reporting for rank 3-4.

[0608] The above-mentioned alternatives are applicable to rank 5-8 codebooks. For instance, i'_1 may be reported using a 4-bit indication, whose 2 bits are for i_1 ($i_{1,1}$ and $i_{1,2}$) indication and 2 bits are for orthogonal beam type ($\delta_{1,1}, \delta_{1,2}, \delta_{1,3}, \delta_{2,1}, \delta_{2,2}, \delta_{2,3}$) indication.

[0609] Other rank 3-8 codebook design alternatives

[0610] In some embodiments, rank 3-8 codebooks can be constructed according to alternative master codebook alternatives 1-4 shown in Figure 37, Figure 38, Figure 39, and Figure 40, according to some embodiments of this disclosure.

[0611] Figure 37 illustrates an alternate rank 3-8 codebook design 1 3700: $(L_1, L_2) = (4, 2)$ according to embodiments of the present disclosure;

[0612] Figure 38 illustrates an Alternate rank 3-8 codebook design 2 3800: $(L_1, L_2) = (4, 1)$ according to embodiments of the present disclosure;

[0613] Figure 39 illustrates an alternate rank 3-8 codebook design 3 3900: $(L_1, L_2) = (2, 2)$ according to embodiments of the present disclosure.

[0614] Figure 40 illustrates an alternate rank 3-8 codebook design 4 4000: $(L_1, L_2) = (2, 1)$ according to embodiments of the present disclosure.

[0615] In some embodiments, as shown in Figure 36B, the rank 3-4 master beam group consists of 4 orthogonal beam types of size $(L_1, L_2) = (4, 2)$ in 2D for $N_1 \geq N_2$ configuration, where the orthogonal beam types are as follows: Orthogonal beam type 0 corresponds to the orthogonal beam group pair located at $\{(0, 0), (O_1, 0)\}$. Orthogonal beam type 1 corresponds to the orthogonal beam group pair located at $\{(0, 0), (O_1, O_2)\}$. Orthogonal beam type 2 corresponds to the orthogonal beam group pair located at $\{(0, 0), (0, O_2)\}$. Orthogonal beam type 3 corresponds to the orthogonal beam group pair located at $\{(0, 0), ((N_1 - 1)O_1, 0)\}$.

[0616] The rank-3 and rank-4 codebooks according to construction is shown in Table 66 and Table 67, respectively, where Table 65 is used for δ_1 and δ_2 values and the indices $k = 0, 1, 2$, and 3 are used for Orthogonal beam type 0, Orthogonal beam type 1, Orthogonal beam type 2, and Orthogonal beam type 3, respectively. Note that the codebooks can be used for any of $Q = 8, 12, 16$, and 32 antenna port configurations. Note also that $k = 3$ is applicable to $Q = 12, 16$, and 32 ports.

[0617] Table 65: Orthogonal beam type to (δ_1, δ_2) mapping for $N_1 \geq N_2$

	δ	k			
		0	1	2	3
If $N_1 > 1$ and $N_2 > 1$	δ_1	O_1	0	O_1	$(N_1 - 1)O_1$
	δ_2	0	O_2	O_2	0
If $N_2 = 1$	δ_1	O_1	$2O_1$	$3O_1$	$(N_1 - 1)O_1$
	δ_2	0	0	0	0

[0618] The UE is configured to report $i_{1,1}$, $i_{1,2}$, and k jointly WB and long-term according to some embodiments of this disclosure, where the range of values that they take are follows: $i_{1,1} = 0, 1, \dots, \frac{O_1 N_1}{s_1} - 1$; $i_{1,2} = 0, 1, \dots, \frac{O_2 N_2}{s_2} - 1$; and $k = 0, 1, 2, 3$. Note that 2-bit indication is needed to report the orthogonal beam type k .

[0619] Please see the below Table Section for Tables 66 and 67.

[0620] In some embodiments, a UE is configured with a beam group configuration from four configurations, namely Config 1, Config 2, Config 3, and Config 4, for codebook subset selection on master rank 3-4 codebooks. For $k = 0$, an illustration of the four configurations is shown Figure 41. Depending on the configuration, the UE selects i'_2 indices (in Table 66 and Table 67) according to Table 68 and Table 69 for rank 3 and rank 4, respectively, for PMI reporting. The parameters (s_1, s_2) and (p_1, p_2) for the four configurations are shown in Table 68 and Table 69. Note that three options are provided for s_2 in case of Config 4. Depending on the desired number of beams (or resolution) in the shorter dimension, the UE is configured with one option.

[0621] Figure 41 illustrates example orthogonal beams 4100 for rank 3-4 when $k = 0$ according to some embodiments of the present disclosure.

[0622] Table 68: Selected i'_2 indices for rank-3 CSI reporting (in Table 66)

Config	Selected i'_2 indices	(s_1, s_2)	(p_1, p_2)
1	0, 2	(1, 1)	(-, -)
2	0 - 7, 16 - 23	(O_1, O_2)	$(\frac{O_1}{2}, \frac{O_2}{2})$
3	0 - 3, 8 - 11, 20 - 23, 28 - 31	(O_1, O_2)	$(\frac{O_1}{4}, \frac{O_2}{2})$

4	0 - 15	$(O_1, -)$ If $N_2 = 1$ Option 0: $(O_1, 2)$ If $N_1 > 1$ and $N_2 > 1$ Option 1: $(O_1, \frac{O_2}{2})$ If $N_1 > 1$ and $N_2 > 1$ Option 2: (O_1, O_2) If $N_1 > 1$ and $N_2 > 1$	$(\frac{O_1}{4}, -)$
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[0623] Table 69: Selected i'_2 indices for rank-4 CSI reporting (in Table 67)

Config	Selected i'_2 indices	$(s1, s2)$	(p_1, p_2)
1	0, 1	(1,1)	$(-, -)$
2	0 - 3, 8 - 11	(O_1, O_2)	$(\frac{O_1}{2}, \frac{O_2}{2})$
3	0 - 1, 4 - 5, 10 - 11, 14 - 15	(O_1, O_2)	$(\frac{O_1}{4}, \frac{O_2}{2})$
4	0 - 7	$(O_1, -)$ If $N_2 = 1$ Option 0: $(O_1, 2)$ If $N_1 > 1$ and $N_2 > 1$ Option 1: $(O_1, \frac{O_2}{2})$ If $N_1 > 1$ and $N_2 > 1$ Option 2: (O_1, O_2) If $N_1 > 1$ and $N_2 > 1$	$(\frac{O_1}{4}, -)$

[0624] Note that $p_1 = s_1/L_1$ for Configs 2-4, where L_1 is the number of included beam indices along the first dimension of the master codebook. In other words, for Configs 2-4, the effective oversampling is kept fixed for rank 3-4.

[0625] In some embodiments, a UE is configured with a larger table of δ_1 and δ_2 values (index k). In one example, the table of δ_1 and δ_2 values include all orthogonal pairs with the leading beam (0,0). An example of such a table is shown in Table 70. Depending on the number of antenna ports (Q), the UE uses a subset of δ_1, δ_2 (or k values). For instance, if $Q = 8$, the UE uses $k = 0 - 2$; if Q

= 12, the UE uses $k = 0 - 4$; and $Q = 16$, the UE uses $k = 0 - 6$. Note the 2-bit indication is needed for $Q = 8$, and 3-bit indication is needed for $Q = 12, 16$.

[0626] Table 70 Orthogonal beam type to (δ_1, δ_2) mapping for $N_1 \geq N_2$

	δ	k						
		0	1	2	3	4	5	6
If $N_1 > 1$ and $N_2 > 1$	δ_1	0_1	0	0_1	20_1	20_1	30_1	30_1
	δ_2	0	0_2	0_2	0	0_2	0	0_2
If $N_2 = 1$	δ_1	0_1	20_1	30_1	40_1	50_1	60_1	70_1
	δ_2	0	0	0	0	0	0	0

[0627] In some embodiments, a UE is configured with rank 3-4 codebooks with codebook subset restriction (CSR) on k , which determines a subset of values of k UE can report.

[0628] In one method, the CSR configuration is based on a bitmap.

[0629] For example, for k values in Table 70, a 7-bit bitmap can be configured to indicate a subset of k values that UE can report.

[0630] For example, for k values in Table 65, a 4-bit bitmap can be configured to indicate a subset of k values that UE can report.

[0631] It is straightforward for the skilled-in-the-art to recognize that the this embodiment is applicable to antenna port configuration $N_1 < N_2$ and other orthogonal beam group sizes including size $(L_1, L_2) = (4, 1), (2, 2), (2, 1),$ and $(1, 1)$.

[0632] Alternate rank 5-6 codebooks for $N_1 \geq N_2$

[0633] Figure 42 illustrates alternate rank 5-6 orthogonal beam types 4200 according to embodiments of the present disclosure.

[0634] In some embodiments, a UE reports or is configured with a orthogonal beam type for rank 5-6 codebooks from Orthogonal beam types 0-7 as shown in Figure 42 according to some embodiments of this disclosure. Depending on the configuration, the UE selects the three orthogonal beams, the first beam is located at $(0, 0)$, and the 2nd and 3rd beams correspond to indices (k_1, k_2) as in Table 71, where k_1 , and k_2 take k values in Table 70. The UE then derives rank-5 and rank-6 pre-coders $W_{i_1, i_1, i_2}^{(5)}$ and $W_{i_1, i_1, i_2}^{(6)}$ as defined above.

[0635] Table 71: Orthogonal beam type to $\delta_{1,1}, \delta_{1,2}, \delta_{2,1}, \delta_{2,2}$ for rank 5-6 codebook for 12 or 16 port with $N_1 \geq N_2 > 1$

Orthogonal beam type	(k_1, k_2) from Table 70 for $\delta_{1,k_1}, \delta_{1,k_2}, \delta_{2,k_1}, \delta_{2,k_2}$
0	(0,3)
1	(2,3)
2	(0,1)
3	(0,2)
4	$(0, N_1+1)$
5	$(2, N_1+1)$
6	$(1, N_1+1)$
7	(N_1+1, N_1+2)

[0636] For $N_1 < N_2$, the rank 5-6 codebook design is similar.

[0637] Alternate rank 7-8 codebooks for $N_1 \geq N_2$

[0638] Figure 43 illustrates alternate rank 7-8 orthogonal beam types 4300 according to embodiments of the present disclosure.

[0639] In some embodiments, a UE reports or is configured with a orthogonal beam type for rank 7-8 codebooks from Orthogonal beam types 0-7 as shown in Figure 43 according to some embodiments of this disclosure. Depending on the configuration, the UE selects the four orthogonal beams, the first beam is located at (0,0), and the 2nd, 3rd, and 4th beams correspond to indices (k_1, k_2, k_3) as in Table 72 (for 16 ports), where k_1, k_2 , and k_3 take k values in Table 70. The UE then derives rank-7 and rank-8 pre-coders $W_{i_1, i_1, i_2}^{(7)}$ and $W_{i_1, i_1, i_2}^{(8)}$ as defined above. The delta table for 12 ports can be constructed similarly.

[0640] Table 72: Orthogonal beam type to $\delta_{1,1}, \delta_{1,2}, \delta_{2,1}, \delta_{2,2}, \delta_{1,3}, \delta_{2,3}$ for rank 7-8 codebook for 16 port with $N_1 \geq N_2 > 1$

Orthogonal beam type	(k_1, k_2, k_3) from Table 70 for $\delta_{1,k_1}, \delta_{1,k_2}, \delta_{1,k_3}, \delta_{2,k_1}, \delta_{2,k_2}, \delta_{2,k_3}$
0	(0,3,5)
1	(2,3,6)
2	(0,1,2)
3	(0,1,5)
4	(0,2,5)
5	(0,1,3)

6	(0,2,3)
7	(1,5,6)

[0641] For $N_1 < N_2$, the rank 7-8 codebook design is similar.

[0642] Embodiments on delta reporting with i_1 ($i_{1,1}$ and $i_{1,2}$)

[0643] In some embodiments, a UE reports δ_1, δ_2 (or $\delta_{1,0}^{(0)}, \delta_{2,0}^{(0)}, \delta_{1,1}^{(0)}$, and $\delta_{2,1}^{(0)}$) for rank 3-4 codebooks and $\delta_{1,1}, \delta_{1,2}, \delta_{1,3}, \delta_{2,1}, \delta_{2,2}, \delta_{2,3}$ for rank 5-8 codebooks, according to some embodiments of this disclosure, jointly with i_1 (or $i_{1,1}$ or $i_{1,2}$).

[0644] In one alternative, the UE reports $i'_1 = (i_1, j)$ where i_1 corresponds to the W1 beam group reporting and j corresponds to the orthogonal beam type (δ_1, δ_2 or $\delta_{1,0}^{(0)}, \delta_{2,0}^{(0)}, \delta_{1,1}^{(0)}$, and $\delta_{2,1}^{(0)}$) reporting for rank 3-4. For example, for rank 3-4 codebook tables in Table 56 and Table 57, the UE reports i'_1 using a 4-bit indication, where the 2 bits are used to indicate i_1 and 2 bits are used indicate j .

[0645] In one method, the two most significant bits (MSB) corresponds to the orthogonal beam type (j) and the 2 two least significant bits (LSB) corresponds to i_1 . Table 73 shows an example of such i'_1 reporting.

[0646] Table 73: i'_1 to (i_1, j) mapping for rank 3-4 codebooks (Table 56 and Table 57)

$b_3b_2b_1b_0$		j	b_1b_0	i_1
0000	00	Orthogonal beam type 0	00	0
0001			01	1
0010			10	2
0011			11	3
0100-0111	01	Orthogonal beam type 1	00,01,10,11	0-3
1000-1011	10	Orthogonal beam type 2	00,01,10,11	0-3
1100-1111	11	Orthogonal beam type 3	00,01,10,11	0-3

[0647] In another method, the two most significant bits (MSB) corresponds to i_1 and the 2 two least significant bits (LSB) corresponds to the orthogonal beam type (j).

[0648] In another alternative, the UE reports $i'_{1,1} = (i_{1,1}, j)$ where $i_{1,1}$ corresponds to the W1 beam group reporting in the 1st dimension and j corresponds to the orthogonal beam type (δ_1, δ_2 or $\delta_{1,0}^{(0)}$,

$\delta_{2,0}^{(0)}$, $\delta_{1,1}^{(0)}$, and $\delta_{2,1}^{(0)}$) reporting for rank 3-4. For example, for rank 3-4 codebook tables in Table 56 and Table 57, the UE reports $i'_{1,1}$ using a 4-bit indication, where the 2 bits are used to indicate $i_{1,1}$ and 2 bits are used indicate j . Similar to the first alternative, 2 bits to indicate j may either be 2 LSBs or 2 MSBs of the 4-bit indication.

[0649] In yet another alternative, the UE reports $i'_{1,2} = (i_{1,2}, j)$ where $i_{1,2}$ corresponds to the W1 beam group reporting in the 2nd dimension and j corresponds to the orthogonal beam type (δ_1, δ_2 or $\delta_{1,0}^{(0)}$, $\delta_{2,0}^{(0)}$, $\delta_{1,1}^{(0)}$, and $\delta_{2,1}^{(0)}$) reporting for rank 3-4.

[0650] The above-mentioned alternatives are applicable to rank 5-8 codebooks. For instance, i'_1 may be reported using a 4-bit indication, whose 2 bits are for i_1 ($i_{1,1}$ and $i_{1,2}$) indication and 2 bits are for orthogonal beam type ($\delta_{1,1}, \delta_{1,2}, \delta_{1,3}, \delta_{2,1}, \delta_{2,2}, \delta_{2,3}$) indication.

[0651] In another alternative, for rank 3-4 codebook, the UE reports $i'_1 = (i_1, k)$ or $i'_{11} = (i_{11}, k)$ or $i'_{1,2} = (i_{1,2}, k)$ where i_1 (or $i_{1,1}$ or $i_{1,2}$) corresponds to the W1 beam group reporting and k corresponds to the orthogonal beam pair from Table 70. For example, the UE reports i'_1 or $i'_{1,1}$ or $i'_{1,2}$ using a (x+y)-bit indication, where the x bits are used to indicate i_1 (or $i_{1,1}$ or $i_{1,2}$) and y bits are used to indicate k .

[0652] In another alternative, for rank 5-6 codebook, the UE reports $i'_1 = (i_1, k_1, k_2)$ or $i'_{11} = (i_{11}, k_1, k_2)$ or $i'_{1,2} = (i_{1,2}, k_1, k_2)$ where i_1 (or $i_{1,1}$ or $i_{1,2}$) corresponds to the W1 beam group reporting and k_1, k_2 corresponds to the orthogonal beam type from Table 70 and Table 71. For example, the UE reports i'_1 or $i'_{1,1}$ or $i'_{1,2}$ using a (x+y)-bit indication, where the x bits are used to indicate i_1 (or $i_{1,1}$ or $i_{1,2}$) and y bits are used to indicate k_1, k_2 .

[0653] In another alternative, for rank 5-6 codebook, the UE reports $i'_1 = (i_1, k_1, k_2, k_3)$ or $i'_{11} = (i_{11}, k_1, k_2, k_3)$ or $i'_{1,2} = (i_{1,2}, k_1, k_2, k_3)$ where i_1 (or $i_{1,1}$ or $i_{1,2}$) corresponds to the W1 beam group reporting and k_1, k_2, k_3 corresponds to the orthogonal beam type from Table 70 and Table 72. For example, the UE reports i'_1 or $i'_{1,1}$ or $i'_{1,2}$ using a (x+y)-bit indication, where the x bits are used to indicate i_1 (or $i_{1,1}$ or $i_{1,2}$) and y bits are used to indicate k_1, k_2, k_3 .

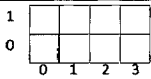
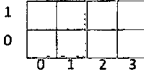
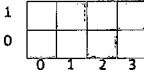
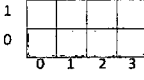
[0654] Embodiment on Master Codebook for all Config

[0655] Master Rank-1 Codebook

[0656] In some embodiments, the rank-1 class A codebook is described in Table 74 and Table 75.

[0657] A UE is configured with one of Config 1, Config 2, Config 3, and Config 4. Depending on the configured Config parameter, the UE performs codebook subset selection (CSS) by selecting a subset of i'_2 indices in Table 75 according to Table 74.

[0658] Table 74: CSS table for four configurations

Config	Selected i'_2 indices	(s1,s2)
Config 1 	0 – 3	(1,1)
Config 2 	0 – 7, 16 – 23	(2,2)
Config 3 	0-3, 8-11, 20-23, 28-31	(2,2)
Config 4 	0 – 15	(2,2)

$$W_{m_1, m_2, n}^{(1)} = \frac{1}{\sqrt{Q}} \begin{bmatrix} v_{m_1} \otimes u_{m_2} \\ \varphi_n v_{m_1} \otimes u_{m_2} \end{bmatrix}$$

$$v_{m_1} = \begin{bmatrix} 1 & e^{j \frac{2\pi m_1}{O_1 N_1}} & \dots & e^{j \frac{2\pi m_1 (N_1-1)}{O_1 N_1}} \end{bmatrix}^t, u_{m_2} = \begin{bmatrix} 1 & e^{j \frac{2\pi m_2}{O_2 N_2}} & \dots & e^{j \frac{2\pi m_2 (N_2-1)}{O_2 N_2}} \end{bmatrix}^t$$

$$i_{1,1} = 0, 1, \dots, O_1 N_1 / s_1 - 1$$

$$i_{1,2} = 0, 1, \dots, O_2 N_2 / s_2 - 1$$

$p_1 = 1$ and $p_2 = 1$.

[0659] The proposed rank-1 codebook is characterized by three parameters: $\{i_{11}, i_{12}, i_2\}$, where i_2 corresponds to the selected i'_2 indices from Table 75 according to the Config parameter.

[0660] Table 75: Master codebook for 1 layer CSI reporting

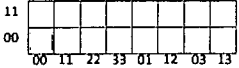
i'_2	0	1	2	3
Precoder	$W_{s_{1i_{1,1}}, s_{2i_{1,2}}, 0}^{(1)}$	$W_{s_{1i_{1,1}}, s_{2i_{1,2}}, 1}^{(1)}$	$W_{s_{1i_{1,1}}, s_{2i_{1,2}}, 2}^{(1)}$	$W_{s_{1i_{1,1}}, s_{2i_{1,2}}, 3}^{(1)}$
i'_2	4	5	6	7
Precoder	$W_{s_{1i_{1,1}}+1, s_{2i_{1,2}}, 0}^{(1)}$	$W_{s_{1i_{1,1}}+1, s_{2i_{1,2}}, 1}^{(1)}$	$W_{s_{1i_{1,1}}+1, s_{2i_{1,2}}, 2}^{(1)}$	$W_{s_{1i_{1,1}}+1, s_{2i_{1,2}}, 3}^{(1)}$
i'_2	8	9	10	11
Precoder	$W_{s_{1i_{1,1}}+2, s_{2i_{1,2}}, 0}^{(1)}$	$W_{s_{1i_{1,1}}+2, s_{2i_{1,2}}, 1}^{(1)}$	$W_{s_{1i_{1,1}}+2, s_{2i_{1,2}}, 2}^{(1)}$	$W_{s_{1i_{1,1}}+2, s_{2i_{1,2}}, 3}^{(1)}$
i'_2	12	13	14	15
Precoder	$W_{s_{1i_{1,1}}+3, s_{2i_{1,2}}, 0}^{(1)}$	$W_{s_{1i_{1,1}}+3, s_{2i_{1,2}}, 1}^{(1)}$	$W_{s_{1i_{1,1}}+3, s_{2i_{1,2}}, 2}^{(1)}$	$W_{s_{1i_{1,1}}+3, s_{2i_{1,2}}, 3}^{(1)}$
i'_2	16 – 31			
Precoder	Entries 16-31 constructed with replacing the second subscript $s_{2i_{1,2}}$ with $s_{2i_{1,2}} + 1$ in entries 0 – 15.			

[0661] Master Rank-2 Codebook

[0662] In some embodiments, the rank-2 class A codebook is described in Table 76 and Table 77. Note that in Config 3 and Config 4, the four beams shown in grey are numbered 0-3, and legacy 8-Tx rank-2 beam pairs {00,11,22,33,01,12,13,03} are formed according to this numbering in the proposed rank-2 codebook. Also note that for Config 1, the rank-2 codebook corresponds to a single beam and QPSK $\{1, j, -1, -j\}$ co-phase.

[0663] A UE is configured with one of Config 1, Config 2, Config 3, and Config 4. Depending on the configured Config parameter, the UE performs codebook subset selection (CSS) by selecting a subset of i'_2 indices in Table 77 according to Table 76.

[0664] Table 76: CSS table for four configurations

Config	Selected i'_2 indices	(s1,s2)
Config 1 	0-1,36-37	(1,1)

Config 2 	0-3, 8-9, 16-19, 22-23, 32-35	(2,2)
Config 3 	0-1, 4-5, 18-21, 24-31	(2,2)
Config 4 	0-15	(2,2)

$$W_{m_1, m_1', m_2, m_2', n}^{(2)} = \frac{1}{\sqrt{2Q}} \begin{bmatrix} v_{m_1} \otimes u_{m_2} & v_{m_1'} \otimes u_{m_2'} \\ \phi_n v_{m_1} \otimes u_{m_2} & -\phi_n v_{m_1'} \otimes u_{m_2'} \end{bmatrix}$$

$$v_{m_1} = \begin{bmatrix} 1 & e^{j \frac{2\pi m_1}{O_1 N_1}} & \dots & e^{j \frac{2\pi m_1 (N_1-1)}{O_1 N_1}} \end{bmatrix}^t, u_{m_2} = \begin{bmatrix} 1 & e^{j \frac{2\pi m_2}{O_2 N_2}} & \dots & e^{j \frac{2\pi m_2 (N_2-1)}{O_2 N_2}} \end{bmatrix}^t$$

$$i_{1,1} = 0, 1, \dots, O_1 N_1 / s_1 - 1$$

$$i_{1,2} = 0, 1, \dots, O_2 N_2 / s_2 - 1$$

If Config 2 and $N_1 \leq N_2$, then

$p_1 = O_1$ and $p_2 = 1$.

Otherwise

$p_1 = 1$ and $p_2 = 1$.

[0665] The proposed rank-2 codebook is characterized by three parameters: $\{i_{11}, i_{12}, i_2\}$, where i_2 corresponds to the selected i_2' indices from Table 76 according to the Config parameter.

[0666] Please see the below Table Section for Table 77.

[0667] Master Rank 3-4 Codebook

[0668] In some embodiments, the codebook for rank 3-4 is characterized by four parameters: $\{i_{11}, i_{12}, k, i_2\}$, and codewords are identified by $\{i_{1,1}', i_{1,2}, i_2\}$ in CSI feedback. Different values of the parameter k are used to construct different orthogonal beam groups for rank 3-4 codebooks.

[0669] Figure 44 illustrates three example orthogonal-beam groups 4400, indexed by $k = 0, 1, 2$ for Ranks 3-4 according to some embodiments of the present disclosure.

[0670] Table 79 and Table 80 show the rank 3-4 codebook tables that can be used for any of $Q = 8, 12$, and 16 antenna port configurations, where δ_1, δ_2 are selected from Table 78 depending on the k value, the corresponding rank 3 precoder is either

$$W_{m_1, m_1', m_2, m_2'}^{(3)} = \frac{1}{\sqrt{3Q}} \begin{bmatrix} v_{m_1} \otimes u_{m_2} & v_{m_1} \otimes u_{m_2} & v_{m_1'} \otimes u_{m_2'} \\ v_{m_1} \otimes u_{m_2} & -v_{m_1} \otimes u_{m_2} & -v_{m_1'} \otimes u_{m_2'} \end{bmatrix}, \text{ or}$$

$$\tilde{W}_{m_1, m_1', m_2, m_2'}^{(3)} = \frac{1}{\sqrt{3Q}} \begin{bmatrix} v_{m_1} \otimes u_{m_2} & v_{m_1'} \otimes u_{m_2'} & v_{m_1'} \otimes u_{m_2'} \\ v_{m_1} \otimes u_{m_2} & v_{m_1'} \otimes u_{m_2'} & -v_{m_1'} \otimes u_{m_2'} \end{bmatrix}, \text{ and the corresponding}$$

$$\text{rank 4 precoder is } W_{m_1, m_1', m_2, m_2', n}^{(4)} = \frac{1}{\sqrt{4Q}} \begin{bmatrix} v_{m_1} \otimes u_{m_2} & v_{m_1'} \otimes u_{m_2'} & v_{m_1} \otimes u_{m_2} & v_{m_1'} \otimes u_{m_2'} \\ \phi_n v_{m_1} \otimes u_{m_2} & \phi_n v_{m_1'} \otimes u_{m_2'} & -\phi_n v_{m_1} \otimes u_{m_2} & -\phi_n v_{m_1'} \otimes u_{m_2'} \end{bmatrix}.$$

[0671] UE feeds back k in PMI as part of the W1 indication. In particular, k is jointly encoded with i_1 indication(s), where $i'_{1,1} = (O_1 N_1 / s_1)k + i_{1,1}$ is reported in CSI feedback.

[0672] There are two alternatives for the number of values of k :

If $N_1 > 1$ and $N_2 > 1$: $k = 0, 1$ in Table 78.

If $N_2 = 1$: $k = 0, 1, 2$ in Table 78.

[0673] Table 78: Orthogonal beam type to (δ_1, δ_2) mapping

K		0	1	2
If $N_1 > 1$ and $N_2 > 1$	δ_1	O_1	0	
	δ_2	0	O_2	
If $N_2 = 1$		O_1	$2O_1$	$3O_1$
		0	0	0

$$i_{1,1} = 0, 1, \dots, O_1 N_1 / s_1 - 1$$

$$i_{1,2} = 0, 1, \dots, O_2 N_2 / s_2 - 1$$

[0674] Please see the below Table Section for Tables 79 and 80.

[0675] Codebook Subset Selection

[0676] Figure 45 illustrates example orthogonal beams 4500 for rank 3-4 when $k = 0$ according to some embodiments of the present disclosure.

[0677] Table 81 Selected i'_2 indices for rank-3 CSI reporting (in Table 79)

Config	Selected i'_2 indices	$(s1, s2)$	(p_1, p_2)
1	0, 2	(1, 1)	(-, -)

2	0 - 7, 16 - 23	$(\frac{O_1}{2}, \frac{O_2}{2})$	$(\frac{O_1}{4}, \frac{O_2}{4})$
3	8-23	$(O_1, \frac{O_2}{2})$	$(\frac{O_1}{4}, \frac{O_2}{4})$
4	0 - 15	$(O_1, \frac{O_2}{4})$	$(\frac{O_1}{4}, -)$

[0678] Table 82 Selected i'_2 indices for rank-4 CSI reporting (in Table 80)

Config	Selected i'_2 indices	(s1, s2)	(p1, p2)
1	0, 1	(1,1)	(-, -)
2	0 - 3, 8 - 11	$(\frac{O_1}{2}, \frac{O_2}{2})$	$(\frac{O_1}{4}, \frac{O_2}{4})$
3	4-11	$(O_1, \frac{O_2}{2})$	$(\frac{O_1}{4}, \frac{O_2}{4})$
4	0 - 7	$(O_1, \frac{O_2}{4})$	$(\frac{O_1}{4}, -)$

[0679] With the (s1,s2) and (p1,p2) parameters proposed in Table 81 and Table 82:

when O1=8 the effective oversampling factor is the same as legacy (i.e., 4), and;

when O1=4 the effective oversampling factor is same as the configured one (i.e., 4).

[0680] Master Rank 5-8 Codebook

[0681] For ranks 5-8, the proposed codebooks are characterized by two parameters: $\{i_{11}, i_{12}\}$, and these are used to form i_1 indication(s), rather than $\{i_{11}, i_{12}, k\}$ that is used for ranks 3-4. For rank 5, 6, 7, 8, the precoding matrices are as in the following, where $\delta_{1,1}, \delta_{1,2}, \delta_{1,3}, \delta_{2,1}, \delta_{2,2}, \delta_{2,3}$ are determined by the RRC 'Config' parameter, and

$(s_1, s_2) = (1, 1)$ for Config 1; and

$(s_1, s_2) = (\frac{O_1}{4}, \frac{O_2}{4})$ for Config 2, 3, 4;

$$W_{i_1, i_2}^{(5)} = \frac{1}{\sqrt{5Q}} \begin{bmatrix} v_{s_1 i_{1,1}} \otimes u_{s_2 i_{1,2}} & v_{s_1 i_{1,1}} \otimes u_{s_2 i_{1,2}} & v_{s_1 i_{1,1} + \delta_{1,1}} \otimes u_{s_2 i_{1,2} + \delta_{2,1}} & v_{s_1 i_{1,1} + \delta_{1,1}} \otimes u_{s_2 i_{1,2} + \delta_{2,1}} \\ v_{s_1 i_{1,1}} \otimes u_{s_2 i_{1,2}} & -v_{s_1 i_{1,1}} \otimes u_{s_2 i_{1,2}} & v_{s_1 i_{1,1} + \delta_{1,1}} \otimes u_{s_2 i_{1,2} + \delta_{2,1}} & -v_{s_1 i_{1,1} + \delta_{1,1}} \otimes u_{s_2 i_{1,2} + \delta_{2,1}} \\ v_{s_1 i_{1,1} + \delta_{1,2}} \otimes u_{s_2 i_{1,2} + \delta_{2,2}} & & & \\ v_{s_1 i_{1,1} + \delta_{1,2}} \otimes u_{s_2 i_{1,2} + \delta_{2,2}} & & & \\ \dots & & & \end{bmatrix}$$

$$W_{i_{1,1},i_{1,2}}^{(6)} = \frac{1}{\sqrt{6Q}} \begin{bmatrix} v_{s_1 i_{1,1}} \otimes u_{s_2 i_{1,2}} & v_{s_1 i_{1,1}} \otimes u_{s_2 i_{1,2}} & v_{s_1 i_{1,1} + \delta_{1,1}} \otimes u_{s_2 i_{1,2} + \delta_{2,1}} & v_{s_1 i_{1,1} + \delta_{1,1}} \otimes u_{s_2 i_{1,2} + \delta_{2,1}} \\ v_{s_1 i_{1,1}} \otimes u_{s_2 i_{1,2}} & -v_{s_1 i_{1,1}} \otimes u_{s_2 i_{1,2}} & v_{s_1 i_{1,1} + \delta_{1,1}} \otimes u_{s_2 i_{1,2} + \delta_{2,1}} & -v_{s_1 i_{1,1} + \delta_{1,1}} \otimes u_{s_2 i_{1,2} + \delta_{2,1}} \\ v_{s_1 i_{1,1} + \delta_{1,2}} \otimes u_{s_2 i_{1,2} + \delta_{2,2}} & v_{s_1 i_{1,1} + \delta_{1,2}} \otimes u_{s_2 i_{1,2} + \delta_{2,2}} & & \\ v_{s_1 i_{1,1} + \delta_{1,2}} \otimes u_{s_2 i_{1,2} + \delta_{2,2}} & -v_{s_1 i_{1,1} + \delta_{1,2}} \otimes u_{s_2 i_{1,2} + \delta_{2,2}} & & \end{bmatrix}$$

$$W_{i_{1,1},i_{1,2}}^{(7)} = \frac{1}{\sqrt{7Q}} \begin{bmatrix} v_{s_1 i_{1,1}} \otimes u_{s_2 i_{1,2}} & v_{s_1 i_{1,1}} \otimes u_{s_2 i_{1,2}} & v_{s_1 i_{1,1} + \delta_{1,1}} \otimes u_{s_2 i_{1,2} + \delta_{2,1}} & v_{s_1 i_{1,1} + \delta_{1,1}} \otimes u_{s_2 i_{1,2} + \delta_{2,1}} \\ v_{s_1 i_{1,1}} \otimes u_{s_2 i_{1,2}} & -v_{s_1 i_{1,1}} \otimes u_{s_2 i_{1,2}} & v_{s_1 i_{1,1} + \delta_{1,1}} \otimes u_{s_2 i_{1,2} + \delta_{2,1}} & -v_{s_1 i_{1,1} + \delta_{1,1}} \otimes u_{s_2 i_{1,2} + \delta_{2,1}} \\ v_{s_1 i_{1,1} + \delta_{1,2}} \otimes u_{s_2 i_{1,2} + \delta_{2,2}} & v_{s_1 i_{1,1} + \delta_{1,2}} \otimes u_{s_2 i_{1,2} + \delta_{2,2}} & v_{s_1 i_{1,1} + \delta_{1,3}} \otimes u_{s_2 i_{1,2} + \delta_{2,3}} & \\ v_{s_1 i_{1,1} + \delta_{1,2}} \otimes u_{s_2 i_{1,2} + \delta_{2,2}} & -v_{s_1 i_{1,1} + \delta_{1,2}} \otimes u_{s_2 i_{1,2} + \delta_{2,2}} & v_{s_1 i_{1,1} + \delta_{1,3}} \otimes u_{s_2 i_{1,2} + \delta_{2,3}} & \end{bmatrix}$$

$$W_{i_{1,1},i_{1,2}}^{(8)} = \frac{1}{\sqrt{8Q}} \begin{bmatrix} v_{s_1 i_{1,1}} \otimes u_{s_2 i_{1,2}} & v_{s_1 i_{1,1}} \otimes u_{s_2 i_{1,2}} & v_{s_1 i_{1,1} + \delta_{1,1}} \otimes u_{s_2 i_{1,2} + \delta_{2,1}} & v_{s_1 i_{1,1} + \delta_{1,1}} \otimes u_{s_2 i_{1,2} + \delta_{2,1}} & v_{s_1 i_{1,1} + \delta_{1,2}} \otimes u_{s_2 i_{1,2} + \delta_{2,2}} \\ v_{s_1 i_{1,1}} \otimes u_{s_2 i_{1,2}} & -v_{s_1 i_{1,1}} \otimes u_{s_2 i_{1,2}} & v_{s_1 i_{1,1} + \delta_{1,1}} \otimes u_{s_2 i_{1,2} + \delta_{2,1}} & -v_{s_1 i_{1,1} + \delta_{1,1}} \otimes u_{s_2 i_{1,2} + \delta_{2,1}} & v_{s_1 i_{1,1} + \delta_{1,2}} \otimes u_{s_2 i_{1,2} + \delta_{2,2}} \\ v_{s_1 i_{1,1} + \delta_{1,2}} \otimes u_{s_2 i_{1,2} + \delta_{2,2}} & v_{s_1 i_{1,1} + \delta_{1,3}} \otimes u_{s_2 i_{1,2} + \delta_{2,3}} & v_{s_1 i_{1,1} + \delta_{1,3}} \otimes u_{s_2 i_{1,2} + \delta_{2,3}} & & \\ -v_{s_1 i_{1,1} + \delta_{1,2}} \otimes u_{s_2 i_{1,2} + \delta_{2,2}} & v_{s_1 i_{1,1} + \delta_{1,3}} \otimes u_{s_2 i_{1,2} + \delta_{2,3}} & -v_{s_1 i_{1,1} + \delta_{1,3}} \otimes u_{s_2 i_{1,2} + \delta_{2,3}} & & \end{bmatrix}$$

[0682] Figure 46 illustrates orthogonal beam grouping 4600 for rank 5-8: 16 ports according to some embodiments of the present disclosure.

[0683] For 16 ports, $\delta_{1,1}, \delta_{1,2}, \delta_{1,3}, \delta_{2,1}, \delta_{2,2}, \delta_{2,3}$ are defined as the following Table 83.

[0684] Table 83: Delta values for 16-port rank 5-8 codebooks

	Antenna configuration	$\delta_{1,1}$	$\delta_{2,1}$	$\delta_{1,2}$	$\delta_{2,2}$	$\delta_{1,3}$	$\delta_{2,3}$
config = 4	$N_1 \geq N_2$	O_1	0	$2O_1$	0	$3O_1$	0
	$N_1 < N_2$	0	O_2	0	$2O_2$	0	$3O_2$
config = 3	$N_1 \geq N_2$	O_1	0	$2O_1$	O_2	$3O_1$	O_2
	$N_1 < N_2$	0	O_2	O_1	$2O_2$	O_1	$3O_2$
Config = 1, 2	Both	O_1	0	O_1	O_2	0	O_2

[0685] Figure 47 illustrates example orthogonal beam grouping 4700 for rank 5-8: 12 ports according to embodiments of the present disclosure.

[0686] For 12 ports, $\delta_{1,1}, \delta_{1,2}, \delta_{1,3}, \delta_{2,1}, \delta_{2,2}, \delta_{2,3}$ are defined as the following Table 84:

[0687] Table 84 Delta values for 12-port rank 5-8 codebooks

Type	Configuration	$\delta_{1,1}$	$\delta_{2,1}$	$\delta_{1,2}$	$\delta_{2,2}$	$\delta_{1,3}$	$\delta_{2,3}$
Config= 4	$N_1 \geq N_2$	O_1	0	$2O_1$	0	0	O_2
	$N_1 < N_2$	0	O_2	0	$2O_2$	O_1	0
Config= 3	$N_1 \geq N_2$	O_1	0	$2O_1$	O_2	O_1	O_2
	$N_1 < N_2$	0	O_2	O_1	$2O_2$	O_1	O_2
Config= 1, 2	Both	O_1	0	O_1	O_2	0	O_2

[0688] Figure 48 illustrates example orthogonal beam grouping 4800 for rank 5-8: 8 ports according to embodiments of the present disclosure.

[0689] For 8 ports, $\delta_{1,1}, \delta_{1,2}, \delta_{1,3}, \delta_{2,1}, \delta_{2,2}, \delta_{2,3}$ are defined as the following Table 85:

[0690] Table 85: Delta values for 8-port rank 5-8 codebooks

Type	Configuration	$\delta_{1,1}$	$\delta_{2,1}$	$\delta_{1,2}$	$\delta_{2,2}$	$\delta_{1,3}$	$\delta_{2,3}$
Config= 1, 2, 3, 4	$N_1 = N_2$	O_1	0	O_1	O_2	0	O_2

[0691] Embodiment on Separate Codebook of each Config

[0692] In some embodiment, the rank 1-8 codebook tables can be alternatively written as four separate rank 1-8 codebook tables in their respective tables, one for each of Config 1, Config 2, Config 3, and Config 4.

[0693] For instance, the rank-1 codebook for Config 1 according to the master codebook table in Table 75 can be written alternatively according to the first codebook table in Table 87; the rank-1 codebook for Config 2 according to the master codebook table in Table 75 can be written alternatively according to the second codebook table in Table 87; the rank-1 codebook for Config 3 according to the master codebook table in Table 75 can be written alternatively according to the third codebook table in Table 87; and the rank-1 codebook for Config 4 according to the master codebook table in Table 75 can be written alternatively according to the fourth codebook table in Table 87.

[0694] The separate codebook tables for rank 2-8 can be constructed similarly.

[0695] In some embodiment, for 8 antenna ports $\{15,16,17,18,19,20,21,22\}$, 12 antenna ports $\{15,16,17,18,19,20,21,22,23,24,25,26\}$, 16 antenna ports $\{15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30\}$, and UE configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting Type* is set to 'CLASS A', each PMI value corresponds to three codebook indices $(i_{1,1}, i_{1,2}, i_2)$ given in Table 87, Table 88, Table 89, Table 90, Table 91, Table 92, Table 93, or Table 94, where the quantities φ_n , u_m and $v_{l,m}$ are given by

$$\begin{aligned}\varphi_n &= e^{j\pi n/2} \\ u_m &= \begin{bmatrix} 1 & e^{j\frac{2\pi m}{O_2 N_2}} & \dots & e^{j\frac{2\pi m(N_2-1)}{O_2 N_2}} \end{bmatrix}^T \\ v_{l,m} &= \begin{bmatrix} u_m & e^{j\frac{2\pi l}{O_1 N_1}} u_m & \dots & e^{j\frac{2\pi l(N_1-1)}{O_1 N_1}} u_m \end{bmatrix}^T\end{aligned}$$

[0696] The values of N_1 , N_2 , O_1 , and O_2 are configured with the higher-layer parameters *Codebook-Config-N1*, *Codebook-Config-N2*, *Codebook-Over-Sampling-RateConfig-O1*, and *Codebook-Over-Sampling-RateConfig-O2*, respectively. The supported configurations of (O_1, O_2) and (N_1, N_2) for a given number of CSI-RS ports are given in Table 86. The number of CSI-RS ports, P , is $2N_1N_2$.

[0697] UE is not expected to be configured with value of *CodebookConfig* set to 2 or 3, if the value of *codebookConfigN2* is set to 1.

[0698] UE shall only use $i_{1,2}=0$ and shall not report $i_{1,2}$ if the value of *codebookConfigN2* is set to 1.

[0699] A first PMI value i_1 corresponds to the codebook indices pair $\{i_{1,1}, i_{1,2}\}$, and a second PMI value i_2 corresponds to the codebook index i_2 given in Table j with v equal to the associated RI value and where $j = v + 62$.

[0700] In some cases codebook subsampling is supported. The sub-sampled codebook for PUCCH mode 2-1 for value of parameter *Codebook-Config* set to 2, 3, or 4 is defined in Table 7.2.2-1F for PUCCH Reporting Type 1a of the specification TS36.213.

[0701] In some cases codebook subsampling is supported. For instance, the sub-sampled codebook for PUCCH mode 2-1 for value of parameter *Codebook-Config* set to 2, 3, or 4 is defined according to that for the legacy 8-Tx codebook. For *Codebook-Config*=1, no subsampling is done for i_2 .

[0702] Table 86 Supported configurations of (O_1, O_2) and (N_1, N_2)

Number CSI-RS antenna ports, P	of (N_1, N_2)	(O_1, O_2)
8	(2,2)	(4,4), (8,8)
12	(2,3)	(8,4), (8,8)
	(3,2)	(8,4), (4,4)
16	(2,4)	(8,4), (8,8)
	(4,2)	(8,4), (4,4)
	(8,1)	(4,-), (8,-)

[0703] Please see the below Table Section for Tables 87-1 to 87-4.

[0704] Please see the below Table Section for Tables 88-1 to 88-4.

[0705] Please see the below Table Section for Tables 89-1 to 89-5.

[0706] Please see the below Table Section for Tables 90-1 to 90-6.

[0707] Please see the below Table Section for Tables 91-1 to 91-4.

[0708] Please see the below Table Section for Tables 92-1 to 92-4.

[0709] Please see the below Table Section for Tables 93-1 to 93-5.

[0710] Please see the below Table Section for Tables 94-1 to 94-5.

[0711] In an alternate embodiment, the rank 1-8 codebook tables are given as in Tables 95-1 to 95-3, Tables 96-1 to 96-4, Table 97-1 to 97-4, Tables 98-1 to 98-4, Table 99, Table 100, Table 101, and Table 102.

[0712] Please see the below Table Section for Tables 95-1 to 95-3.

[0713] Please see the below Table Section for Tables 96-1 to 96-4.

[0714] Please see the below Table Section for Tables 97-1 to 97-4.

[0715] Please see the below Table Section for Tables 98-1 to 98-4.

[0716] Please see the below Table Section for Table 99.

[0717] Please see the below Table Section for Table 100.

[0718] Please see the below Table Section for Table 101.

[0719] Please see the below Table Section for Table 102.

[0720] Embodiment on rank 5-8 codebook for 1D port layout

[0721] In some embodiments, the rank 5-8 codebooks in case of the 1D port layouts such as $(N_1, N_2) = (6,1), (8,1), (1,6)$ and $(1,8)$, the 1D orthogonal beam groups are used for different Codebook-Config values including Codebook-Config = 1,2,3,4.

[0722] In one example of $N_2 = 1$, the same orthogonal beam group is used irrespective of whether Codebook-Config = 1 or 4 for rank 5-8 codebooks. An example of the orthogonal beam group is shown in Figure 49.

[0723] Figure 49 illustrates an example of orthogonal beam group for 1D port layout according to embodiments of the present disclosure.

[0724] In another example of $N_2 = 1$, the different orthogonal beam groups are used for Codebook-Config = 1 and 4 for rank 5-8 codebooks. An example of the orthogonal beam group is shown in Figure 50.

[0725] Figure 50 illustrates an example of orthogonal beam group 5000 for 1D port layout according to embodiments of the present disclosure.

[0726] In another example of $N_2 = 1$, the same orthogonal beam group is used irrespective of whether Codebook-Config = 1, 2, 3 or 4 for rank 5-8 codebooks. An example of the orthogonal beam group is shown in Figure 51.

[0727] Figure 51 illustrates an example of orthogonal beam group 5100 for 1D port layout according to embodiments of the present disclosure.

[0728] In another example of $N_2 = 1$, the different orthogonal beam groups are used for Codebook-Config = 1 and 4 for rank 5-8 codebooks. An example of the orthogonal beam group is shown in Figure 52.

[0729] Figure 52 illustrates an example of orthogonal beam group 5200 for 1D port layout according to embodiments of the present disclosure.

[0730] These Codebook-Config to orthogonal beam group mappings are for illustration only, and they can be mapped to other orthogonal beam groups including the ones shown here or not shown.

[0731] Other rank 3-8 codebook design alternatives

[0732] In some embodiments, rank 3-8 codebooks can be constructed according to alternative master codebook alternatives 1-4 shown in Figure 53, Figure 54, Figure 55, and Figure 56, according to some embodiments of this disclosure.

[0733] Figures 53A and 53B illustrate an alternate rank 3-8 codebook design 1 5300A, 5300B: $(L_1, L_2) = (4,2)$ according to embodiments of the present disclosure.

[0734] Figure 54 illustrates an alternate rank 3-8 codebook design 2 5400: $(L_1, L_2) = (4,1)$ according to embodiments of the present disclosure.

[0735] Figures 55A and 55B illustrate an alternate rank 3-8 codebook design 3 5500A, 5500B : $(L_1, L_2) = (2, 2)$ according to embodiments of the present disclosure.

[0736] Figures 56A and 56B illustrate an alternate rank 3-8 codebook design 4 5600A, 5600B: $(L_1, L_2) = (2, 1)$ according to embodiments of the present disclosure.

[0737] To aid the Patent Office and any readers of any patent issued on this application in interpreting the claims appended hereto, applicants wish to note that they do not intend any of the appended claims or claim elements to invoke 35 U.S.C. § 112(f) unless the words “means for” or “step for” are explicitly used in the particular claim. Use of any other term, including without limitation “mechanism,” “module,” “device,” “unit,” “component,” “element,” “member,” “apparatus,” “machine,” “system,” “processor,” or “controller,” within a claim is understood by the applicants to refer to structures known to those skilled in the relevant art and is not intended to invoke 35 U.S.C. § 112(f).

[0738] Although the present disclosure has been described with an exemplary embodiment, various changes and modifications may be suggested to one skilled in the art. It is intended that the present disclosure encompass such changes and modifications as fall within the scope of the appended claims.

TABLE SECTION

[0739] Table 9: Single rank 2 codebook table for $N_1 = 8$, $N_2 = 2$, $o_1 = o_2 = 4$: Beam group type 1, Example 1 (Refer to Fig. 57 for Table 9)

[0740] Table 10: Single rank 2 codebook table for $N_1 = 8$, $N_2 = 2$, $o_1 = o_2 = 4$: Beam group type 1 and Beam group Type 4 Alt 1 (Refer to Fig. 58 for Table 10)

[0741] Tables 11-1 to 11-3: Two rank 2 codebook tables for $N_1 = 8$, $N_2 = 2$, $o_1 = o_2 = 4$ (Refer to Fig. 59A for Table 11-1, Refer to Fig. 59B for Table 11-2, Refer to Fig. 59C for Table 11-3)

[0742] Table 11-1: A first beam group type (type 1)

[0743] Table 11-2: A second beam group type (type 4 Alt 1)

[0744] Table 11-3: i_1 to (i_{1H}, i_{1V}) mapping

[0745] Tables 12-1 to 12-4: Three rank 2 codebook tables for $N_1 = 8$, $N_2 = 2$, $o_1 = o_2 = 4$ (Refer to Fig. 60A for Table 12-1, Refer to Fig. 60B for Table 12-2, Refer to Fig. 60C for Table 12-3, Refer to Fig. 60D for Table 12-4)

[0746] Table 12-1: A first beam group type (type 1)

[0747] Table 12-2: A second beam group type (type 4 Alt 1)

[0748] Table 12-3: A third beam group type (type 4 Alt 2)

[0749] Table 12-4: i_1 to (i_{1H}, i_{1V}) mapping

[0750] Table 13-1 to 13-4: Three rank 2 codebook tables for $N_1 = 8, N_2 = 2, o_1 = o_2 = 4$ (Refer to Fig. 61A for Table 13-1, Refer to Fig. 61B for Table 13-2, Refer to Fig. 61C for Table 13-3, Refer to Fig. 61D for Table 13-4)

[0751] Table 13-1: A first beam group type (type 1)

[0752] Table 13-2: A second beam group type (type 2 Alt 1)

[0753] Table 13-3: A third beam group type (type 4 Alt 1)

[0754] Table 13-4: i_1 to (i_{IH}, i_{IV}) mapping

- [0755] Table 14-1: A first beam group type (type 1) (Refer to Fig. 62A for Table 14-1)
- [0756] Table 14-2: A second beam group type (type 3 Alt 1) (Refer to Fig. 62B for Table 14-2)
- [0757] Table 14-3: A third beam group type (type 4 Alt 1) (Refer to Fig. 62C for Table 14-3)
- [0758] Table 14-4: i_1 to (i_{1H}, i_{1V}) mapping (Refer to Fig. 62D for Table 14-4)
- [0759] Tables 15-1 to 15-4 Three rank 2 codebook tables for $N_1 = 8, N_2 = 2, o_1 = o_2 = 4$ (Refer to Fig. 63A for Table 15-1, Refer to Fig. 63B for Table 15-2, Refer to Fig. 63C for Table 15-3, Refer to Fig. 63D for Table 15-4)
- [0760] Table 15-1: A first beam group type (type 1)
- [0761] Table 15-2: A second beam group type (type 2 Alt 1)
- [0762] Table 15-3: A third beam group type (type 3 Alt 1)
- [0763] Table 15-4: i_1 to (i_{1H}, i_{1V}) mapping
- [0764] Table 19: Master codebook for 2 layer CSI reporting for $L_1 = L_2 = 4$ (Option 1) (Refer to Fig. 64A, 64B and 64C for Table 19)
- [0765] Table 20: Alternate master codebook for 2 layer CSI reporting ($s_1 = s_2 = 2$ and $p_1 = p_2 = 1$) (Refer to Fig. 65A and 65B for Table 20)
- [0766] Table 21: An illustration of subset restriction on rank-2 i_2 (Table 20) (Refer to Fig. 66 for Table 21)
- [0767] Table 25: Master codebook for 2 layer CSI reporting for $(L_1, L_2) = (4, 2)$ (Refer to Fig. 67 for Table 25)
- [0768] Table 29: Master codebook for 3 layer CSI reporting for $(N_1, N_2) = (4, 2)$ and $(L_1, L_2) = (4, 2)$ (Refer to Fig. 68A and 68B for Table 29)
- [0769] Table 32: Master codebook for 4 layer CSI reporting for $(N_1, N_2) = (4, 2)$ and $(L_1, L_2) = (4, 2)$ (Refer to Fig. 69 for Table 32)
- [0770] Table 35: Master codebook for 5 layer CSI reporting for $(N_1, N_2) = (4, 2)$ and $(L_1, L_2) = (4, 2)$ (Refer to Fig. 70 for Table 35)
- [0771] Table 36: Master codebook for 6 layer CSI reporting for $(N_1, N_2) = (4, 2)$ and $(L_1, L_2) = (4, 2)$ (Refer to Fig. 71 for Table 36)
- [0772] Table 43: Master codebook for 3 layer CSI reporting for $(N_1, N_2) = (4, 2)$ and $(L_1, L_2) = (2, 2)$ (Refer to Fig. 72 for Table 43)
- [0773] Table 44: Master codebook for 4 layer CSI reporting for $(N_1, N_2) = (4, 2)$ and $(L_1, L_2) = (2, 2)$ (Refer to Fig. 73 for Table 44)
- [0774] Table 48: Master codebook for 3 layer CSI reporting and $N_1 \geq N_2$ (Refer to Fig. 74 for Table 48)

[0775] Table 49: Master codebook for 4 layer CSI reporting and $N_1 \geq N_2$ (Refer to Fig. 75 for Table 49)

[0776] Table 56: Master codebook for 3 layer CSI reporting (Refer to Fig. 76 for Table 56)

[0777] Table 57: Master codebook for 4 layer CSI reporting (Refer to Fig. 77 for Table 57)

[0778] Table 59: Master codebook for 3 layer CSI reporting (Refer to Fig. 78 for Table 59)

[0779] Table 60: Master codebook for 4 layer CSI reporting (Refer to Fig. 79 for Table 60)

[0780] Table 62: Master codebook for 3 layer CSI reporting (Refer to Fig. 80 for Table 62)

[0781] Table 63: Master codebook for 4 layer CSI reporting (Refer to Fig. 81 for Table 63)

[0782] Table 66: Master codebook for 3 layer CSI reporting for $N_1 \geq N_2$ (Refer to Fig. 82 for Table 66)

[0783] Table 67: Master codebook for 4 layer CSI reporting for $N_1 \geq N_2$ (Refer to Fig. 83 for Table 67)

[0784] Table 77: Master codebook for 2 layer CSI reporting (Refer to Fig. 84A and 84B for Table 77)

[0785] Table 79: Master codebook for 3 layer CSI reporting (Refer to Fig. 85 for Table 79)

[0786] Table 80: Codebook for 4 layer CSI reporting (Refer to Fig. 86 for Table 80)

[0787] Table 87-1 Codebook for 1-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No. 1) (Refer to Fig. 87A for Table 87-1)

[0788] Table 87-2 Codebook for 1-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No. 2) (Refer to Fig. 87B for Table 87-2)

[0789] Table 87-3 Codebook for 1-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No.3) (Refer to Fig. 87C for Table 87-3)

[0790] Table 87-4 Codebook for 1-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No. 4) (Refer to Fig. 87D for Table 87-4)

[0791] Table 88-1 Codebook for 2-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No. 1) (Refer to Fig. 88A for Table 88-1)

[0792] Table 88-2 Codebook for 2-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No. 2) (Refer to Fig. 88B for Table 88-2)

[0793] Table 88-3 Codebook for 2-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No. 3) (Refer to Fig. 88C for Table 88-3)

[0794] Table 88-4 Codebook for 2-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No. 4) (Refer to Fig. 88D for Table 88-4)

[0795] Table 89-1 Codebook for 3-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No. 1) (Refer to Fig. 89A for Table 89-1)

[0796] Table 89-2 Codebook for 3-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No. 2) (Refer to Fig. 89B for Table 89-2)

[0797] Table 89-3 Codebook for 3-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No. 3) (Refer to Fig. 89C for Table 89-3)

[0798] Table 89-4 Codebook for 3-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No. 4) (Refer to Fig. 89D for Table 89-4)

[0799] Table 89-5 Codebook for 3-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No. 4) (Refer to Fig. 89E for Table 89-5)

- [0800] Table 90-1 Codebook for 4-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No. 1) (Refer to Fig. 90A for Table 90-1)
- [0801] Table 90-2 Codebook for 4-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No. 1) (Refer to Fig. 90B for Table 90-2)
- [0802] Table 90-3 Codebook for 4-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No. 2) (Refer to Fig. 90C for Table 90-3)
- [0803] Table 90-4 Codebook for 4-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No. 3) (Refer to Fig. 90D for Table 90-4)
- [0804] Table 90-5 Codebook for 4-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No. 4) (Refer to Fig. 90E for Table 90-5)
- [0805] Table 90-6 Codebook for 4-layer CSI reporting using antenna ports 15 to $14+P$ (Codebook-Config No. 4) (Refer to Fig. 90F for Table 90-6)
- [0806] Table 91-1 Codebook for 5-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 91A for Table 91-1)
- [0807] Table 91-2 Codebook for 5-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 91B for Table 91-2)
- [0808] Table 91-3 Codebook for 5-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 91C for Table 91-3)
- [0809] Table 91-4 Codebook for 5-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 91D for Table 91-4)
- [0810] Table 92-1 Codebook for 6-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 92A for Table 92-1)
- [0811] Table 92-2 Codebook for 6-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 92B for Table 92-2)
- [0812] Table 92-3 Codebook for 6-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 92C for Table 92-3)
- [0813] Table 92-4 Codebook for 6-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 92D for Table 92-4)
- [0814] Table 93-1 Codebook for 7-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 93A for Table 93-1)
- [0815] Table 93-2 Codebook for 7-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 93B for Table 93-2)

[0816] Table 93-3 Codebook for 7-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 93C for Table 93-3)

[0817] Table 93-4 Codebook for 7-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 93D for Table 93-4)

[0818] Table 93-5 Codebook for 7-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 93E for Table 93-5)

[0819] Table 94-1 Codebook for 8-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 94A for Table 94-1)

[0820] Table 94-2 Codebook for 8-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 94B for Table 94-2)

[0821] Table 94-3 Codebook for 8-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 94C for Table 94-3)

[0822] Table 94-4 Codebook for 8-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 94D for Table 94-4)

[0823] Table 94-5 Codebook for 8-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 94E for Table 94-5)

[0824] Table 95-1 Codebook for 1-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 95A for Table 95-1)

[0825] Table 95-2 Codebook for 1-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 95B for Table 95-2)

[0826] Table 95-2 Codebook for 1-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 95C for Table 95-2)

[0827] Table 95-3 Codebook for 1-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 95D for Table 95-3)

[0828] Table 96-1 Codebook for 2-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 96A for Table 96-1)

[0829] Table 96-2 Codebook for 1-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 96B for Table 96-2)

[0830] Table 96-3 Codebook for 1-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 96C for Table 96-3)

[0831] Table 96-4 Codebook for 1-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 96D for Table 96-4)

[0832] Table 97-1 Codebook for 3-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 97A for Table 97-1)

[0833] Table 97-2 Codebook for 3-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 97B for Table 97-2)

[0834] Table 97-3 Codebook for 3-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 97C for Table 97-3)

[0835] Table 97-4 Codebook for 3-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 97D, 97E and 97F for Table 97-4)

[0836] Table 98-1 Codebook for 4-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 98A for Table 98-1)

[0837] Table 98-2 Codebook for 4-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 98B for Table 98-2)

[0838] Table 98-3 Codebook for 4-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 98C for Table 98-3)

[0839] Table 98-4 Codebook for 4-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 98D, 98E and 98F for Table 98-4)

[0840] Table 99 Codebook for 5-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 99A and 99B for Table 99)

[0841] Table 100 Codebook for 6-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 100A and 100B for Table 100)

[0842] Table 101 Codebook for 7-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 101A, 101B, 101C and 101D for Table 101)

[0843] Table 102 Codebook for 8-layer CSI reporting using antenna ports 15 to $14+P$ (Refer to Fig. 102A, 102B, 102C and 102D for Table 102)

【CLAIMS】**【Claim 1】**

A method of a base station, the method comprising:
 transmitting information on precoder codebook parameters; and
 receiving channel state information comprising at least one precoding matrix indicator (PMI) which is determined based on the information on precoder codebook parameters, and
 wherein the information on precoder codebook parameters comprises first and second quantities of antenna ports indicating respective quantities of antenna ports in a first dimension and a second dimension, first and second oversampling factors indicating respective oversampling factors associated with the first dimension and the second dimension, and codebook configuration information, and

wherein at least one PMI comprising a first PMI pair $i_{1,1}$ and $i_{1,2}$ and a second PMI i_2 .

【Claim 2】

The method of claim 1, wherein a first beam skip number and a second beam skip number are determined based on at least one of the codebook configuration information and the first and second oversampling factors if a rank is one of 3 to 8.

【Claim 3】

The method of claim 2, wherein a number of bits indicating the first PMI pair $i_{1,1}$ and $i_{1,2}$ is determined based on a number $N_{1,1} = \frac{N_1 O_1}{S_1}$ and $N_{1,2} = \frac{N_2 O_2}{S_2}$ respectively, and

wherein N_1 and N_2 are the first or second quantities of antenna ports, O_1 and O_2 are the first and second oversampling factors, and S_1 and S_2 is the first and the second beam skip numbers.

【Claim 4】

The method of claim 1, wherein the channel state information further comprises information on a beam group type.

【Claim 5】

The method of claim 3, wherein if the codebook configuration information is 1, sizes of a codebook for 2-layer for the first PMI pair $i_{1,1}$ and $i_{1,2}$ are $N_1 O_1$ and $N_2 O_2$, and

if the codebook configuration information is one of 2 to 4, the sizes of the a codebook for 2-layer for the first PMI pair $i_{1,1}$ and $i_{1,2}$ are $N_1 O_1 / 2$ and $N_2 O_2 / 2$.

【Claim 6】

A method of a terminal, the method comprising:

receiving information on precoder codebook parameters;

determining at least one precoding matrix indicator (PMI) precoding matrix indicator (PMI); and

transmitting channel state information comprising the at least one precoding matrix indicator (PMI), and

wherein the information on precoder codebook parameters comprises first and second quantities of antenna ports indicating respective quantities of antenna ports in a first dimension and a second dimension, first and second oversampling factors indicating respective oversampling factors associated with the first dimension and the second dimension, and codebook configuration information, and

wherein at least one PMI comprising a first PMI pair $i_{1,1}$ and $i_{1,2}$ and a second PMI i_2 .

【Claim 7】

The method of claim 6, wherein a first beam skip number and a second beam skip number are determined based on at least one of the codebook configuration information and the first and second oversampling factors if a rank is one of 3 to 8.

【Claim 8】

The method of claim 7, wherein a number of bits indicating the first PMI pair $i_{1,1}$ and $i_{1,2}$ is determined based on a number $N_{1,1} = \frac{N_1 O_1}{S_1}$ and $N_{1,2} = \frac{N_2 O_2}{S_2}$ respectively, and

wherein N_1 and N_2 are the first or second quantities of antenna ports, O_1 and O_2 are the first and second oversampling factors, and S_1 and S_2 is the first and the second beam skip numbers.

【Claim 9】

The method of claim 6, wherein the channel state information further comprises information on a beam group type.

【Claim 10】

The method of claim 8, wherein if the codebook configuration information is 1, sizes of a codebook for 2-layer for the first PMI pair $i_{1,1}$ and $i_{1,2}$ are $N_1 O_1$ and $N_2 O_2$, and

if the codebook configuration information is one of 2 to 4, the sizes of the a codebook for 2-layer for the first PMI pair $i_{1,1}$ and $i_{1,2}$ are $N_1 O_1 / 2$ and $N_2 O_2 / 2$.

【Claim 11】

A base station comprising:

a transceiver to transmit and receive signals to and from a terminal; and

a controller configured to control to transmit information on precoder codebook parameters, and receive channel state information comprising at least one precoding matrix indicator (PMI) which is determined based on the information on precoder codebook parameters, and

wherein the information on precoder codebook parameters comprises first and second quantities of antenna ports indicating respective quantities of antenna ports in a first dimension and a second dimension, first and second oversampling factors indicating respective oversampling factors associated with the first dimension and the second dimension, and codebook configuration information, and

wherein at least one PMI comprising a first PMI pair $i_{1,1}$ and $i_{1,2}$ and a second PMI i_2 .

【Claim 12】

A terminal comprising:

a transceiver to transmit and receive signals to and from a base station; and

a controller configured to control to receive information on precoder codebook parameters, determine at least one precoding matrix indicator (PMI) precoding matrix indicator (PMI), and transmit channel state information comprising the at least one precoding matrix indicator (PMI), and

wherein the information on precoder codebook parameters comprises first and second quantities of antenna ports indicating respective quantities of antenna ports in a first dimension and a second dimension, first and second oversampling factors indicating respective oversampling factors associated with the first dimension and the second dimension, and codebook configuration information, and

wherein at least one PMI comprising a first PMI pair $i_{1,1}$ and $i_{1,2}$ and a second PMI i_2 .

【Claim 13】

The base station of claim 11 or the terminal of claim 12, wherein a first beam skip number and a second beam skip number are determined based on at least one of the codebook configuration information and the first and second oversampling factors if a rank is one of 3 to 8.

【Claim 14】

The base station or the terminal of claim 13, wherein a number of bits indicating the first PMI pair $i_{1,1}$ and $i_{1,2}$ is determined based on a number $N_{1,1} = \frac{N_1 O_1}{S_1}$ and $N_{1,2} = \frac{N_2 O_2}{S_2}$ respectively, and

wherein N_1 and N_2 are the first or second quantities of antenna ports, O_1 and O_2 are the first and second oversampling factors, and S_1 and S_2 is the first and the second beam skip numbers.

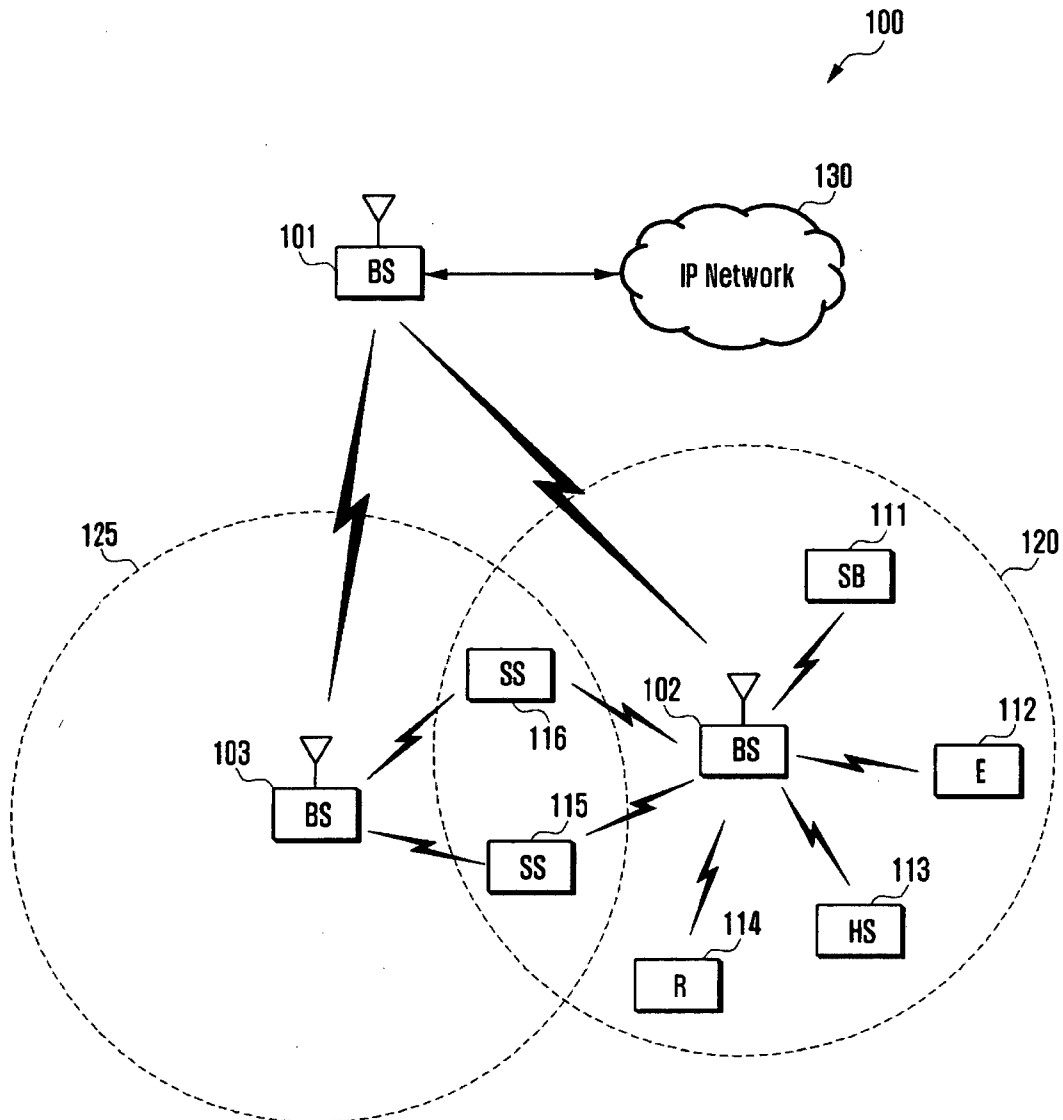
【Claim 15】

The base station or the terminal of claim 14, wherein if the codebook configuration information is 1, sizes of a codebook for 2-layer for the first PMI pair $i_{1,1}$ and $i_{1,2}$ are $N_1 O_1$ and $N_2 O_2$, and

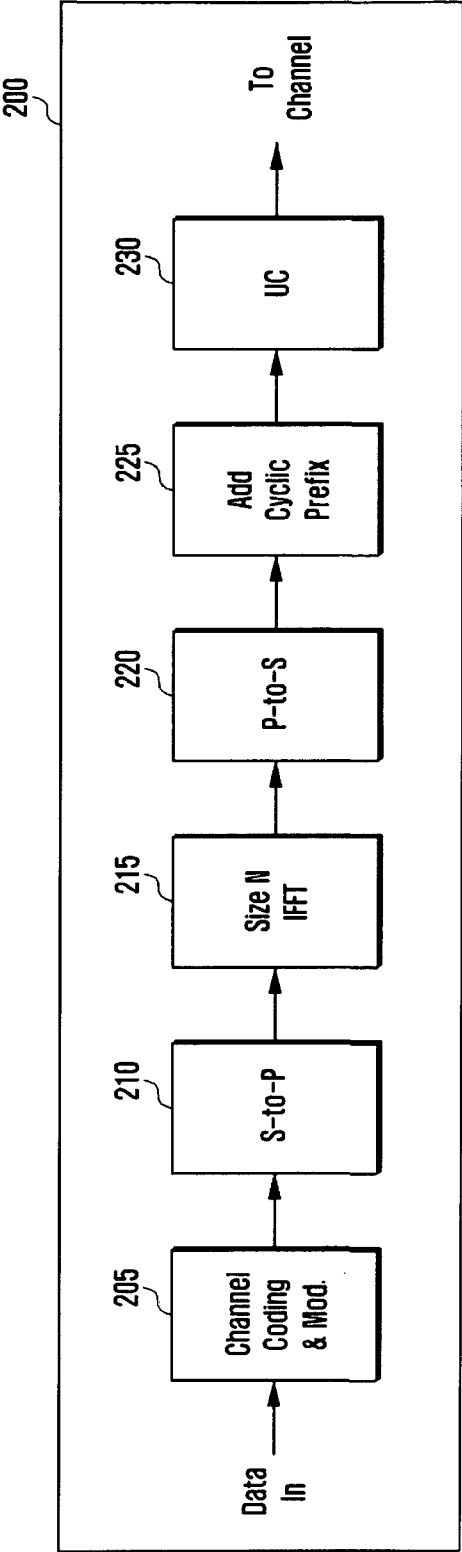
if the codebook configuration information is one of 2 to 4, the sizes of the a codebook for 2-layer for the first PMI pair $i_{1,1}$ and $i_{1,2}$ are $N_1 O_1 / 2$ and $N_2 O_2 / 2$.

【DRAWINGS】

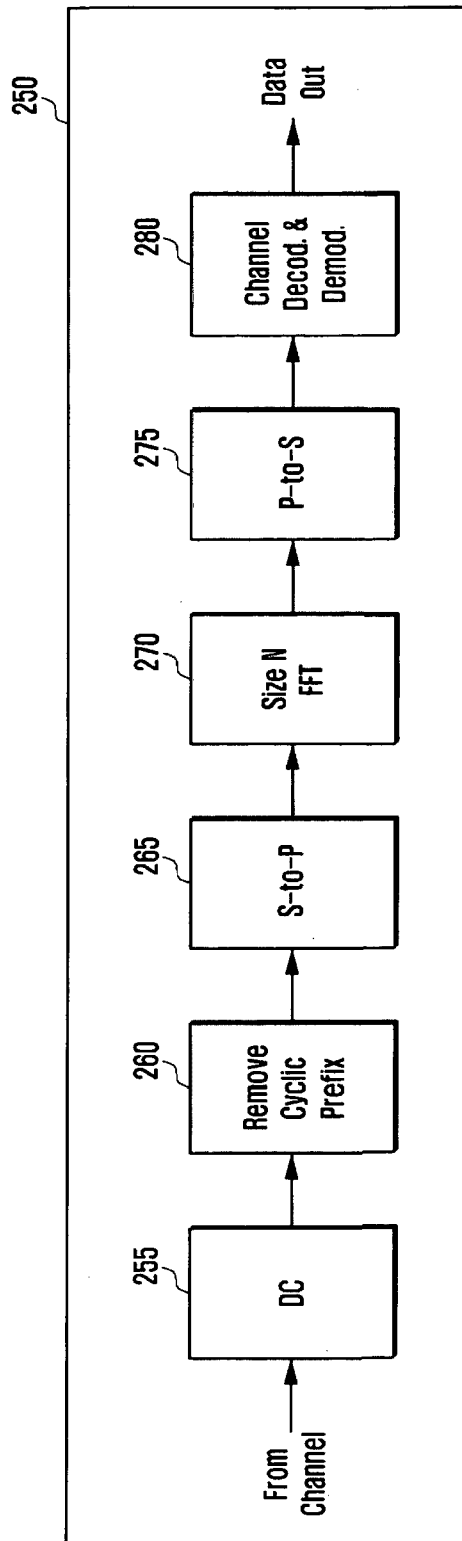
【Figure 1】



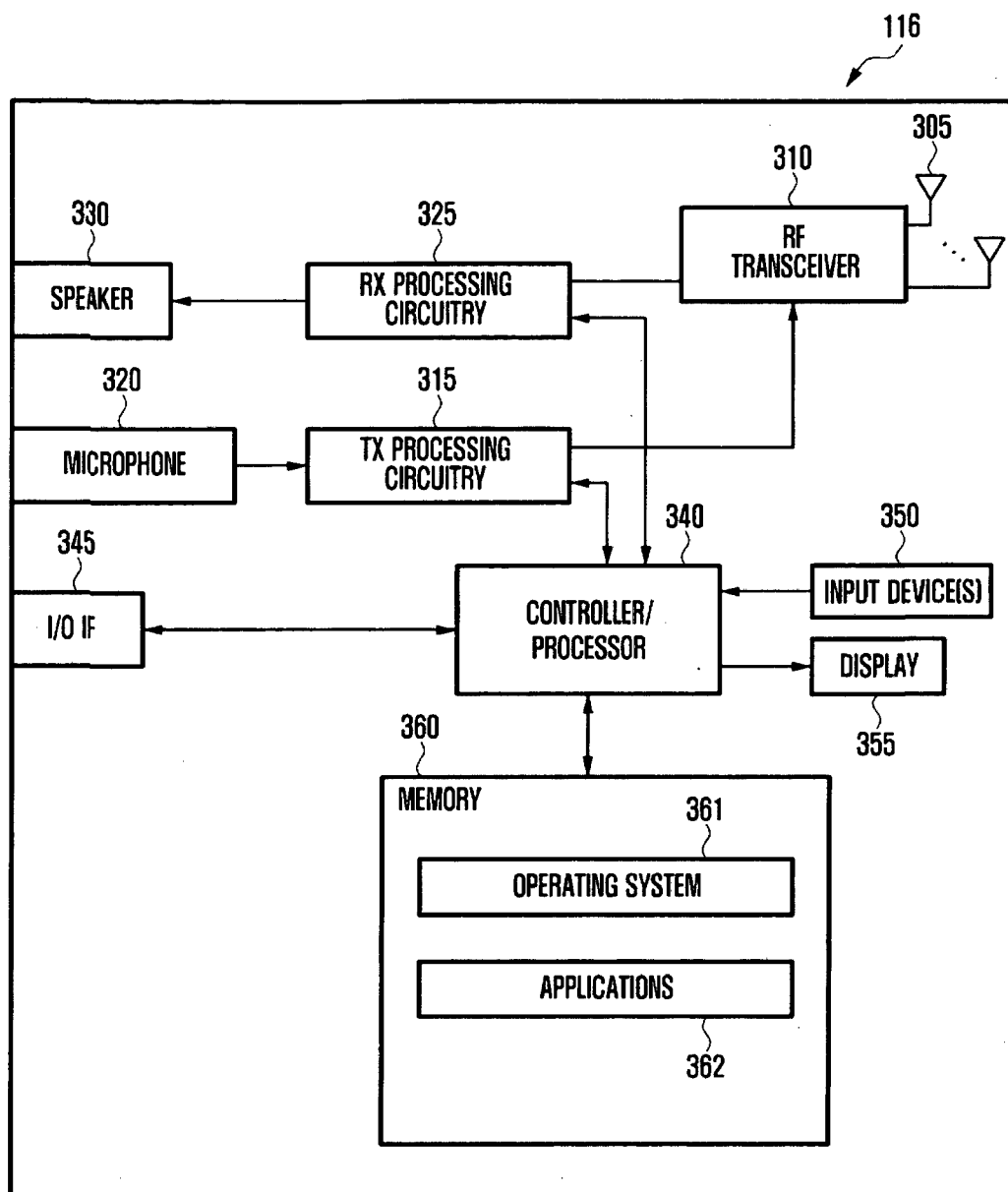
【Figure 2a】



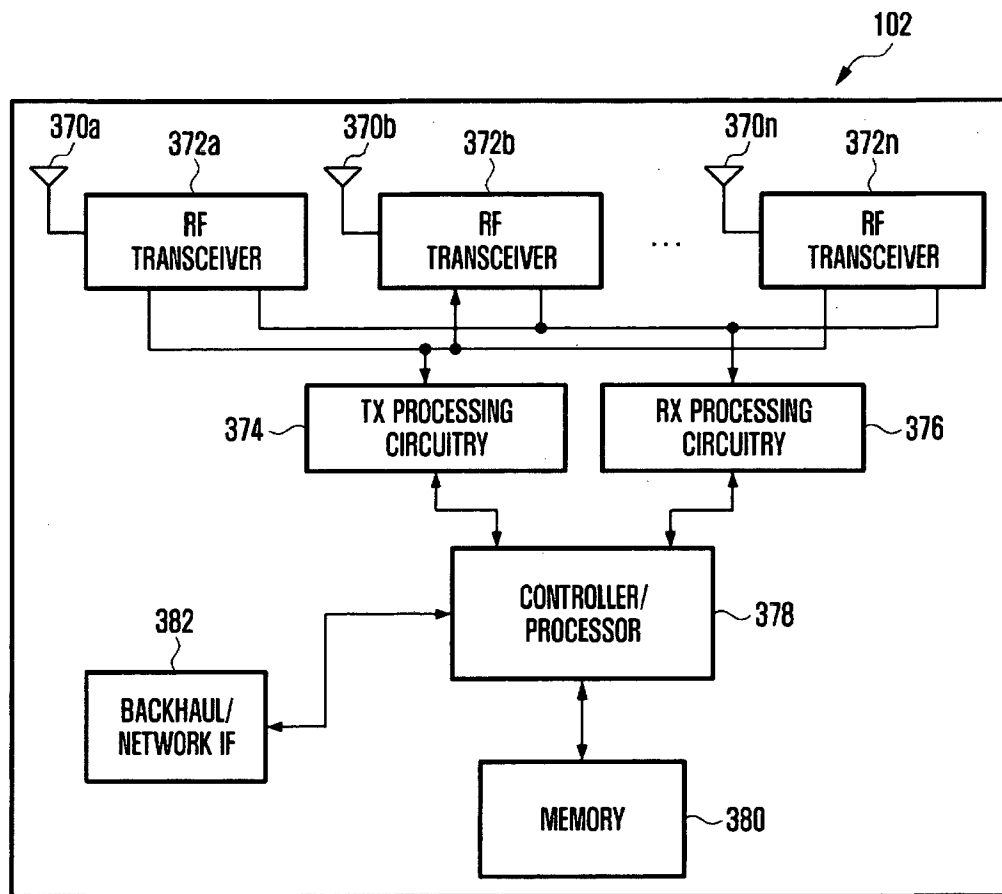
【Figure 2b】



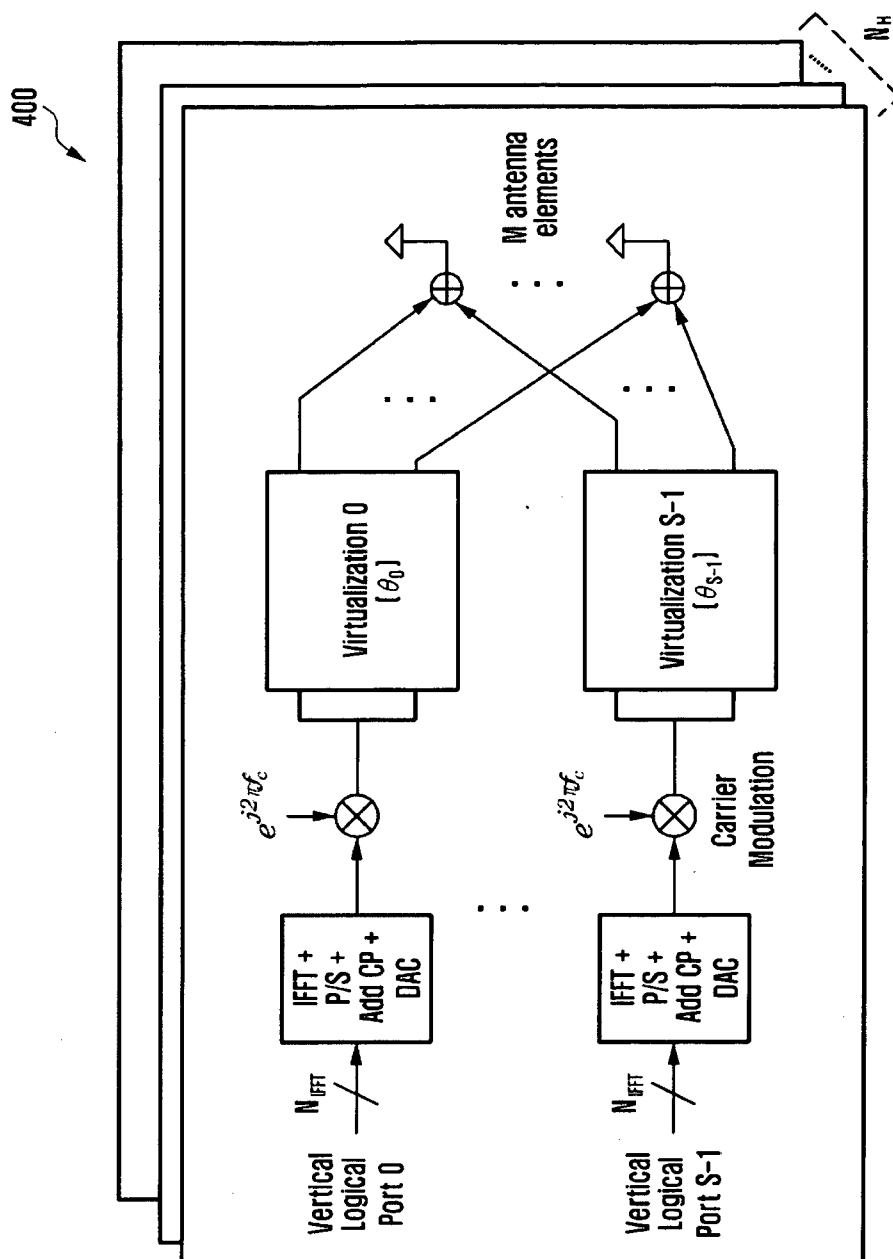
【Figure 3a】



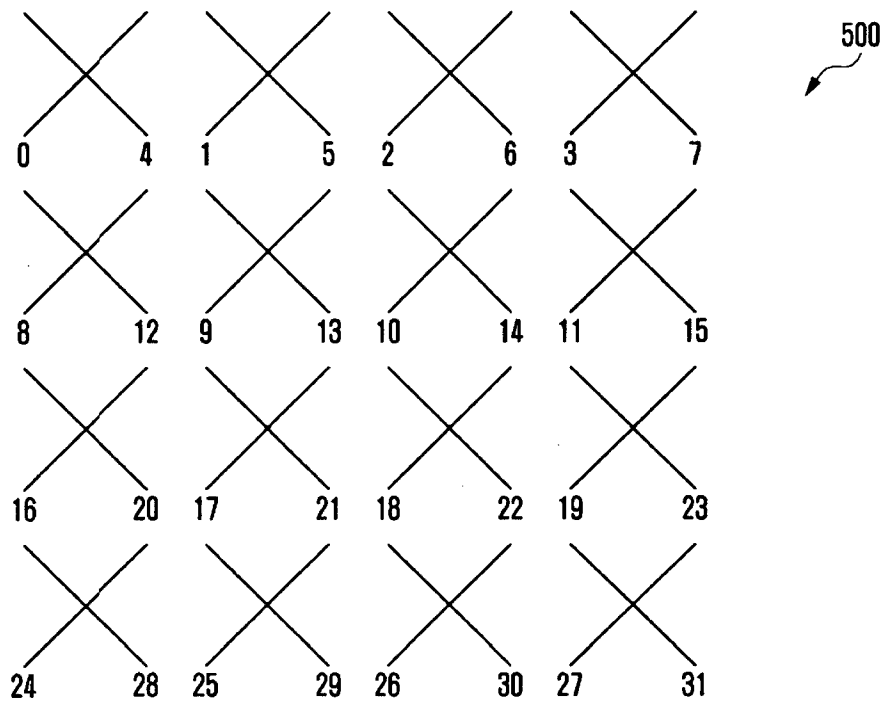
【Figure 3b】



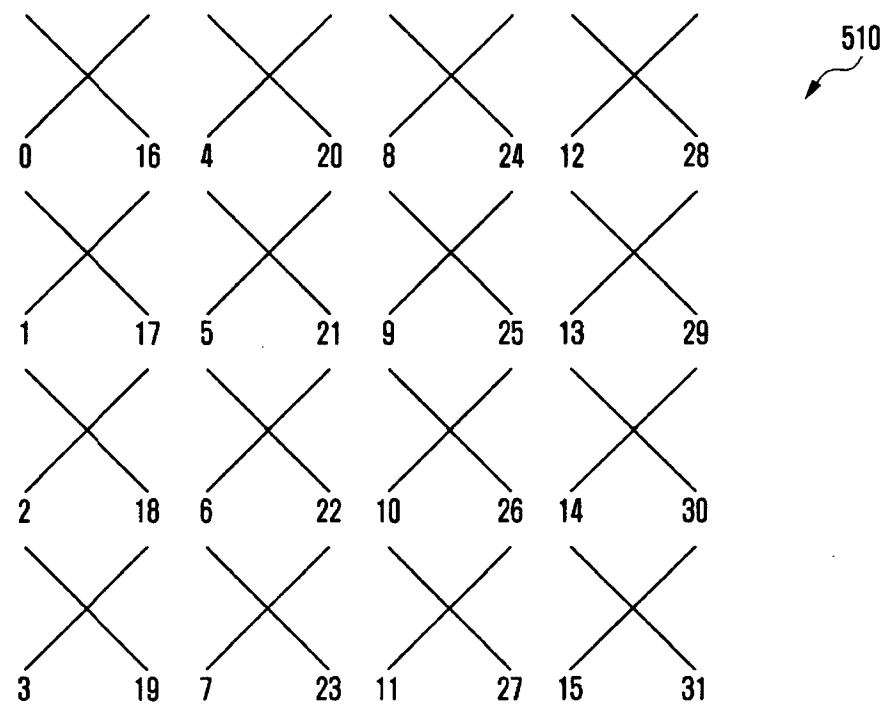
【Figure 4】



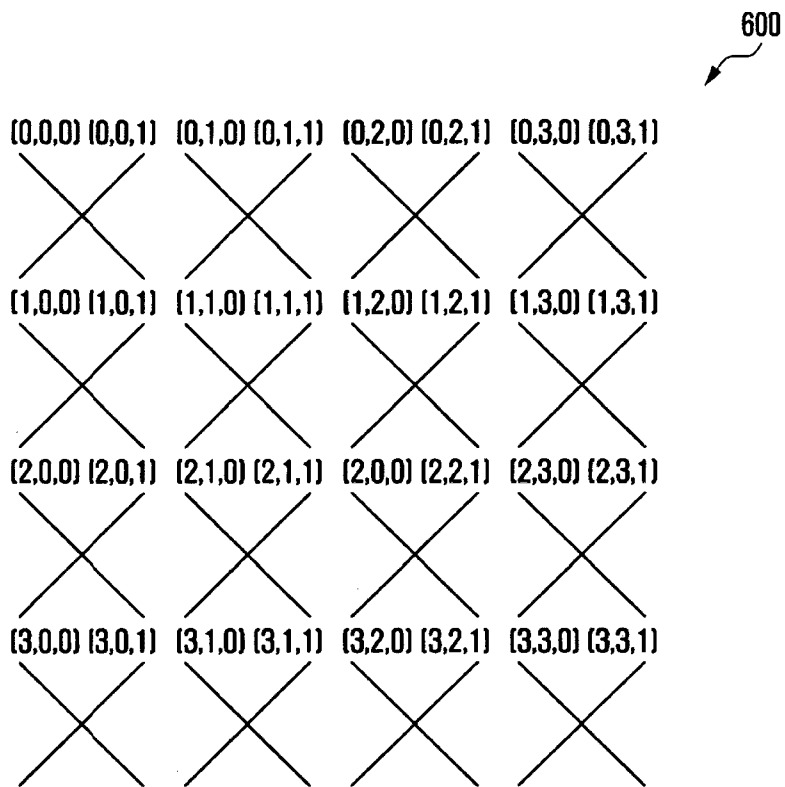
【Figure 5a】



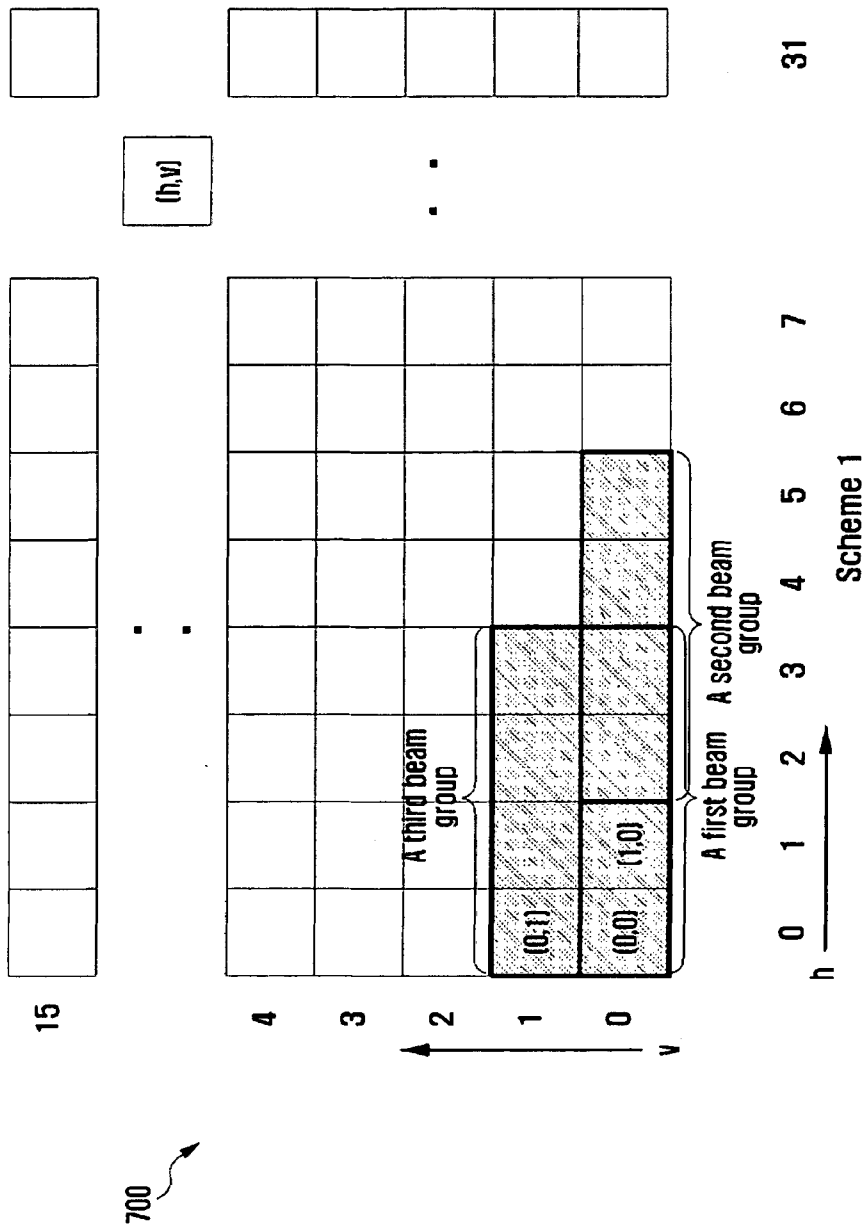
【Figure 5b】



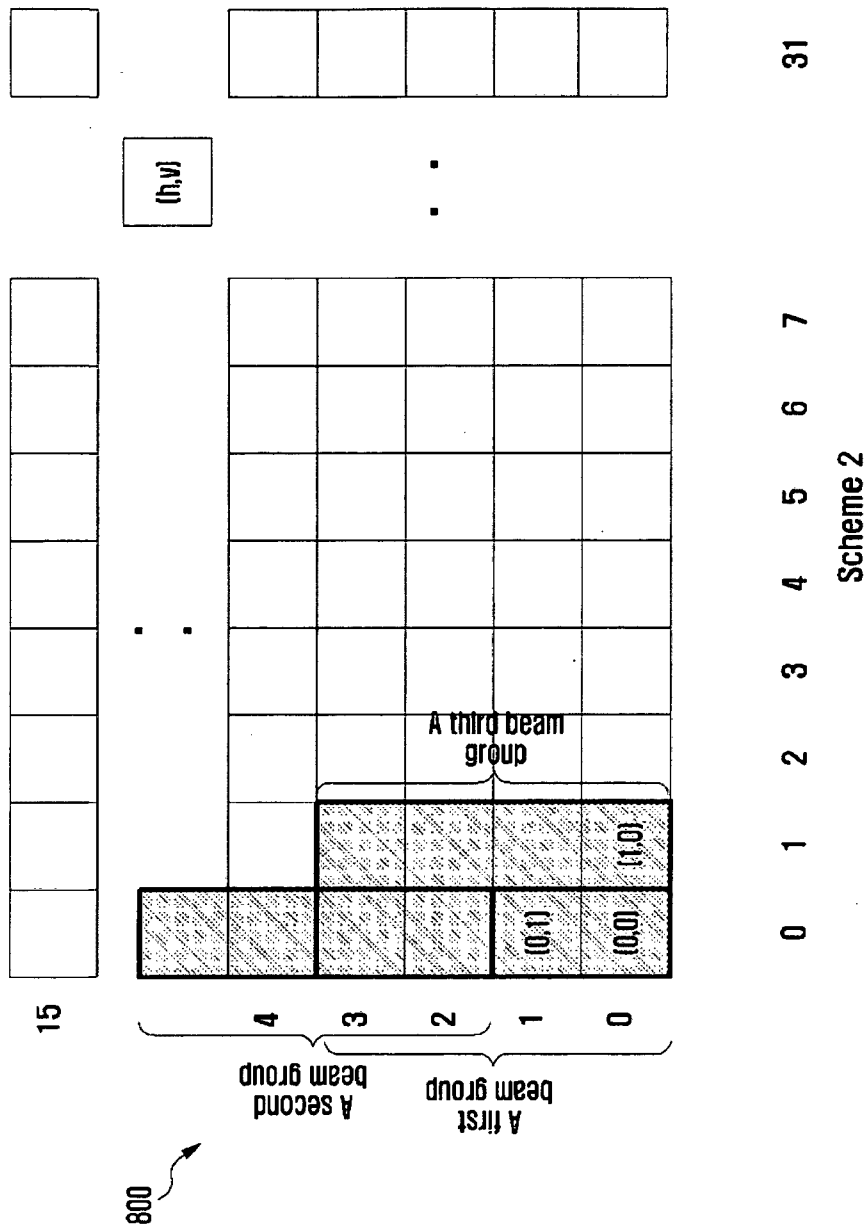
【Figure 6】



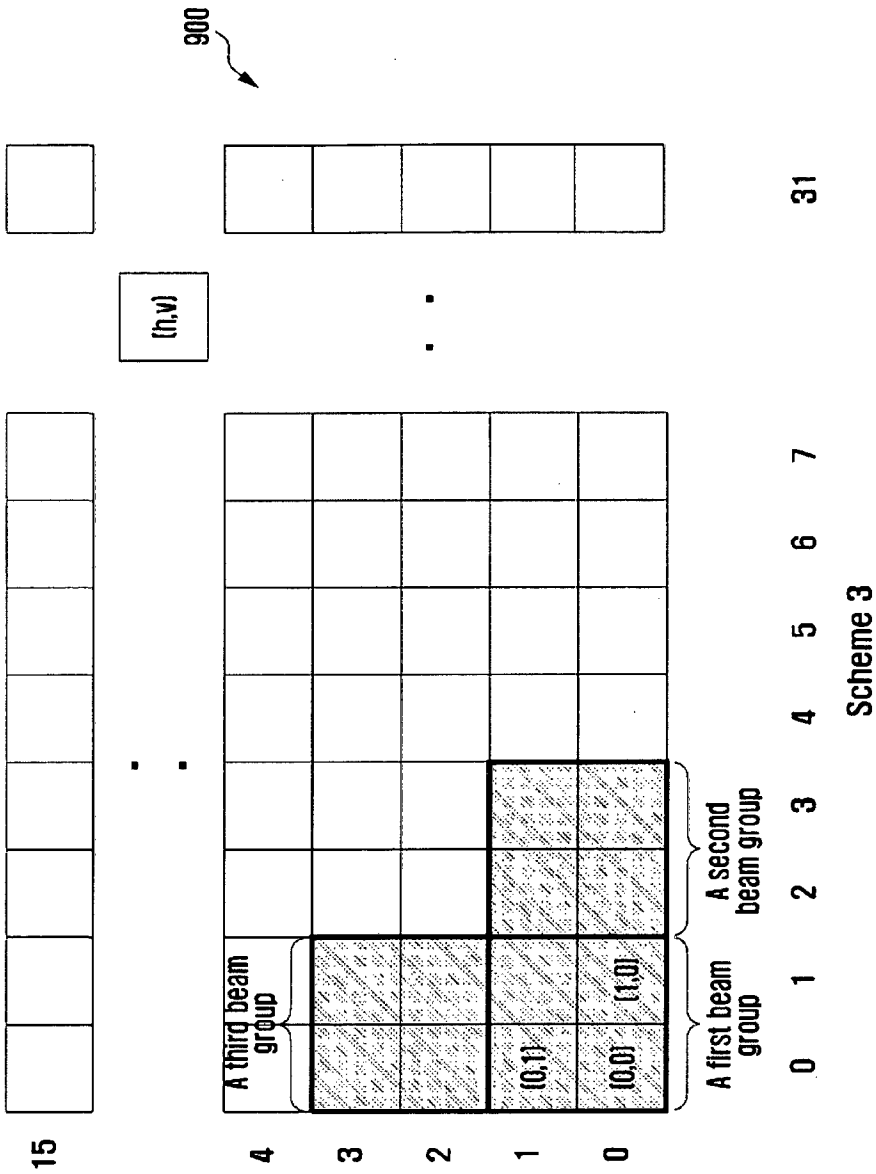
【Figure 7】



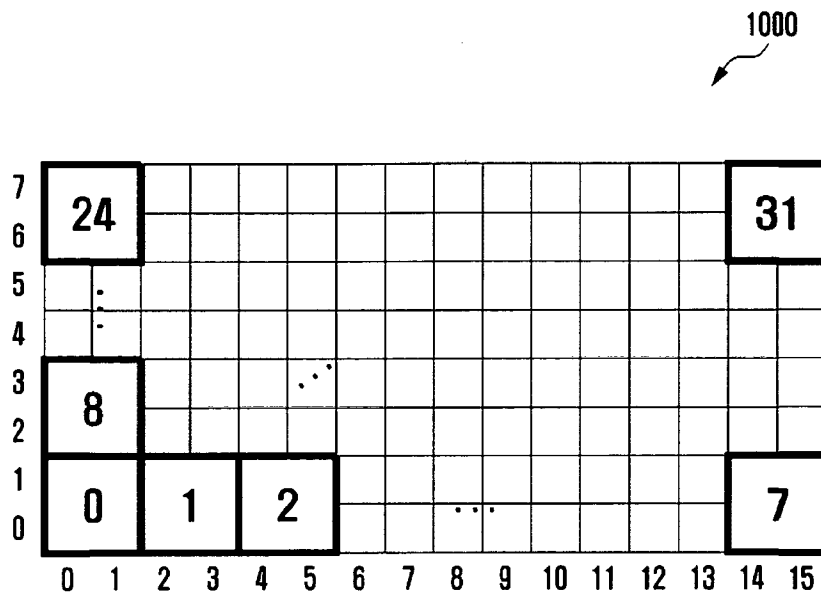
【Figure 8】



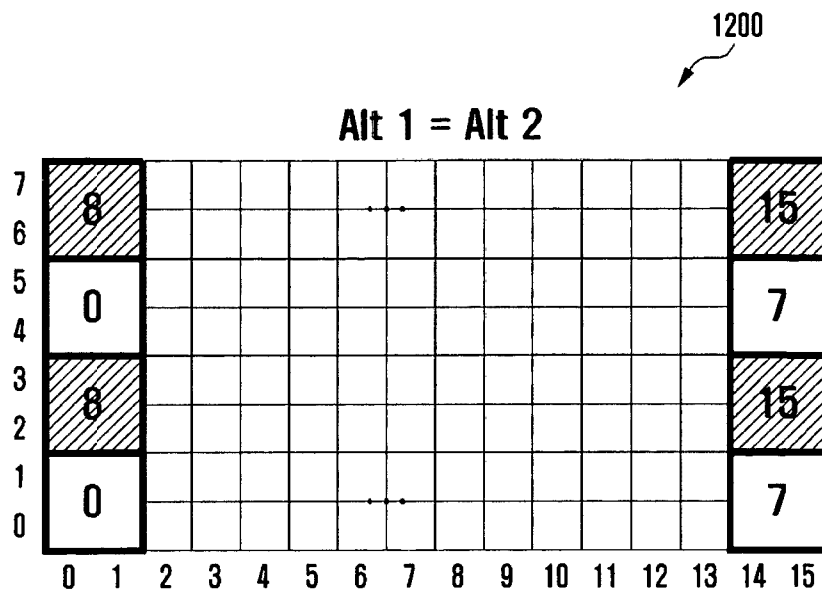
【Figure 9】



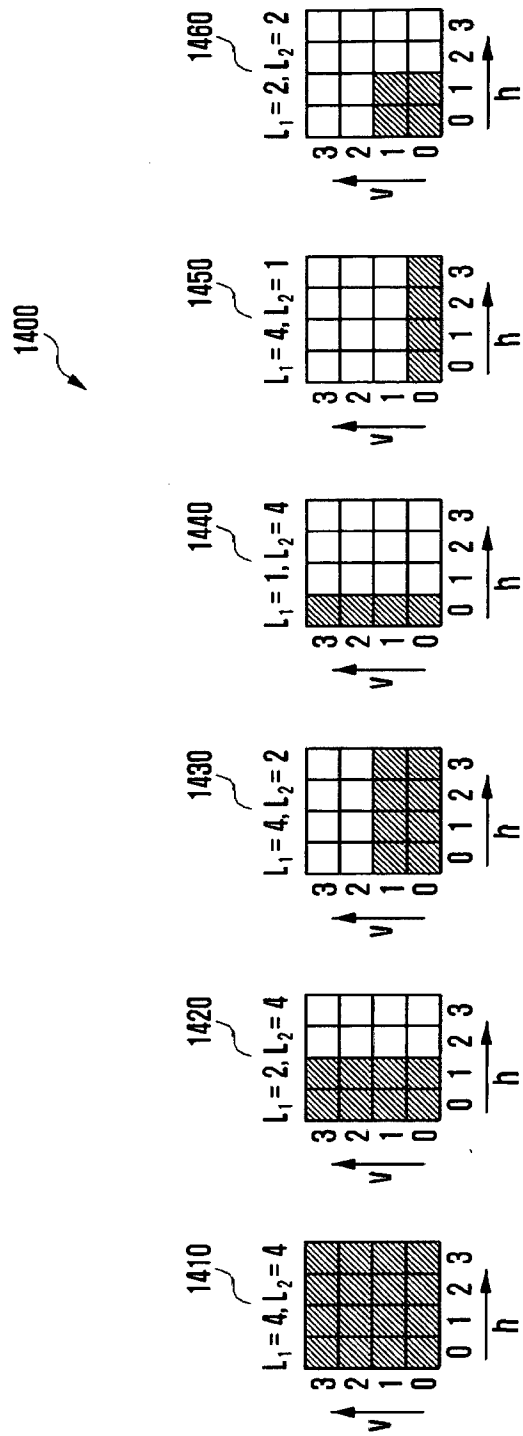
【Figure 10】



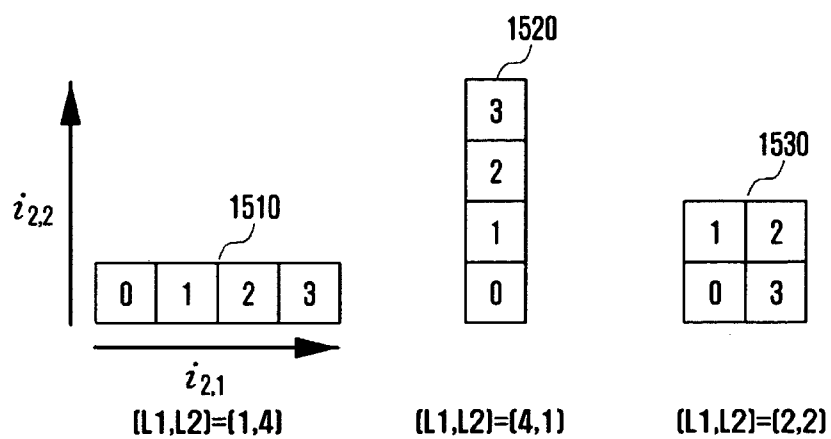
【Figure 12】



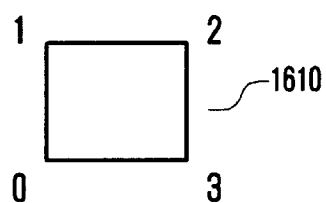
[Figure 14]



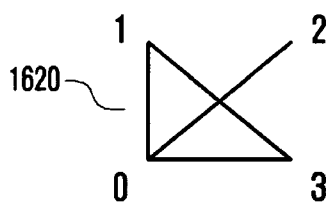
【Figure 15】



【Figure 16】

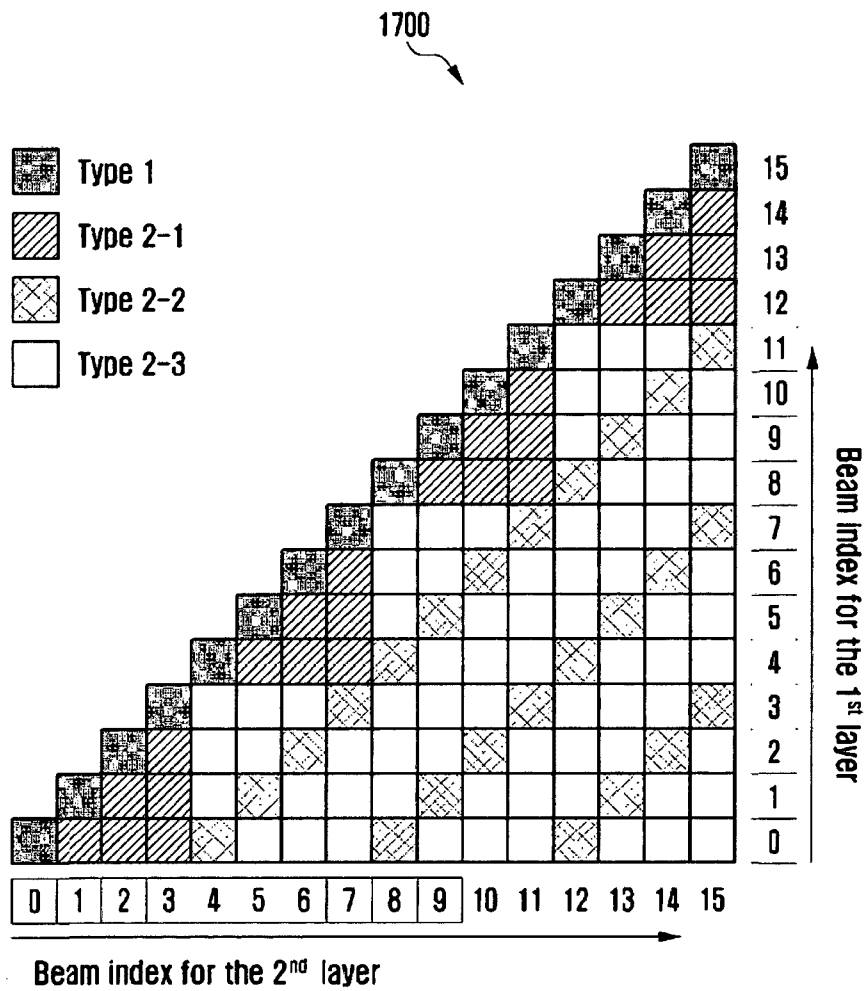


Scheme 1

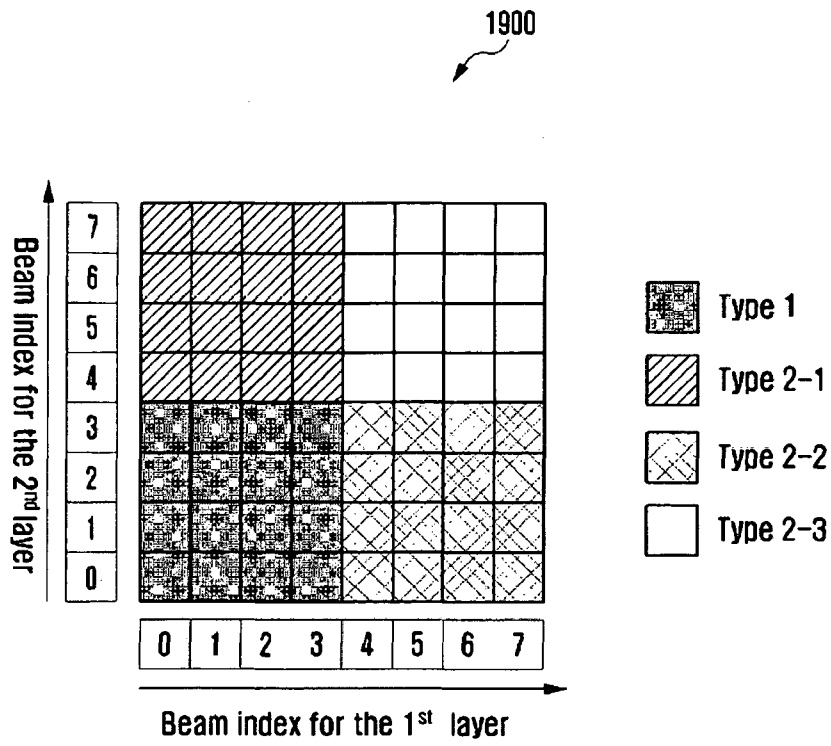


Scheme 2

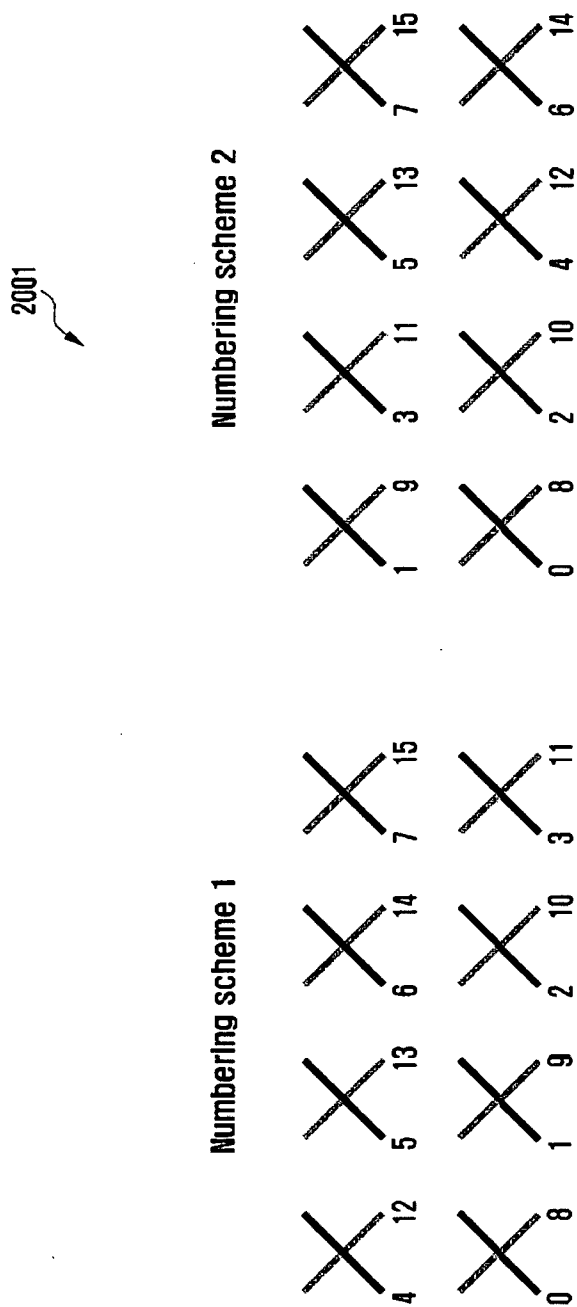
【Figure 17】



【Figure 19】



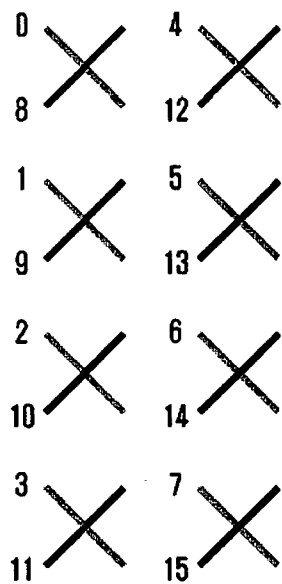
【Figure 20a】



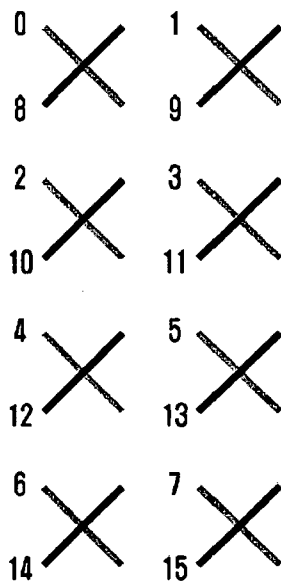
【Figure 20b】

2002
↙

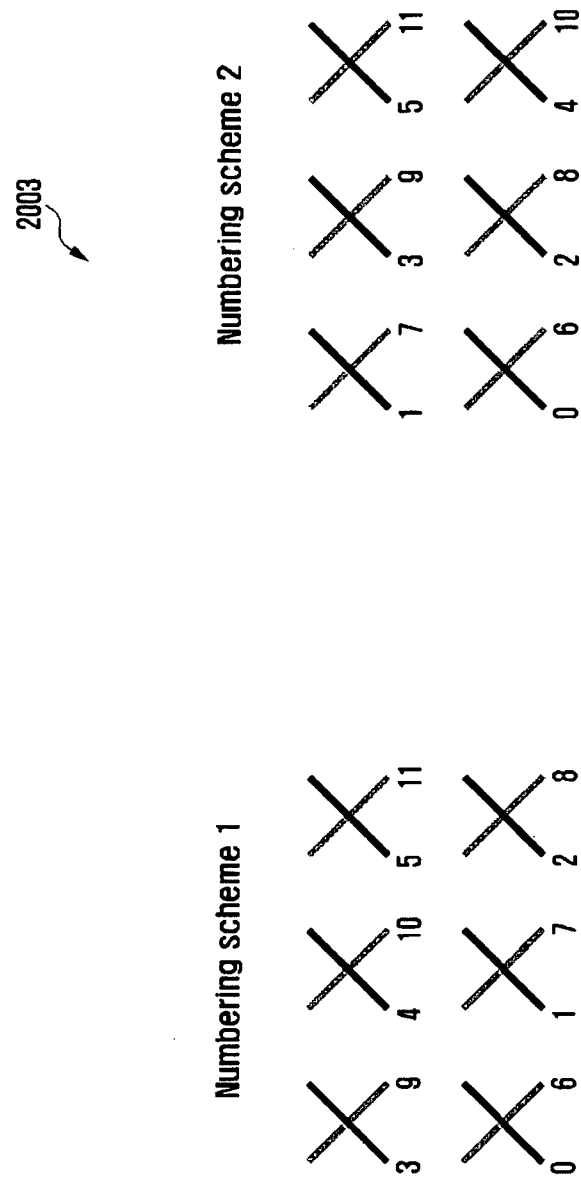
Numbering scheme 1



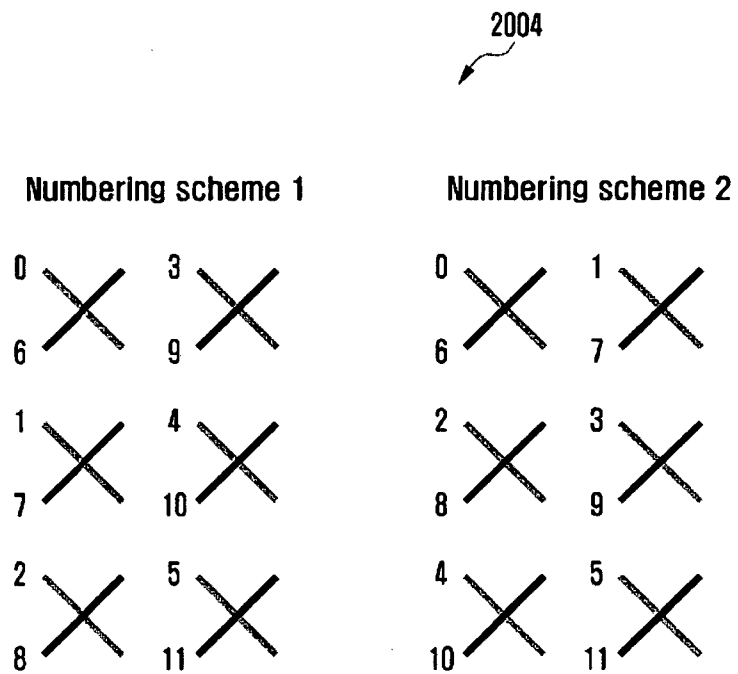
Numbering scheme 2



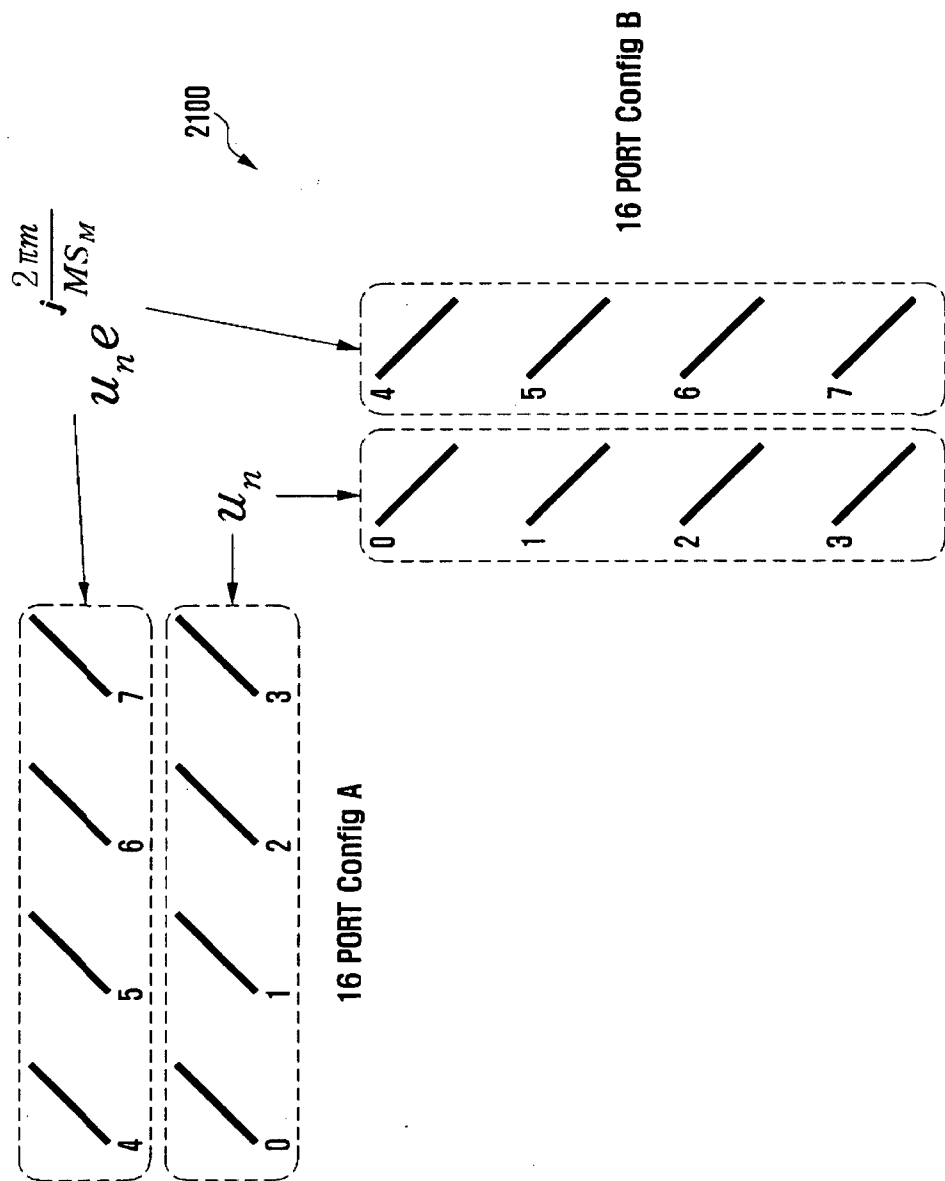
【Figure 20c】



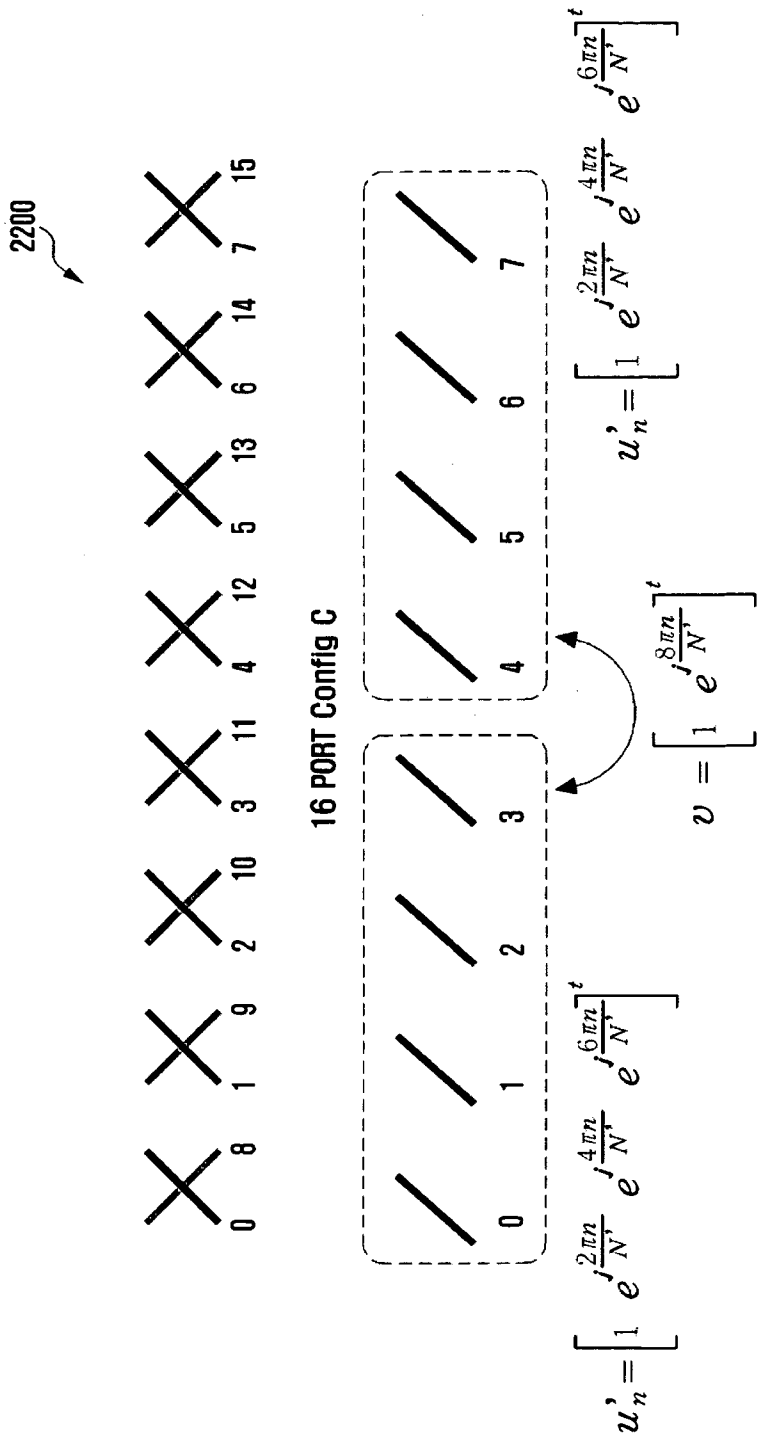
【Figure 20d】



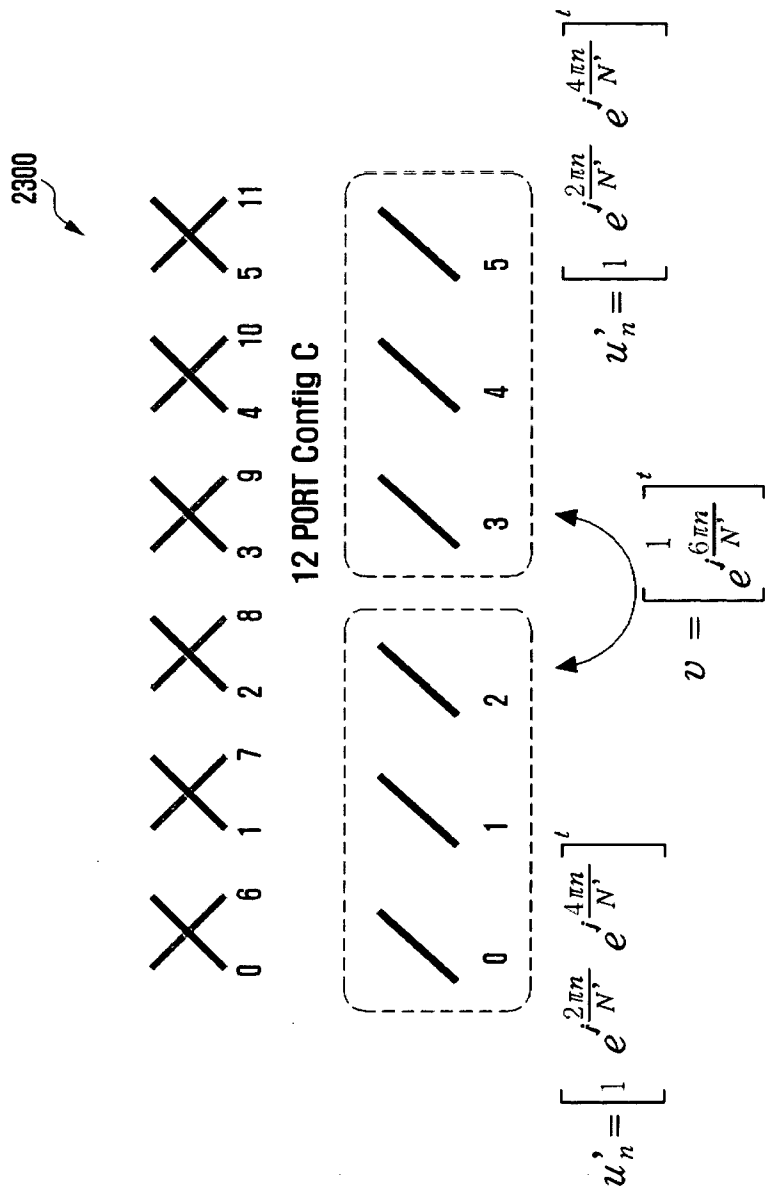
【Figure 21】



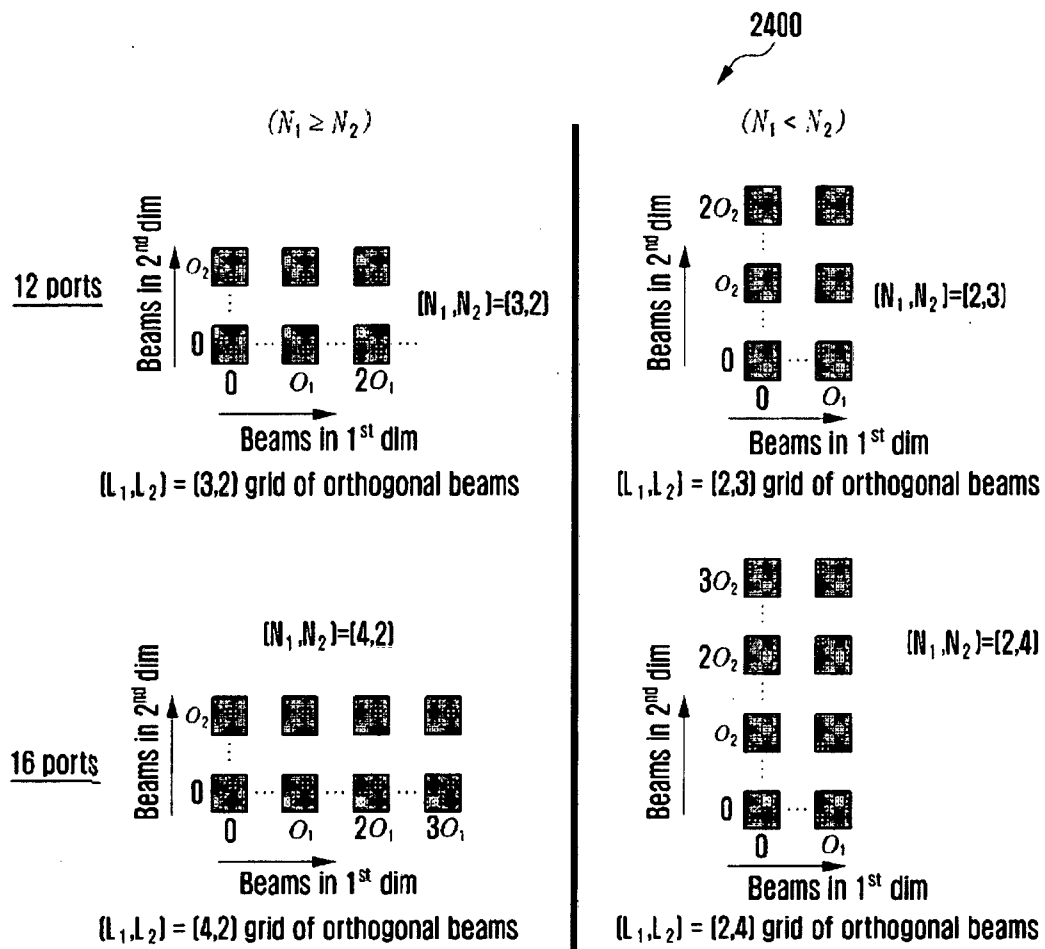
[Figure 22]



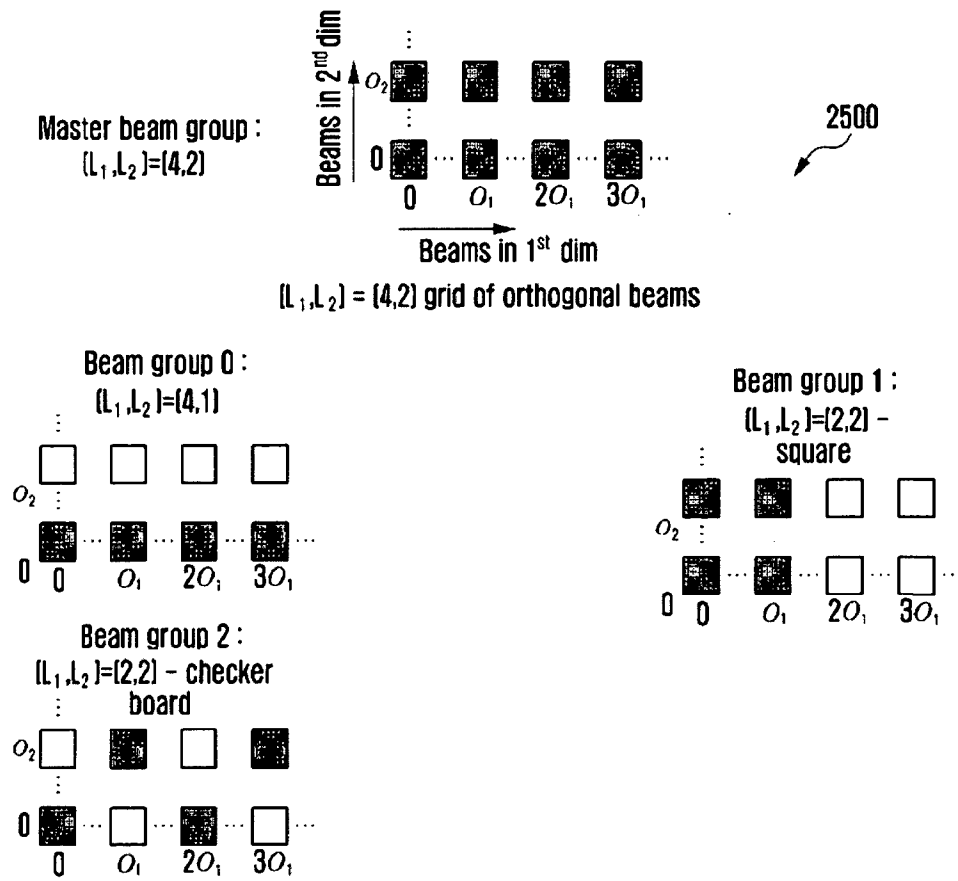
[Figure 23]



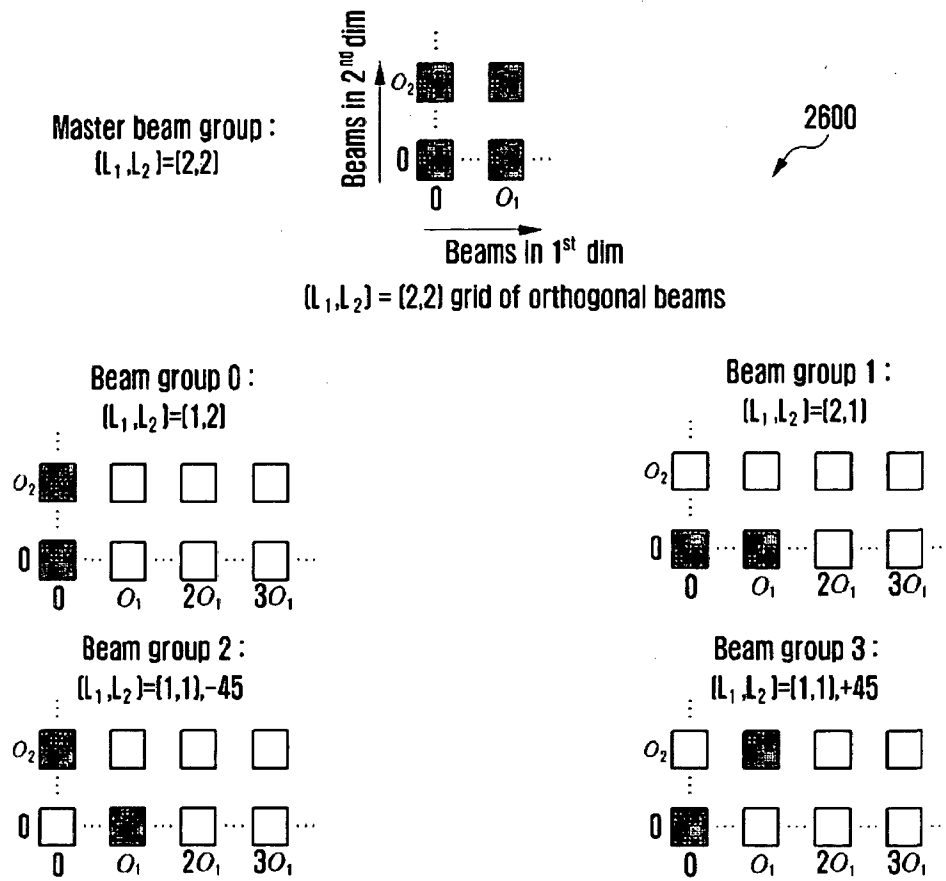
【Figure 24】



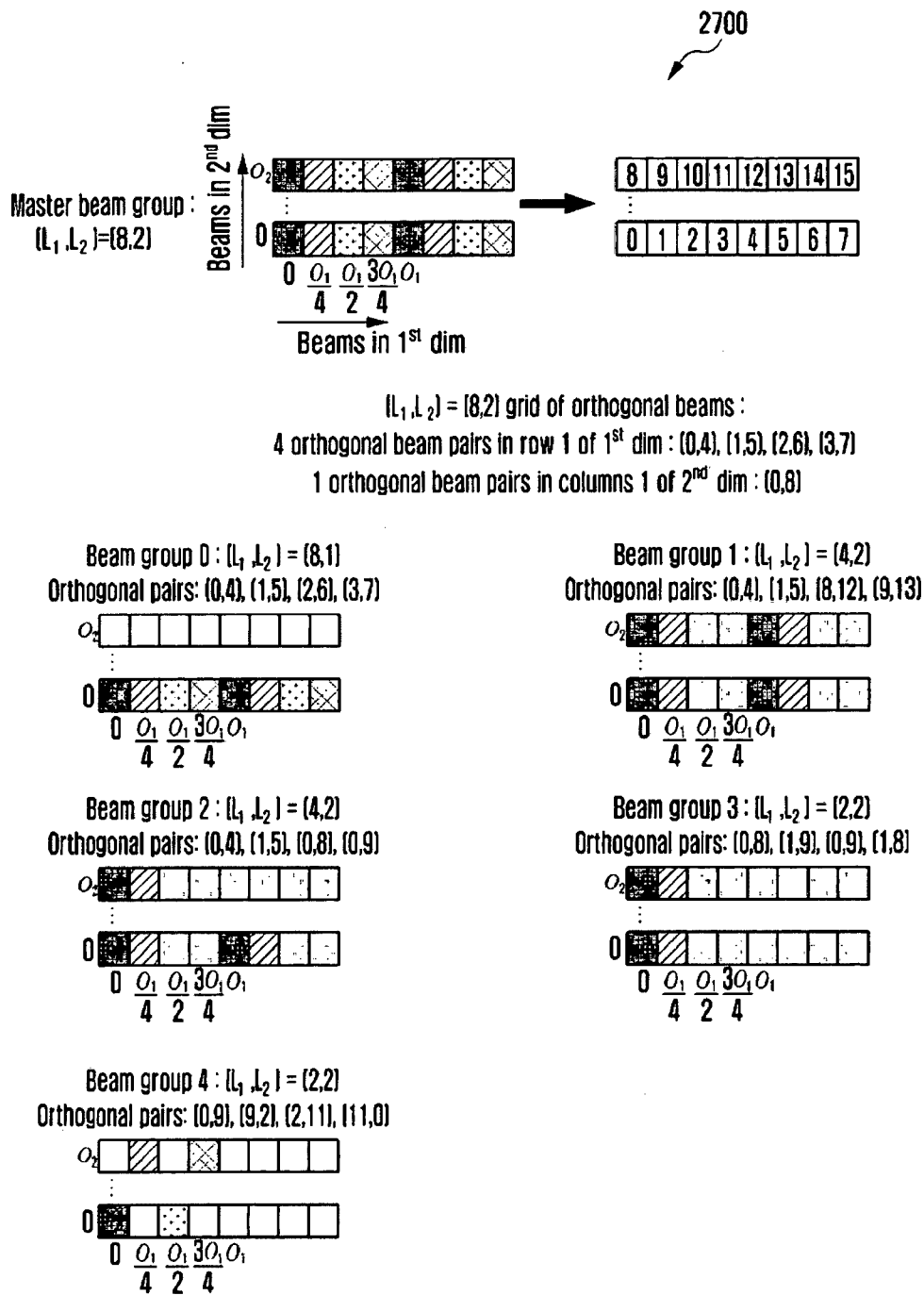
【Figure 25】



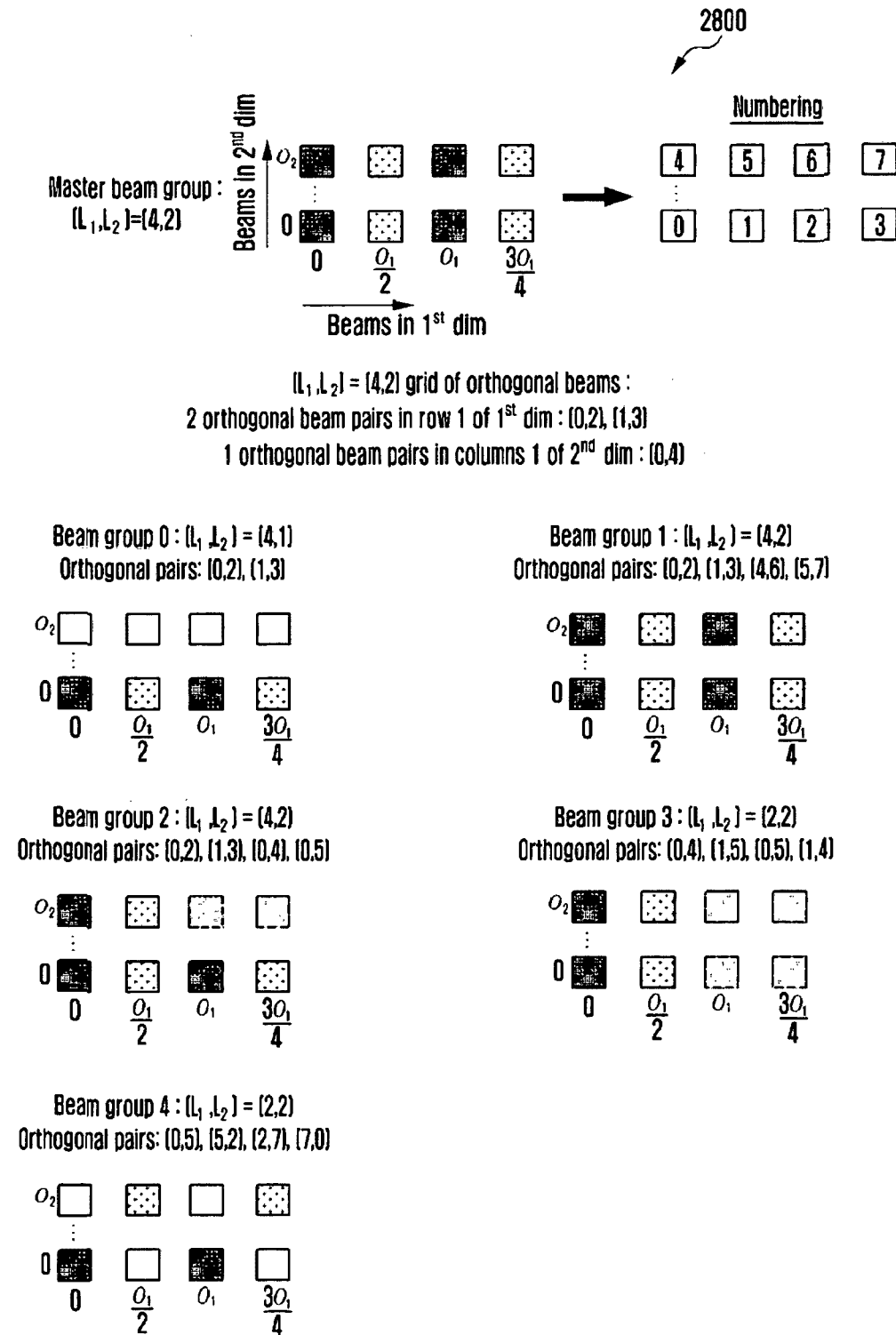
【Figure 26】



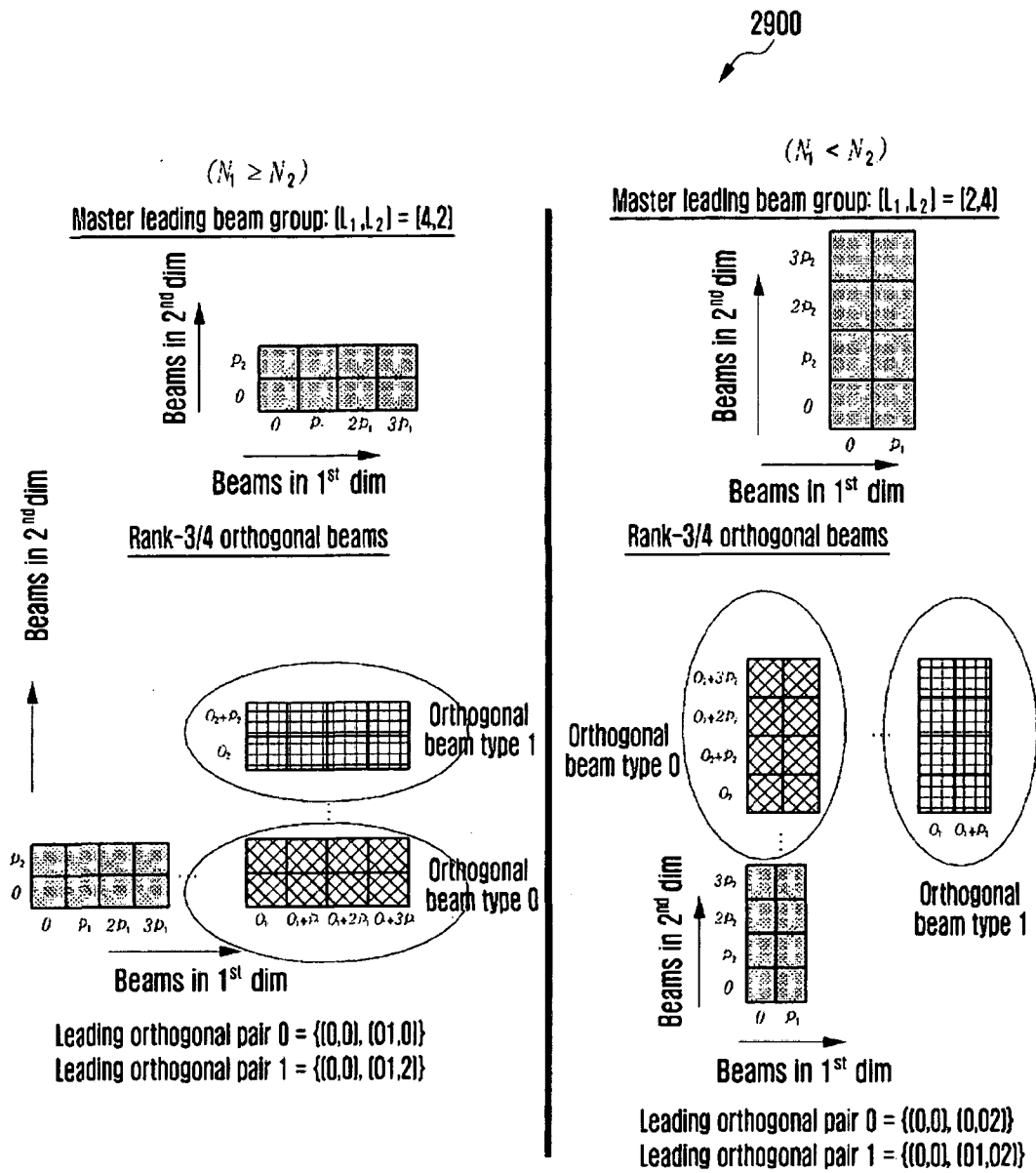
[Figure 27]



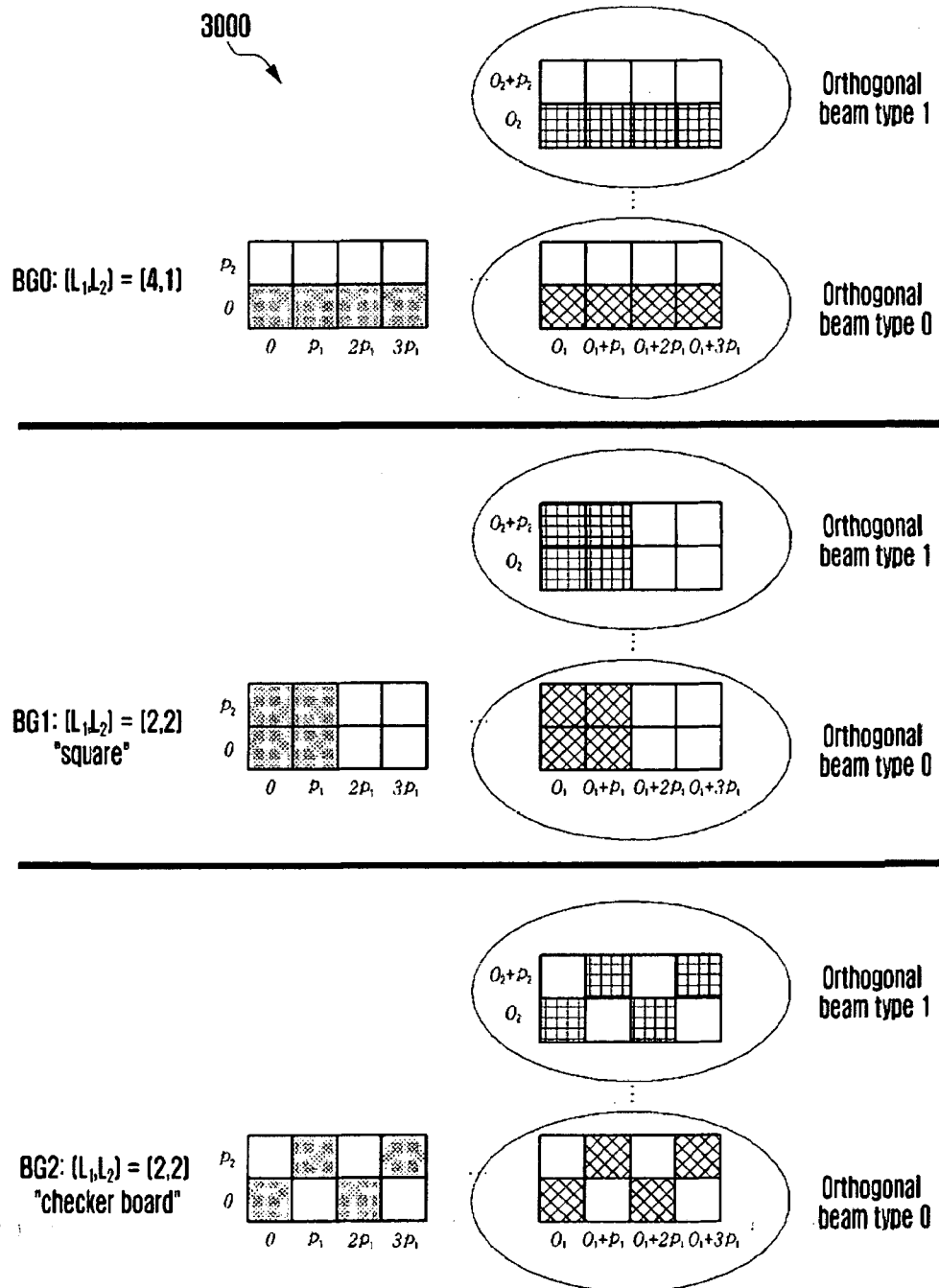
【Figure 28】



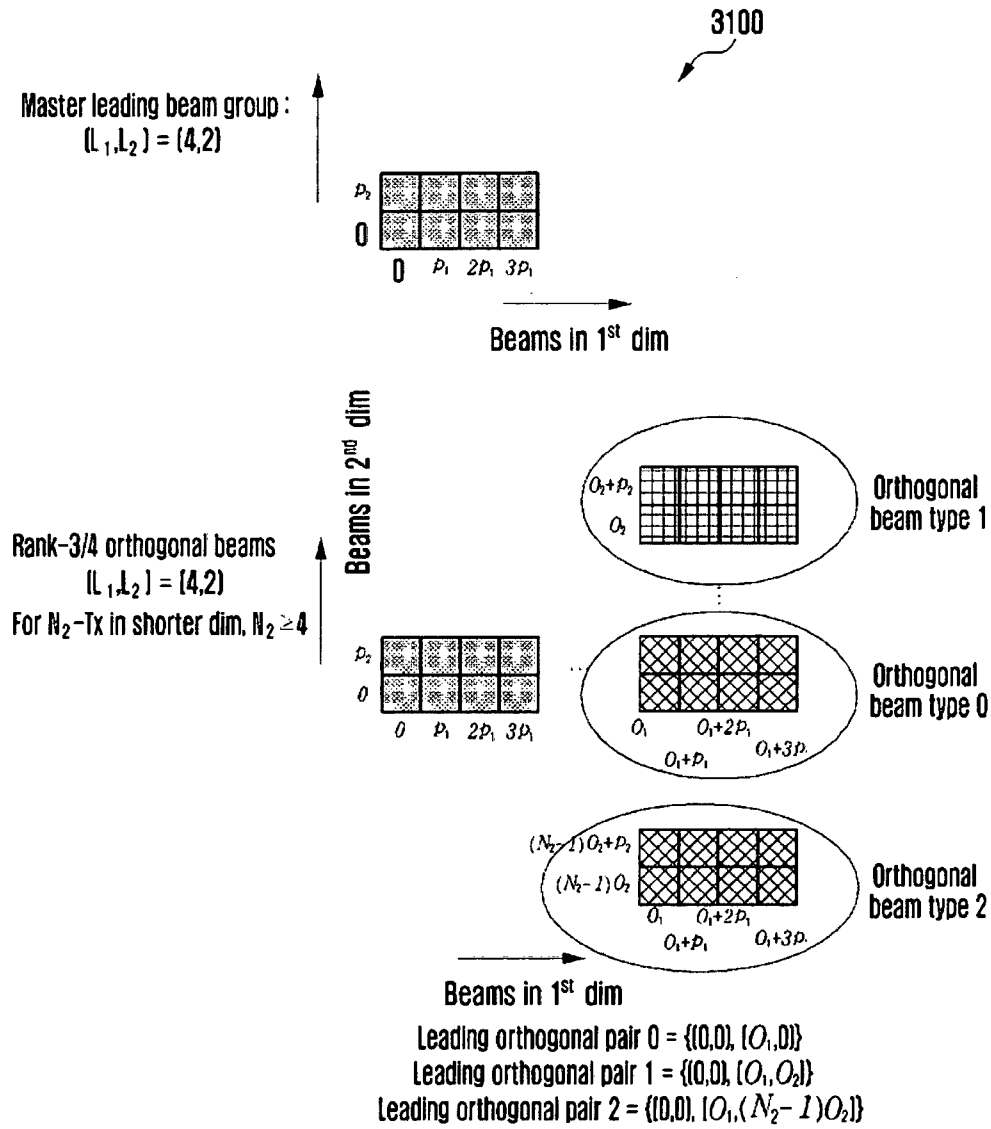
[Figure 29]



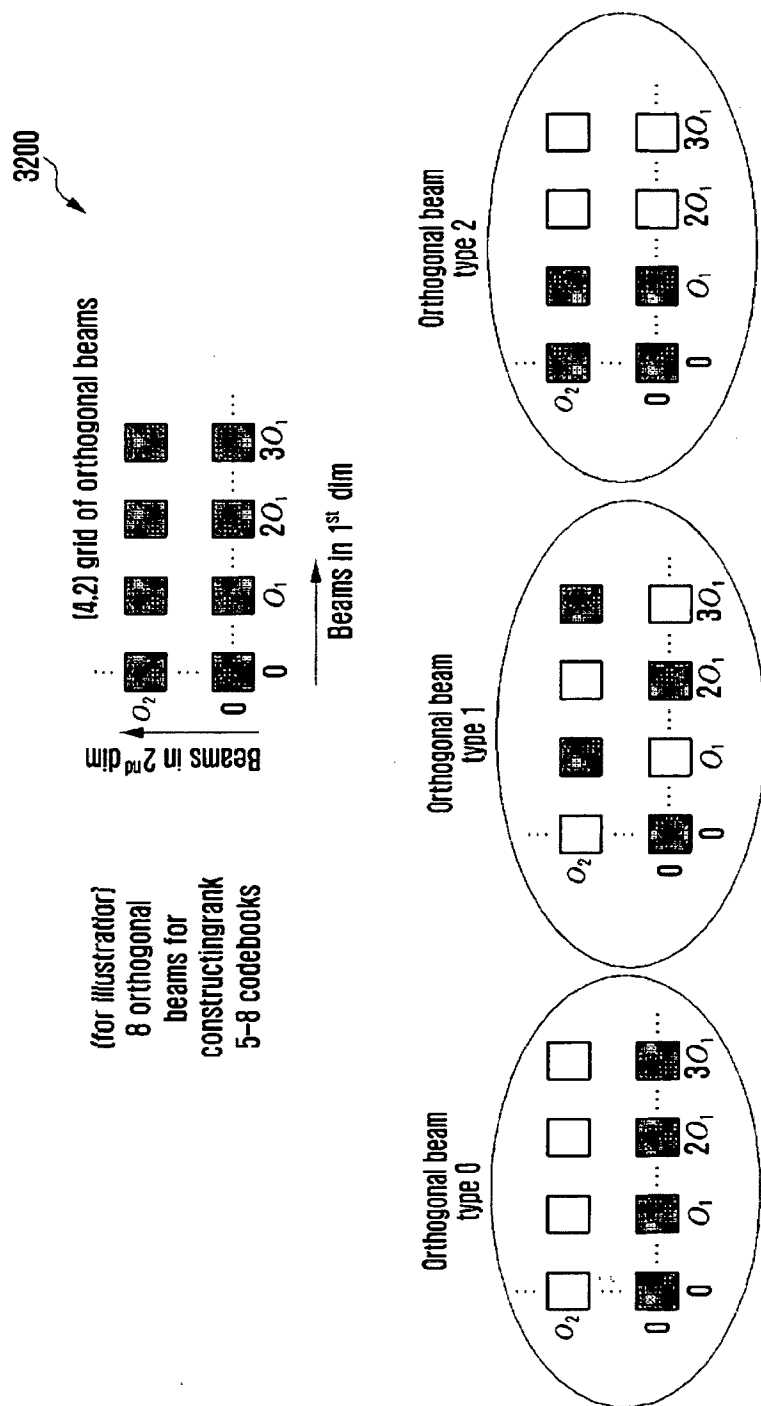
【Figure 30】



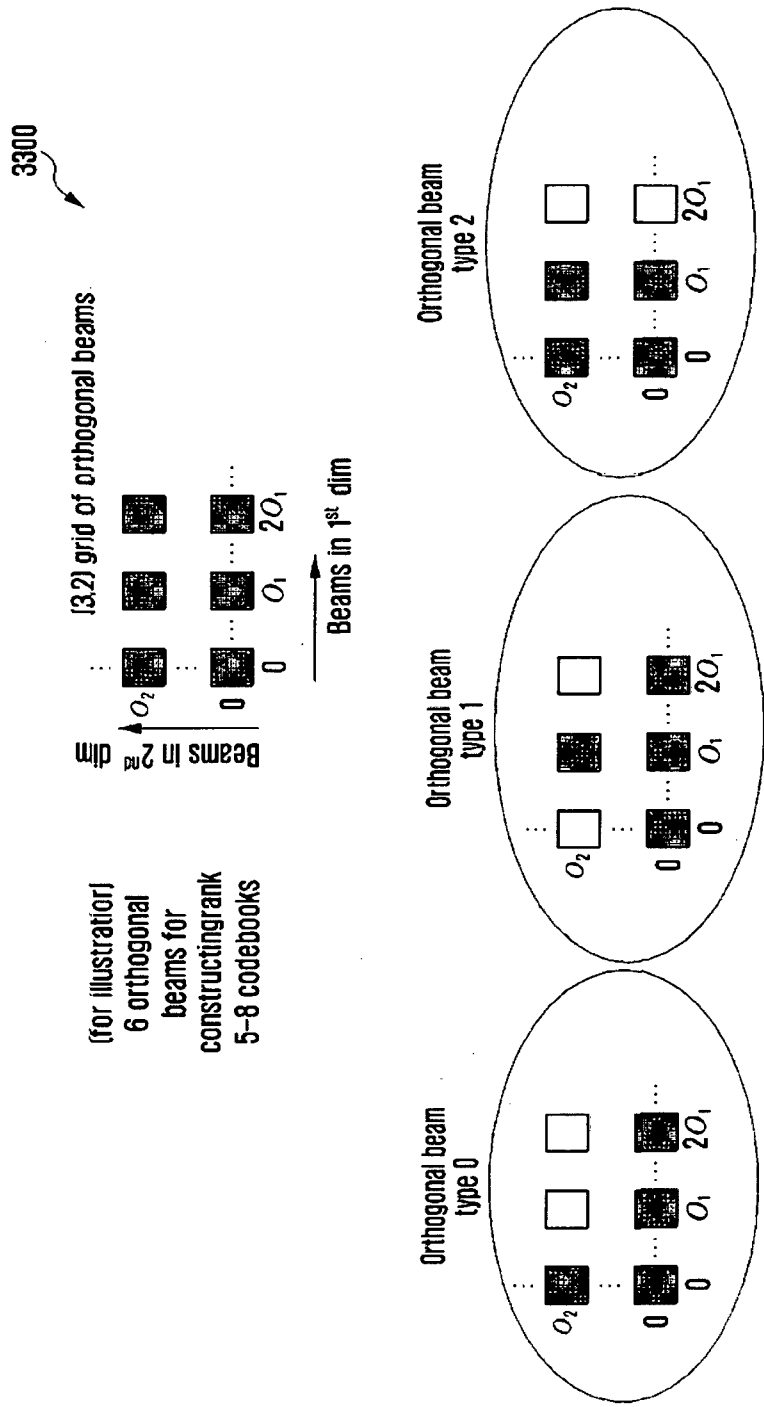
【Figure 31】



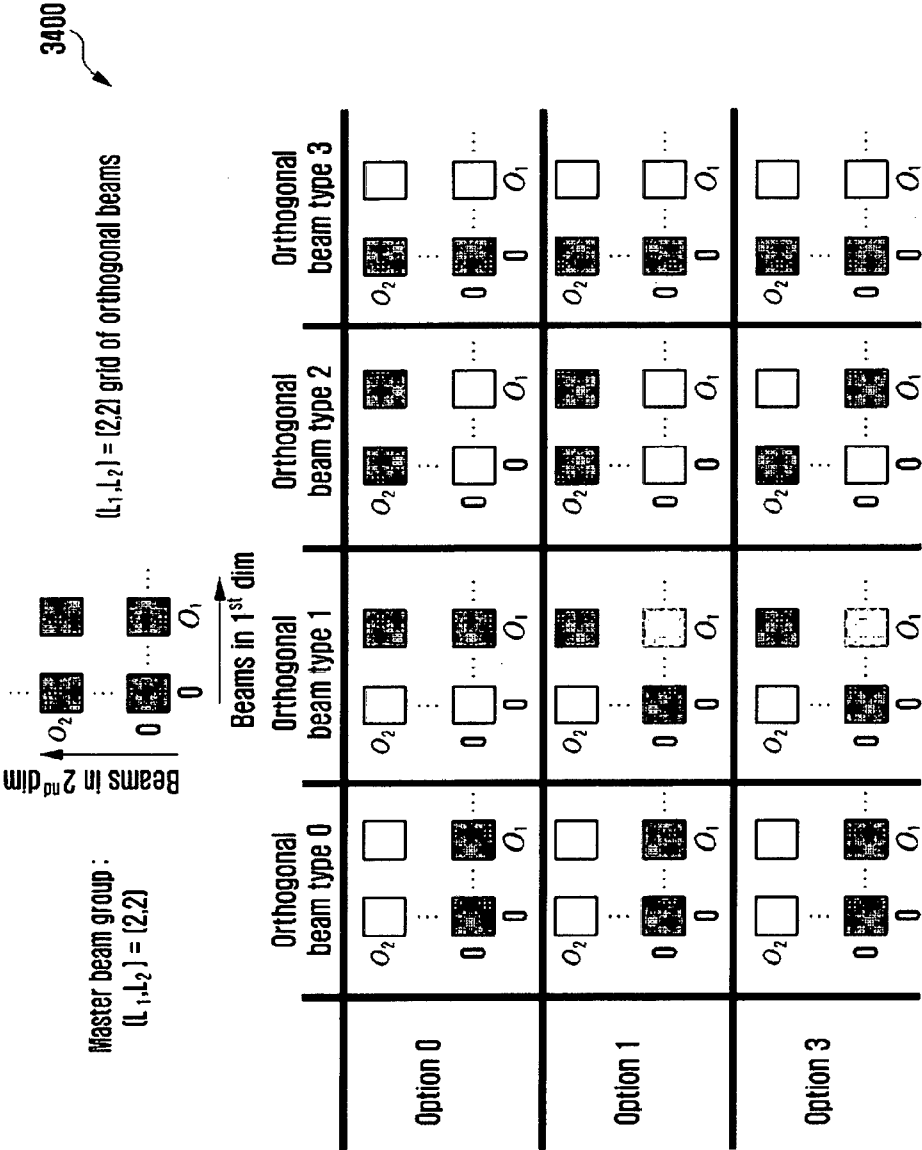
【Figure 32】



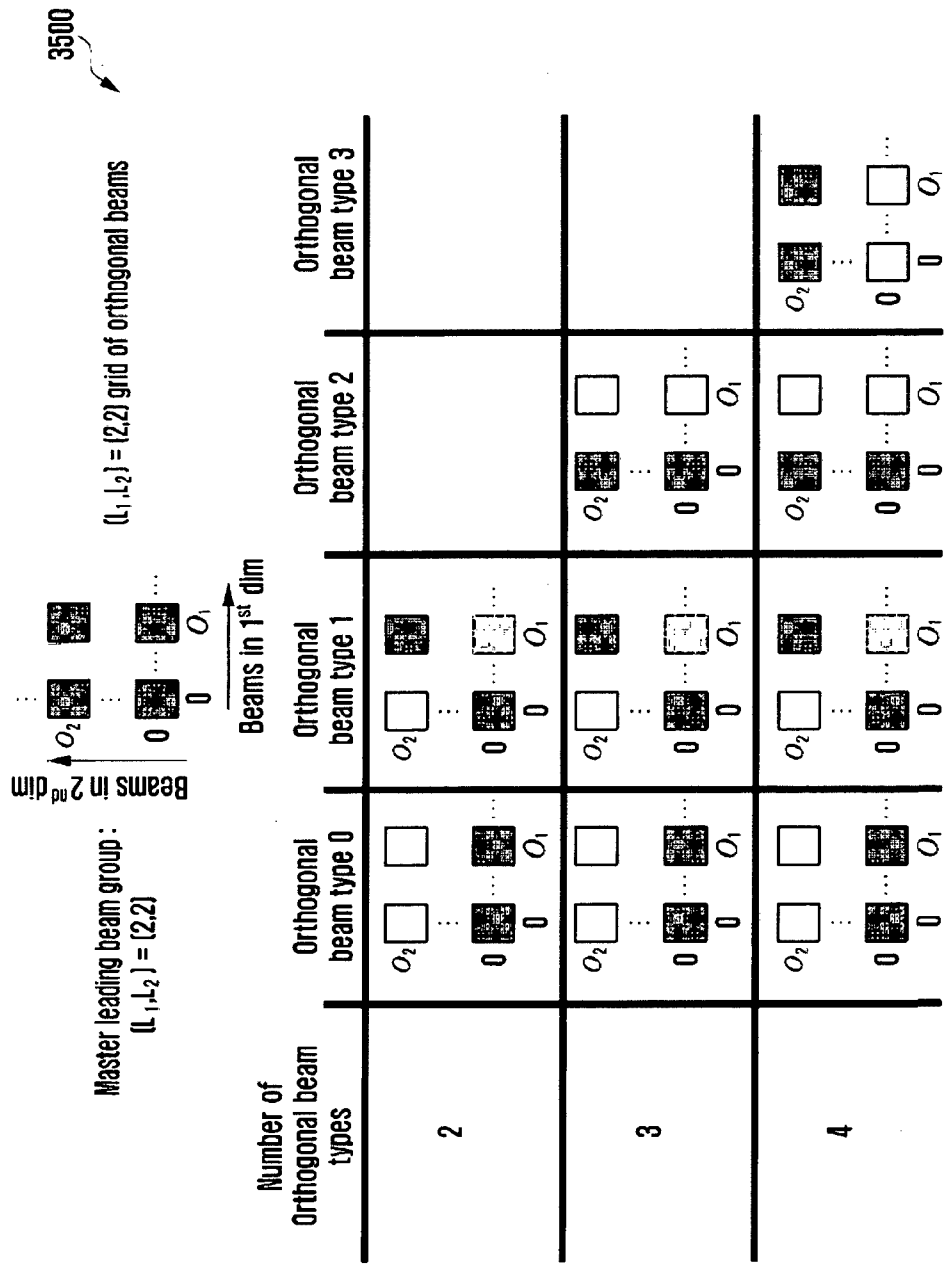
【Figure 33】



【Figure 34】

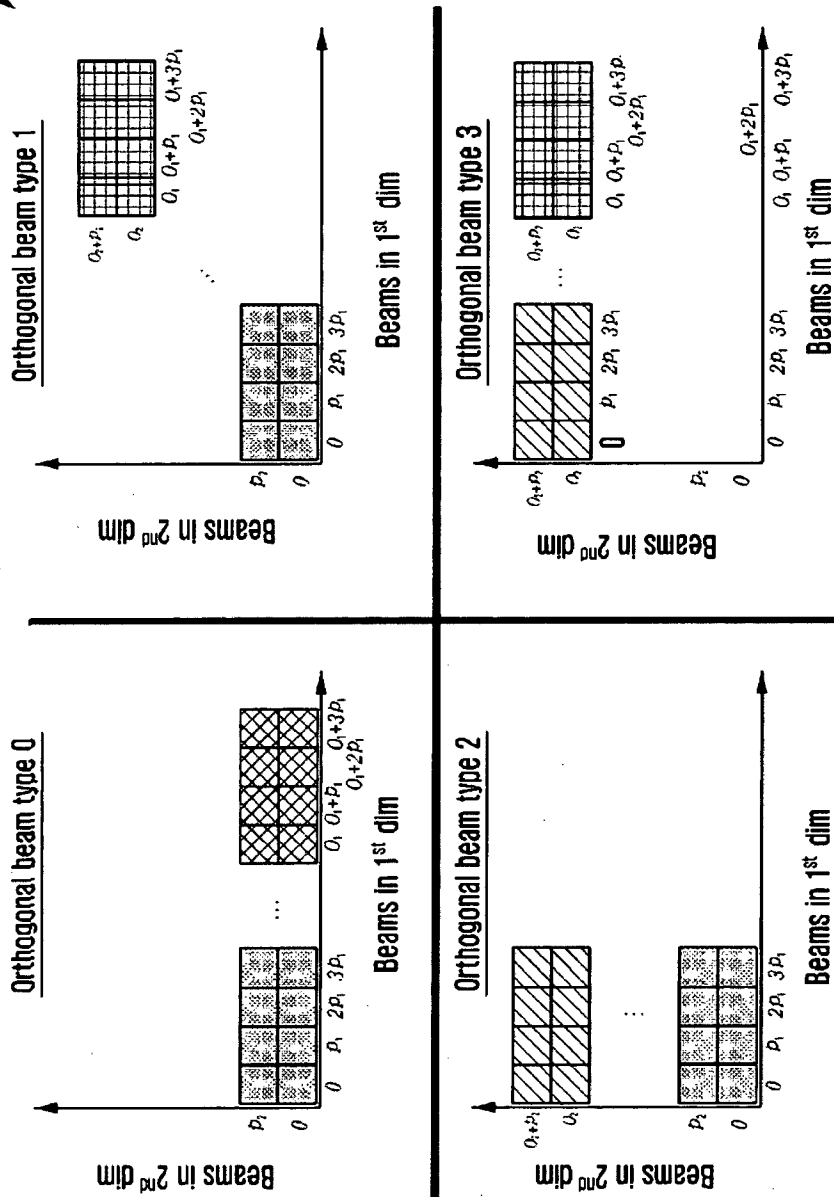


[Figure 35]



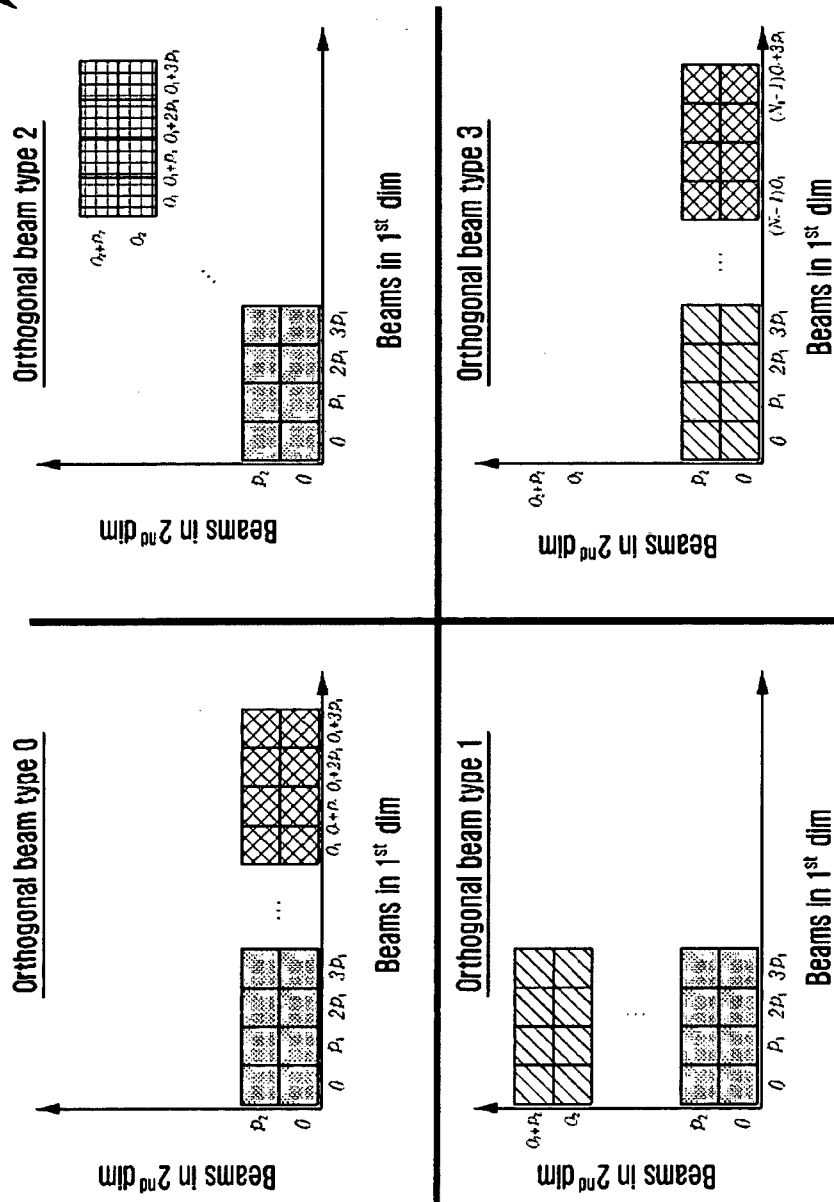
[Figure 36a]

3600A

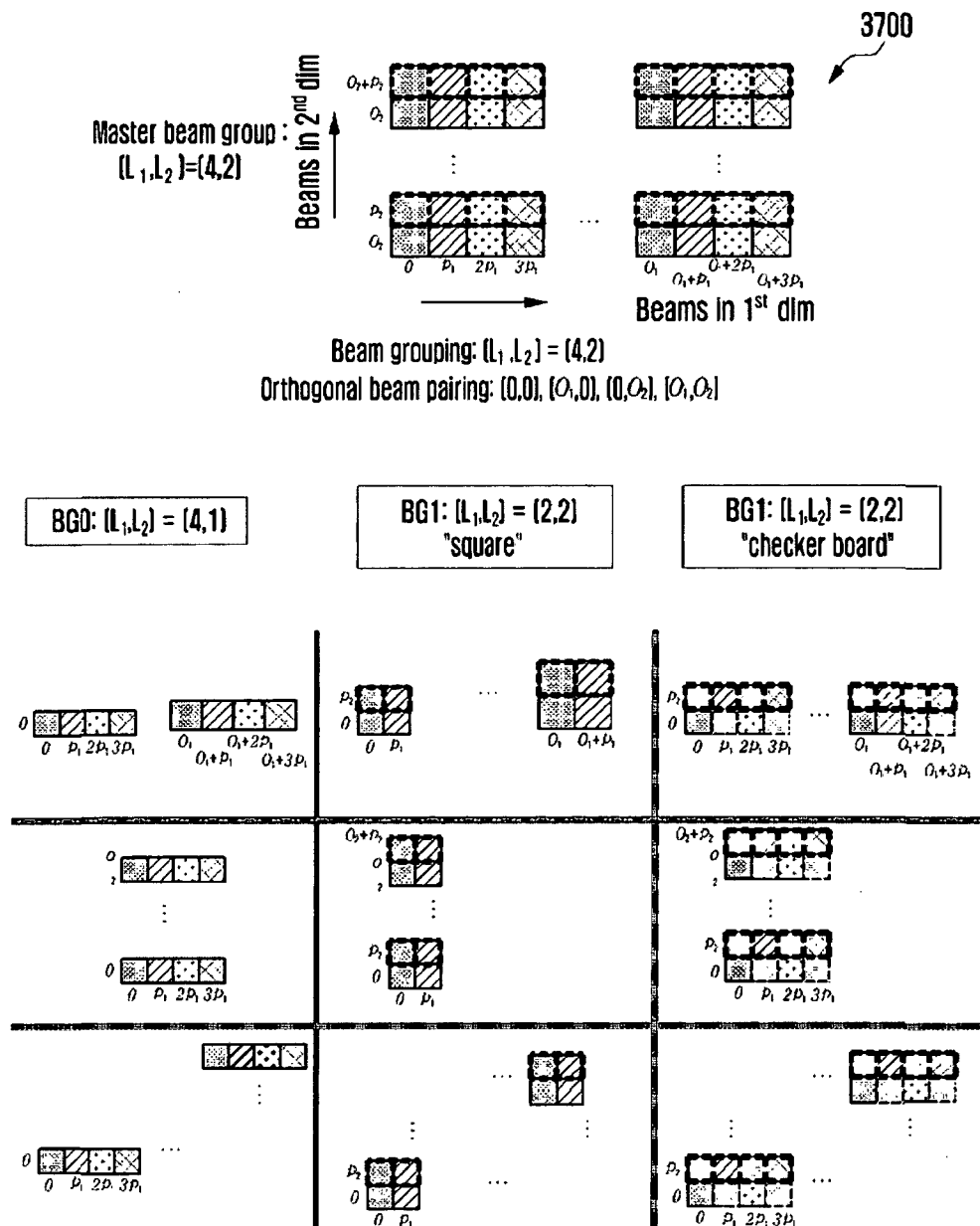


【Figure 36b】

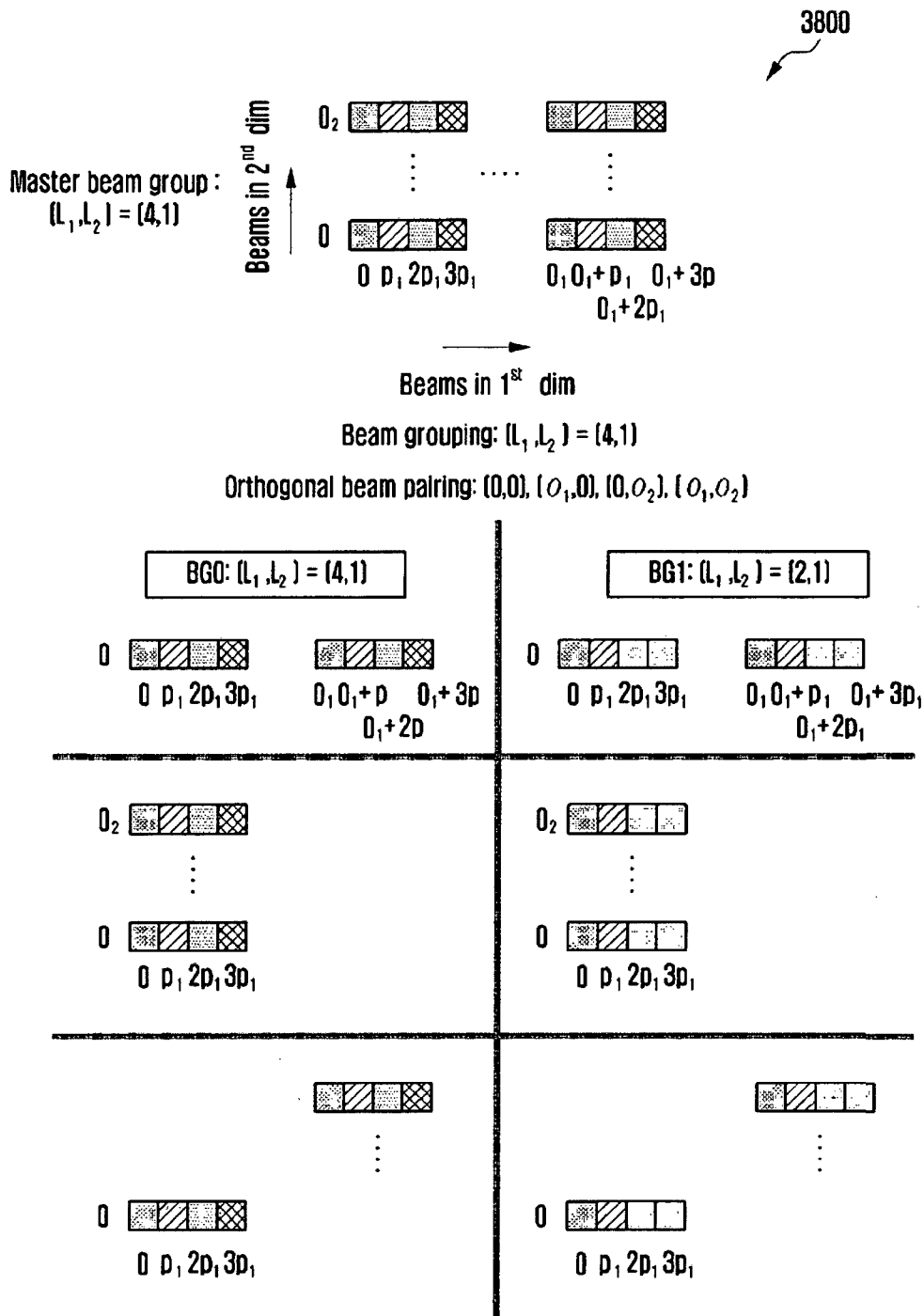
3600B



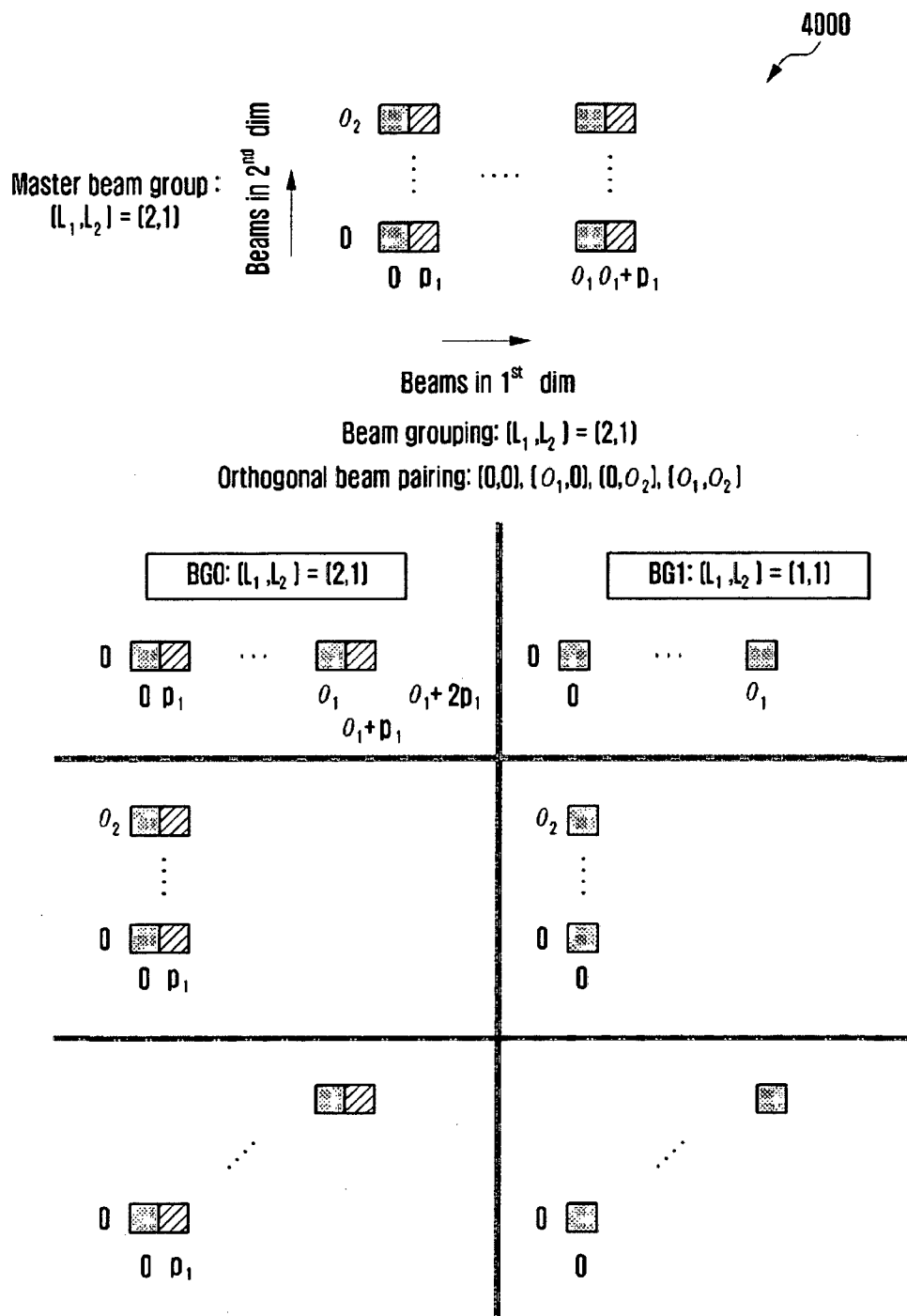
【Figure 37】



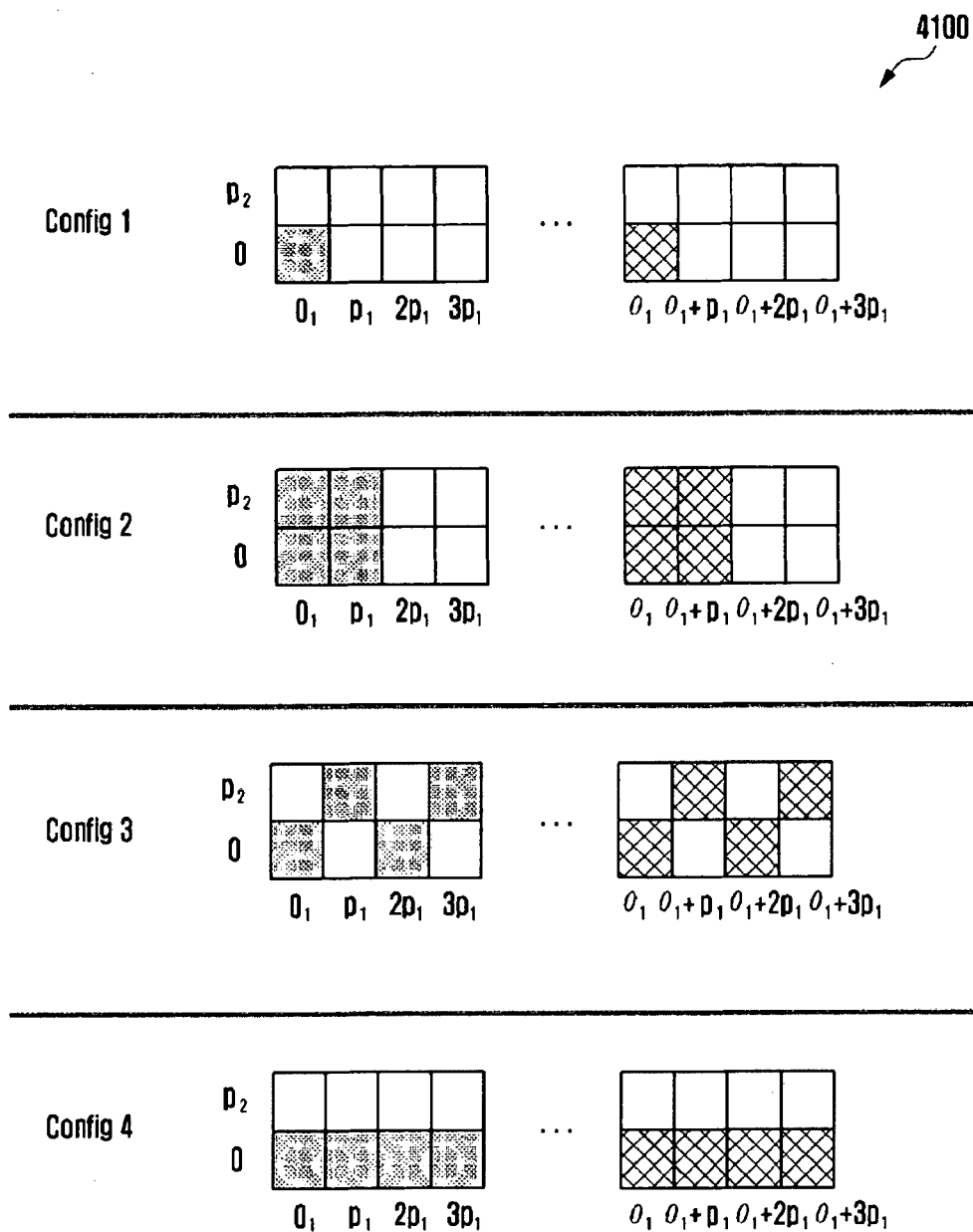
【Figure 38】



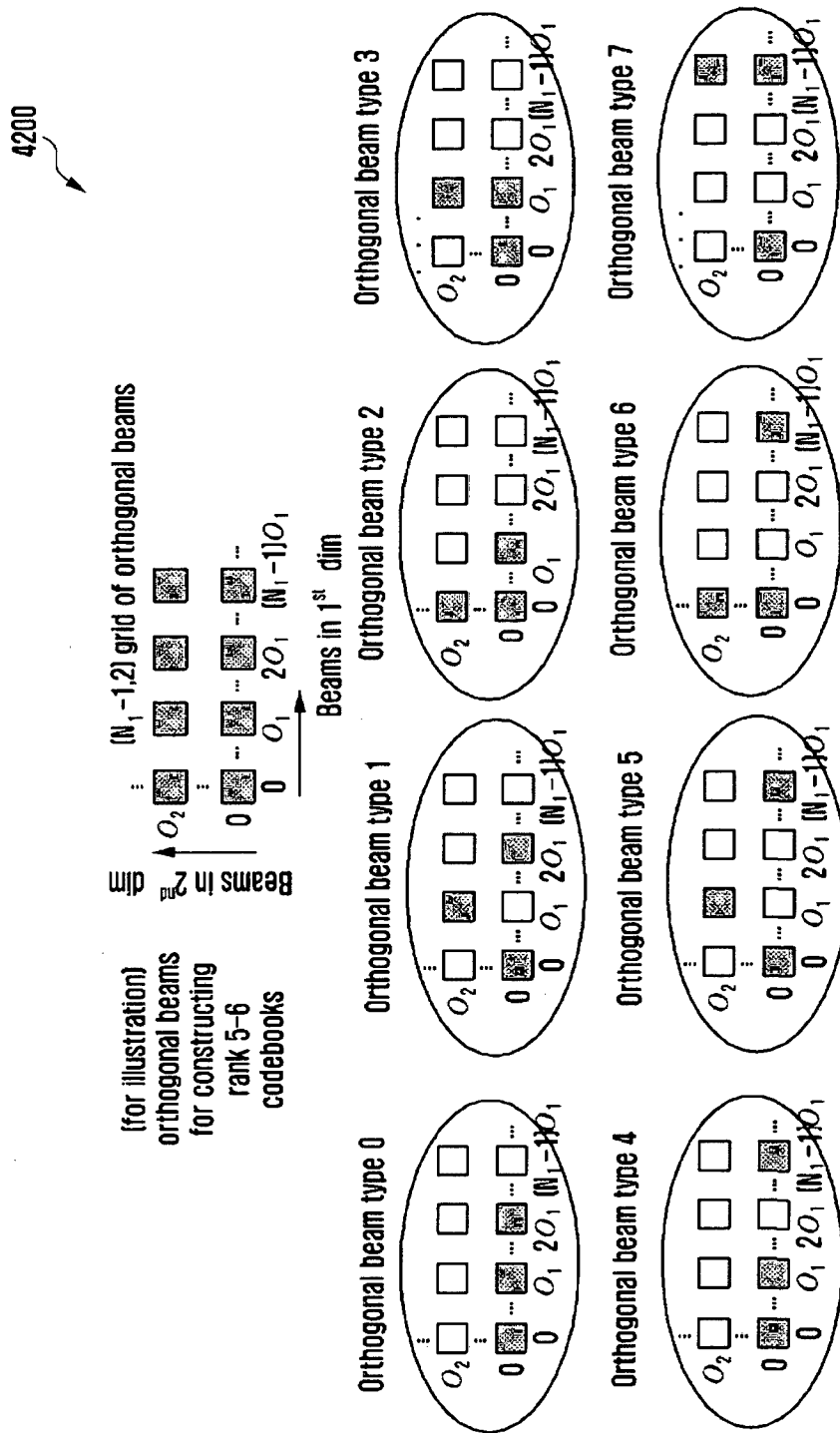
【Figure 40】



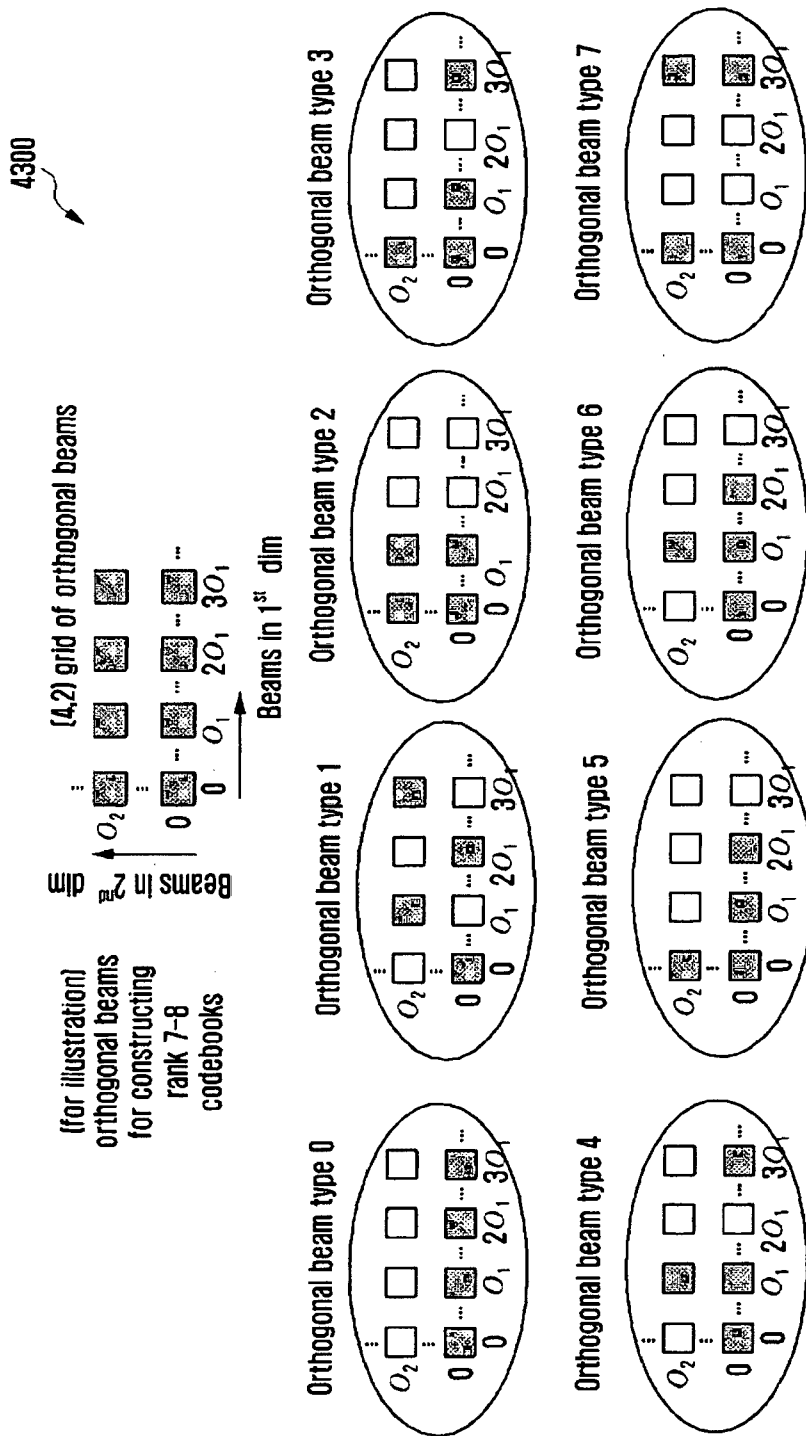
【Figure 41】



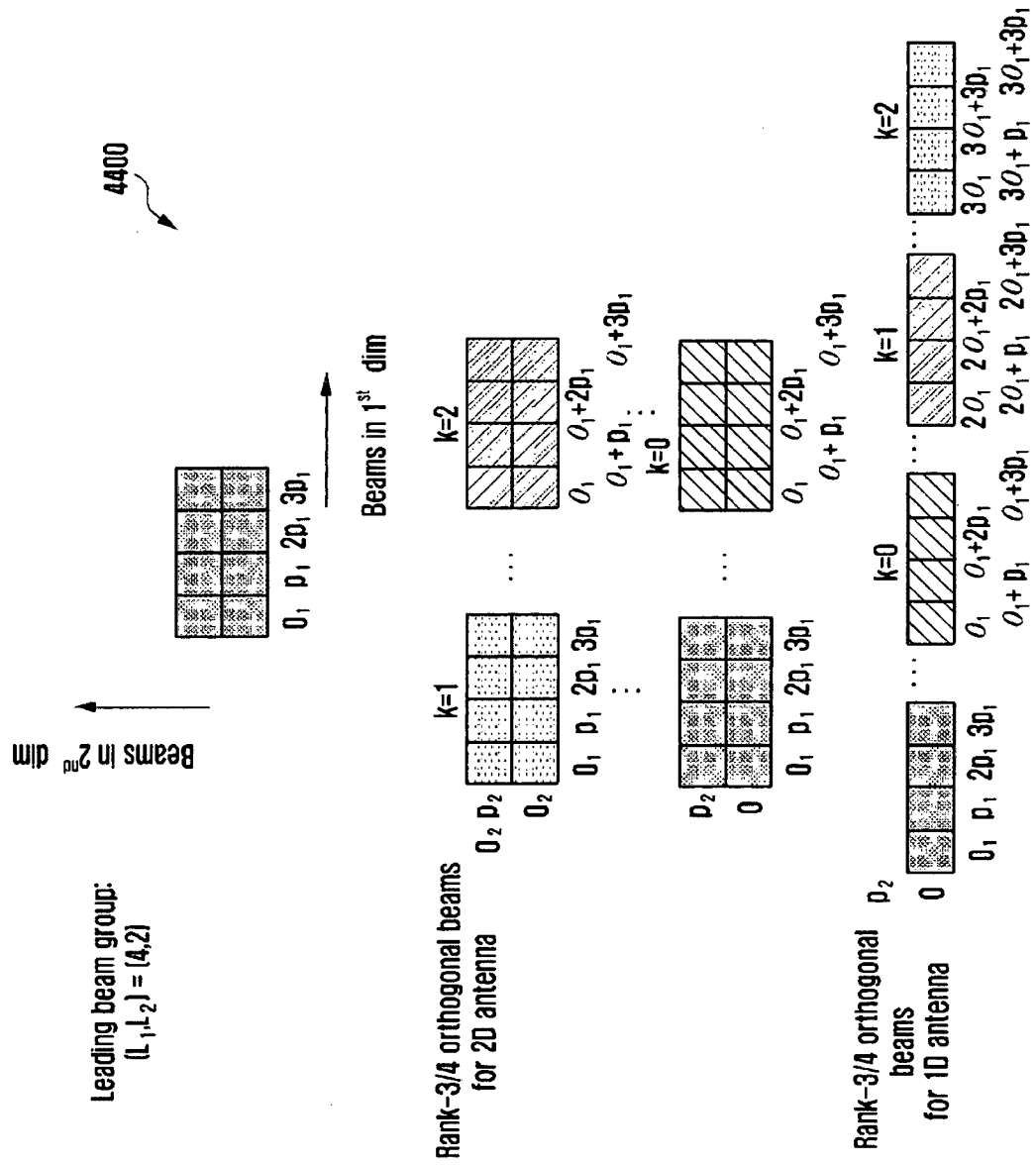
【Figure 42】



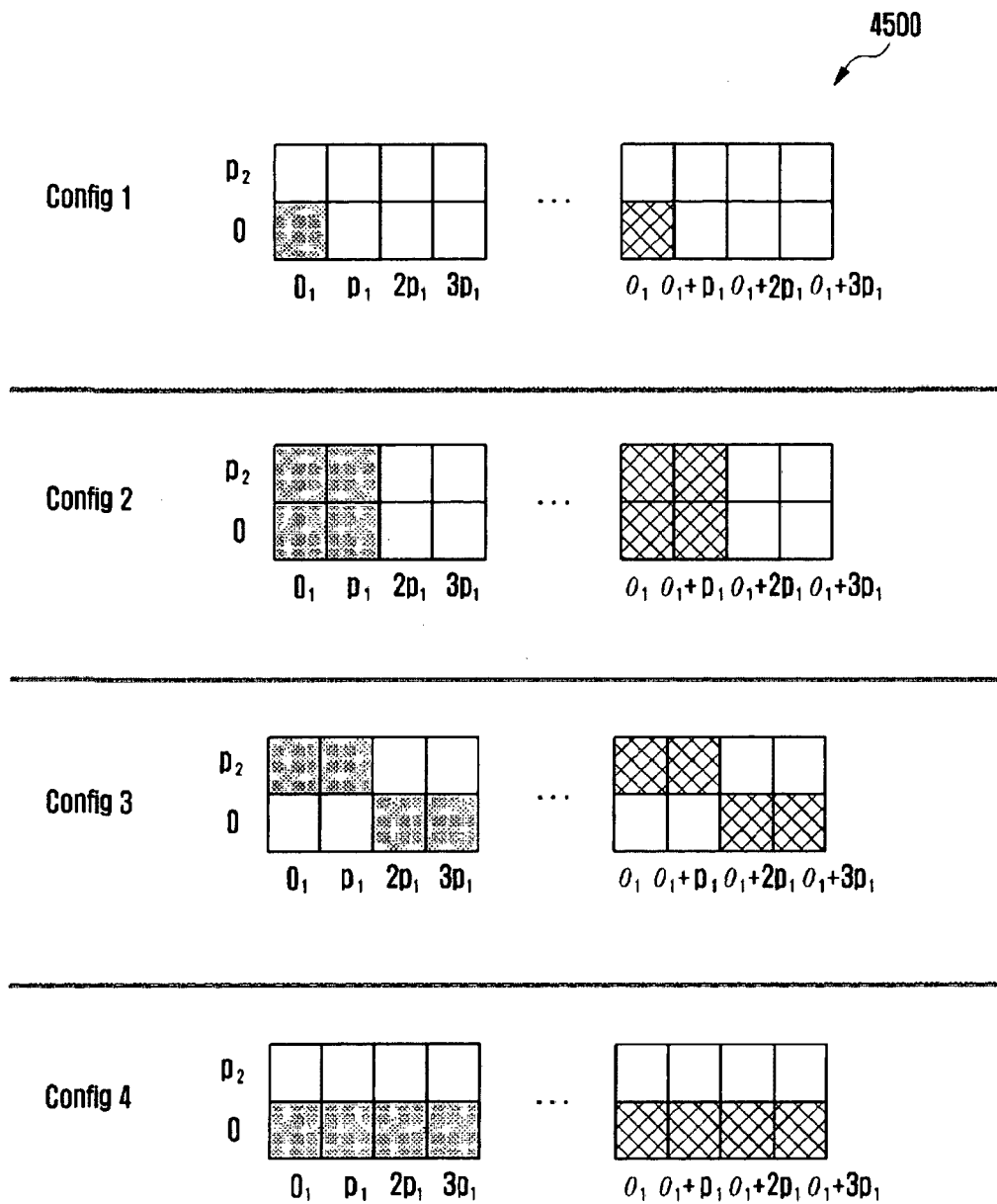
【Figure 43】



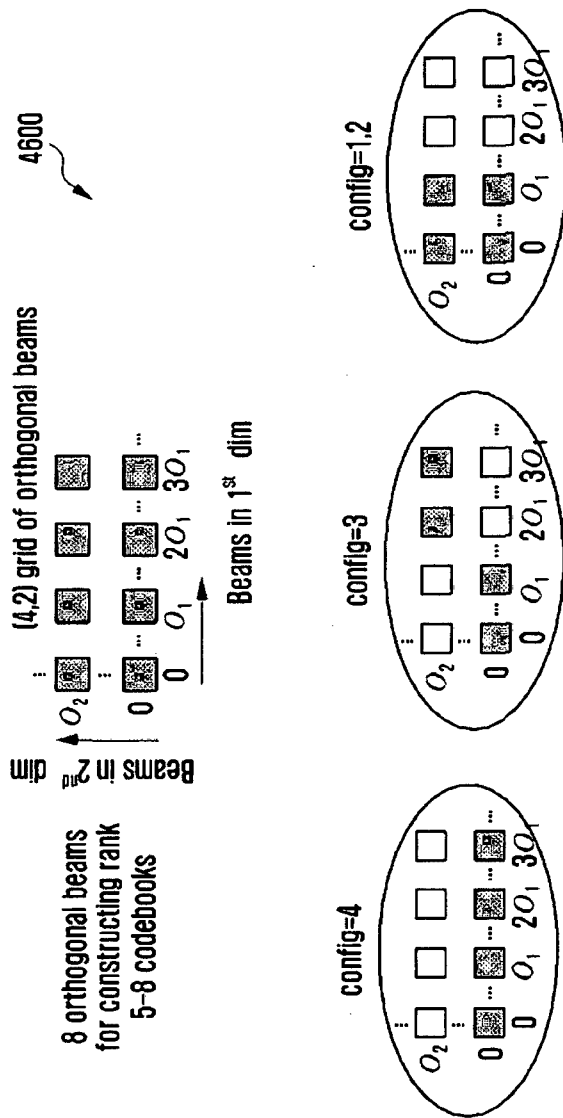
【Figure 44】



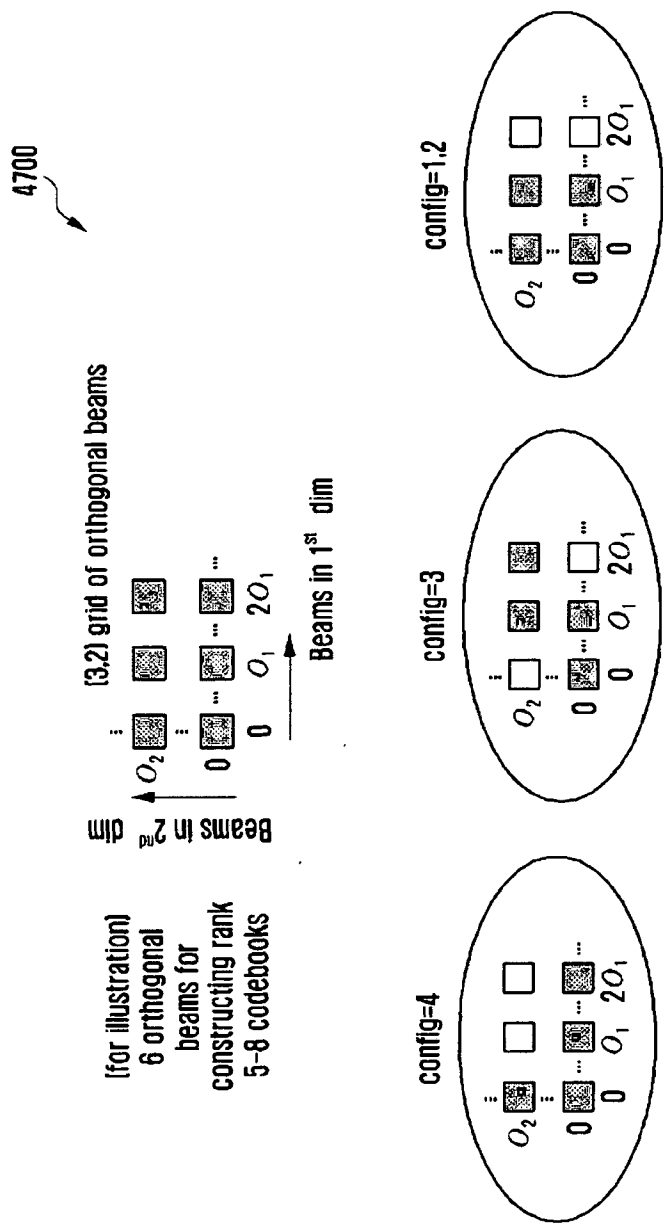
[Figure 45]



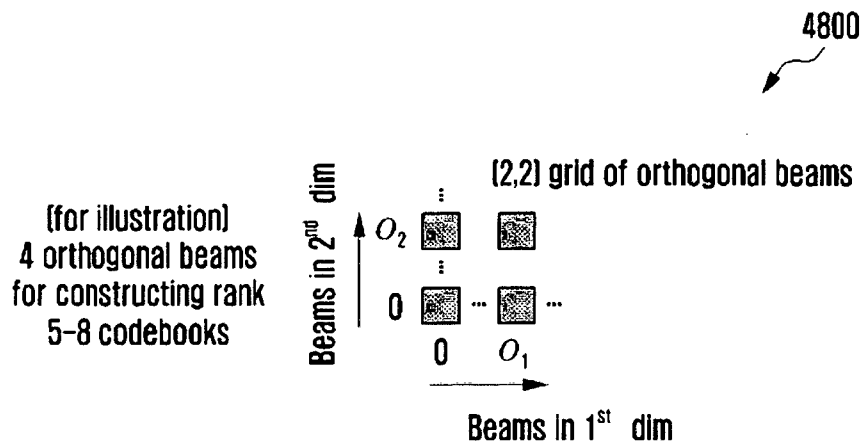
【Figure 46】



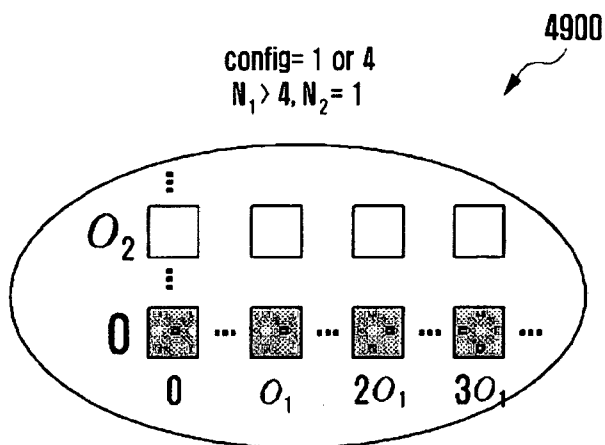
[Figure 47]



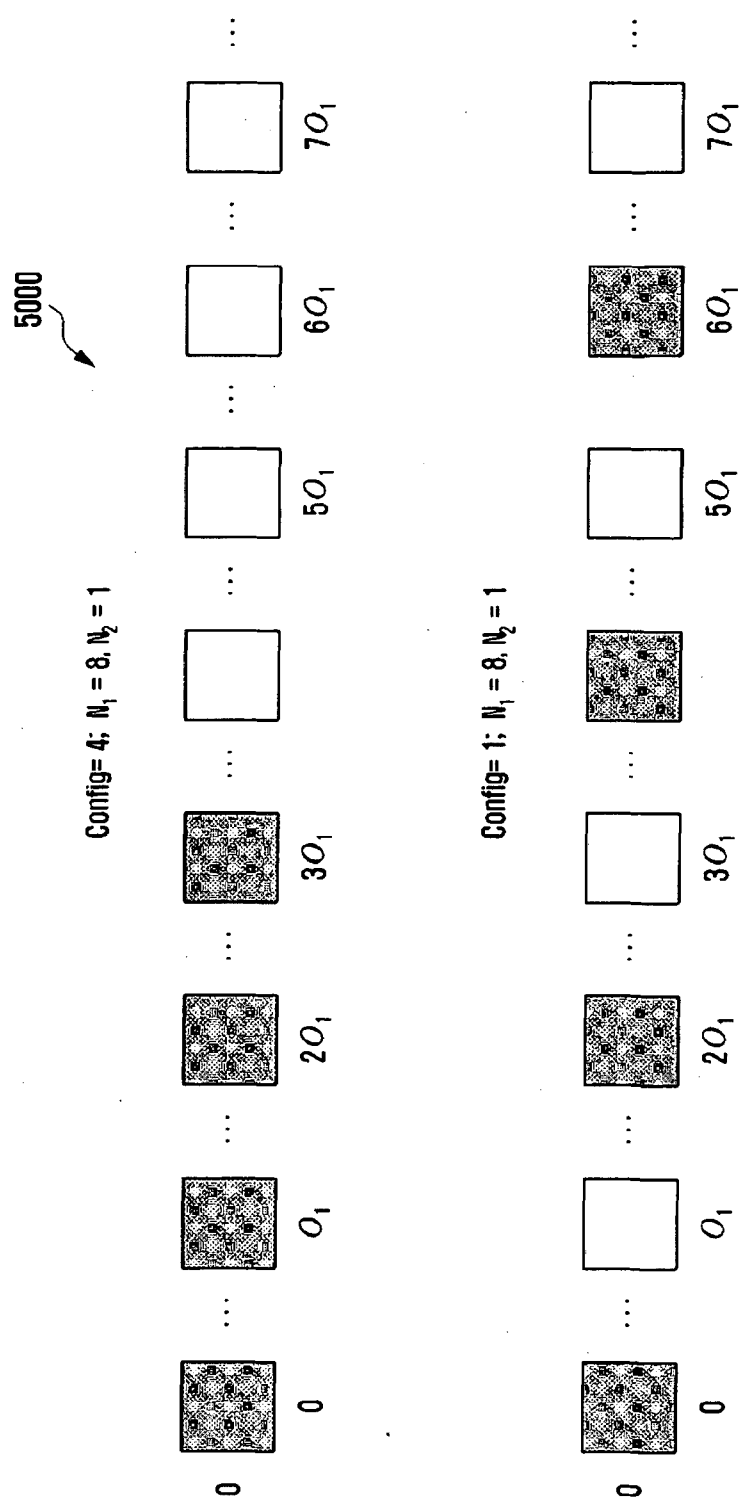
【Figure 48】



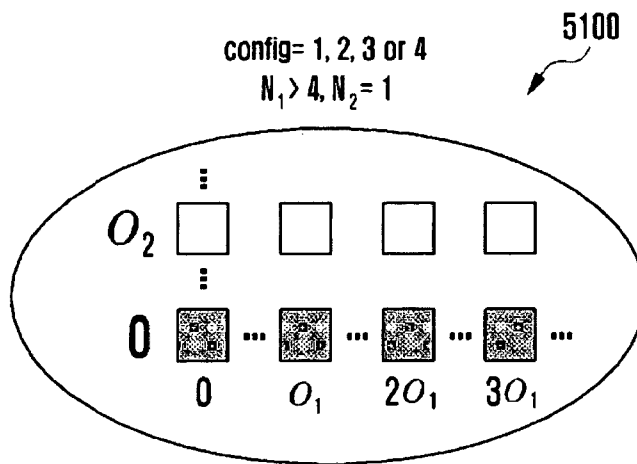
【Figure 49】



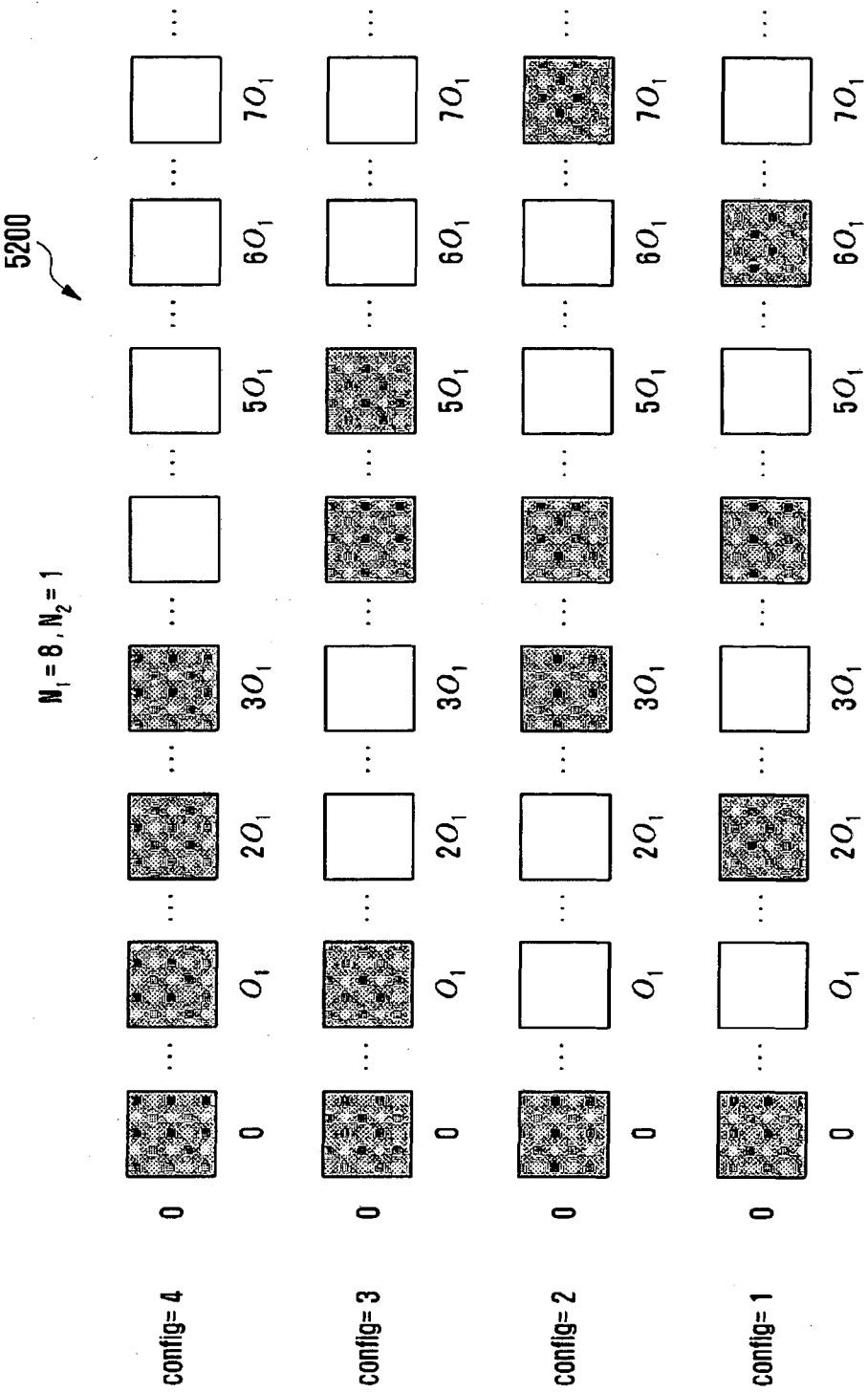
【Figure 50】



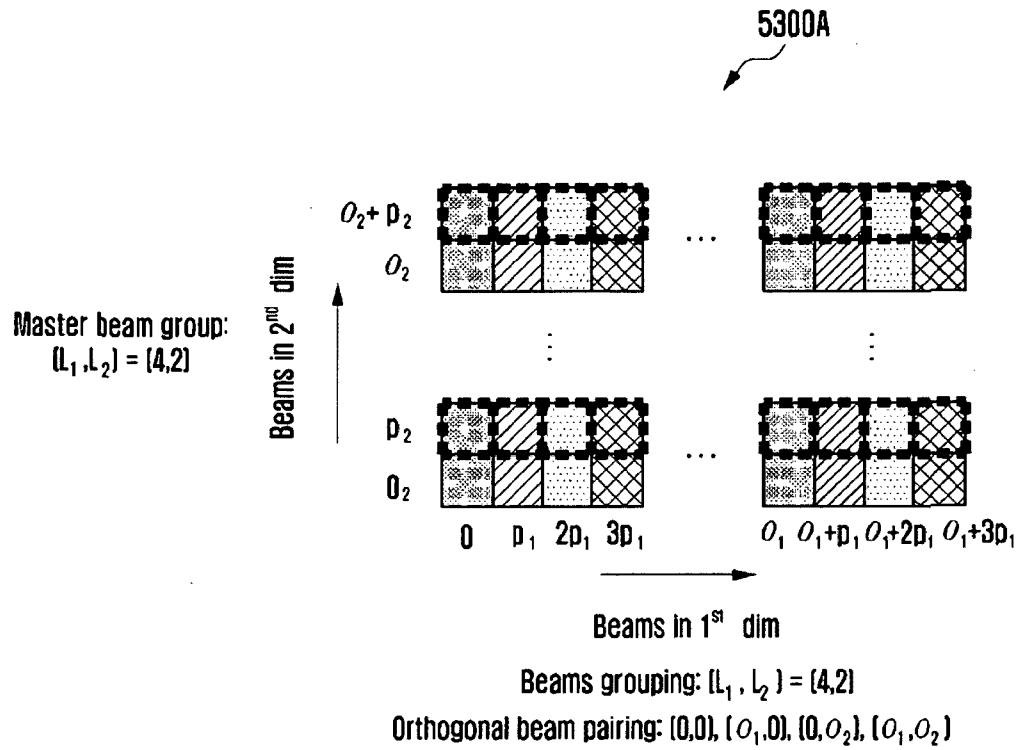
【Figure 51】



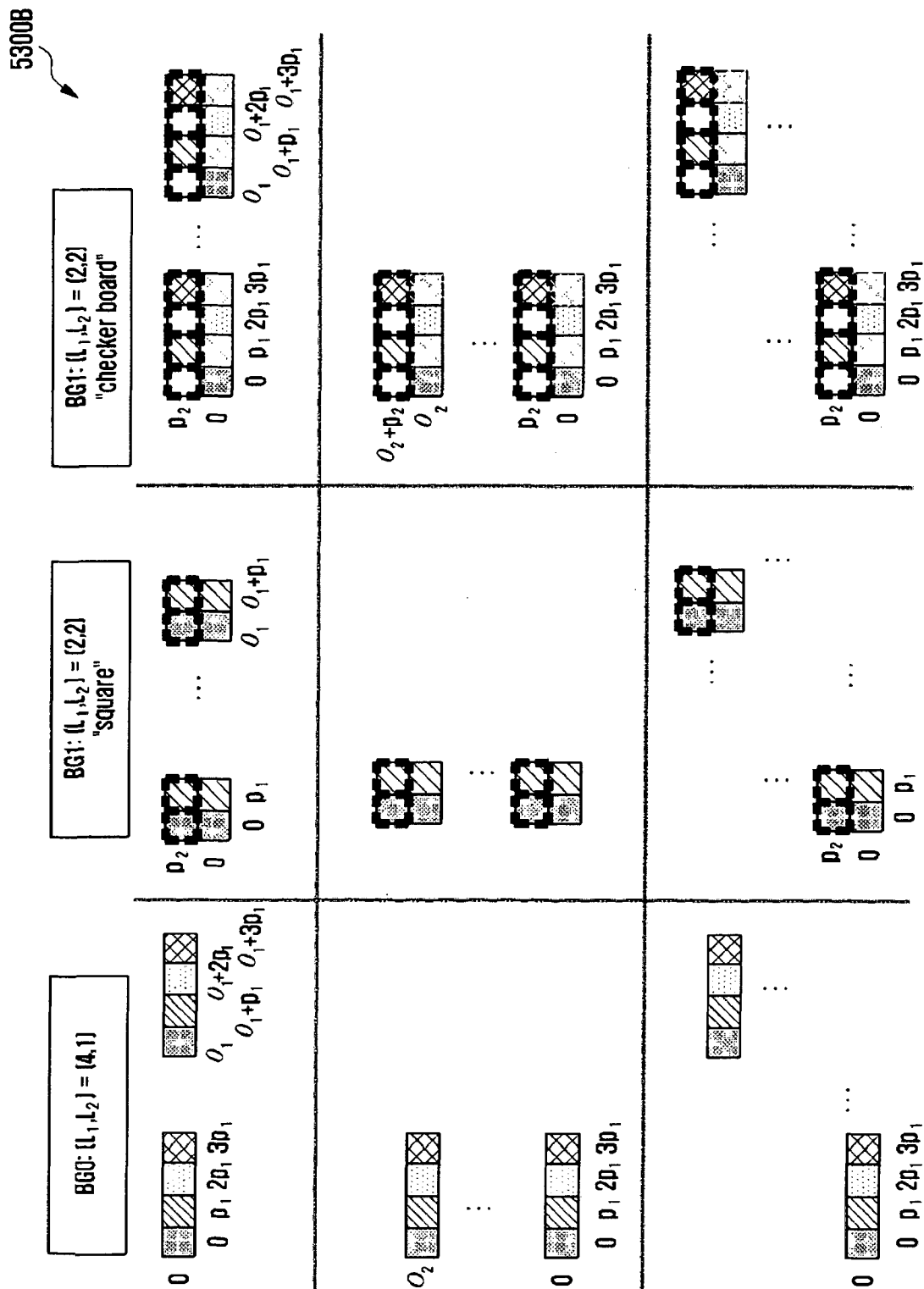
[Figure 52]



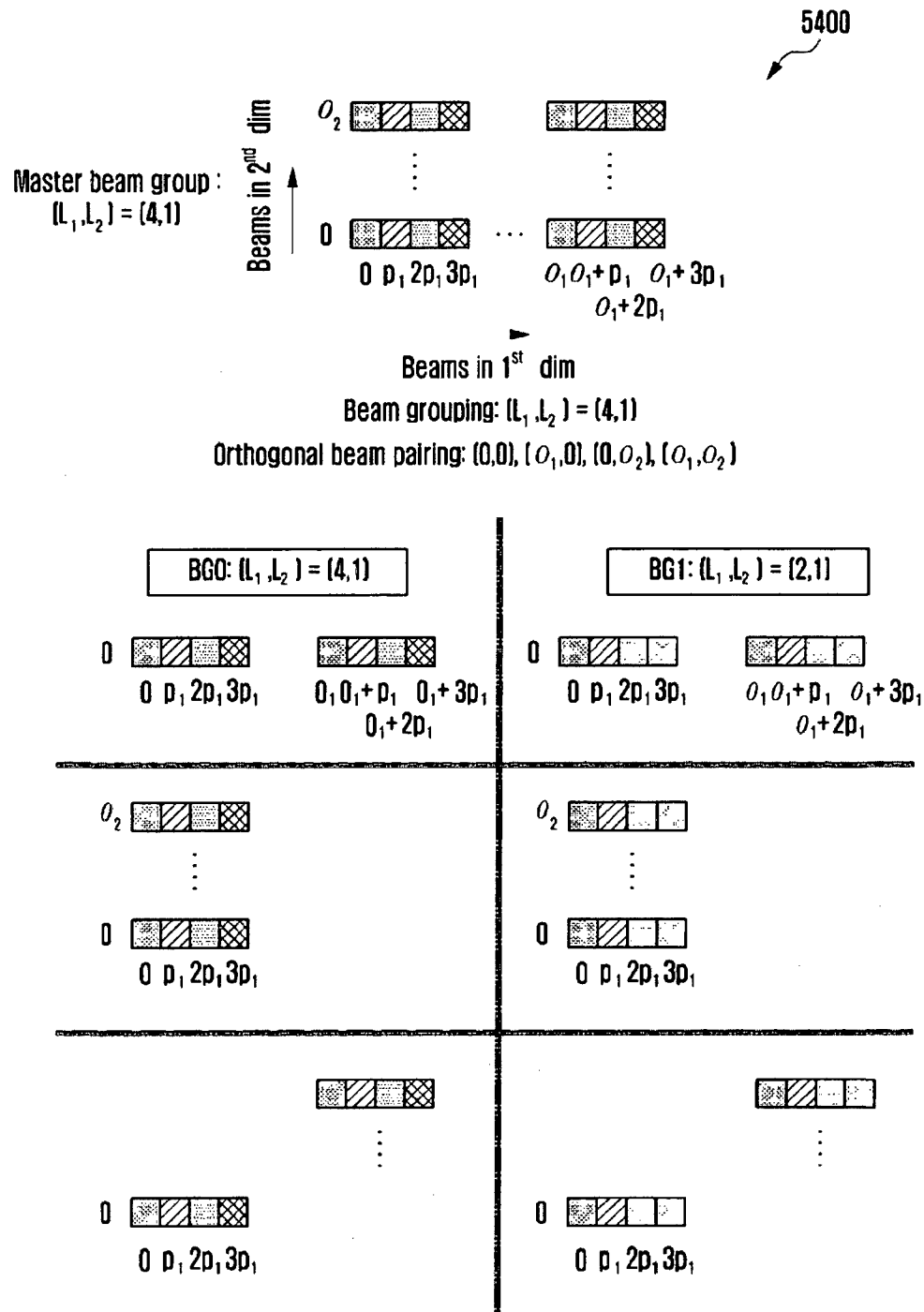
【Figure 53a】



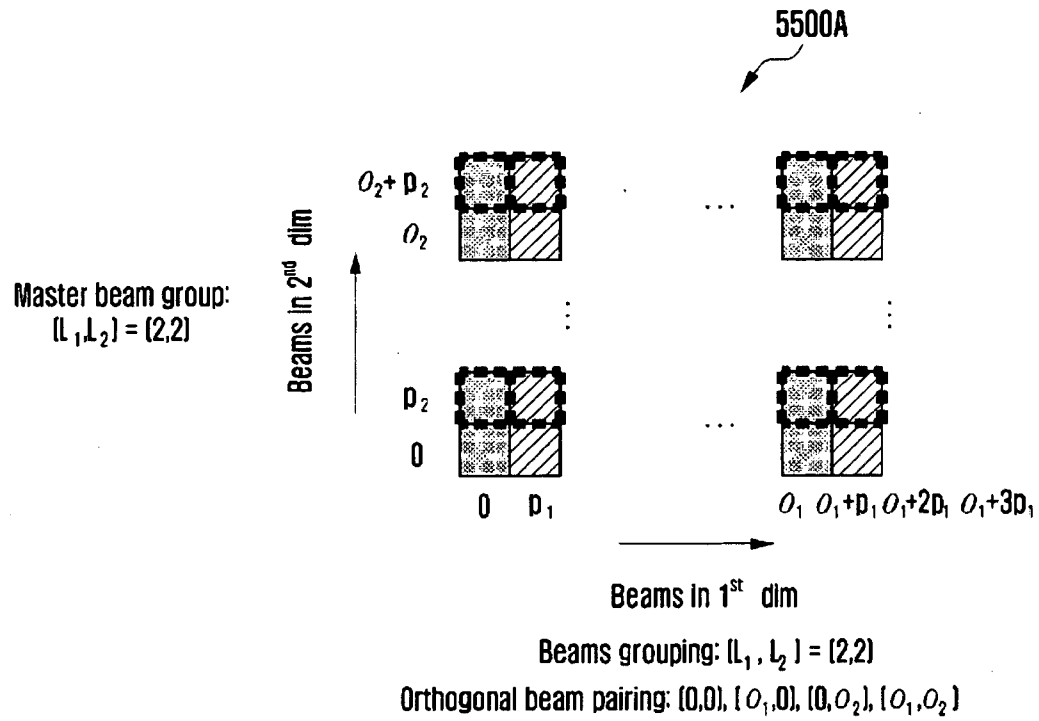
【Figure 53b】



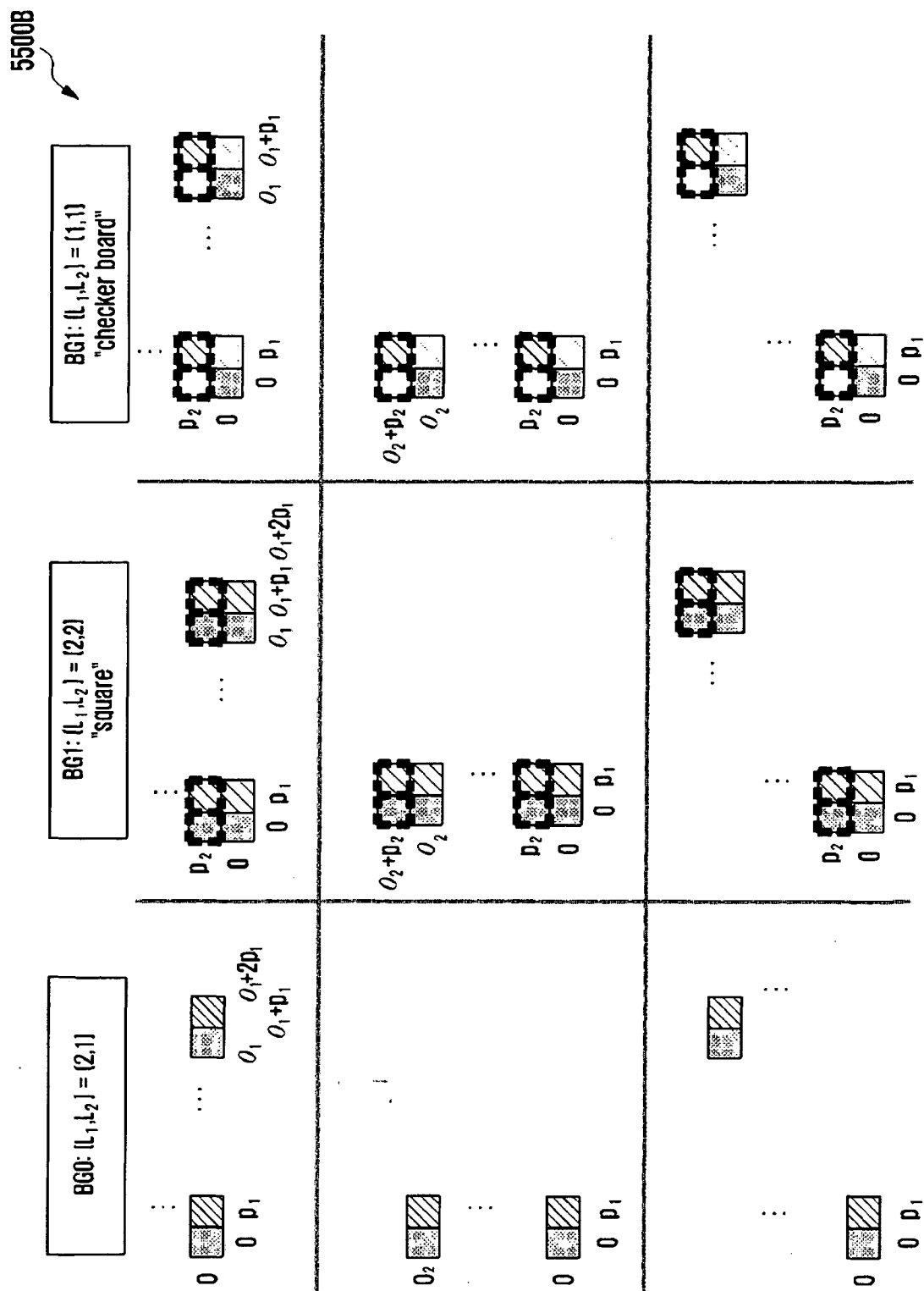
【Figure 54】



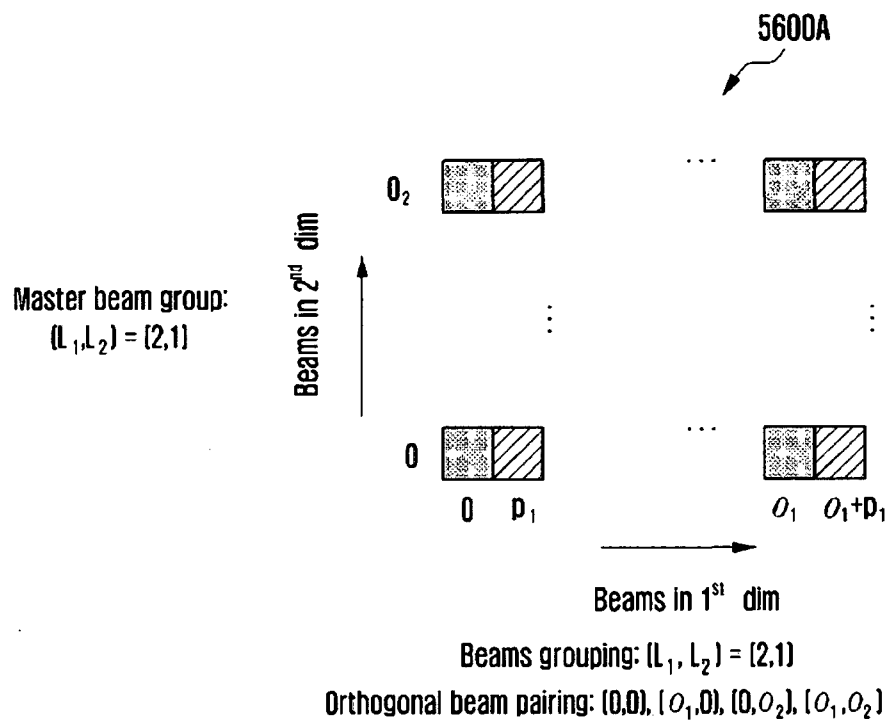
【Figure 55a】



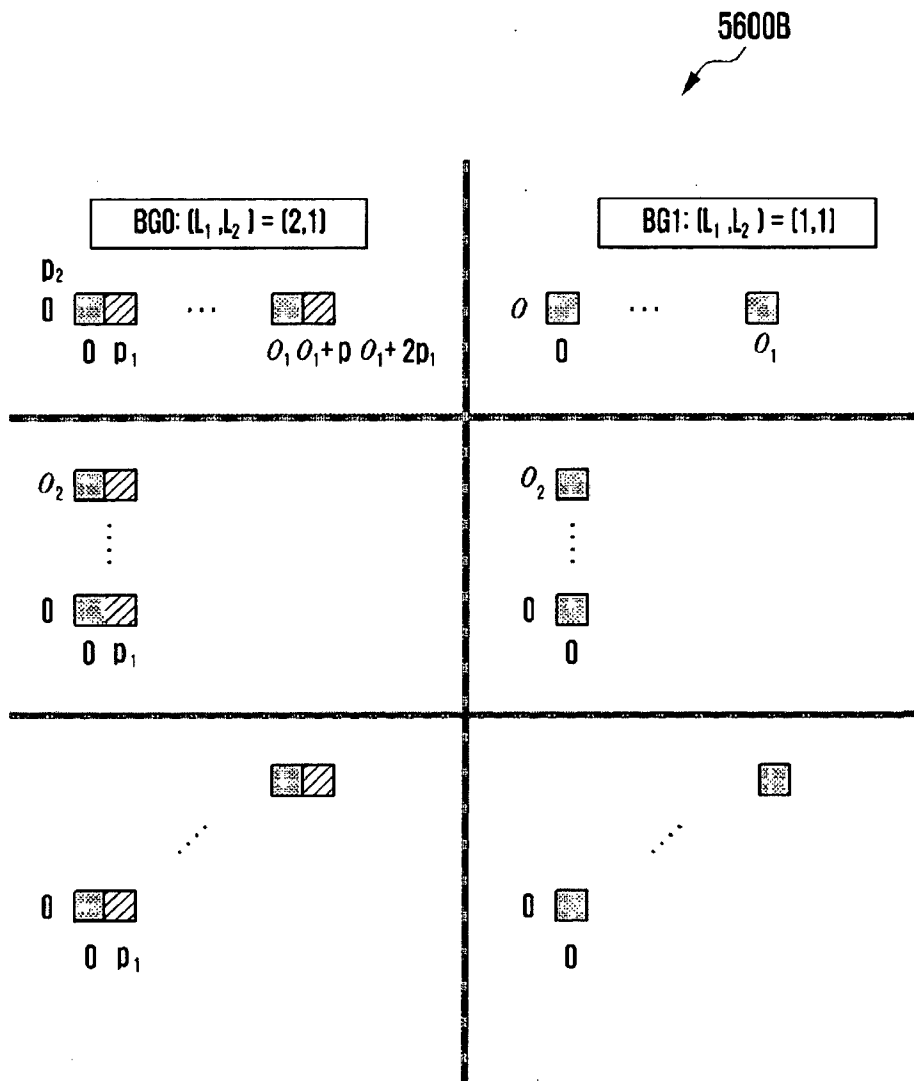
[Figure 55b]



【Figure 56a】



【Figure 56b】



[Figure 57]

i_1	i_2	1	2	3
0	0			
-				
3		$W_{2i_H, 2i_V, 2i_H, 2i_V, 0}^{(2)}$	$W_{2i_H+1, 2i_V, 2i_H+1, 2i_V, 0}^{(2)}$	$W_{2i_H+1, 2i_V, 2i_H+1, 2i_V, 1}^{(2)}$
1				
i_1	i_2			
4	4	5	6	7
0				
-				
3		$W_{2i_H, 2i_V+1, 2i_H, 2i_V+1, 0}^{(2)}$	$W_{2i_H+1, 2i_V+1, 2i_H+1, 2i_V+1, 0}^{(2)}$	$W_{2i_H+1, 2i_V+1, 2i_H+1, 2i_V+1, 1}^{(2)}$
1				
where $W_{m_H, m_V, m_H, m_V, n}^{(2)} = \frac{1}{4} \left[\begin{matrix} v_{m_H} \otimes v_{m_V} & v_{m_H} \otimes v_{m_V} \\ \varphi_n v_{m_H} \otimes v_{m_V} & -\varphi_n v_{m_H} \otimes v_{m_V} \end{matrix} \right]$				
i_1		$i_{1,H}$		$i_{1,V}$
0-7		0-7		0
8-15		0-7		1
16-23		0-7		2
24-31		0-7		3

【Figure 58】

i_2	i_1	i_2	i_1
4	0	3	
0			
$W_{2i_H, 2i_Y, 2i_H, 2i_Y, 0}^{(2)}$	$W_{2i_H, 2i_Y, 2i_H, 2i_Y, 1}^{(2)}$	$W_{2i_H+1, 2i_Y, 2i_H+1, 2i_Y, 0}^{(2)}$	$W_{2i_H+1, 2i_Y, 2i_H+1, 2i_Y, 1}^{(2)}$
31			
i_2	i_1	i_2	i_1
4	0	7	
0			
$W_{2i_H, 2i_Y+1, 2i_H, 2i_Y+1, 0}^{(2)}$	$W_{2i_H, 2i_Y+1, 2i_H, 2i_Y+1, 1}^{(2)}$	$W_{2i_H+1, 2i_Y+1, 2i_H+1, 2i_Y+1, 0}^{(2)}$	$W_{2i_H+1, 2i_Y+1, 2i_H+1, 2i_Y+1, 1}^{(2)}$
31			
i_2	i_1	i_2	i_1
4	0	10	
0			
$W_{2i_H, 2i_Y+1, 2i_H, 2i_Y+1, 0}^{(2)}$	$W_{2i_H, 2i_Y+1, 2i_H, 2i_Y+1, 1}^{(2)}$	$W_{2i_H+1, 2i_Y+1, 2i_H+1, 2i_Y+1, 0}^{(2)}$	$W_{2i_H+1, 2i_Y+1, 2i_H+1, 2i_Y+1, 1}^{(2)}$
31			
i_2	i_1	i_2	i_1
4	0	13	
0			
$W_{2i_H, 2i_Y+1, 2i_H, 2i_Y+1, 0}^{(2)}$	$W_{2i_H, 2i_Y+1, 2i_H, 2i_Y+1, 1}^{(2)}$	$W_{2i_H+1, 2i_Y+1, 2i_H+1, 2i_Y+1, 0}^{(2)}$	$W_{2i_H+1, 2i_Y+1, 2i_H+1, 2i_Y+1, 1}^{(2)}$
31			
i_2	i_1	i_2	i_1
4	0	14	
0			
$W_{2i_H, 2i_Y+1, 2i_H, 2i_Y+1, 0}^{(2)}$	$W_{2i_H, 2i_Y+1, 2i_H, 2i_Y+1, 1}^{(2)}$	$W_{2i_H+1, 2i_Y+1, 2i_H+1, 2i_Y+1, 0}^{(2)}$	$W_{2i_H+1, 2i_Y+1, 2i_H+1, 2i_Y+1, 1}^{(2)}$
31			
$W_{m_H, m_Y, m_H, m_Y, n}^{(2)} = \frac{1}{4} \begin{bmatrix} v_{m_H} \otimes v_{m_Y} & v_{m_H} \otimes v_{m_Y} \\ \varphi_n v_{m_H} \otimes v_{m_Y} & -\varphi_n v_{m_H} \otimes v_{m_Y} \end{bmatrix}$			
where			
i_1	i_1	i_1	i_1
0-7	0-7	0	
8-15	0-7	1	
16-23	0-7	2	
24-31	0-7	3	

【Figure 59a】

i_1	i_2	1	2	3	
0	0				
-	$W_{2i_1, H, 2i_1, \nu, 2i_1, H, 2i_1, \nu, 0}^{(2)}$	$W_{2i_1, H, 2i_1, \nu, 2i_1, H, 2i_1, \nu, 1}^{(2)}$	$W_{2i_1, H+1, 2i_1, \nu, 2i_1, H+1, 2i_1, \nu, 0}^{(2)}$	$W_{2i_1, H+1, 2i_1, \nu, 2i_1, H+1, 2i_1, \nu, 1}^{(2)}$	
3					
1					
i_1	i_2	4	5	6	7
0	4				
-	$W_{2i_1, H, 2i_1, \nu+1, 2i_1, H, 2i_1, \nu+1, 0}^{(2)}$	$W_{2i_1, H, 2i_1, \nu+1, 2i_1, H, 2i_1, \nu+1, 1}^{(2)}$	$W_{2i_1, H+1, 2i_1, \nu+1, 2i_1, H+1, 2i_1, \nu+1, 0}^{(2)}$	$W_{2i_1, H+1, 2i_1, \nu+1, 2i_1, H+1, 2i_1, \nu+1, 1}^{(2)}$	
3					
1					
where $W_{m_H, m_V, m_H, m_V, n}^{(2)} = \frac{1}{4} \begin{bmatrix} \nu_{m_H} \otimes \nu_{m_V} & \nu_{m_H} \otimes \nu_{m_V} \\ \varphi_n \nu_{m_H} \otimes \nu_{m_V} & -\varphi_n \nu_{m_H} \otimes \nu_{m_V} \end{bmatrix}$					

【Figure 59b】

i_1	i_2	1	2	3
Method 1: 0 - 15 Method 2: 32 - 47	0			
	$W_{2i_1, H, 2i_1, \nu}^{(2)}$	$W_{2i_1, H, 2i_1, \nu}^{(2)} + 8, 2i_1, \nu + 4, 0$	$W_{2i_1, H, 2i_1, \nu}^{(2)} + 8, 2i_1, \nu + 4, 1$	$W_{2i_1, H, 2i_1, \nu}^{(2)} + 1, 2i_1, \nu, 2i_1, H + 9, 2i_1, \nu + 4, 1$
i_1	i_2			
	4	5	6	7
Method 1: 0 - 15 Method 2: 32 - 47	$W_{2i_1, H, 2i_1, \nu}^{(2)}$	$W_{2i_1, H, 2i_1, \nu}^{(2)} + 1, 2i_1, H + 8, 2i_1, \nu + 5, 0$	$W_{2i_1, H, 2i_1, \nu}^{(2)} + 1, 2i_1, \nu + 1, 2i_1, H + 9, 2i_1, \nu + 5, 0$	$W_{2i_1, H, 2i_1, \nu}^{(2)} + 1, 2i_1, \nu + 1, 2i_1, H + 9, 2i_1, \nu + 5, 1$
where $W_{m_H, m_V, m_H, m_V, n}^{(2)} = \frac{1}{4} \begin{bmatrix} v_{m_H} \otimes v_{m_V} & v_{m_H} \otimes v_{m_V} \\ \varphi_n v_{m_H} \otimes v_{m_V} & -\varphi_n v_{m_H} \otimes v_{m_V} \end{bmatrix}$				

【Figure 59c】

Method 1 i_1 (in each table)	Method 2 i_1 (across the two tables)	$i_{1,H}$	$i_{1,V}$
0 - 7 (the first table / beam group)	0 - 7	0 - 7	0
8 - 15 (the first table / beam group)	8 - 15	0 - 7	1
16 - 23 (the first table / beam group)	16 - 23	0 - 7	2
24 - 31 (the first table / beam group)	24 - 31	0 - 7	3
0-7 (the second table / beam group)	32 - 39	0 - 7	0
8-15 (the second table / beam group)	40 - 47	0 - 7	1

[Figure 60a]

i_1	i_2	1	2	3
0	0			
0-31	$W_{2i_1, H, 2i_1, V, 2i_1, H, 2i_1, V, 0}^{(2)}$	$W_{2i_1, H, 2i_1, V, 2i_1, H, 2i_1, V, 1}^{(2)}$	$W_{2i_1, H+1, 2i_1, V, 2i_1, H+1, 2i_1, V, 0}^{(2)}$	$W_{2i_1, H+1, 2i_1, V, 2i_1, H+1, 2i_1, V, 1}^{(2)}$
i_1	i_2	5	6	7
4	4			
0-31	$W_{2i_1, H, 2i_1, V+1, 2i_1, H, 2i_1, V+1, 0}^{(2)}$	$W_{2i_1, H, 2i_1, V+1, 2i_1, H, 2i_1, V+1, 1}^{(2)}$	$W_{2i_1, H+1, 2i_1, V+1, 2i_1, H+1, 2i_1, V+1, 0}^{(2)}$	$W_{2i_1, H+1, 2i_1, V+1, 2i_1, H+1, 2i_1, V+1, 1}^{(2)}$
$W_{m_H, m_V, m_H, m_V, n}^{(2)} = \frac{1}{4} \left[\begin{array}{cccc} v_{m_H} \otimes v_{m_V} & v_{m_H} \otimes v_{m_V} & v_{m_H} \otimes v_{m_V} & v_{m_H} \otimes v_{m_V} \\ \varphi_n v_{m_H} \otimes v_{m_V} & \varphi_n v_{m_H} \otimes v_{m_V} & -\varphi_n v_{m_H} \otimes v_{m_V} & -\varphi_n v_{m_H} \otimes v_{m_V} \end{array} \right]$ where				

[Figure 60b]

i_1	i_2	1	2	3
Method 1: 0 - 15 Method 2: 32 - 47	0			
		$W_{2i_H, 2i_V, 2i_H+4, 2i_V+4, 0}^{(2)}$	$W_{2i_H, 2i_V, 2i_H+4, 2i_V+4, 1}^{(2)}$	$W_{2i_H+1, 2i_V, 2i_H+5, 2i_V+4, 1}^{(2)}$
i_1	i_2			
	4			
Method 1: 0 - 15 Method 2: 32 - 47	4			
		$W_{2i_H, 2i_V+1, 2i_H+4, 2i_V+5, 0}^{(2)}$	$W_{2i_H, 2i_V+1, 2i_H+4, 2i_V+5, 1}^{(2)}$	$W_{2i_H+1, 2i_V+1, 2i_H+5, 2i_V+5, 1}^{(2)}$
$W_{m_H, m_V, m_H, m_V, n}^{(2)} = \frac{1}{4} \begin{bmatrix} v_{m_H} \otimes v_{m_V} & v_{m_H} \otimes v_{m_V} \\ \varphi_n v_{m_H} \otimes v_{m_V} & -\varphi_n v_{m_H} \otimes v_{m_V} \end{bmatrix}$ where				

【Figure 60c】

i_1	i_2	1	2	3
Method 1: 0 - 15 Method 2: 48 - 63	0			
		$W_{2i_H, 2i_Y, 2i_H+12, 2i_Y+4, 0}^{(2)}$	$W_{2i_H, 2i_Y, 2i_H+12, 2i_Y+4, 1}^{(2)}$	$W_{2i_H+1, 2i_Y, 2i_H+13, 2i_Y+4, 0}^{(2)}$
				$W_{2i_H+1, 2i_Y, 2i_H+13, 2i_Y+4, 1}^{(2)}$
i_1	i_2	5	6	7
Method 1: 0 - 15 Method 2: 48 - 63	4			
		$W_{2i_H, 2i_Y+1, 2i_H+12, 2i_Y+5, 0}^{(2)}$	$W_{2i_H, 2i_Y+1, 2i_H+12, 2i_Y+5, 1}^{(2)}$	$W_{2i_H+1, 2i_Y+1, 2i_H+13, 2i_Y+5, 0}^{(2)}$
				$W_{2i_H+1, 2i_Y+1, 2i_H+13, 2i_Y+5, 1}^{(2)}$
$W_{m_H, m_Y, m_H, m_Y, n}^{(2)} = \frac{1}{4} \begin{bmatrix} v_{m_H} \otimes v_{m_Y} & v_{m_H} \otimes v_{m_Y} \\ \varphi_n v_{m_H} \otimes v_{m_Y} & -\varphi_n v_{m_H} \otimes v_{m_Y} \end{bmatrix}$ where				

【Figure 60d】

Method 1 i_1 (in each table)	Method 2 i_1 (across the three tables)	$i_{1,H}$	$i_{1,V}$
0-7 (the first table / beam group)	0-7	0-7	0
8-15 (the first table / beam group)	8-15	0-7	1
16-23 (the first table / beam group)	16-23	0-7	2
24-31 (the first table / beam group)	24-31	0-7	3
0-7 (the second table / beam group)	32-39	0-7	0
8-15 (the second table / beam group)	40-47	0-7	1
0-7 (the third table / beam group)	48-55	0-7	0
8-15 (the third table / beam group)	56-63	0-7	1

【Figure 61a】

i_1	i_2	1	2	3
0	0			
-				
31		$W_{2i_1, H, 2i_1, V, 2i_1, H, 2i_1, V, 0}^{(2)}$	$W_{2i_1, H, 2i_1, V, 2i_1, H, 2i_1, V, 1}^{(2)}$	$W_{2i_1, H+1, 2i_1, V, 2i_1, H+1, 2i_1, V, 1}^{(2)}$
i_1	i_2			
4	4	5	6	7
0				
-				
31		$W_{2i_1, H, 2i_1, V+1, 2i_1, H, 2i_1, V+1, 0}^{(2)}$	$W_{2i_1, H, 2i_1, V+1, 2i_1, H, 2i_1, V+1, 1}^{(2)}$	$W_{2i_1, H+1, 2i_1, V+1, 2i_1, H+1, 2i_1, V+1, 1}^{(2)}$
where $W_{m_H, m_V, m_H, m_V, n}^{(2)} = \frac{1}{4} \begin{bmatrix} v_{m_H} \otimes v_{m_V} & v_{m_H} \otimes v_{m_V} \\ \varphi_n v_{m_H} \otimes v_{m_V} & -\varphi_n v_{m_H} \otimes v_{m_V} \end{bmatrix}$				

【Figure 61b】

i_1	i_2	1	2	3
Method 1: 0-15 Method 2: 32-47	0			
		$W_{2i_H, 2i_V, 2i_H+8, 2i_V, 0}^{(2)}$	$W_{2i_H+1, 2i_V, 2i_H+9, 2i_V, 0}^{(2)}$	$W_{2i_H+1, 2i_V, 2i_H+9, 2i_V, 1}^{(2)}$
i_1	i_2			
4				
Method 1: 0-15 Method 2: 32-47	4			
		$W_{2i_H, 2i_V+1, 2i_H+8, 2i_V+1, 0}^{(2)}$	$W_{2i_H, 2i_V+1, 2i_H+8, 2i_V+1, 1}^{(2)}$	$W_{2i_H+1, 2i_V+1, 2i_H+9, 2i_V+1, 1}^{(2)}$
where $W_{m_H, m_V, m_H, m_V, n}^{(2)} = \frac{1}{4} \begin{bmatrix} v_{m_H} \otimes v_{m_V} & v_{m_H} \otimes v_{m_V} \\ \varphi_n v_{m_H} \otimes v_{m_V} & -\varphi_n v_{m_H} \otimes v_{m_V} \end{bmatrix}$				

【Figure 61c】

i_1	i_2	1	2	3	
Method 1: 0 - 15	0				
Method 2: 48 - 63	$W_{2i_1 H, 2i_1 V, 2i_1 H+8, 2i_1 V+4, 0}^{(2)}$	$W_{2i_1 H, 2i_1 V, 2i_1 H+8, 2i_1 V+4, 1}^{(2)}$	$W_{2i_1 H+1, 2i_1 V, 2i_1 H+9, 2i_1 V+4, 0}^{(2)}$	$W_{2i_1 H+1, 2i_1 V, 2i_1 H+9, 2i_1 V+4, 1}^{(2)}$	
i_1	i_2	4	5	6	7
Method 1: 0 - 15	$W_{2i_1 H, 2i_1 V+1, 2i_1 H+8, 2i_1 V+5, 0}^{(2)}$	$W_{2i_1 H, 2i_1 V+1, 2i_1 H+8, 2i_1 V+5, 1}^{(2)}$	$W_{2i_1 H+1, 2i_1 V+1, 2i_1 H+9, 2i_1 V+5, 0}^{(2)}$	$W_{2i_1 H+1, 2i_1 V+1, 2i_1 H+9, 2i_1 V+5, 1}^{(2)}$	
Method 2: 48 - 63					
where $W_{m_H, m_V, m_H, m_V, n}^{(2)} = \frac{1}{4} \left[\begin{matrix} v_{m_H} \otimes v_{m_V} & v_{m_H} \otimes v_{m_V} \\ \varphi_{m_H} v_{m_H} \otimes v_{m_V} & -\varphi_{m_H} v_{m_H} \otimes v_{m_V} \end{matrix} \right]$					

【Figure 61d】

Method 1 i_1 (in each table)	Method 2 i_1 (across the three tables)	$i_{1,H}$	$i_{1,V}$
0-7 (the first table / beam group)	0-7	0-7	0
8-15 (the first table / beam group)	8-15	0-7	1
16-23 (the first table / beam group)	16-23	0-7	2
24-31 (the first table / beam group)	24-31	0-7	3
0-3 (the second table / beam group)	32-35	0-3	0
4-7 (the second table / beam group)	36-39	0-3	1
8-11 (the second table / beam group)	40-43	0-3	2
12-15 (the second table / beam group)	44-47	0-3	3
0-7 (the third table / beam group)	48-55	0-7	0
8-15 (the third table / beam group)	56-63	0-7	1

【Figure 62a】

i_1	i_2	1	2	3
0-31	0			
	$W_{2i_1, H, 2i_1, V, 2i_1, H, 2i_1, V, 0}^{(2)}$	$W_{2i_1, H, 2i_1, V, 2i_1, H, 2i_1, V, 1}^{(2)}$	$W_{2i_1, H+1, 2i_1, V, 2i_1, H+1, 2i_1, V, 0}^{(2)}$	$W_{2i_1, H+1, 2i_1, V, 2i_1, H+1, 2i_1, V, 1}^{(2)}$
i_1	i_2			
4	5	6	7	
0-31	$W_{2i_1, H, 2i_1, V+1, 2i_1, H, 2i_1, V+1, 0}^{(2)}$	$W_{2i_1, H, 2i_1, V+1, 2i_1, H, 2i_1, V+1, 1}^{(2)}$	$W_{2i_1, H+1, 2i_1, V+1, 2i_1, H+1, 2i_1, V+1, 0}^{(2)}$	$W_{2i_1, H+1, 2i_1, V+1, 2i_1, H+1, 2i_1, V+1, 1}^{(2)}$
where $W_{m_H, m_V, m_H, m_V, n}^{(2)} = \frac{1}{4} \left[\begin{array}{c} v_{m_H} \otimes v_{m_V} \quad v_{m_H} \otimes v_{m_V} \\ \varphi_n v_{m_H} \otimes v_{m_V} \quad -\varphi_n v_{m_H} \otimes v_{m_V} \end{array} \right]$				

【Figure 62b】

i_1	i_2	1	2	3
Method 1: 0-15 Method 2: 32-47	0			
		$W_{2i_1, H, 2i_1, V, 2i_1, H, 2i_1, V+4, 0}^{(2)}$	$W_{2i_1, H+1, 2i_1, V, 2i_1, H+1, 2i_1, V+4, 0}^{(2)}$	$W_{2i_1, H+1, 2i_1, V, 2i_1, H+1, 2i_1, V+4, 1}^{(2)}$
i_1	i_2	4	5	6
Method 1: 0-15 Method 2: 32-47	4			
		$W_{2i_1, H, 2i_1, V+1, 2i_1, H, 2i_1, V+5, 0}^{(2)}$	$W_{2i_1, H, 2i_1, V+1, 2i_1, H, 2i_1, V+5, 1}^{(2)}$	$W_{2i_1, H+1, 2i_1, V+1, 2i_1, H+1, 2i_1, V+5, 1}^{(2)}$
$W_{m_H, m_V, m_H, m_V, n}^{(2)} = \frac{1}{4} \left[\begin{array}{c} v_{m_H} \otimes v_{m_V} \\ \varphi_n v_{m_H} \otimes v_{m_V} \end{array} \right. \left. \begin{array}{c} v_{m_H} \otimes v_{m_V} \\ -\varphi_n v_{m_H} \otimes v_{m_V} \end{array} \right]$ where				

【Figure 62c】

i_1	i_2	1	2	3
Method 1: 0 - 15 Method 2: 48 - 63	0			
	$W_{2i_1, H, 2i_1, V, 2i_1, H+8, 2i_1, V+4, 0}^{(2)}$	$W_{2i_1, H, 2i_1, V, 2i_1, H+8, 2i_1, V+4, 1}^{(2)}$	$W_{2i_1, H+1, 2i_1, V, 2i_1, H+9, 2i_1, V+4, 0}^{(2)}$	$W_{2i_1, H+1, 2i_1, V, 2i_1, H+9, 2i_1, V+4, 1}^{(2)}$
i_1	i_2	5	6	7
Method 1: 0 - 15 Method 2: 48 - 63	4			
	$W_{2i_1, H, 2i_1, V+1, 2i_1, H+8, 2i_1, V+5, 0}^{(2)}$	$W_{2i_1, H, 2i_1, V+1, 2i_1, H+8, 2i_1, V+5, 1}^{(2)}$	$W_{2i_1, H+1, 2i_1, V+1, 2i_1, H+9, 2i_1, V+5, 0}^{(2)}$	$W_{2i_1, H+1, 2i_1, V+1, 2i_1, H+9, 2i_1, V+5, 1}^{(2)}$
where $W_{mH, mV, mH, mV, n}^{(2)} = \frac{1}{4} \begin{bmatrix} v_{mH} \otimes v_{mV} & v_{mH} \otimes v_{mV} \\ \phi_{mH} v_{mH} \otimes v_{mV} & -\phi_{mH} v_{mH} \otimes v_{mV} \end{bmatrix}$				

【Figure 62d】

Method 1 i_1 (in each table)	Method 2 i_1 (across the three tables)	$i_{1,H}$	$i_{1,V}$
0-7 (the first table / beam group)	0-7	0-7	0
8-15 (the first table / beam group)	8-15	0-7	1
16-23 (the first table / beam group)	16-23	0-7	2
24-31 (the first table / beam group)	24-31	0-7	3
0-7 (the second table / beam group)	32-39	0-7	0
8-15 (the second table / beam group)	40-47	0-7	1
0-7 (the third table / beam group)	48-55	0-7	0
8-15 (the third table / beam group)	56-63	0-7	1

【Figure 63a】

i_1	i_2	1	2	3
0-31	0	$W_{2i_1 H, 2i_1 V, 2i_1 H, 2i_1 V, 0}^{(2)}$	$W_{2i_1 H, 2i_1 V, 2i_1 H, 2i_1 V, 1}^{(2)}$	$W_{2i_1 H, 2i_1 V, 2i_1 H, 2i_1 V, 1}^{(2)}$
i_1	i_2			
0-31	4	$W_{2i_1 H, 2i_1 V, 2i_1 H, 2i_1 V, 0}^{(2)}$	$W_{2i_1 H, 2i_1 V, 2i_1 H, 2i_1 V, 1}^{(2)}$	$W_{2i_1 H, 2i_1 V, 2i_1 H, 2i_1 V, 1}^{(2)}$
0-31	5	$W_{2i_1 H, 2i_1 V, 2i_1 H, 2i_1 V, 0}^{(2)}$	$W_{2i_1 H, 2i_1 V, 2i_1 H, 2i_1 V, 1}^{(2)}$	$W_{2i_1 H, 2i_1 V, 2i_1 H, 2i_1 V, 1}^{(2)}$
0-31	6	$W_{2i_1 H, 2i_1 V, 2i_1 H, 2i_1 V, 0}^{(2)}$	$W_{2i_1 H, 2i_1 V, 2i_1 H, 2i_1 V, 1}^{(2)}$	$W_{2i_1 H, 2i_1 V, 2i_1 H, 2i_1 V, 1}^{(2)}$
0-31	7	$W_{2i_1 H, 2i_1 V, 2i_1 H, 2i_1 V, 0}^{(2)}$	$W_{2i_1 H, 2i_1 V, 2i_1 H, 2i_1 V, 1}^{(2)}$	$W_{2i_1 H, 2i_1 V, 2i_1 H, 2i_1 V, 1}^{(2)}$
where $W_{m H, m V, m H, m V, n}^{(2)} = \frac{1}{4} \begin{bmatrix} \nu_{m H} \otimes \nu_{m V} & \nu_{m H} \otimes \nu_{m V} \\ \varphi_H \nu_{m H} \otimes \nu_{m V} & -\varphi_H \nu_{m H} \otimes \nu_{m V} \end{bmatrix}$				

【Figure 63b】

i_1	i_2	1	2	3
Method 1: 0 - 15	0			
Method 2: 32 - 47	$W_{2i_1, H, 2i_1, V, 2i_1, H+8, 2i_1, V, 0}^{(2)}$	$W_{2i_1, H, 2i_1, V, 2i_1, H+8, 2i_1, V, 1}^{(2)}$	$W_{2i_1, H+1, 2i_1, V, 2i_1, H+9, 2i_1, V, 0}^{(2)}$	$W_{2i_1, H+1, 2i_1, V, 2i_1, H+9, 2i_1, V, 1}^{(2)}$
i_1	i_2			
	4	5	6	7
Method 1: 0 - 15	$W_{2i_1, H, 2i_1, V+1, 2i_1, H+8, 2i_1, V+1, 0}^{(2)}$	$W_{2i_1, H, 2i_1, V+1, 2i_1, H+8, 2i_1, V+1, 1}^{(2)}$	$W_{2i_1, H+1, 2i_1, V+1, 2i_1, H+9, 2i_1, V+1, 0}^{(2)}$	$W_{2i_1, H+1, 2i_1, V+1, 2i_1, H+9, 2i_1, V+1, 1}^{(2)}$
Method 2: 32 - 47				
where $W_{m_H, m_V, m_H, m_V, n}^{(2)} = \frac{1}{4} \left[\begin{matrix} v_{m_H} \otimes v_{m_V} & v_{m_H} \otimes v_{m_V} \\ \phi_{n, v_{m_H}} & -\phi_{n, v_{m_H}} \end{matrix} \right]$				

【Figure 63c】

i_1	i_2	1	2	3
Method 1: 0 - 15	0			
Method 2: 48 - 63	$W_{2i_1, H, 2i_1, V+4, 0}^{(2)}$	$W_{2i_1, H, 2i_1, V+4, 1}^{(2)}$	$W_{2i_1, H+1, 2i_1, V+4, 0}^{(2)}$	$W_{2i_1, H+1, 2i_1, V+4, 1}^{(2)}$
i_1	i_2			
	4	5	6	7
Method 1: 0 - 15	$W_{2i_1, H, 2i_1, V+5, 0}^{(2)}$	$W_{2i_1, H, 2i_1, V+5, 1}^{(2)}$	$W_{2i_1, H+1, 2i_1, V+5, 0}^{(2)}$	$W_{2i_1, H+1, 2i_1, V+5, 1}^{(2)}$
Method 2: 48 - 63				
where $W_{m_H, m_V, m_H, m_V}^{(2)} = \frac{1}{4} \left[\begin{array}{c} v_{m_H} \otimes v_{m_V} \\ \varphi_n v_{m_H} \otimes v_{m_V} \\ v_n \otimes v_{m_H} \\ - \varphi_n v_n \otimes v_{m_V} \end{array} \right]$				

【Figure 63d】

Method 1 i_1 (in each table)	Method 2 i_1 (across the three tables)	$i_{1,H}$	$i_{1,V}$
0-7 (the first table / beam group)	0-7	0-7	0
8-15 (the first table / beam group)	8-15	0-7	1
16-23 (the first table / beam group)	16-23	0-7	2
24-31 (the first table / beam group)	24-31	0-7	3
0-3 (the second table / beam group)	32-35	0-3	0
4-7 (the second table / beam group)	36-39	0-3	1
8-11 (the second table / beam group)	40-43	0-3	2
12-15 (the second table / beam group)	44-47	0-3	3
0-7 (the third table / beam group)	48-55	0-7	0
8-15 (the third table / beam group)	56-63	0-7	1

【Figure 64a】

i_2	0	1	2	3
Precoder	$W^{(2)}_{s_1 i_1, H, s_2 i_1, V, s_1 i_1, H, s_2 i_1, V, 0}$	$W^{(2)}_{s_1 i_1, H, s_2 i_1, V, s_1 i_1, H, s_2 i_1, V, 1}$	$W^{(2)}_{s_1 i_1, H, s_2 i_1, V, s_1 i_1, H, s_2 i_1, V, p_2, 0}$	$W^{(2)}_{s_1 i_1, H, s_2 i_1, V, s_1 i_1, H, s_2 i_1, V, p_2, 1}$
i_2	4	5	6	7
Precoder	$W^{(2)}_{s_1 i_1, H, s_2 i_1, V, s_1 i_1, H, s_2 i_1, V, -2p_2, 0}$	$W^{(2)}_{s_1 i_1, H, s_2 i_1, V, s_1 i_1, H, s_2 i_1, V, -2p_2, 1}$	$W^{(2)}_{s_1 i_1, H, s_2 i_1, V, s_1 i_1, H, s_2 i_1, V, -2p_2, 0}$	$W^{(2)}_{s_1 i_1, H, s_2 i_1, V, s_1 i_1, H, s_2 i_1, V, -2p_2, 1}$
i_2	8 - 15			
Precoder	Entries 8-15 constructed with replacing the first and third subscripts $s_1 i_1, H$ with $s_1 i_1, H + p_1$ in entries 0 - 15.			
i_2	16 - 23			
Precoder	Entries 16-23 constructed with replacing the first and third subscripts $s_1 i_1, H$ with $s_1 i_1, H + 2p_1$ in entries 0 - 15.			
i_2	24 - 31			
Precoder	Entries 24-31 constructed with replacing the first and third subscripts $s_1 i_1, H$ with $s_1 i_1, H + 3p_1$ in entries 0 - 15.			
i_2	32	33	34	35
Precoder	$W^{(2)}_{s_1 i_1, H, s_2 i_1, V, s_1 i_1, H, s_2 i_1, V, p_2, 0}$	$W^{(2)}_{s_1 i_1, H, s_2 i_1, V, s_1 i_1, H, s_2 i_1, V, p_2, 1}$	$W^{(2)}_{s_1 i_1, H, s_2 i_1, V, s_1 i_1, H, s_2 i_1, V, p_2, 0}$	$W^{(2)}_{s_1 i_1, H, s_2 i_1, V, s_1 i_1, H, s_2 i_1, V, p_2, 1}$

【Figure 64b】

i_2	36	37	38	39
Precoder	$W^{(2)}_{s_{1i_1,H}, s_{2i_1,V}, s_{1i_1,H}, s_{2i_1,V} + 3p_{2,0}}$	$W^{(2)}_{s_{1i_1,H}, s_{2i_1,V}, s_{1i_1,H}, s_{2i_1,V} + 3p_{2,1}}$	$W^{(2)}_{s_{1i_1,H}, s_{2i_1,V} + p_{2,0}, s_{1i_1,H}, s_{2i_1,V} + 3p_{2,0}}$	$W^{(2)}_{s_{1i_1,H}, s_{2i_1,V} + p_{2,0}, s_{1i_1,H}, s_{2i_1,V} + 3p_{2,1}}$
i_2	40	41	42	43
Precoder	$W^{(2)}_{s_{1i_1,H}, s_{2i_1,V}, s_{1i_1,H}, s_{2i_1,V} + 2p_{2,0}}$	$W^{(2)}_{s_{1i_1,H}, s_{2i_1,V}, s_{1i_1,H}, s_{2i_1,V} + 2p_{2,1}}$	$W^{(2)}_{s_{1i_1,H}, s_{2i_1,V} + 2p_{2,0}, s_{1i_1,H}, s_{2i_1,V} + 3p_{2,0}}$	$W^{(2)}_{s_{1i_1,H}, s_{2i_1,V} + 2p_{2,0}, s_{1i_1,H}, s_{2i_1,V} + 3p_{2,1}}$
i_2	44 - 55			
Precoder	Entries 44-55 constructed with replacing the first and third subscripts $s_{1i_1,H}$ with $s_{1i_1,H} + p_1$ in entries 32 - 43.			
i_2	56 - 67			
Precoder	Entries 55-67 constructed with replacing the first and third subscripts $s_{1i_1,H}$ with $s_{1i_1,H} + 2p_1$ in entries 32 - 43.			
i_2	68 - 79			
Precoder	Entries 68-79 constructed with replacing the first and third subscripts $s_{1i_1,H}$ with $s_{1i_1,H} + 3p_1$ in entries 32 - 43.			
i_2	80 - 127			
Precoder	Entries 80-127 constructed similar to entries 32 - 79 in the other dimension.			
i_2	128	129	130	131

【Figure 64c】

Precoder	$W^{(2)}_{2i_1, H, 2i_1, V, 2i_1, H+P_1, 2i_1, V+P_2, 0}$	$W^{(2)}_{2i_1, H, 2i_1, V, 2i_1, H+P_1, 2i_1, V+P_2, 1}$	$W^{(2)}_{2i_1, H, 2i_1, V+P_2, 0}$	$W^{(2)}_{2i_1, H, 2i_1, V+P_2, 1}$
i_2	132	133	134	135
Precoder	$W^{(2)}_{2i_1, H, 2i_1, V+2P_2, 2i_1, H+P_1, 2i_1, V+3P_2, 0}$	$W^{(2)}_{2i_1, H, 2i_1, V+2P_2, 2i_1, H+P_1, 2i_1, V+3P_2, 1}$	$W^{(2)}_{2i_1, H, 2i_1, V+3P_2, 2i_1, H+P_1, 2i_1, V+P_2, 0}$	$W^{(2)}_{2i_1, H, 2i_1, V+3P_2, 2i_1, H+P_1, 2i_1, V+P_2, 1}$
i_2	136 - 159			
Precoder	Entries 136-159 constructed similar to entries 128 - 135 by considering remaining +45 degree closest diagonal pairs.			
i_2	160 - 191			
Precoder	Entries 160-191 constructed similar to entries 128 - 159 by considering -45 degree closest diagonal pairs.			

【Figure 65a】

i_2	0	1	2	3
Precoder	$W_{2i_1, H, 2i_1, v+2, 2i_1, H, 2i_1, v+0}^{(2)}$	$W_{2i_1, H, 2i_1, v+2, 2i_1, H, 2i_1, v+1}^{(2)}$	$W_{2i_1, H, 2i_1, v+1, 2i_1, H, 2i_1, v+1, 0}^{(2)}$	$W_{2i_1, H, 2i_1, v+1, 2i_1, H, 2i_1, v+1, 1}^{(2)}$
i_2	4	5	6	7
Precoder	$W_{2i_1, H, 2i_1, v+2, 2i_1, H, 2i_1, v+2, 0}^{(2)}$	$W_{2i_1, H, 2i_1, v+2, 2i_1, H, 2i_1, v+2, 1}^{(2)}$	$W_{2i_1, H, 2i_1, v+3, 2i_1, H, 2i_1, v+3, 0}^{(2)}$	$W_{2i_1, H, 2i_1, v+3, 2i_1, H, 2i_1, v+3, 1}^{(2)}$
i_2	8	9	10	11
Precoder	$W_{2i_1, H, 2i_1, v+2i_1, H, 2i_1, v+1, 0}^{(2)}$	$W_{2i_1, H, 2i_1, v+2i_1, H, 2i_1, v+1, 1}^{(2)}$	$W_{2i_1, H, 2i_1, v+1, 2i_1, H, 2i_1, v+2, 0}^{(2)}$	$W_{2i_1, H, 2i_1, v+1, 2i_1, H, 2i_1, v+2, 1}^{(2)}$
i_2	12	13	14	15
Precoder	$W_{2i_1, H, 2i_1, v+2i_1, H, 2i_1, v+3, 0}^{(2)}$	$W_{2i_1, H, 2i_1, v+2i_1, H, 2i_1, v+3, 1}^{(2)}$	$W_{2i_1, H, 2i_1, v+1, 2i_1, H, 2i_1, v+3, 0}^{(2)}$	$W_{2i_1, H, 2i_1, v+1, 2i_1, H, 2i_1, v+3, 1}^{(2)}$
i_2	16	17	18	19
Precoder	$W_{2i_1, H+1, 2i_1, v+1, 2i_1, H+1, 2i_1, v+1, 0}^{(2)}$	$W_{2i_1, H+1, 2i_1, v+1, 2i_1, H+1, 2i_1, v+1, 1}^{(2)}$	$W_{2i_1, H, 2i_1, v+1, 2i_1, H+1, 2i_1, v+1, 0}^{(2)}$	$W_{2i_1, H, 2i_1, v+1, 2i_1, H+1, 2i_1, v+1, 1}^{(2)}$
i_2	20	21	22	23
Precoder	$W_{2i_1, H+1, 2i_1, v+2i_1, H+1, 2i_1, v+1, 0}^{(2)}$	$W_{2i_1, H+1, 2i_1, v+2i_1, H+1, 2i_1, v+1, 1}^{(2)}$	$W_{2i_1, H, 2i_1, v+2i_1, H+1, 2i_1, v+1, 0}^{(2)}$	$W_{2i_1, H, 2i_1, v+2i_1, H+1, 2i_1, v+1, 1}^{(2)}$
i_2	24	25	26	27

【Figure 65b】

Precoder	$W_{2i_1, H, 2i_1, V}^{(2)} + 1, 2i_1, H + 1, 2i_1, V, 0$	$W_{2i_1, H, 2i_1, V}^{(2)} + 1, 2i_1, H + 1, 2i_1, V, 1$	$W_{2i_1, H}^{(2)} + 1, 2i_1, V, 2i_1, H + 1, 2i_1, V, 0$	$W_{2i_1, H}^{(2)} + 1, 2i_1, V, 2i_1, H + 1, 2i_1, V, 1$
i_2	28	29	30	31
Precoder	$W_{2i_1, H}^{(2)} + 2, 2i_1, V, 2i_1, H + 2, 2i_1, V, 0$	$W_{2i_1, H}^{(2)} + 2, 2i_1, V, 2i_1, H + 2, 2i_1, V, 1$	$W_{2i_1, H}^{(2)} + 3, 2i_1, V, 2i_1, H + 3, 2i_1, V, 0$	$W_{2i_1, H}^{(2)} + 3, 2i_1, V, 2i_1, H + 3, 2i_1, V, 1$
i_2	32	33	34	35
Precoder	$W_{2i_1, H}^{(2)} + 2, 2i_1, V, 2i_1, H + 1, 2i_1, V, 0$	$W_{2i_1, H}^{(2)} + 2, 2i_1, V, 2i_1, H + 1, 2i_1, V, 1$	$W_{2i_1, H}^{(2)} + 1, 2i_1, V, 2i_1, H + 2, 2i_1, V, 0$	$W_{2i_1, H}^{(2)} + 1, 2i_1, V, 2i_1, H + 2, 2i_1, V, 1$
i_2	36	37	38	39
Precoder	$W_{2i_1, H}^{(2)} + 2, 2i_1, V, 2i_1, H + 3, 2i_1, V, 0$	$W_{2i_1, H}^{(2)} + 2, 2i_1, V, 2i_1, H + 3, 2i_1, V, 1$	$W_{2i_1, H}^{(2)} + 1, 2i_1, V, 2i_1, H + 3, 2i_1, V, 0$	$W_{2i_1, H}^{(2)} + 1, 2i_1, V, 2i_1, H + 3, 2i_1, V, 1$

【Figure 66】

Beam grouping configuration	(L_1, L_2)	i_2 after subset restriction	Number of i_2 indices	Mapping to reported i_2 indices
0	(4,1)	0-1, 26-39	16	0-15
1	(1,4)	0-15	16	0-15
2	(2,2)	Scheme 0: 0-3, 8-9, 16-19, 24-27, 32-33 Scheme 1: 0-3, 8-9, 16-21, 26-27, 32-33 Scheme 2: 0-3, 8-9, 16-17, 22-27, 32-33	16	0-15

【Figure 67】

i_2	0	1	2	3
Precoder	$W^{(2)}_{s_{1i_{1,1}, s_{2i_{1,2}}, 2, s_{1i_{1,1}, s_{2i_{1,2}}, 0}}$	$W^{(2)}_{s_{1i_{1,1}, s_{2i_{1,2}}, 2, s_{1i_{1,1}, s_{2i_{1,2}}, 1}}$	$W^{(2)}_{s_{1i_{1,1}, s_{2i_{1,2}}, 2, s_{1i_{1,1}, s_{2i_{1,2}}, 0}}$	$W^{(2)}_{s_{1i_{1,1}, s_{2i_{1,2}}, 2, s_{1i_{1,1}, s_{2i_{1,2}}, 1}}$
i_2	4	5	6	7
Precoder	$W^{(2)}_{s_{1i_{1,1}, s_{2i_{1,2}}, 2, s_{1i_{1,1}, s_{2i_{1,2}}, 0}}$	$W^{(2)}_{s_{1i_{1,1}, s_{2i_{1,2}}, 2, s_{1i_{1,1}, s_{2i_{1,2}}, 1}}$	$W^{(2)}_{s_{1i_{1,1}, s_{2i_{1,2}}, 2, s_{1i_{1,1}, s_{2i_{1,2}}, 0}}$	$W^{(2)}_{s_{1i_{1,1}, s_{2i_{1,2}}, 2, s_{1i_{1,1}, s_{2i_{1,2}}, 1}}$
i_2	8	9	10	11
Precoder	$W^{(2)}_{s_{1i_{1,1}, s_{2i_{1,2}}, 2, s_{1i_{1,1}, s_{2i_{1,2}}, 0}}$	$W^{(2)}_{s_{1i_{1,1}, s_{2i_{1,2}}, 2, s_{1i_{1,1}, s_{2i_{1,2}}, 1}}$	$W^{(2)}_{s_{1i_{1,1}, s_{2i_{1,2}}, 2, s_{1i_{1,1}, s_{2i_{1,2}}, 0}}$	$W^{(2)}_{s_{1i_{1,1}, s_{2i_{1,2}}, 2, s_{1i_{1,1}, s_{2i_{1,2}}, 1}}$
i_2	12	13	14	15
Precoder	$W^{(2)}_{s_{1i_{1,1}, s_{2i_{1,2}}, 2, s_{1i_{1,1}, s_{2i_{1,2}}, 0}}$	$W^{(2)}_{s_{1i_{1,1}, s_{2i_{1,2}}, 2, s_{1i_{1,1}, s_{2i_{1,2}}, 1}}$	$W^{(2)}_{s_{1i_{1,1}, s_{2i_{1,2}}, 2, s_{1i_{1,1}, s_{2i_{1,2}}, 0}}$	$W^{(2)}_{s_{1i_{1,1}, s_{2i_{1,2}}, 2, s_{1i_{1,1}, s_{2i_{1,2}}, 1}}$
i_2	16-31			
Precoder	Entries 16-31 constructed with replacing the second subscript $s_{2i_{1,2}}$ with $s_{2i_{1,2}} + p_2$ in entries 0 - 15.			

[Figure 68a]

i'_2	0	1	2	3
Precoder	$W_{s_{i_{1,1}}, s_{i_{1,1}} + O_1, s_{2i_{1,2}}, s_{2i_{1,2}}}^{(3)}$	$W_{s_{i_{1,1}}, s_{i_{1,1}} + O_1, s_{2i_{1,2}}, s_{2i_{1,2}}}^{(3)}$	$\tilde{W}_{s_{i_{1,1}}, s_{i_{1,1}} + O_1, s_{2i_{1,2}}, s_{2i_{1,2}}}^{(3)}$	$\tilde{W}_{s_{i_{1,1}} + O_1, s_{i_{1,1}}, s_{2i_{1,2}}, s_{2i_{1,2}}}^{(3)}$
i'_2	4	5	6	7
Precoder	$W_{s_{i_{1,1}} + O_1, s_{i_{1,1}} + 2O_1, s_{2i_{1,2}}, s_{2i_{1,2}}}^{(3)}$	$W_{s_{i_{1,1}} + 2O_1, s_{i_{1,1}} + O_1, s_{2i_{1,2}}, s_{2i_{1,2}}}^{(3)}$	$\tilde{W}_{s_{i_{1,1}} + O_1, s_{i_{1,1}} + 2O_1, s_{2i_{1,2}}, s_{2i_{1,2}}}^{(3)}$	$\tilde{W}_{s_{i_{1,1}} + 2O_1, s_{i_{1,1}} + O_1, s_{2i_{1,2}}, s_{2i_{1,2}}}^{(3)}$
i'_2	8	9	10	11
Precoder	$W_{s_{i_{1,1}} + 2O_1, s_{i_{1,1}} + 3O_1, s_{2i_{1,2}}, s_{2i_{1,2}}}^{(3)}$	$W_{s_{i_{1,1}} + 3O_1, s_{i_{1,1}} + 2O_1, s_{2i_{1,2}}, s_{2i_{1,2}}}^{(3)}$	$\tilde{W}_{s_{i_{1,1}} + 2O_1, s_{i_{1,1}} + 3O_1, s_{2i_{1,2}}, s_{2i_{1,2}}}^{(3)}$	$\tilde{W}_{s_{i_{1,1}} + 3O_1, s_{i_{1,1}} + 2O_1, s_{2i_{1,2}}, s_{2i_{1,2}}}^{(3)}$
i'_2	12	13	14	15
Precoder	$W_{s_{i_{1,1}} + 3O_1, s_{i_{1,1}} + 3O_1, s_{2i_{1,2}}, s_{2i_{1,2}}}^{(3)}$	$W_{s_{i_{1,1}} + 3O_1, s_{i_{1,1}} + 3O_1, s_{2i_{1,2}}, s_{2i_{1,2}}}^{(3)}$	$\tilde{W}_{s_{i_{1,1}} + 3O_1, s_{i_{1,1}} + 3O_1, s_{2i_{1,2}}, s_{2i_{1,2}}}^{(3)}$	$\tilde{W}_{s_{i_{1,1}} + 3O_1, s_{i_{1,1}} + 3O_1, s_{2i_{1,2}}, s_{2i_{1,2}}}^{(3)}$
i'_2	16	17	18	19
Precoder	$W_{s_{i_{1,1}} + O_1, s_{2i_{1,2}} + O_2, s_{2i_{1,2}} + O_2}^{(3)}$	$W_{s_{i_{1,1}} + O_1, s_{2i_{1,2}} + O_2, s_{2i_{1,2}} + O_2}^{(3)}$	$\tilde{W}_{s_{i_{1,1}} + O_1, s_{2i_{1,2}} + O_2, s_{2i_{1,2}} + O_2}^{(3)}$	$\tilde{W}_{s_{i_{1,1}} + O_1, s_{2i_{1,2}} + O_2, s_{2i_{1,2}} + O_2}^{(3)}$
i'_2	20	21	22	23

【Figure 68b】

Precoder	$W_{s1h,1,s1h,1,s2h,2,s2h,2}^{(3)} + O_2$	$W_{s1h,1,s1h,1,s2h,2,s2h,2}^{(3)}$	$\tilde{W}_{s1h,1,s1h,1,s2h,2,s2h,2}^{(3)} + O_2$	$\tilde{W}_{s1h,1,s1h,1,s2h,2,s2h,2}^{(3)}$
i'_2	24	25	26	27
Precoder	$W_{s1h,1+Q_1,s1h,1+Q_1,s2h,2,s2h,2}^{(3)} + O_2$	$W_{s1h,1+Q_1,s1h,1+Q_1,s2h,2,s2h,2}^{(3)}$	$\tilde{W}_{s1h,1+Q_1,s1h,1+Q_1,s2h,2,s2h,2}^{(3)} + O_2$	$\tilde{W}_{s1h,1+Q_1,s1h,1+Q_1,s2h,2,s2h,2}^{(3)}$
i'_2	28	29	30	31
Precoder	$W_{s1h,1,s1h,1+Q_1,s2h,2,s2h,2}^{(3)} + O_2$	$W_{s1h,1,s1h,1+Q_1,s2h,2,s2h,2}^{(3)}$	$\tilde{W}_{s1h,1,s1h,1+Q_1,s2h,2,s2h,2}^{(3)} + O_2$	$\tilde{W}_{s1h,1+Q_1,s1h,1,s2h,2,s2h,2}^{(3)} + O_2$
i'_2	32	33	34	35
Precoder	$W_{s1h,1+Q_1,s1h,1+2Q_1,s2h,2+O_2,s2h,2}^{(3)}$	$W_{s1h,1+2Q_1,s1h,1+Q_1,s2h,2,s2h,2}^{(3)} + O_2$	$\tilde{W}_{s1h,1+Q_1,s1h,1+2Q_1,s2h,2,s2h,2}^{(3)} + O_2$	$\tilde{W}_{s1h,1+2Q_1,s1h,1+Q_1,s2h,2,s2h,2}^{(3)}$
i'_2	36	37	38	39
Precoder	$W_{s1h,1+2Q_1,s1h,1+3Q_1,s2h,2+O_2}^{(3)}$	$W_{s1h,1+3Q_1,s1h,1+2Q_1,s2h,2}^{(3)} + O_2$	$\tilde{W}_{s1h,1+2Q_1,s1h,1+3Q_1,s2h,2}^{(3)} + O_2$	$\tilde{W}_{s1h,1+3Q_1,s1h,1+2Q_1,s2h,2}^{(3)}$
i'_2	40	41	42	43
Precoder	$W_{s1h,1+3Q_1,s1h,1+3Q_1,s2h,2+O_2}^{(3)}$	$W_{s1h,1+3Q_1,s1h,1+3Q_1,s2h,2}^{(3)} + O_2$	$\tilde{W}_{s1h,1+3Q_1,s1h,1+3Q_1,s2h,2}^{(3)}$	$\tilde{W}_{s1h,1+3Q_1,s1h,1+3Q_1,s2h,2}^{(3)}$

【Figure 69】

i'_2	0	1	2	3
Preceder	$W^{(4)}_{s_{i_1,1}, s_{i_1,1} + O_1, s_{i_1,2}, s_{i_1,2}, 0}$	$W^{(4)}_{s_{i_1,1}, s_{i_1,1} + O_1, s_{i_1,2}, s_{i_1,2}, 1}$	$W^{(4)}_{s_{i_1,1} + O_1, s_{i_1,1} + 2O_1, s_{i_1,2}, s_{i_1,2}, 0}$	$W^{(4)}_{s_{i_1,1} + O_1, s_{i_1,1} + 2O_1, s_{i_1,2}, s_{i_1,2}, 1}$
i'_2	4	5	6	7
Preceder	$W^{(4)}_{s_{i_1,1} + 2O_1, s_{i_1,1} + 3O_1, s_{i_1,2}, s_{i_1,2}, 0}$	$W^{(4)}_{s_{i_1,1} + 2O_1, s_{i_1,1} + 3O_1, s_{i_1,2}, s_{i_1,2}, 1}$	$W^{(4)}_{s_{i_1,1} + 3O_1, s_{i_1,1}, s_{i_1,2}, s_{i_1,2}, 0}$	$W^{(4)}_{s_{i_1,1} + 3O_1, s_{i_1,1}, s_{i_1,2}, s_{i_1,2}, 1}$
i'_2	8	9	10	11
Preceder	$W^{(3)}_{s_{i_1,1}, s_{i_1,1} + O_1, s_{i_1,2} + O_2, s_{i_1,2} + O_2, 0}$	$W^{(3)}_{s_{i_1,1}, s_{i_1,1} + O_1, s_{i_1,2} + O_2, s_{i_1,2} + O_2, 1}$	$W^{(4)}_{s_{i_1,1}, s_{i_1,1}, s_{i_1,2}, s_{i_1,2} + O_2, 0}$	$W^{(4)}_{s_{i_1,1}, s_{i_1,1}, s_{i_1,2}, s_{i_1,2} + O_2, 1}$
i'_2	12	13	14	15
Preceder	$W^{(3)}_{s_{i_1,1} + O_1, s_{i_1,1} + O_1, s_{i_1,2}, s_{i_1,2} + O_2, 0}$	$W^{(3)}_{s_{i_1,1} + O_1, s_{i_1,1} + O_1, s_{i_1,2}, s_{i_1,2} + O_2, 1}$	$W^{(3)}_{s_{i_1,1}, s_{i_1,1} + O_1, s_{i_1,2}, s_{i_1,2} + O_2, 0}$	$W^{(3)}_{s_{i_1,1}, s_{i_1,1} + O_1, s_{i_1,2}, s_{i_1,2} + O_2, 1}$
i'_2	16	17	18	19
Preceder	$W^{(3)}_{s_{i_1,1} + O_1, s_{i_1,1} + 2O_1, s_{i_1,2} + O_2, s_{i_1,2}, 0}$	$W^{(3)}_{s_{i_1,1} + O_1, s_{i_1,1} + 2O_1, s_{i_1,2} + O_2, s_{i_1,2}, 1}$	$W^{(3)}_{s_{i_1,1} + 2O_1, s_{i_1,1} + 3O_1, s_{i_1,2}, s_{i_1,2} + O_2, 0}$	$W^{(3)}_{s_{i_1,1} + 2O_1, s_{i_1,1} + 3O_1, s_{i_1,2}, s_{i_1,2} + O_2, 1}$
i'_2	20	21		
Preceder	$W^{(3)}_{s_{i_1,1} + 3O_1, s_{i_1,1}, s_{i_1,2}, s_{i_1,2} + O_2, s_{i_1,2}, 0}$	$W^{(3)}_{s_{i_1,1} + 3O_1, s_{i_1,1}, s_{i_1,2}, s_{i_1,2} + O_2, s_{i_1,2}, 1}$		

[Figure 70]

i'_2	0	1	
Precoder	$W_{s_{1i,1},s_{1i,1}+O_1,s_{2i,2}+2O_1,s_{2i,2},s_{2i,2},s_{2i,2}}^{(5)}$	$W_{s_{1i,1}+O_1,s_{1i,1}+2O_1,s_{1i,1}+3O_1,s_{2i,2},s_{2i,2},s_{2i,2}}^{(5)}$	
i'_2	2	3	
Precoder	$W_{s_{1i,1}+2O_1,s_{1i,1}+3O_1,s_{1i,1},s_{2i,2},s_{2i,2},s_{2i,2}}^{(5)}$	$W_{s_{1i,1}+3O_1,s_{1i,1},s_{1i,1}+O_1,s_{2i,2},s_{2i,2},s_{2i,2}}^{(5)}$	
i'_2	4	5	
Precoder	$W_{s_{1i,1},s_{1i,1}+O_1,s_{1i,1}+O_1,s_{2i,2},s_{2i,2},s_{2i,2}+O_2}^{(5)}$	$W_{s_{1i,1}+O_1,s_{1i,1}+O_1,s_{1i,1},s_{2i,2},s_{2i,2}+O_2,s_{2i,2}+O_2}^{(5)}$	
i'_2	6	7	
Precoder	$W_{s_{1i,1}+O_1,s_{1i,1},s_{1i,1},s_{2i,2}+O_2,s_{2i,2}+O_2,s_{2i,2}}^{(5)}$	$W_{s_{1i,1},s_{1i,1},s_{1i,1}+O_1,s_{2i,2}+O_2,s_{2i,2},s_{2i,2}}^{(5)}$	
i'_2	8	9	
Precoder	$W_{s_{1i,1},s_{1i,1}+O_1,s_{1i,1}+2O_1,s_{1i,2},s_{2i,2}+O_2,s_{2i,2}}^{(5)}$	$W_{s_{1i,1}+O_1,s_{1i,1}+2O_1,s_{1i,1}+3O_1,s_{2i,2}+O_2,s_{2i,2}+O_2}^{(5)}$	
i'_2	10	11	
Precoder	$W_{s_{1i,1}+2O_1,s_{1i,1}+3O_1,s_{1i,1},s_{2i,2},s_{2i,2}+O_2,s_{2i,2}}^{(5)}$	$W_{s_{1i,1}+3O_1,s_{1i,1},s_{1i,1}+O_1,s_{2i,2}+O_2,s_{2i,2},s_{2i,2}+O_2}^{(5)}$	

【Figure 71】

i'_2	0	1
Precoder	$W^{(6)}_{s1i_{1,1},s1i_{1,1}+O_1,s1i_{1,1}+2O_1,s2i_{1,2},s2i_{1,2}}$	$W^{(6)}_{s1i_{1,1}+O_1,s1i_{1,1}+2O_1,s1i_{1,1}+3O_1,s2i_{1,2},s2i_{1,2}}$
i'_2	2	3
Precoder	$W^{(6)}_{s1i_{1,1}+2O_1,s1i_{1,1}+3O_1,s1i_{1,1},s2i_{1,2},s2i_{1,2}}$	$W^{(6)}_{s1i_{1,1}+3O_1,s1i_{1,1},s1i_{1,1}+O_1,s2i_{1,2},s2i_{1,2}}$
i'_2	4	5
Precoder	$W^{(6)}_{s1i_{1,1},s1i_{1,1}+O_1,s1i_{1,1}+O_1,s2i_{1,2},s2i_{1,2}+O_2}$	$W^{(6)}_{s1i_{1,1}+O_1,s1i_{1,1}+O_1,s1i_{1,1},s2i_{1,2}+O_2,s2i_{1,2}+O_2}$
i'_2	6	7
Precoder	$W^{(6)}_{s1i_{1,1}+O_1,s1i_{1,1},s1i_{1,1},s2i_{1,2}+O_2,s2i_{1,2}}$	$W^{(6)}_{s1i_{1,1},s1i_{1,1},s1i_{1,1}+O_1,s2i_{1,2}+O_2,s2i_{1,2},s2i_{1,2}}$
i'_2	8	9
Precoder	$W^{(6)}_{s1i_{1,1},s1i_{1,1}+O_1,s1i_{1,1}+2O_1,s2i_{1,2},s2i_{1,2}+O_2,s2i_{1,2}}$	$W^{(6)}_{s1i_{1,1}+O_1,s1i_{1,1}+2O_1,s1i_{1,1}+3O_1,s2i_{1,2}+O_2,s2i_{1,2}+O_2}$
i'_2	10	11
Precoder	$W^{(6)}_{s1i_{1,1}+2O_1,s1i_{1,1}+3O_1,s1i_{1,1},s2i_{1,2}+O_2,s2i_{1,2}}$	$W^{(6)}_{s1i_{1,1}+3O_1,s1i_{1,1},s1i_{1,1}+O_1,s2i_{1,2}+O_2,s2i_{1,2}+O_2}$

【Figure 72】

i'_2	0	1	2	3
Precoder	$W^{(3)}_{s1i_{1,1},s1i_{1,2},s2i_{1,2}+O_2}$	$W^{(3)}_{s1i_{1,1},s1i_{1,2},s2i_{1,2}+O_2}$	$\widetilde{W}^{(3)}_{s1i_{1,1},s1i_{1,2},s2i_{1,2}+O_2}$	$\widetilde{W}^{(3)}_{s1i_{1,1},s1i_{1,2},s2i_{1,2}+O_2,s2i_{1,2}}$
i'_2	4	5	6	7
Precoder	$W^{(3)}_{s1i_{1,1},s1i_{1,1}+O_1,s2i_{1,2},s2i_{1,2}}$	$W^{(3)}_{s1i_{1,1},s1i_{1,1}+O_1,s2i_{1,2},s2i_{1,2}}$	$\widetilde{W}^{(3)}_{s1i_{1,1},s1i_{1,1}+O_1,s2i_{1,2},s2i_{1,2}}$	$W^{(3)}_{s1i_{1,1}+O_1,s1i_{1,1},s2i_{1,2},s2i_{1,2}}$
i'_2	8	9	10	11
Precoder	$W^{(3)}_{s1i_{1,1},s1i_{1,1}+O_1,s2i_{1,2}+O_2,s2i_{1,2}}$	$W^{(3)}_{s1i_{1,1},s1i_{1,1}+O_1,s1i_{1,1},s2i_{1,2}+O_2}$	$\widetilde{W}^{(3)}_{s1i_{1,1},s1i_{1,1}+O_1,s2i_{1,2}+O_2,s2i_{1,2}}$	$\widetilde{W}^{(3)}_{s1i_{1,1}+O_1,s1i_{1,1},s2i_{1,2},s2i_{1,2}+O_2}$
i'_2	12	13	14	15
Precoder	$W^{(3)}_{s1i_{1,1},s1i_{1,1}+O_1,s2i_{1,2},s2i_{1,2}+O_2}$	$W^{(3)}_{s1i_{1,1},s1i_{1,1}+O_1,s1i_{1,1},s2i_{1,2}+O_2,s2i_{1,2}}$	$\widetilde{W}^{(3)}_{s1i_{1,1},s1i_{1,1}+O_1,s2i_{1,2},s2i_{1,2}+O_2}$	$\widetilde{W}^{(3)}_{s1i_{1,1}+O_1,s1i_{1,1},s2i_{1,2}+O_2,s2i_{1,2}}$

【Figure 73】

i'_2	0	1	2	3
Precoder	$W_{s_{1i_1,1}, s_{1i_1,1}, s_{2i_1,2}, s_{2i_1,2} + O_2, 0}^{(4)}$	$W_{s_{1i_1,1}, s_{1i_1,1}, s_{2i_1,2}, s_{2i_1,2} + O_2, 1}^{(4)}$	$W_{s_{1i_1,1}, s_{1i_1,1} + O_1, s_{2i_1,2}, s_{2i_1,2}, 0}^{(4)}$	$W_{s_{1i_1,1}, s_{1i_1,1} + O_1, s_{2i_1,2}, s_{2i_1,2}, 1}^{(4)}$
i'_2	4	5	6	7
Precoder	$W_{s_{1i_1,1}, s_{1i_1,1} + O_1, s_{2i_1,2} + O_2, s_{2i_1,2}, 0}^{(4)}$	$W_{s_{1i_1,1}, s_{1i_1,1} + O_1, s_{2i_1,2} + O_2, s_{2i_1,2}, 1}^{(4)}$	$W_{s_{1i_1,1}, s_{1i_1,1} + O_1, s_{2i_1,2}, s_{2i_1,2} + O_2, 0}^{(4)}$	$W_{s_{1i_1,1}, s_{1i_1,1} + O_1, s_{2i_1,2}, s_{2i_1,2} + O_2, 1}^{(4)}$

[Figure 74]

$\tilde{L}'_2$	0	1	2	3
Precoder	$\tilde{W}^{(3)}_{s_{1,1}, s_{1,1} + \delta_1, s_{2,1,2}, s_{2,1,2} + \delta_2}$	$\tilde{W}^{(3)}_{s_{1,1} + \delta_1, s_{1,1}, s_{2,1,2}, s_{2,1,2}}$	$\tilde{W}^{(3)}_{s_{1,1}, s_{1,1} + \delta_1, s_{2,1,2}, s_{2,1,2} + \delta_2}$	$\tilde{W}^{(3)}_{s_{1,1} + \delta_1, s_{1,1} + \delta_1, s_{2,1,2} + \delta_2, s_{2,1,2}}$
$\tilde{L}'_2$	4	5	6	7
Precoder	$\tilde{W}^{(3)}_{s_{1,1} + p_1, s_{1,1} + p_1 + \delta_1, s_{2,1,2}, s_{2,1,2} + \delta_2}$	$\tilde{W}^{(3)}_{s_{1,1} + p_1 + \delta_1, s_{1,1}, s_{2,1,2} + \delta_2, s_{2,1,2}}$	$\tilde{W}^{(3)}_{s_{1,1} + p_1, s_{1,1} + p_1 + \delta_1, s_{2,1,2}, s_{2,1,2} + \delta_2}$	$\tilde{W}^{(3)}_{s_{1,1} + p_1 + \delta_1, s_{1,1} + p_1 + \delta_1, s_{2,1,2} + \delta_2, s_{2,1,2}}$
$\tilde{L}'_2$	8	9	10	11
Precoder	$\tilde{W}^{(3)}_{s_{1,1} + 2p_1, s_{1,1} + 2p_1 + \delta_1, s_{2,1,2}, s_{2,1,2} + \delta_2}$	$\tilde{W}^{(3)}_{s_{1,1} + 2p_1 + \delta_1, s_{1,1}, s_{2,1,2} + \delta_2, s_{2,1,2}}$	$\tilde{W}^{(3)}_{s_{1,1} + 2p_1, s_{1,1} + 2p_1 + \delta_1, s_{2,1,2}, s_{2,1,2} + \delta_2}$	$\tilde{W}^{(3)}_{s_{1,1} + 2p_1 + \delta_1, s_{1,1} + 2p_1 + \delta_1, s_{2,1,2} + \delta_2, s_{2,1,2}}$
$\tilde{L}'_2$	12	13	14	15
Precoder	$\tilde{W}^{(3)}_{s_{1,1} + 3p_1, s_{1,1} + 3p_1 + \delta_1, s_{2,1,2}, s_{2,1,2} + \delta_2}$	$\tilde{W}^{(3)}_{s_{1,1} + 3p_1 + \delta_1, s_{1,1}, s_{2,1,2} + \delta_2, s_{2,1,2}}$	$\tilde{W}^{(3)}_{s_{1,1} + 3p_1, s_{1,1} + 3p_1 + \delta_1, s_{2,1,2}, s_{2,1,2} + \delta_2}$	$\tilde{W}^{(3)}_{s_{1,1} + 3p_1 + \delta_1, s_{1,1} + 3p_1 + \delta_1, s_{2,1,2} + \delta_2, s_{2,1,2}}$
$\tilde{L}'_2$	16-31			
Precoder	Entries 16-31 constructed with replacing $s_{1,1}$ in third and fourth subscripts with $s_{1,1} + p_1$ in entries 0-15.			

【Figure 75】

i_2'	0	1	2	3
Precode r	$W^{(+)}_{s_1 i_{1,1}, s_1 i_{1,1} + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2, 0}$	$W^{(+)}_{s_1 i_{1,1}, s_1 i_{1,1} + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2, 1}$	$W^{(+)}_{s_1 i_{1,1} + p_1, s_1 i_{1,1} + p_1 + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2, 0}$	$W^{(+)}_{s_1 i_{1,1} + p_1, s_1 i_{1,1} + p_1 + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2, 1}$
i_2'	4	5	6	7
Precode r	$W^{(+)}_{s_1 i_{1,1} + 2p_1, s_1 i_{1,1} + 2p_1 + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2, 0}$	$W^{(+)}_{s_1 i_{1,1} + 2p_1, s_1 i_{1,1} + 2p_1 + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2, 1}$	$W^{(+)}_{s_1 i_{1,1} + 3p_1, s_1 i_{1,1} + 3p_1 + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2, 0}$	$W^{(+)}_{s_1 i_{1,1} + 3p_1, s_1 i_{1,1} + 3p_1 + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2, 1}$
i_2'	8 - 15			
Precode r	Entries 8-15 constructed with replacing $s_2 i_{1,2}$ in third and fourth subscripts with $s_2 i_{1,2} + p_2$ in entries 0 - 7.			

【Figure 76】

i_2'	0	1	
Precoder	$\mathcal{W}^{(3)}$ $s_{1i,1} + \sigma_{1,0}^0 s_{1i,1} + \sigma_{1,1}^0 s_{2i,2} + \sigma_{2,0}^0 s_{2i,2} + \sigma_{2,1}^0$	$\mathcal{W}^{(3)}$ $s_{1i,1} + \sigma_{1,1}^0 s_{1i,1} + \sigma_{1,0}^0 s_{2i,2} + \sigma_{2,1}^0 s_{2i,2} + \sigma_{2,0}^0$	
i_2'	2	3	
Precoder	$\widetilde{\mathcal{W}}^{(3)}$ $s_{1i,1} + \sigma_{1,0}^0 s_{1i,1} + \sigma_{1,1}^0 s_{2i,2} + \sigma_{2,0}^0 s_{2i,2} + \sigma_{2,1}^0$	$\widetilde{\mathcal{W}}^{(3)}$ $s_{1i,1} + \sigma_{1,1}^0 s_{1i,1} + \sigma_{1,0}^0 s_{2i,2} + \sigma_{2,1}^0 s_{2i,2} + \sigma_{2,0}^0$	
i_2'	4-15		
Precoder	Entries 4-15 constructed with replacing the superscript 0 in $\sigma_{1,0}^{(0)}$, $\sigma_{2,0}^{(0)}$, and $\sigma_{2,1}^{(0)}$ with 1, 2, and 3.		

【Figure 77】

i_2'	0	1	
Precoder	$\mathcal{W}^{(4)}_{i_1,1} + \delta_{i_1,0}^0 s_{i_1,1} + \delta_{i_1,1}^0 s_{i_1,2} + \delta_{i_1,2}^0 s_{i_1,0}$	$\mathcal{W}^{(4)}_{i_1,1} + \delta_{i_1,0}^0 s_{i_1,1} + \delta_{i_1,1}^0 s_{i_1,2} + \delta_{i_1,2}^0 s_{i_1,0}$	
i_2'	2-7		
Precoder	Entries 2-7 constructed with replacing the superscript 0 in $\delta_{i_1,0}^{(0)}$, $\delta_{i_1,1}^{(0)}$, and $\delta_{i_1,2}^{(0)}$ with 1, 2, and 3.		

【Figure 78】

i'_2	0	1	
Precoder	$\tilde{W}^{(3)}$ $s_{1,1} + \sigma_{1,0} s_{1,1} + \sigma_{1,1} s_{2,2} + \sigma_{2,0} s_{2,2} + \sigma_{2,1}$	$\tilde{W}^{(3)}$ $s_{1,1} + \sigma_{1,1} s_{1,1} + \sigma_{1,0} s_{2,2} + \sigma_{2,1} s_{2,2} + \sigma_{2,0}$	
i'_2	2	3	
Precoder	$\tilde{W}^{(3)}$ $s_{1,1} + \sigma_{1,0} s_{1,1} + \sigma_{1,1} s_{2,2} + \sigma_{2,0} s_{2,2} + \sigma_{2,1}$	$\tilde{W}^{(3)}$ $s_{1,1} + \sigma_{1,1} s_{1,1} + \sigma_{1,0} s_{2,2} + \sigma_{2,1} s_{2,2} + \sigma_{2,0}$	
i'_2	4 - (4K-1)		
Precoder	Entries 4 - (4K-1) constructed with replacing the superscript 0 in $\delta_{i,0}^{(0)}$, $\delta_{i,0}^{(0)}$, and $\delta_{i,1}^{(0)}$ with 1,...,K-1 in entries 0-3.		

【Figure 79】

i'_2	0	1
Precoder	$W^{(4)}_{s_1 i_{1,1} + \delta_{1,0}^0, s_1 i_{1,1} + \delta_{1,1}^0, s_2 i_{1,2} + \delta_{2,0}^0, s_2 i_{1,2} + \delta_{2,1}^0, 0}$	$W^{(4)}_{s_1 i_{1,1} + \delta_{1,0}^0, s_1 i_{1,1} + \delta_{1,1}^0, s_2 i_{1,2} + \delta_{2,0}^0, s_2 i_{1,2} + \delta_{2,1}^0, 1}$
i'_2	2 - (2K-1)	
Precoder	Entries 2 - (2K-1) constructed with replacing the superscript 0 in $\delta_{1,0}^{(0)}$, $\delta_{2,0}^{(0)}$, $\delta_{1,1}^{(0)}$, and $\delta_{2,1}^{(0)}$ with 1...K-1 in entries 0-1.	

【Figure 80】

i'_2	0	1	
Precoder	$\mathcal{W}^{(3)}$ $s_{1i_{1,1}} + \sigma_{1,0}^0, s_{1i_{1,1}} + \sigma_{1,1}^0, s_{2i_{1,2}} + \sigma_{2,0}^0, s_{2i_{1,2}} + \sigma_{2,1}^0$	$\mathcal{W}^{(3)}$ $s_{1i_{1,1}} + \sigma_{1,1}^0, s_{1i_{1,1}} + \sigma_{1,0}^0, s_{2i_{1,2}} + \sigma_{2,1}^0, s_{2i_{1,2}} + \sigma_{2,0}^0$	
i'_2	2	3	
Precoder	$\tilde{\mathcal{W}}^{(3)}$ $s_{1i_{1,1}} + \sigma_{1,0}^0, s_{1i_{1,1}} + \sigma_{1,1}^0, s_{2i_{1,2}} + \sigma_{2,0}^0, s_{2i_{1,2}} + \sigma_{2,1}^0$	$\tilde{\mathcal{W}}^{(3)}$ $s_{1i_{1,1}} + \sigma_{1,1}^0, s_{1i_{1,1}} + \sigma_{1,0}^0, s_{2i_{1,2}} + \sigma_{2,1}^0, s_{2i_{1,2}} + \sigma_{2,0}^0$	
i'_2	4-15		
Precoder	Entries 4-15 constructed with replacing $s_{1i_{1,1}}$ in first and second subscripts with $s_{1i_{1,1}} + p_1$, $s_{1i_{1,1}} + 2p_1$, and $s_{1i_{1,1}} + 3p_1$ in entries 0-3.		
i'_2	16-31		
Precoder	Entries 16-31 constructed with replacing $s_{2i_{1,2}}$ in third and fourth subscripts with $s_{2i_{1,2}} + p_2$ in entries 0-15.		
i'_2	32-(32K-1)		
Precoder	Entries 32-(32K-1) constructed with replacing the superscript 0 in $\sigma_{1,0}^{(0)}$, $\sigma_{2,0}^{(0)}$, $\sigma_{1,1}^{(0)}$, and $\sigma_{2,1}^{(0)}$ with 1,...,K-1 in entries 0-31.		

【Figure 81】

i'_2	0	1	
Precoder	$W^{(4)}$ $s_{i_{1,1}} + \delta_{i_{1,0}}^{(0)} s_{i_{1,1}} + \delta_{i_{1,1}}^{(0)} s_{i_{1,2}} + \delta_{i_{2,0}}^{(0)} s_{i_{2,1}} + \delta_{i_{2,1}}^{(0)} s_{i_{2,2}} + \delta_{i_{2,2}}^{(0)} s_{i_{2,1}} + \delta_{i_{2,1}}^{(0)} s_{i_{2,2}}$	$W^{(4)}$ $s_{i_{1,1}} + \delta_{i_{1,0}}^{(0)} s_{i_{1,1}} + \delta_{i_{1,1}}^{(0)} s_{i_{1,2}} + \delta_{i_{2,0}}^{(0)} s_{i_{2,1}} + \delta_{i_{2,1}}^{(0)} s_{i_{2,2}} + \delta_{i_{2,2}}^{(0)} s_{i_{2,1}} + \delta_{i_{2,1}}^{(0)} s_{i_{2,2}}$	
i'_2	2-7		
Precoder	Entries 2-7 constructed with replacing $s_{i_{1,1}}$ in first and second subscripts with $s_{i_{1,1}} + p_1$, $s_{i_{1,1}} + 2p_1$, and $s_{i_{1,1}} + 3p_1$ in entries 0 - 1.		
i'_2	8-15		
Precoder	Entries 8-15 constructed with replacing $s_{i_{1,2}}$ in third and fourth subscripts with $s_{i_{1,2}} + p_2$ in entries 0 - 7.		
i'_2	16 - (16K-1)		
Precoder	Entries 16 - (16K-1) constructed with replacing the superscript 0 in $\delta_{i_{1,0}}^{(0)}$, $\delta_{i_{1,1}}^{(0)}$, and $\delta_{i_{2,1}}^{(0)}$ with 1, ..., K-1 in entries 0-15.		

【Figure 82】

i'_{12}	0	1	2	3
$i_{1,1}, i_{1,2},$ k	$\mathcal{W}^{(3)}_{s_1 h_{1,1}, s_1 h_{1,1} + \delta_1, s_2 h_{1,2}, s_2 h_{1,2} + \delta_2}$	$\mathcal{W}^{(3)}_{s_1 h_{1,1} + \delta_1, s_1 h_{1,1}, s_2 h_{1,2} + \delta_2, s_2 h_{1,2}}$	$\tilde{\mathcal{W}}^{(3)}_{s_1 h_{1,1}, s_1 h_{1,1} + \delta_1, s_2 h_{1,2}, s_2 h_{1,2} + \delta_2}$	$\tilde{\mathcal{W}}^{(3)}_{s_1 h_{1,1} + \delta_1, s_1 h_{1,1}, s_2 h_{1,2} + \delta_2, s_2 h_{1,2}}$
i'_{12}	4	5	6	7
$i_{1,1}, i_{1,2},$ k	$\mathcal{W}^{(3)}_{s_1 h_{1,1} + p_1, s_1 h_{1,1} + p_1 + \delta_1, s_2 h_{1,2}, s_2 h_{1,2} + \delta_2}$	$\mathcal{W}^{(3)}_{s_1 h_{1,1} + p_1 + \delta_1, s_1 h_{1,1} + p_1, s_2 h_{1,2} + \delta_2, s_2 h_{1,2}}$	$\tilde{\mathcal{W}}^{(3)}_{s_1 h_{1,1} + p_1, s_1 h_{1,1} + p_1 - \delta_1, s_2 h_{1,2}, s_2 h_{1,2} + \delta_2}$	$\tilde{\mathcal{W}}^{(3)}_{s_1 h_{1,1} + p_1 + \delta_1, s_1 h_{1,1} + p_1, s_2 h_{1,2} + \delta_2, s_2 h_{1,2}}$
i'_{12}	8	9	10	11
$i_{1,1}, i_{1,2},$ k	$\mathcal{W}^{(3)}_{s_1 h_{1,1} + 2p_1 - \delta_1, s_1 h_{1,1} + 2p_1 - \delta_1, s_2 h_{1,2}, s_2 h_{1,2} + \delta_2}$	$\mathcal{W}^{(3)}_{s_1 h_{1,1} + 2p_1 + \delta_1, s_1 h_{1,1} + 2p_1, s_2 h_{1,2} + \delta_2, s_2 h_{1,2}}$	$\tilde{\mathcal{W}}^{(3)}_{s_1 h_{1,1} - 2p_1, s_1 h_{1,1} + 2p_1 + \delta_1, s_2 h_{1,2}, s_2 h_{1,2} + \delta_2}$	$\tilde{\mathcal{W}}^{(3)}_{s_1 h_{1,1} + 2p_1 + \delta_1, s_1 h_{1,1} + 2p_1, s_2 h_{1,2} + \delta_2, s_2 h_{1,2}}$
i'_{12}	12	13	14	15
$i_{1,1}, i_{1,2},$ k	$\mathcal{W}^{(3)}_{s_1 h_{1,1} + 3p_1 - \delta_1, s_1 h_{1,1} + 3p_1 - \delta_1, s_2 h_{1,2}, s_2 h_{1,2} + \delta_2}$	$\mathcal{W}^{(3)}_{s_1 h_{1,1} + 3p_1 + \delta_1, s_1 h_{1,1} + 3p_1, s_2 h_{1,2} + \delta_2, s_2 h_{1,2}}$	$\tilde{\mathcal{W}}^{(3)}_{s_1 h_{1,1} + 3p_1, s_1 h_{1,1} + 3p_1 + \delta_1, s_2 h_{1,2}, s_2 h_{1,2} + \delta_2}$	$\tilde{\mathcal{W}}^{(3)}_{s_1 h_{1,1} + 3p_1 + \delta_1, s_1 h_{1,1} + 3p_1, s_2 h_{1,2} + \delta_2, s_2 h_{1,2}}$
i'_{12}	16 - 31			
$i_{1,1}, i_{1,2},$ k	Entries 16-31 constructed with replacing $s_1 h_{1,1}$ in third and fourth subscripts with $s_1 h_{1,1} + p_1$ in entries 0 - 15.			

[Figure 83]

i'_2	0	1	2	3
$i_{1,1}$				
$i_{1,2}$	$W^{(4)}_{s_1 i_{1,1}, s_1 i_{1,1} + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2, 0}$	$W^{(4)}_{s_1 i_{1,1}, s_1 i_{1,1} + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2, 1}$	$W^{(4)}_{s_1 i_{1,1} + p_1, s_1 i_{1,1} + p_1 + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2, 0}$	$W^{(4)}_{s_1 i_{1,1} + p_1, s_1 i_{1,1} + p_1 + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2, 1}$
k				
i'_2	4	5	6	7
$i_{1,1}$				
$i_{1,2}$	$W^{(4)}_{s_1 i_{1,1} + 2p_1, s_1 i_{1,1} + 2p_1 + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2, 0}$	$W^{(4)}_{s_1 i_{1,1} + 2p_1, s_1 i_{1,1} + 2p_1 + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2, 1}$	$W^{(4)}_{s_1 i_{1,1} + 3p_1, s_1 i_{1,1} + 3p_1 + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2, 0}$	$W^{(4)}_{s_1 i_{1,1} + 3p_1, s_1 i_{1,1} + 3p_1 + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2, 1}$
k				
i'_2	8-15			
$i_{1,1}$	Entries 8-15 constructed with replacing $s_2 i_{1,2}$ in third and fourth subscripts with $s_2 i_{1,2} + p_2$ in entries 0-7.			
$i_{1,2}$				
k				

[Figure 84a]

$i'_{1,2}$	0	1	2	3
$i_{1,1}, i_{1,2}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 0}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 1}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 0}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 1}$
$i'_{1,2}$	4	5	6	7
$i_{1,1}, i_{1,2}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 0}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 1}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 0}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 1}$
$i'_{1,2}$	8	9	10	11
$i_{1,1}, i_{1,2}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 0}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 1}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 0}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 1}$
$i'_{1,2}$	12	13	14	15
$i_{1,1}, i_{1,2}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 0}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 1}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 0}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 1}$
$i'_{1,2}$	16	17	18	19
$i_{1,1}, i_{1,2}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 0}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 1}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 0}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 1}$
$i'_{1,2}$	20	21	22	23
$i_{1,1}, i_{1,2}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 0}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 1}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 0}$	$W^{(2)}_{s_{1,1}, s_{1,1}, s_{2,1}, s_{2,1}, s_{2,2}, 1}$

【Figure 84b】

[illegible]

【Figure 85】

i'_2	0	1	2	3
$i_{1,1}, i_{1,2}, k$	$W^{(3)}_{s_1 i_{1,1}, s_1 i_{1,1} + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2}$	$W^{(3)}_{s_1 i_{1,1} + \delta_1, s_1 i_{1,1}, s_2 i_{1,2} + \delta_2, s_2 i_{1,2}}$	$\tilde{W}^{(3)}_{s_1 i_{1,1}, s_1 i_{1,1} + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2}$	$\tilde{W}^{(3)}_{s_1 i_{1,1} + \delta_1, s_1 i_{1,1}, s_2 i_{1,2} + \delta_2, s_2 i_{1,2}}$
i'_2	4	5	6	7
$i_{1,1}, i_{1,2}, k$	$W^{(3)}_{s_1 i_{1,1} - p_1, s_1 i_{1,1} - p_1 + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2}$	$W^{(3)}_{s_1 i_{1,1} + p_1 + \delta_1, s_1 i_{1,1} + p_1, s_2 i_{1,2} + \delta_2, s_2 i_{1,2}}$	$\tilde{W}^{(3)}_{s_1 i_{1,1} + p_1, s_1 i_{1,1} + p_1 + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2}$	$\tilde{W}^{(3)}_{s_1 i_{1,1} + p_1 + \delta_1, s_1 i_{1,1} + p_1, s_2 i_{1,2} + \delta_2, s_2 i_{1,2}}$
i'_2	8	9	10	11
$i_{1,1}, i_{1,2}, k$	$W^{(3)}_{s_1 i_{1,1} - 2p_1, s_1 i_{1,1} - 2p_1 + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2}$	$W^{(3)}_{s_1 i_{1,1} + 2p_1 - \delta_1, s_1 i_{1,1} + 2p_1, s_2 i_{1,2} + \delta_2, s_2 i_{1,2}}$	$\tilde{W}^{(3)}_{s_1 i_{1,1} - 2p_1, s_1 i_{1,1} - 2p_1 + \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2}$	$\tilde{W}^{(3)}_{s_1 i_{1,1} - 2p_1 + \delta_1, s_1 i_{1,1} - 2p_1, s_2 i_{1,2} + \delta_2, s_2 i_{1,2}}$
i'_2	12	13	14	15
$i_{1,1}, i_{1,2}, k$	$W^{(3)}_{s_1 i_{1,1} + 3p_1, s_1 i_{1,1} + 3p_1 - \delta_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2}$	$W^{(3)}_{s_1 i_{1,1} - 3p_1 + \delta_1, s_1 i_{1,1} - 3p_1, s_2 i_{1,2} + \delta_2, s_2 i_{1,2}}$	$\tilde{W}^{(3)}_{s_1 i_{1,1} + 3p_1 - \delta_1, s_1 i_{1,1} + 3p_1, s_2 i_{1,2}, s_2 i_{1,2} + \delta_2}$	$\tilde{W}^{(3)}_{s_1 i_{1,1} + 3p_1 - \delta_1, s_1 i_{1,1} + 3p_1, s_2 i_{1,2} + \delta_2, s_2 i_{1,2}}$
i'_2	16-31			
$i_{1,1}, i_{1,2}, k$	Entries 16-31 constructed with replacing $s_2 i_{1,2}$ in third and fourth subscripts with $s_2 i_{1,2} + p_2$ in entries 0 - 15.			

[Figure 86]

i'_2	0	1	2	3
$i_{1,1}$				
$i_{1,2}$	$W^{(4)}$ $s_{1,1}, s_{1,1} + \delta_1, s_{2,1,2}, s_{2,1,2} + \delta_{2,0}$	$W^{(4)}$ $s_{1,1}, s_{1,1} + \delta_1, s_{2,1,2}, s_{2,1,2} + \delta_{2,1}$	$W^{(4)}$ $s_{1,1}, s_{1,1} + p_1, s_{2,1,2}, s_{2,1,2} + \delta_{2,0}$	$W^{(4)}$ $s_{1,1}, s_{1,1} + p_1, s_{2,1,2}, s_{2,1,2} + \delta_{2,1}$
k				
i'_2	4	5	6	7
$i_{1,1}$				
$i_{1,2}$	$W^{(4)}$ $s_{1,1}, s_{1,1} + 2p_1 + \delta_1, s_{2,1,2}, s_{2,1,2} + \delta_{2,0}$	$W^{(4)}$ $s_{1,1}, s_{1,1} + 2p_1 + \delta_1, s_{2,1,2}, s_{2,1,2} + \delta_{2,1}$	$W^{(4)}$ $s_{1,1}, s_{1,1} + 3p_1 + \delta_1, s_{2,1,2}, s_{2,1,2} + \delta_{2,0}$	$W^{(4)}$ $s_{1,1}, s_{1,1} + 3p_1 + \delta_1, s_{2,1,2}, s_{2,1,2} + \delta_{2,1}$
k				
i'_2	8-15			
$i_{1,1}$				
$i_{1,2}$				
k				

Entries 8-15 constructed with replacing $s_{1,1}$ in third and fourth subscripts with $s_{1,1} + p_i$ in entries 0-7.

【Figure 88a】

Value of Codebook-Config		i_{t1}	i_{t2}	i_2			
				0	1	2	3
1		$0,1,\dots,O_1N_1-1$	$0,1,\dots,O_2N_2-1$	$W_{i_1,i_1,i_2,i_2,0}^{(2)}$	$W_{i_1,i_1,i_2,i_2,1}^{(2)}$	$W_{i_1,i_1,i_2,i_2,2}^{(2)}$	$W_{i_1,i_1,i_2,i_2,3}^{(2)}$
	where $W_{l',m',n}^{(2)}$	$= \frac{1}{\sqrt{2P}} \begin{bmatrix} v_{l',m} & v_{l',m} \\ \varphi n v_{l',m} & -\varphi n v_{l',m} \end{bmatrix}$					

【Figure 88b】

Value of Codebook-Config	i_{t1}	i_{t2}	i_2	1	2	3
2	$q_{1, \dots, \frac{N_1 Q_1}{2} - 1}$	$q_{1, \dots, \frac{N_2 Q_2}{2} - 1}$	0	$W_{2h_{1,1}, 2h_{1,1}, 2h_{1,2}, 2h_{1,2}, 1}^{(2)}$	$W_{2h_{1,1}, 2h_{1,1}, 2h_{1,2}, 2h_{1,2}, 0}^{(2)}$	$W_{2h_{1,1}, 2h_{1,1}, 2h_{1,2}, 2h_{1,2}, 1}^{(2)}$
Value of Codebook-Config	i_{t1}	i_{t2}	i_2	4	5	6
2	$q_{1, \dots, \frac{N_1 Q_1}{2} - 1}$	$q_{1, \dots, \frac{N_2 Q_2}{2} - 1}$	4	$W_{2h_{1,1}, 2h_{1,1}, 2h_{1,2}, 2h_{1,2}, 1}^{(2)}$	$W_{2h_{1,1}, 2h_{1,1}, 2h_{1,2}, 2h_{1,2}, 0}^{(2)}$	$W_{2h_{1,1}, 2h_{1,1}, 2h_{1,2}, 2h_{1,2}, 1}^{(2)}$
Value of Codebook-Config	i_{t1}	i_{t2}	i_2	8	9	10
2	$q_{1, \dots, \frac{N_1 Q_1}{2} - 1}$	$q_{1, \dots, \frac{N_2 Q_2}{2} - 1}$	8	$W_{2h_{1,1}, 2h_{1,1}, 2h_{1,2}, 2h_{1,2}, 0}^{(2)}$	$W_{2h_{1,1}, 2h_{1,1}, 2h_{1,2}, 2h_{1,2}, 1}^{(2)}$	$W_{2h_{1,1}, 2h_{1,1}, 2h_{1,2}, 2h_{1,2}, 1}^{(2)}$
Value of Codebook-Config	i_{t1}	i_{t2}	i_2	12	13	14
2	$q_{1, \dots, \frac{N_1 Q_1}{2} - 1}$	$q_{1, \dots, \frac{N_2 Q_2}{2} - 1}$	12	$W_{2h_{1,1}, 2h_{1,1}, 2h_{1,2}, 2h_{1,2}, 1}^{(2)}$	$W_{2h_{1,1}, 2h_{1,1}, 2h_{1,2}, 2h_{1,2}, 1}^{(2)}$	$W_{2h_{1,1}, 2h_{1,1}, 2h_{1,2}, 2h_{1,2}, 1}^{(2)}$
where $W_{l, l', m, m'}^{(2)} = \frac{1}{\sqrt{2P}} \begin{bmatrix} v_{l, m} & v_{l', m'} \\ \varphi_n v_{l, m} & -\varphi_n v_{l', m'} \end{bmatrix}$; If $N_1 > N_2$, then $p = 1$ otherwise $p = 0$.						

【Figure 88c】

Value of Codebook-Config	i_{11}	i_{12}	i_2	1	2	3
3	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2x, 2x, 2y, 2y, 0}^{(2)}$	$W_{2x, 2x, 2y, 2y, 1}^{(2)}$	$W_{2x+1, 2x+1, 2y+1, 2y+1, 0}^{(2)}$	$W_{2x+1, 2x+1, 2y+1, 2y+1, 1}^{(2)}$
Value of Codebook-Config	i_{11}	i_{12}	i_2	5	6	7
3	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2x+2, 2x+2, 2y, 2y, 0}^{(2)}$	$W_{2x+2, 2x+2, 2y, 2y, 1}^{(2)}$	$W_{2x+3, 2x+3, 2y+1, 2y+1, 0}^{(2)}$	$W_{2x+3, 2x+3, 2y+1, 2y+1, 1}^{(2)}$
Value of Codebook-Config	i_{11}	i_{12}	i_2	9	10	11
3	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2x, 2x+1, 2y, 2y+1, 0}^{(2)}$	$W_{2x, 2x+1, 2y, 2y+1, 1}^{(2)}$	$W_{2x+1, 2x+2, 2y+1, 2y, 0}^{(2)}$	$W_{2x+1, 2x+2, 2y+1, 2y, 1}^{(2)}$
Value of Codebook-Config	i_{11}	i_{12}	i_2	13	14	15
3	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2x, 2x+3, 2y, 2y+1, 0}^{(2)}$	$W_{2x, 2x+3, 2y, 2y+1, 1}^{(2)}$	$W_{2x+1, 2x+3, 2y+1, 2y+1, 0}^{(2)}$	$W_{2x+1, 2x+3, 2y+1, 2y+1, 1}^{(2)}$
where $x = i_{11}$, $y = i_{12}$, $W_{i_{11}, i_{12}, y}^{(2)} = \frac{1}{\sqrt{2P}} \begin{bmatrix} v_{i_{11}, y} & v_{i_{12}, y} \\ \varphi_1 v_{i_{11}, y} & -\varphi_2 v_{i_{12}, y} \end{bmatrix}$ if $N_1 \geq N_2$ and $x = i_{12}$, $y = i_{11}$, $W_{i_{12}, i_{11}, y}^{(2)} = \frac{1}{\sqrt{2P}} \begin{bmatrix} v_{i_{12}, y} & v_{i_{11}, y} \\ \varphi_1 v_{i_{12}, y} & -\varphi_2 v_{i_{11}, y} \end{bmatrix}$, if $N_1 < N_2$						

[Figure 88d]

Value of Codebook-Config	i_{11}	i_{12}	i_2	1	2	3
4	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2x, 2x, 2y, 2y, 0}^{(2)}$	$W_{2x, 2x, 2y, 2y, 1}^{(2)}$	$W_{2x+1, 2x+1, 2y, 2y, 0}^{(2)}$	$W_{2x+1, 2x+1, 2y, 2y, 1}^{(2)}$
Value of Codebook-Config	i_{11}	i_{12}	i_2	5	6	7
4	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2x+2, 2x+2, 2y, 2y, 0}^{(2)}$	$W_{2x+2, 2x+2, 2y, 2y, 1}^{(2)}$	$W_{2x+3, 2x+3, 2y, 2y, 0}^{(2)}$	$W_{2x+3, 2x+3, 2y, 2y, 1}^{(2)}$
Value of Codebook-Config	i_{11}	i_{12}	i_2	9	10	11
4	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2x, 2x+1, 2y, 2y, 0}^{(2)}$	$W_{2x, 2x+1, 2y, 2y, 1}^{(2)}$	$W_{2x+1, 2x+1, 2y, 2y, 0}^{(2)}$	$W_{2x+1, 2x+1, 2y, 2y, 1}^{(2)}$
Value of Codebook-Config	i_{11}	i_{12}	i_2	13	14	15
4	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2x, 2x+3, 2y, 2y, 0}^{(2)}$	$W_{2x, 2x+3, 2y, 2y, 1}^{(2)}$	$W_{2x+1, 2x+3, 2y, 2y, 0}^{(2)}$	$W_{2x+1, 2x+3, 2y, 2y, 1}^{(2)}$
where $x = i_{11}$, $y = i_{12}$, $W_{i, j, m, m'}^{(2)} = \frac{1}{\sqrt{2P}} \begin{bmatrix} v_{i, m} & v_{i, m'} \\ \phi_n v_{i, m} & -\phi_n v_{i, m'} \end{bmatrix}$ if $N_1 \geq N_2$ and $x = i_{12}$, $y = i_{11}$, $W_{i, j, m, m'}^{(2)} = \frac{1}{\sqrt{2P}} \begin{bmatrix} v_{m, j} & v_{m, j'} \\ \phi_n v_{m, j} & -\phi_n v_{m, j'} \end{bmatrix}$, if $N_1 < N_2$						

【Figure 89a】

$N_1 > 1, N_2 > 1$			
Value of Codebook-Config		i_{12}	i_2
1		0	1
$0, 1, \dots, O_1 N_1 - 1$		$0, 1, \dots, O_2 N_2 - 1$	$\tilde{W}_{i_{1,1}, i_{1,2} + O_1, i_{1,2}, i_{1,2}}^{(3)}$
$O_1 N_1, O_1 N_1 + 1, \dots, 2O_1 N_1 - 1$		$0, 1, \dots, O_2 N_2 - 1$	$\tilde{W}_{i_{1,1}, i_{1,1}, i_{1,2}, i_{1,2} + O_2}^{(3)}$
$W_{l,i,m,m'}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l,m'} & v_{l,m'} \\ v_{l,m} & -v_{l,m} & -v_{l,m'} & -v_{l,m'} \end{bmatrix}$ where $\tilde{W}_{l,i,m,m'}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{l,m} & v_{l,m'} & v_{l,m'} & v_{l,m'} \\ v_{l,m} & v_{l,m} & v_{l,m'} & -v_{l,m'} \end{bmatrix}$ and $\tilde{W}_{l,i,m,m'}^{(3)}$			
$N_2 = 1$			
Value of Codebook-Config		i_{12}	i_2
1		0	1
$0, 1, \dots, O_1 N_1 - 1$		0	$\tilde{W}_{i_{1,1}, i_{1,1} + O_1, 0, 0}^{(3)}$
$O_1 N_1, O_1 N_1 + 1, \dots, 2O_1 N_1 - 1$		0	$\tilde{W}_{i_{1,1}, i_{1,1} + 2O_1, 0, 0}^{(3)}$
$2O_1 N_1, \dots, 3O_1 N_1 - 1$		0	$\tilde{W}_{i_{1,1}, i_{1,1} + 3O_1, 0, 0}^{(3)}$
$W_{l,i,m,m'}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l,m'} & v_{l,m'} \\ v_{l,m} & -v_{l,m} & -v_{l,m'} & -v_{l,m'} \end{bmatrix}$ where $\tilde{W}_{l,i,m,m'}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l,m'} & v_{l,m'} \\ v_{l,m} & v_{l,m} & v_{l,m'} & -v_{l,m'} \end{bmatrix}$ and $\tilde{W}_{l,i,m,m'}^{(3)}$			

【Figure 89b】

Value	i_{t1}	i_{t2}	i_2	1	2	3
Codebook-Config						
2	$0, \dots, 2N_i - 1$	i_{t2}	0	$W_{2i_{t1}, 2i_{t1}+4, 2i_{t2}, 2i_{t2}}^{(3)}$	$\tilde{W}_{2i_{t1}, 2i_{t1}+4, 2i_{t2}, 2i_{t2}}^{(3)}$	$\tilde{W}_{2i_{t1}, 2i_{t1}+4, 2i_{t2}, 2i_{t2}}^{(3)}$
	$2N_i, \dots, 4N_i - 1$	i_{t2}	$W_{2i_{t1}, 2i_{t1}, 2i_{t2}, 2i_{t2}+4}^{(3)}$	$W_{2i_{t1}, 2i_{t1}, 2i_{t2}+4, 2i_{t2}}^{(3)}$	$\tilde{W}_{2i_{t1}, 2i_{t1}, 2i_{t2}+4, 2i_{t2}}^{(3)}$	$\tilde{W}_{2i_{t1}, 2i_{t1}, 2i_{t2}+4, 2i_{t2}}^{(3)}$
Value			i_2	5	6	7
Codebook-Config		i_{t2}	4			
2	$0, \dots, 2N_i - 1$	$0, 1, \dots, 2N_i - 1$	$W_{2i_{t1}, 2i_{t1}+5, 2i_{t2}, 2i_{t2}}^{(3)}$	$W_{2i_{t1}, 2i_{t1}+5, 2i_{t2}, 2i_{t2}}^{(3)}$	$\tilde{W}_{2i_{t1}, 2i_{t1}+5, 2i_{t2}, 2i_{t2}}^{(3)}$	$\tilde{W}_{2i_{t1}, 2i_{t1}+5, 2i_{t2}, 2i_{t2}}^{(3)}$
	$2N_i, \dots, 4N_i - 1$	$0, 1, \dots, 2N_i - 1$	$W_{2i_{t1}, 2i_{t1}+1, 2i_{t2}, 2i_{t2}+4}^{(3)}$	$W_{2i_{t1}, 2i_{t1}+1, 2i_{t2}, 2i_{t2}+4}^{(3)}$	$\tilde{W}_{2i_{t1}, 2i_{t1}+1, 2i_{t2}, 2i_{t2}+4}^{(3)}$	$\tilde{W}_{2i_{t1}, 2i_{t1}+1, 2i_{t2}, 2i_{t2}+4}^{(3)}$
Value			i_2	9	10	11
Codebook-Config		i_{t2}	8			
2	$0, \dots, 2N_i - 1$	$0, 1, \dots, 2N_i - 1$	$W_{2i_{t1}, 2i_{t1}+4, 2i_{t2}, 1, 2i_{t2}, 1}^{(3)}$	$W_{2i_{t1}, 2i_{t1}+4, 2i_{t2}, 1, 2i_{t2}, 1}^{(3)}$	$\tilde{W}_{2i_{t1}, 2i_{t1}+4, 2i_{t2}, 1, 2i_{t2}, 1}^{(3)}$	$\tilde{W}_{2i_{t1}, 2i_{t1}+4, 2i_{t2}, 1, 2i_{t2}, 1}^{(3)}$
	$2N_i, \dots, 4N_i - 1$	$0, 1, \dots, 2N_i - 1$	$W_{2i_{t1}, 2i_{t1}+1, 2i_{t2}, 1, 2i_{t2}, 5}^{(3)}$	$W_{2i_{t1}, 2i_{t1}+1, 2i_{t2}, 5, 2i_{t2}, 1}^{(3)}$	$\tilde{W}_{2i_{t1}, 2i_{t1}+1, 2i_{t2}, 5, 2i_{t2}, 1}^{(3)}$	$\tilde{W}_{2i_{t1}, 2i_{t1}+1, 2i_{t2}, 5, 2i_{t2}, 1}^{(3)}$
Value			i_2	13	14	15
Codebook-Config		i_{t2}	12			
2	$0, \dots, 2N_i - 1$	$0, 1, \dots, 2N_i - 1$	$W_{2i_{t1}, 1, 2i_{t2}, 1, 2i_{t2}, 1, 2i_{t2}, 1}^{(3)}$	$W_{2i_{t1}, 1, 2i_{t2}, 1, 2i_{t2}, 1, 2i_{t2}, 1}^{(3)}$	$\tilde{W}_{2i_{t1}, 1, 2i_{t2}, 1, 2i_{t2}, 1, 2i_{t2}, 1}^{(3)}$	$\tilde{W}_{2i_{t1}, 1, 2i_{t2}, 1, 2i_{t2}, 1, 2i_{t2}, 1}^{(3)}$
	$2N_i, \dots, 4N_i - 1$	$0, 1, \dots, 2N_i - 1$	$W_{2i_{t1}, 1, 2i_{t2}, 1, 2i_{t2}, 1, 2i_{t2}, 5}^{(3)}$	$W_{2i_{t1}, 1, 2i_{t2}, 1, 2i_{t2}, 5, 2i_{t2}, 1}^{(3)}$	$\tilde{W}_{2i_{t1}, 1, 2i_{t2}, 1, 2i_{t2}, 5, 2i_{t2}, 1}^{(3)}$	$\tilde{W}_{2i_{t1}, 1, 2i_{t2}, 1, 2i_{t2}, 5, 2i_{t2}, 1}^{(3)}$
where $W_{i, j, m, m}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{O_1, O_2, \frac{1}{4}, i, \frac{1}{4}, m} & v_{O_1, O_2, \frac{1}{4}, i, \frac{1}{4}, m} & v_{O_1, O_2, \frac{1}{4}, i, \frac{1}{4}, m} \\ v_{O_1, O_2, \frac{1}{4}, i, \frac{1}{4}, m} & v_{O_1, O_2, \frac{1}{4}, i, \frac{1}{4}, m} & v_{O_1, O_2, \frac{1}{4}, i, \frac{1}{4}, m} \\ v_{O_1, O_2, \frac{1}{4}, i, \frac{1}{4}, m} & v_{O_1, O_2, \frac{1}{4}, i, \frac{1}{4}, m} & v_{O_1, O_2, \frac{1}{4}, i, \frac{1}{4}, m} \end{bmatrix}$, $\tilde{W}_{i, j, m, m}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{O_1, O_2, \frac{1}{4}, i, \frac{1}{4}, m} & v_{O_1, O_2, \frac{1}{4}, i, \frac{1}{4}, m} & v_{O_1, O_2, \frac{1}{4}, i, \frac{1}{4}, m} \\ v_{O_1, O_2, \frac{1}{4}, i, \frac{1}{4}, m} & v_{O_1, O_2, \frac{1}{4}, i, \frac{1}{4}, m} & v_{O_1, O_2, \frac{1}{4}, i, \frac{1}{4}, m} \\ v_{O_1, O_2, \frac{1}{4}, i, \frac{1}{4}, m} & v_{O_1, O_2, \frac{1}{4}, i, \frac{1}{4}, m} & v_{O_1, O_2, \frac{1}{4}, i, \frac{1}{4}, m} \end{bmatrix}$						

【Figure 89c】

Value of Codebook-Config	i_{l1}	i_{l2}	i_2	1	2	3
3	$0, \dots, N_1 - 1$ $N_1, \dots, 2N_1 - 1$	$0, \dots, 2N_1 - 1$	0	$W_{4x+2, 4x+6, 2y, 2y}^{(3)}$	$W_{4x+2, 4x+6, 2y, 2y}^{(3)}$	$W_{4x+6, 4x+2, 2y, 2y}^{(3)}$
			$W_{4x+2, 4x+2, 2y+4, 2y}^{(3)}$	$W_{4x+2, 4x+2, 2y+4, 2y}^{(3)}$	$W_{4x+2, 4x+2, 2y+4, 2y}^{(3)}$	
			i_2			
Value of Codebook-Config	i_{l1}	i_{l2}	4	5	6	7
	$0, \dots, N_1 - 1$ $N_1, \dots, 2N_1 - 1$	$0, \dots, 2N_1 - 1$	$W_{4x+7, 4x+3, 2y, 2y}^{(3)}$	$W_{4x+7, 4x+3, 2y, 2y}^{(3)}$	$W_{4x+7, 4x+3, 2y, 2y}^{(3)}$	
			$W_{4x+3, 4x+3, 2y+4, 2y}^{(3)}$	$W_{4x+3, 4x+3, 2y+4, 2y}^{(3)}$	$W_{4x+3, 4x+3, 2y+4, 2y}^{(3)}$	
i_2						
Value of Codebook-Config	i_{l1}	i_{l2}	8	9	10	11
	$0, \dots, N_1 - 1$ $N_1, \dots, 2N_1 - 1$	$0, \dots, 2N_1 - 1$	$W_{4x+4, 4x+4, 2y+1, 2y+1}^{(3)}$	$W_{4x+4, 4x+4, 2y+1, 2y+1}^{(3)}$	$W_{4x+4, 4x+4, 2y+1, 2y+1}^{(3)}$	
			$W_{4x+4, 4x+2y+1, 2y+5}^{(3)}$	$W_{4x+4, 4x+2y+1, 2y+5}^{(3)}$	$W_{4x+4, 4x+2y+1, 2y+5}^{(3)}$	
i_2						
Value of Codebook-Config	i_{l1}	i_{l2}	12	13	14	15
	$0, \dots, N_1 - 1$ $N_1, \dots, 2N_1 - 1$	$0, \dots, 2N_1 - 1$	$W_{4x+1, 4x+5, 2y+1, 2y+1}^{(3)}$	$W_{4x+1, 4x+5, 2y+1, 2y+1}^{(3)}$	$W_{4x+1, 4x+5, 2y+1, 2y+1}^{(3)}$	
			$W_{4x+1, 4x+1, 2y+1, 2y+5}^{(3)}$	$W_{4x+1, 4x+1, 2y+1, 2y+5}^{(3)}$	$W_{4x+1, 4x+1, 2y+1, 2y+5}^{(3)}$	
i_2						

where $x = i_{l1}, y = i_{l2}, W_{i,j,m,n}^{(3)} = \frac{1}{\sqrt{3P}} \left[\begin{matrix} v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} \\ v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} \\ v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} \end{matrix} \right], W_{i,j,m,n}^{(3)} = \frac{1}{\sqrt{3P}} \left[\begin{matrix} v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} \\ v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} \\ v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} \end{matrix} \right],$

if $N_1 \geq N_2$ and

$x = i_{l2}, y = i_{l1}, W_{i,j,m,n}^{(3)} = \frac{1}{\sqrt{3P}} \left[\begin{matrix} v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} \\ v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} \\ v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} \end{matrix} \right], W_{i,j,m,n}^{(3)} = \frac{1}{\sqrt{3P}} \left[\begin{matrix} v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} \\ v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} \\ v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} \end{matrix} \right],$

if $N_1 < N_2$.

where $x = i_{l1}$, $y = i_{l2}$, $W_{i,j,m,n}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} \\ v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} \end{bmatrix}$, $W_{i,j,m,n}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} \\ v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} \end{bmatrix}$, if $N_1 \geq N_2$ and

$x = i_{l2}$, $y = i_{l1}$, $W_{i,j,m,n}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} \\ v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} & -v_{\frac{Q}{4}, \frac{Q}{4}, m} \end{bmatrix}$, $W_{i,j,m,n}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} \\ v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} & v_{\frac{Q}{4}, \frac{Q}{4}, m} \end{bmatrix}$, if $N_1 < N_2$.

【Figure 89d】

$N_1 > 1, N_2 > 1$									
Value	of	i_{11}	i_{12}	i_2	1	2	3		
Codebook-Config									
4		$0, \dots, N_1 - 1$	$0, 1, \dots, \#N_1 - 1$	$W_{4x-4, 4x-4, y}^{(3)}$	$W_{4x-4, 4x-4, y}^{(3)}$	$\tilde{W}_{4x-4, 4x-4, y}^{(3)}$	$\tilde{W}_{4x-4, 4x-4, y}^{(3)}$		
		$N_1, \dots, 2N_1 - 1$	$0, 1, \dots, \#N_1 - 1$	$W_{4x-4, 4x-4, y+4}^{(3)}$	$W_{4x-4, 4x-4, y+4}^{(3)}$	$\tilde{W}_{4x-4, 4x-4, y+4}^{(3)}$	$\tilde{W}_{4x-4, 4x-4, y+4}^{(3)}$		
Value									
Codebook-Config									
4		$0, \dots, N_1 - 1$	$0, 1, \dots, \#N_1 - 1$	$W_{4x-1, 4x-5, y}^{(3)}$	$W_{4x-1, 4x-5, y}^{(3)}$	$\tilde{W}_{4x-1, 4x-5, y}^{(3)}$	$\tilde{W}_{4x-1, 4x-5, y}^{(3)}$		
		$N_1, \dots, 2N_1 - 1$	$0, 1, \dots, \#N_1 - 1$	$W_{4x-1, 4x-1, y+4}^{(3)}$	$W_{4x-1, 4x-1, y+4}^{(3)}$	$\tilde{W}_{4x-1, 4x-1, y+4}^{(3)}$	$\tilde{W}_{4x-1, 4x-1, y+4}^{(3)}$		
Value									
Codebook-Config									
4		$0, \dots, N_1 - 1$	$0, 1, \dots, \#N_1 - 1$	$W_{4x-2, 4x-6, y}^{(3)}$	$W_{4x-2, 4x-6, y}^{(3)}$	$\tilde{W}_{4x-2, 4x-6, y}^{(3)}$	$\tilde{W}_{4x-2, 4x-6, y}^{(3)}$		
		$N_1, \dots, 2N_1 - 1$	$0, 1, \dots, \#N_1 - 1$	$W_{4x-2, 4x-2, y+4}^{(3)}$	$W_{4x-2, 4x-2, y+4}^{(3)}$	$\tilde{W}_{4x-2, 4x-2, y+4}^{(3)}$	$\tilde{W}_{4x-2, 4x-2, y+4}^{(3)}$		
Value									
Codebook-Config									
4		$0, \dots, N_1 - 1$	$0, 1, \dots, \#N_1 - 1$	$W_{4x-3, 4x-7, y}^{(3)}$	$W_{4x-3, 4x-7, y}^{(3)}$	$\tilde{W}_{4x-3, 4x-7, y}^{(3)}$	$\tilde{W}_{4x-3, 4x-7, y}^{(3)}$		
		$N_1, \dots, 2N_1 - 1$	$0, 1, \dots, \#N_1 - 1$	$W_{4x-3, 4x-3, y+4}^{(3)}$	$W_{4x-3, 4x-3, y+4}^{(3)}$	$\tilde{W}_{4x-3, 4x-3, y+4}^{(3)}$	$\tilde{W}_{4x-3, 4x-3, y+4}^{(3)}$		

$\text{where } x = i_{11}, y = i_{12}, W_{i, j, m, m}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{Q_1, \frac{Q_2}{4}, m} & v_{Q_1, \frac{Q_2}{4}, m} & v_{Q_1, \frac{Q_2}{4}, m} \\ v_{Q_1, \frac{Q_2}{4}, m} & -v_{Q_1, \frac{Q_2}{4}, m} & -v_{Q_1, \frac{Q_2}{4}, m} \end{bmatrix}, \tilde{W}_{i, j, m, m}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{Q_1, \frac{Q_2}{4}, m} & v_{Q_1, \frac{Q_2}{4}, m} & v_{Q_1, \frac{Q_2}{4}, m} \\ v_{Q_1, \frac{Q_2}{4}, m} & -v_{Q_1, \frac{Q_2}{4}, m} & -v_{Q_1, \frac{Q_2}{4}, m} \end{bmatrix}, \text{ if } N_1 \geq N_2 \text{ and}$									
$x = i_{12}, y = i_{11}, W_{i, j, m, m}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{Q_1, \frac{Q_2}{4}, m} & v_{Q_1, \frac{Q_2}{4}, m} & v_{Q_1, \frac{Q_2}{4}, m} \\ v_{Q_1, \frac{Q_2}{4}, m} & -v_{Q_1, \frac{Q_2}{4}, m} & -v_{Q_1, \frac{Q_2}{4}, m} \end{bmatrix}, \tilde{W}_{i, j, m, m}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{Q_1, \frac{Q_2}{4}, m} & v_{Q_1, \frac{Q_2}{4}, m} & v_{Q_1, \frac{Q_2}{4}, m} \\ v_{Q_1, \frac{Q_2}{4}, m} & -v_{Q_1, \frac{Q_2}{4}, m} & -v_{Q_1, \frac{Q_2}{4}, m} \end{bmatrix}, \text{ if } N_1 < N_2.$									

[Figure 89e]

$$N_z = 1$$

Value of Codebook-Config

i_{l1}	i_{l2}	i_2	i_3
4	0	0	3
		$W_{4i_2-4,4i_2-4,0,0}^{(3)}$	$\tilde{W}_{4i_2-4,4i_2-4,0,0}^{(3)}$
		$W_{4i_2-8,4i_2-8,0,0}^{(3)}$	$\tilde{W}_{4i_2-8,4i_2-8,0,0}^{(3)}$
		$W_{4i_2-12,4i_2-12,0,0}^{(3)}$	$\tilde{W}_{4i_2-12,4i_2-12,0,0}^{(3)}$
Value of Codebook-Config			
4	4	4	7
		$W_{4i_2-4,4i_2-4,0,0}^{(3)}$	$\tilde{W}_{4i_2-4,4i_2-4,0,0}^{(3)}$
		$W_{4i_2-8,4i_2-8,0,0}^{(3)}$	$\tilde{W}_{4i_2-8,4i_2-8,0,0}^{(3)}$
		$W_{4i_2-12,4i_2-12,0,0}^{(3)}$	$\tilde{W}_{4i_2-12,4i_2-12,0,0}^{(3)}$
Value of Codebook-Config			
4	8	8	11
		$W_{4i_2-4,4i_2-4,0,0}^{(3)}$	$\tilde{W}_{4i_2-4,4i_2-4,0,0}^{(3)}$
		$W_{4i_2-8,4i_2-8,0,0}^{(3)}$	$\tilde{W}_{4i_2-8,4i_2-8,0,0}^{(3)}$
		$W_{4i_2-12,4i_2-12,0,0}^{(3)}$	$\tilde{W}_{4i_2-12,4i_2-12,0,0}^{(3)}$
Value of Codebook-Config			
4	12	12	15
		$W_{4i_2-4,4i_2-4,0,0}^{(3)}$	$\tilde{W}_{4i_2-4,4i_2-4,0,0}^{(3)}$
		$W_{4i_2-8,4i_2-8,0,0}^{(3)}$	$\tilde{W}_{4i_2-8,4i_2-8,0,0}^{(3)}$
		$W_{4i_2-12,4i_2-12,0,0}^{(3)}$	$\tilde{W}_{4i_2-12,4i_2-12,0,0}^{(3)}$

$$\text{where } W_{l,l',mm}^{(3)} = \frac{1}{\sqrt{3P}} \left[\begin{matrix} v_{Ql} \frac{Q_{lm}}{\frac{1}{2}, \frac{1}{2}} & v_{Ql} \frac{Q_{lm}}{\frac{1}{2}, \frac{1}{2}} & v_{Ql} \frac{Q_{lm}}{\frac{1}{2}, \frac{1}{2}} \\ v_{Ql} \frac{Q_{lm}}{\frac{1}{2}, \frac{1}{2}} & -v_{Ql} \frac{Q_{lm}}{\frac{1}{2}, \frac{1}{2}} & -v_{Ql} \frac{Q_{lm}}{\frac{1}{2}, \frac{1}{2}} \end{matrix} \right] \tilde{W}_{l,l',mm}^{(3)} = \frac{1}{\sqrt{3P}} \left[\begin{matrix} v_{Ql} \frac{Q_{lm}}{\frac{1}{2}, \frac{1}{2}} & v_{Ql} \frac{Q_{lm}}{\frac{1}{2}, \frac{1}{2}} & v_{Ql} \frac{Q_{lm}}{\frac{1}{2}, \frac{1}{2}} \\ v_{Ql} \frac{Q_{lm}}{\frac{1}{2}, \frac{1}{2}} & -v_{Ql} \frac{Q_{lm}}{\frac{1}{2}, \frac{1}{2}} & -v_{Ql} \frac{Q_{lm}}{\frac{1}{2}, \frac{1}{2}} \end{matrix} \right]$$

$$\text{where } W_{l,l',mm}^{(3)} = \frac{1}{\sqrt{3P}} \left[\begin{array}{c} v_{Q_l, O_{l,m}} \frac{v_{Q_{l'}, O_{l',m}}}{\frac{1}{\sqrt{3P}}} \\ v_{Q_l, O_{l,m}} \frac{v_{Q_{l'}, O_{l',m}}}{\frac{1}{\sqrt{3P}}} - v_{Q_{l'}, O_{l',m}} \frac{v_{Q_l, O_{l,m}}}{\frac{1}{\sqrt{3P}}} \end{array} \right], \quad \tilde{W}_{l,l',mm}^{(3)} = \frac{1}{\sqrt{3P}} \left[\begin{array}{c} v_{Q_l, O_{l,m}} \frac{v_{Q_{l'}, O_{l',m}}}{\frac{1}{\sqrt{3P}}} \\ v_{Q_l, O_{l,m}} \frac{v_{Q_{l'}, O_{l',m}}}{\frac{1}{\sqrt{3P}}} - v_{Q_{l'}, O_{l',m}} \frac{v_{Q_l, O_{l,m}}}{\frac{1}{\sqrt{3P}}} \end{array} \right]$$

[Figure 90a]

Value of Codebook-Config		i_{11}	i_{12}	i_2	
1		$0, 1, \dots, O_i N_i - 1$	$0, 1, \dots, O_i N_i - 1$	0	1
		$O_i N_i, O_i N_i + 1, \dots, 2O_i N_i - 1$		$W_{h_{12}, h_{12} + O_i h_{12}, \rho}^{(4)}$	$W_{h_{12}, h_{12} + O_i h_{12}, 1}^{(4)}$
				$W_{h_{12}, h_{12}, h_{12} + O_i, \rho}^{(4)}$	$W_{h_{12}, h_{12}, h_{12} + O_i, 1}^{(4)}$
where $W_{i, l, m, n}^{(4)} = \frac{1}{\sqrt{4P}} \begin{bmatrix} v_{l, m} & v_{l, m} & v_{l, m} & v_{l, m} \\ \varphi_n v_{l, m} & \varphi_n v_{l, m} & -\varphi_n v_{l, m} & -\varphi_n v_{l, m} \end{bmatrix}$					

【Figure 90b】

$N_i = 1$				
Value of Codebook-Config				
	i_{11}	i_{12}	i_2	i
1	$0, 1, \dots, 0, N_i - 1$	0	$W_{h_{11}, h_{12}}^{(4)} = 0, 0, 0, 0$	$W_{h_{11}, h_{12}}^{(4)} = 0, 0, 0, 1$
	$0, N_i, 0, N_i + 1, \dots, 2, 0, N_i - 1$	0	$W_{h_{11}, h_{12}}^{(4)} = 2, 0, 0, 0$	$W_{h_{11}, h_{12}}^{(4)} = 2, 0, 0, 1$
	$2, 0, N_i, \dots, 3, 0, N_i - 1$	0	$W_{h_{11}, h_{12}}^{(4)} = 3, 0, 0, 0$	$W_{h_{11}, h_{12}}^{(4)} = 3, 0, 0, 1$
where $W_{l, l', m, m', n}^{(4)} = \frac{1}{\sqrt{4P}} \begin{bmatrix} v_{l, m} & v_{l', m} & v_{l, m} & v_{l', m} \\ \varphi_n v_{l, m} & \varphi_n v_{l', m} & -\varphi_n v_{l, m} & -\varphi_n v_{l', m} \end{bmatrix}$				

[Figure 90e]

$N_1 > 1, N_2 > 1$						
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	i_2	1	2	3
4	$0, \dots, N_1 - 1$	$Q_{1, \dots, \#N_1} - 1$	$W_{4x+4y+0}^{(4)}$	$W_{4x+4y+1}^{(4)}$	$W_{4x+4y+5y+0}^{(4)}$	$W_{4x+4y+5y+1}^{(4)}$
	$N_1, \dots, 2N_1 - 1$	$Q_{1, \dots, \#N_1} - 1$	$W_{4x+4y+0}^{(4)}$	$W_{4x+4y+1}^{(4)}$	$W_{4x+4y+5y+0}^{(4)}$	$W_{4x+4y+5y+1}^{(4)}$
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	i_2	5	6	7
4	$0, \dots, N_1 - 1$	$Q_{1, \dots, \#N_1} - 1$	$W_{4x+2y+0}^{(4)}$	$W_{4x+2y+5y+1}^{(4)}$	$W_{4x+3y+7y+0}^{(4)}$	$W_{4x+3y+7y+1}^{(4)}$
	$N_1, \dots, 2N_1 - 1$	$Q_{1, \dots, \#N_1} - 1$	$W_{4x+2y+0}^{(4)}$	$W_{4x+2y+5y+1}^{(4)}$	$W_{4x+3y+7y+0}^{(4)}$	$W_{4x+3y+7y+1}^{(4)}$

$W_{i,j,m,n}^{(4)} = \frac{1}{\sqrt{4P}} \begin{bmatrix} v_{Q_1, \frac{Q_2}{4}, m} & v_{Q_1, \frac{Q_2}{4}, m} & v_{Q_1, \frac{Q_2}{4}, m} & v_{Q_1, \frac{Q_2}{4}, m} \\ \varphi_n v_{Q_1, \frac{Q_2}{4}, m} & \varphi_n v_{Q_1, \frac{Q_2}{4}, m} & -\varphi_n v_{Q_1, \frac{Q_2}{4}, m} & -\varphi_n v_{Q_1, \frac{Q_2}{4}, m} \end{bmatrix}, \text{ if } N_1 \geq N_2 \text{ and}$	
$W_{i,j,m,n}^{(4)} = \frac{1}{\sqrt{4P}} \begin{bmatrix} v_{Q_1, \frac{Q_2}{4}, m} & v_{Q_1, \frac{Q_2}{4}, m} & v_{Q_1, \frac{Q_2}{4}, m} & v_{Q_1, \frac{Q_2}{4}, m} \\ \varphi_n v_{Q_1, \frac{Q_2}{4}, m} & \varphi_n v_{Q_1, \frac{Q_2}{4}, m} & -\varphi_n v_{Q_1, \frac{Q_2}{4}, m} & -\varphi_n v_{Q_1, \frac{Q_2}{4}, m} \end{bmatrix}, \text{ if } N_1 < N_2.$	

where $x = i_{1,1}, y = i_{1,2}$

[Figure 90f]

$N_2 = 1$							
Value	of	$i_{1,1}$	$i_{1,2}$	i_2	1	2	3
4	Codebook-Config			0	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 4,0,0,1$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 1,4,1,1 + 5,0,0,1$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 1,4,1,1 + 5,0,0,1$
		$0, \dots, N_i - 1$	0	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 4,0,0,1$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 4,0,0,1$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 1,4,1,1 + 5,0,0,1$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 1,4,1,1 + 5,0,0,1$
		$N_i, \dots, 2N_i - 1$	0	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 8,0,0,0$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 8,0,0,0$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 1,4,1,1 + 9,0,0,0$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 1,4,1,1 + 9,0,0,0$
		$2N_i, \dots, 3N_i - 1$	0	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 12,0,0,0$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 12,0,0,0$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 1,4,1,1 + 13,0,0,0$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 1,4,1,1 + 13,0,0,0$
Value	of			i_2			
	Codebook-Config	$i_{1,1}$	$i_{1,2}$	4	5	6	7
		$0, \dots, N_i - 1$	0	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 2,4b_2 + 6,0,0,0$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 2,4b_2 + 6,0,0,1$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 2,4b_2 + 7,0,0,0$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 2,4b_2 + 7,0,0,1$
		$N_i, \dots, 2N_i - 1$	0	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 2,4b_2 + 10,0,0,0$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 2,4b_2 + 10,0,0,1$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 3,4,1,1 + 11,0,0,0$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 3,4,1,1 + 11,0,0,1$
4		$2N_i, \dots, 3N_i - 1$	0	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 2,4b_2 + 14,0,0,0$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 2,4b_2 + 14,0,0,1$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 3,4,1,1 + 15,0,0,0$	$\mathcal{W}^{(4)}_{4b_1, 4b_2} + 3,4,1,1 + 15,0,0,1$

$$\text{where } W^{(4)}_{i,j,m,n} = \frac{1}{\sqrt{4P}} \begin{bmatrix} v_{\frac{Q_i}{4}, \frac{Q_j}{4}, m} & v_{\frac{Q_i}{4}, \frac{Q_j}{4}, m} \\ \varphi_n v_{\frac{Q_i}{4}, \frac{Q_j}{4}, m} & -\varphi_n v_{\frac{Q_i}{4}, \frac{Q_j}{4}, m} \end{bmatrix}$$

[Figure 91a]

$P=8, N_1=N_2$				
Value of	$i_{1,1}$	$i_{1,2}$	i_2	
Codebook-Config			0	
1	$0, 1, \dots, Q_1 N_1 - 1$	$0, 1, \dots, Q_2 N_2 - 1$		$W_{i_{1,1}, i_{1,2}}^{(5)} + O_1 i_{1,1} + O_2 i_{1,2} + O_2 i_{1,2} + O_2$
2-4	$0, 1, \dots, \frac{1}{4} N_1 - 1$	$0, 1, \dots, \frac{1}{4} N_2 - 1$		$W_{i_{1,1}, i_{1,2}}^{(5)} + 4 i_{1,1} + 4 i_{1,2} + 4 i_{1,2} + 4$
$W_{i,i,m,m'}^{(5)} = \frac{1}{\sqrt{5P}} \begin{bmatrix} v_{Q_1 i, \frac{Q_2 m}{4}} & v_{Q_1 i, \frac{Q_2 m}{4}} & v_{Q_1 i, \frac{Q_2 m}{4}} & v_{Q_1 i, \frac{Q_2 m}{4}} \\ v_{Q_1 i, \frac{Q_2 m}{4}} & -v_{Q_1 i, \frac{Q_2 m}{4}} & v_{Q_1 i, \frac{Q_2 m}{4}} & -v_{Q_1 i, \frac{Q_2 m}{4}} \end{bmatrix} \text{ for Codebook-Config} = 2-4$				
$W_{i,i,m,m'}^{(5)} = \frac{1}{\sqrt{5P}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l,m} & v_{l,m} \\ v_{l,m} & -v_{l,m} & v_{l,m} & -v_{l,m} \end{bmatrix} \text{ for Codebook-Config} = 1$				

【Figure 91b】

$P=12,16, N_1>1, N_2>1$				
Value of	i_{11}	i_{12}	i_2	
Codebook-Config		i_{12}	0	
1	$0,1,\dots,O_1N_1-1$	$0,1,\dots,O_2N_2-1$	$W_{i_1,i_{11}+O_1i_{12},i_2,i_{12}+O_2}^{(S)}$	
$W_{i,j,i_{\max},m}^{(S)} = \frac{1}{\sqrt{SP}} \begin{bmatrix} v_{i,m} & v_{i,m} & v_{i,m} & v_{i,m} \\ v_{i,m} & -v_{i,m} & v_{i,m} & -v_{i,m} \\ v_{i,m} & v_{i,m} & -v_{i,m} & v_{i,m} \\ v_{i,m} & -v_{i,m} & v_{i,m} & -v_{i,m} \end{bmatrix}$				

【Figure 91c】

$P=16, N_2=1$				
Value	of		i_2	
Codebook-Config	i_{11}	i_{12}		i_2
1	$0, 1, \dots, O_1 N_1 - 1$	$0, 1, \dots, O_2 N_2 - 1$		0
				$W^{(5)}_{i_{1,1}, i_{1,1} + O_1, i_{1,1} + 2O_1, i_{1,2}, i_{1,2}, i_{1,2}}$
$W^{(5)}_{l, f, m, m'} = \frac{1}{\sqrt{5P}} \begin{bmatrix} v_{l, m} & v_{l, m'} & v_{l, m} & v_{l, m'} \\ v_{l, m} & -v_{l, m} & v_{l, m'} & -v_{l, m'} \end{bmatrix}$ where				

[Figure 91d]

$P=12,16$				
Value	of	i_{11}	i_{12}	i_2
Codebook-Config				
2		$0_{1 \dots \#N-1}$	$0_{1 \dots \#N-1}$	0
3		$0_{1 \dots \#N-1}$		$W^{(S)}$ $i_{1,1}i_{1,1}+4,i_{1,1}+8,i_{1,2}i_{1,2}+4$ if $N_1 > 1, N_2 > 1$
4		$0_{1 \dots \#N-1}$	$0_{1 \dots \#N-1}$	$W^{(S)}$ $i_{1,1}i_{1,1}+4,i_{1,1}+8,i_{1,2}i_{1,2}+4$ if $N_1 \geq N_2$ $W^{(S)}$ $i_{1,1}i_{1,1}+4,i_{1,1}+4,i_{1,2}i_{1,2}+8$ if $N_1 < N_2$
		$0_{1 \dots \#N-1}$	$0_{1 \dots \#N-1}$	$W^{(S)}$ $i_{1,1}i_{1,1}+4,i_{1,1}+8,i_{1,2}i_{1,2}+4$ if $N_1 \geq N_2$ $W^{(S)}$ $i_{1,1}i_{1,1}+4,i_{1,1}+4,i_{1,2}i_{1,2}+8$ if $N_1 < N_2$
Where $W_{i,j,i,m,m}^{(S)} = \frac{1}{\sqrt{5P}} \begin{bmatrix} v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} & v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} & v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} & v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} \\ v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} & -v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} & v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} & -v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} \end{bmatrix}$				

【Figure 92a】

$P=8, N_1=N_2$				
Value	of	i_{11}	i_{12}	i_2
Codebook-Config				
1		$0, 1, \dots, Q_1 N_1 - 1$		0
2-4		$0, 1, \dots, 4N_1 - 1$		
where				
$W_{i_1 i_2 i_3 i_4}^{(6)} = \frac{1}{\sqrt{6P}} \begin{bmatrix} v_{\frac{Q_1}{4} i_1, \frac{Q_2}{4} i_2} & v_{\frac{Q_1}{4} i_1, \frac{Q_2}{4} i_2} & v_{\frac{Q_1}{4} i_1, \frac{Q_2}{4} i_2} & v_{\frac{Q_1}{4} i_1, \frac{Q_2}{4} i_2} \\ v_{\frac{Q_1}{4} i_1, \frac{Q_2}{4} i_2} & -v_{\frac{Q_1}{4} i_1, \frac{Q_2}{4} i_2} & v_{\frac{Q_1}{4} i_1, \frac{Q_2}{4} i_2} & -v_{\frac{Q_1}{4} i_1, \frac{Q_2}{4} i_2} \end{bmatrix} \text{ for Codebook-Config} = 2-4$				
$W_{i_1 i_2 i_3 i_4}^{(6)} = \frac{1}{\sqrt{6P}} \begin{bmatrix} v_{i_1, i_2} & v_{i_1, i_2} & v_{i_1, i_2} & v_{i_1, i_2} \\ v_{i_1, i_2} & -v_{i_1, i_2} & v_{i_1, i_2} & -v_{i_1, i_2} \end{bmatrix} \text{ for Codebook-Config} = 1$				

[Figure 92b]

$P=12, 16, N_1>1, N_2>1$				
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	i_2	
1	$0, 1, \dots, O_1 N_1 - 1$	$0, 1, \dots, O_2 N_2 - 1$	0	
			$W_{i_{1,1}, i_{1,2}, i_2}^{(6)}$	
where $W_{i_{1,1}, i_{1,2}, i_2}^{(6)} = \frac{1}{\sqrt{6P}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l,m} & v_{l,m} \\ v_{l,m} & -v_{l,m} & v_{l,m} & -v_{l,m} \end{bmatrix}$				

[Figure 92c]

$P=16, N_2=1$				
Value of	i_{11}	i_{12}	i_2	
Codebook-Config			0	
1	$0, 1, \dots, O_1 N_1 - 1$	$0, 1, \dots, O_2 N_2 - 1$	$W^{(6)}_{\hat{h}_{11}, \hat{h}_{12} + O_1 \hat{h}_{11} + 2 O_1 \hat{h}_{12}, \hat{h}_{12}, \hat{h}_{12}}$	
$W^{(6)}_{l,i,l',m,m'} = \frac{1}{\sqrt{6P}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l,m} & v_{l,m} & v_{l,m} \\ v_{l,m} & -v_{l,m} & v_{l,m} & -v_{l,m} & -v_{l,m} \end{bmatrix}$ where				

【Figure 92d】

$P=12, 16$				
Value	of	i_{11}	i_{12}	i_2
Codebook-Config				
2		$0, 1, \dots, 4N_1 - 1$	$0, 1, \dots, 4N_1 - 1$	0
				$W^{(6)}_{i_{11}, i_{11} + 4, i_{11} + 4, i_{12}, i_{12}, i_{12} + 4}$ if $N_1 > 1, N_2 > 1$
3				$W^{(6)}_{i_{11}, i_{11} + 4, i_{11} + 4, i_{12}, i_{12}, i_{12} + 4}$ if $N_1 \geq N_2$
		$0, 1, \dots, 4N_1 - 1$	$0, 1, \dots, 4N_1 - 1$	$W^{(6)}_{i_{11}, i_{11}, i_{11} + 4, i_{12}, i_{12} + 4, i_{12} + 8}$ if $N_1 < N_2$
4				$W^{(6)}_{i_{11}, i_{11} + 4, i_{11} + 8, i_{12}, i_{12}, i_{12}}$ if $N_1 \geq N_2$
		$0, 1, \dots, 4N_1 - 1$	$0, 1, \dots, 4N_1 - 1$	$W^{(6)}_{i_{11}, i_{11}, i_{11}, i_{12}, i_{12} + 4, i_{12} + 8}$ if $N_1 < N_2$
Where $W^{(6)}_{i_1, i_1, i_1, i_1, i_1, i_1} = \frac{1}{\sqrt{6P}}$				
$\begin{bmatrix} v_{Q_l, \frac{Q_l}{4}, m} & v_{Q_l, \frac{Q_l}{4}, m} & v_{Q_l, \frac{Q_l}{4}, m} & v_{Q_l, \frac{Q_l}{4}, m} & v_{Q_l, \frac{Q_l}{4}, m} \\ v_{Q_l, \frac{Q_l}{4}, m} & -v_{Q_l, \frac{Q_l}{4}, m} & -v_{Q_l, \frac{Q_l}{4}, m} & v_{Q_l, \frac{Q_l}{4}, m} & -v_{Q_l, \frac{Q_l}{4}, m} \\ v_{Q_l, \frac{Q_l}{4}, m} & -v_{Q_l, \frac{Q_l}{4}, m} & v_{Q_l, \frac{Q_l}{4}, m} & -v_{Q_l, \frac{Q_l}{4}, m} & v_{Q_l, \frac{Q_l}{4}, m} \\ v_{Q_l, \frac{Q_l}{4}, m} & v_{Q_l, \frac{Q_l}{4}, m} & v_{Q_l, \frac{Q_l}{4}, m} & v_{Q_l, \frac{Q_l}{4}, m} & v_{Q_l, \frac{Q_l}{4}, m} \\ v_{Q_l, \frac{Q_l}{4}, m} & v_{Q_l, \frac{Q_l}{4}, m} & v_{Q_l, \frac{Q_l}{4}, m} & v_{Q_l, \frac{Q_l}{4}, m} & v_{Q_l, \frac{Q_l}{4}, m} \end{bmatrix}$				

【Figure 93a】

$P=8, N_1=N_2$				
Value of	i_{11}	i_{12}	i_2	
Codebook-Config			0	
1	$0, 1, \dots, O_1 N_1 - 1$	$0, 1, \dots, O_2 N_2 - 1$	$W_{i_{11}, i_{12}}^{(1)}$	
2-4	$0, 1, \dots, 4N_1 - 1$	$0, 1, \dots, 4N_2 - 1$	$W_{i_{11}, i_{12}}^{(7)}$	
where	$W_{i_1, i_2, f, m, m', m''}^{(1)} = \frac{1}{\sqrt{7P}} \begin{bmatrix} v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} & v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} & v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} & v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} \\ v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} & -v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} & v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} & -v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} \\ v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} & v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} & v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} & v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} \\ v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} & -v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} & -v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} & v_{\frac{Q_1}{4}, \frac{Q_2}{4}, m} \end{bmatrix}$ for Codebook-Config = 2-4 $W_{i_1, i_2, f, m, m', m''}^{(7)} = \frac{1}{\sqrt{7P}} \begin{bmatrix} v_{l, m} & v_{l, m} & v_{l, m} & v_{l, m} \\ v_{l, m} & -v_{l, m} & v_{l, m} & -v_{l, m} \\ v_{l, m} & v_{l, m} & -v_{l, m} & v_{l, m} \\ v_{l, m} & -v_{l, m} & -v_{l, m} & v_{l, m} \end{bmatrix}$ for Codebook-Config = 1			

【Figure 93b】

$P=12, 16, N_1>1, N_2>1$				
Value of Codebook-Config	i_{11}	i_{12}	i_2	
1	$0, 1, \dots, O_1 N_1 - 1$	$0, 1, \dots, O_2 N_2 - 1$	0	
	$0, 1, \dots, O_1 N_1 - 1$	$0, 1, \dots, O_2 N_2 - 1$	$W_{i_{11}, i_{12} + O_1 i_{11} + O_1 i_{12}, i_{12} + O_2 i_{12} + O_2}$	
$W_{l, l', l'', m, m', m''}^{(1)} = \frac{1}{\sqrt{7P}} \begin{bmatrix} v_{l, m} & v_{l, m} & v_{l, m'} & v_{l, m'} & v_{l, m'} & v_{l, m''} \\ v_{l, m} & -v_{l, m} & v_{l, m'} & v_{l, m'} & -v_{l, m'} & v_{l, m''} \end{bmatrix}$				
where				

[Figure 93c]

$P=16, N_2=1$				
Value	of		i_{l2}	i_2
Codebook-Config		i_{l1}	i_{l2}	0
1		$0, 1, \dots, O_1 N_1 - 1$	$0, 1, \dots, O_2 N_2 - 1$	$W_{\hat{i}_{l1}, \hat{i}_{l1} + Q_1 \hat{i}_{l1} + 2Q_1 \hat{i}_{l1} + 3Q_1 \hat{i}_{l2}, \hat{i}_{l2}, \hat{i}_{l2}}^{(7)}$
$W_{l,l,i,m,m,m,m}^{(7)} = \frac{1}{\sqrt{7P}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l,m} & v_{l,m} & v_{l,m} & v_{l,m} & v_{l,m} \\ v_{l,m} & -v_{l,m} & v_{l,m} & -v_{l,m} & v_{l,m} & -v_{l,m} & v_{l,m} \end{bmatrix}$ where				

【Figure 93d】

$P=12$				
Value	i_{11}	i_{12}	i_2	
Codebook-Config			0	
2	$0,1,...,4N_1-1$	$0,1,...,4N_1-1$	$W^{(T)}$ $i_{11}, i_{11}+4, i_{11}+4, i_{11}, i_{12}, i_{12}+4, i_{12}+4, i_{12}+4$ if $N_1 > 1, N_2 > 1$	
3	$0,1,...,4N_1-1$	$0,1,...,4N_1-1$	$W^{(T)}$ $i_{11}, i_{11}+4, i_{11}+8, i_{11}+4, i_{11}, i_{12}, i_{12}+4, i_{12}+4$ if $N_1 \geq N_2$ $W^{(T)}$ $i_{11}, i_{11}, i_{11}+4, i_{11}+4, i_{11}, i_{12}, i_{12}+4, i_{12}+8, i_{12}+4$ if $N_1 < N_2$	
4	$0,1,...,4N_1-1$	$0,1,...,4N_1-1$	$W^{(T)}$ $i_{11}, i_{11}+4, i_{11}+8, i_{11}, i_{12}, i_{12}, i_{12}+4, i_{12}+4$ if $N_1 \geq N_2$ $W^{(T)}$ $i_{11}, i_{11}, i_{11}, i_{11}+4, i_{11}+4, i_{12}, i_{12}+4, i_{12}+8, i_{12}$ if $N_1 < N_2$	$W_{i_{11}, i_{12}, i_{11}, i_{12}, i_{11}, i_{12}, i_{11}, i_{12}}^{(T)} = \frac{1}{\sqrt{12P}} \begin{bmatrix} v_{Q_i, \frac{1}{4}, m} & v_{Q_i, \frac{1}{4}, m} & v_{Q_i, \frac{1}{4}, m} & v_{Q_i, \frac{1}{4}, m} & v_{Q_i, \frac{1}{4}, m} & v_{Q_i, \frac{1}{4}, m} & v_{Q_i, \frac{1}{4}, m} & v_{Q_i, \frac{1}{4}, m} \\ v_{Q_i, \frac{1}{4}, m} & -v_{Q_i, \frac{1}{4}, m} & v_{Q_i, \frac{1}{4}, m} & -v_{Q_i, \frac{1}{4}, m} & v_{Q_i, \frac{1}{4}, m} & -v_{Q_i, \frac{1}{4}, m} & v_{Q_i, \frac{1}{4}, m} & -v_{Q_i, \frac{1}{4}, m} \end{bmatrix}$
Where				

【Figure 93e】

$P=16$				
Value of	i_{11}	i_{12}	i_2	
Codebook-Config			0	
2	$0, 1, \dots, \#N_1 - 1$	$0, 1, \dots, \#N_1 - 1$	$W^{(T)}$ $h_{1,1} \cdot h_{1,1} + 4 \cdot h_{1,1} + 4 \cdot h_{1,2} \cdot h_{1,2} + 4 \cdot h_{1,2} + 4$ if $N_1 > 1$, $N_2 > 1$	
3	$0, 1, \dots, \#N_1 - 1$	$0, 1, \dots, \#N_1 - 1$	$W^{(T)}$ $h_{1,1} \cdot h_{1,1} + 4 \cdot h_{1,1} + 8 \cdot h_{1,1} + 12 \cdot h_{1,2} \cdot h_{1,2} + 4 \cdot h_{1,2} + 4$ if $N_1 \geq N_2$ $W^{(T)}$ $h_{1,1} \cdot h_{1,1} + 4 \cdot h_{1,1} + 4 \cdot h_{1,2} \cdot h_{1,2} + 4 \cdot h_{1,2} + 8 \cdot h_{1,2} + 12$ if $N_1 < N_2$	
4	$0, 1, \dots, \#N_1 - 1$	$0, 1, \dots, \#N_1 - 1$	$W^{(T)}$ $h_{1,1} \cdot h_{1,1} + 4 \cdot h_{1,1} + 8 \cdot h_{1,1} + 12 \cdot h_{1,2} \cdot h_{1,2} + 4 \cdot h_{1,2}$ if $N_1 \geq N_2$ $W^{(T)}$ $h_{1,1} \cdot h_{1,1} + 4 \cdot h_{1,1} + 4 \cdot h_{1,2} \cdot h_{1,2} + 4 \cdot h_{1,2} + 8 \cdot h_{1,2} + 12$ if $N_1 < N_2$	
Where $W_{i,j,f_{m,m},m,m}^{(T)} = \sqrt{P}$				
	$\begin{bmatrix} V_{O_1, O_2, \frac{1}{4}} \cdot \frac{O_1}{4} \cdot \frac{O_2}{4} \cdot m & V_{O_1, O_2, \frac{1}{4}} \cdot \frac{O_1}{4} \cdot \frac{O_2}{4} \cdot m & V_{O_1, O_2, \frac{1}{4}} \cdot \frac{O_1}{4} \cdot \frac{O_2}{4} \cdot m & V_{O_1, O_2, \frac{1}{4}} \cdot \frac{O_1}{4} \cdot \frac{O_2}{4} \cdot m \\ V_{O_1, O_2, \frac{1}{4}} \cdot \frac{O_1}{4} \cdot \frac{O_2}{4} \cdot m & -V_{O_1, O_2, \frac{1}{4}} \cdot \frac{O_1}{4} \cdot \frac{O_2}{4} \cdot m & V_{O_1, O_2, \frac{1}{4}} \cdot \frac{O_1}{4} \cdot \frac{O_2}{4} \cdot m & -V_{O_1, O_2, \frac{1}{4}} \cdot \frac{O_1}{4} \cdot \frac{O_2}{4} \cdot m \end{bmatrix}$			

[Figure 94a]

$P=8, N_1=N_2$				
Value of	i_{11}	i_{12}	i_2	
Codebook-Config			0	
1	$0, 1, \dots, O_1 N_1 - 1$	$0, 1, \dots, O_2 N_2 - 1$	$W^{(8)}_{i_{11}, i_{12} + O_1 i_{11} + O_1 i_{12} + O_2 i_{12} + O_2 i_{12} + O_2}$	
2-4	$0, 1, \dots, 4N_1 - 1$	$0, 1, \dots, 4N_2 - 1$	$W^{(8)}_{i_{11}, i_{12} + 4i_{11} + 4i_{12}, i_{12} + 4i_{12} + 4}$	
where $W^{(8)}_{i, i', i'', m, m'} = \frac{-1}{\sqrt{8P}} \begin{bmatrix} v_{\frac{O_1 i_{11}}{4}, \frac{O_2 m}{4}} & v_{\frac{O_1 i_{11}}{4}, \frac{O_2 m}{4}} & v_{\frac{O_1 i_{11}}{4}, \frac{O_2 m}{4}} & v_{\frac{O_1 i_{11}}{4}, \frac{O_2 m}{4}} \\ v_{\frac{O_1 i_{11}}{4}, \frac{O_2 m}{4}} & v_{\frac{O_1 i_{11}}{4}, \frac{O_2 m}{4}} & v_{\frac{O_1 i_{11}}{4}, \frac{O_2 m}{4}} & v_{\frac{O_1 i_{11}}{4}, \frac{O_2 m}{4}} \\ -v_{\frac{O_1 i_{11}}{4}, \frac{O_2 m}{4}} & v_{\frac{O_1 i_{11}}{4}, \frac{O_2 m}{4}} & -v_{\frac{O_1 i_{11}}{4}, \frac{O_2 m}{4}} & v_{\frac{O_1 i_{11}}{4}, \frac{O_2 m}{4}} \\ v_{\frac{O_1 i_{11}}{4}, \frac{O_2 m}{4}} & v_{\frac{O_1 i_{11}}{4}, \frac{O_2 m}{4}} & -v_{\frac{O_1 i_{11}}{4}, \frac{O_2 m}{4}} & -v_{\frac{O_1 i_{11}}{4}, \frac{O_2 m}{4}} \end{bmatrix}$ for Codebook-Config = 2-4				
$W^{(8)}_{i, i', i'', m, m'} = \frac{1}{\sqrt{8P}} \begin{bmatrix} v_{i, m} & v_{i, m} & v_{i, m} & v_{i, m} \\ v_{i, m} & v_{i, m} & -v_{i, m} & v_{i, m} \\ -v_{i, m} & v_{i, m} & v_{i, m} & -v_{i, m} \\ v_{i, m} & -v_{i, m} & v_{i, m} & v_{i, m} \end{bmatrix}$ for Codebook-Config = 1				

[Figure 94b]

$P=12,16 \ N_1>1, \ N_2>1$				
Value of	i_{11}	i_{12}	i_2	
Codebook-Config		i_{12}	0	
1	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W_{i_{11}i_{12}}^{(8)}+O_1i_{11}i_{12}+O_2i_{12}+O_3i_{12}+O_2$	
$W_{i,i',i'',m,m',m''}^{(8)}$ where	$\frac{1}{\sqrt{8P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l,m'} & v_{l,m'} & v_{l,m''} & v_{l,m''} & v_{l,m''} & v_{l,m''} \\ v_{l,m} & -v_{l,m} & v_{l,m'} & -v_{l,m'} & v_{l,m''} & -v_{l,m''} & v_{l,m''} & -v_{l,m''} \end{bmatrix}$			

[Figure 94c]

$P=16, N_2=1$

Value of	i_{11}	i_{12}	i_2
Codebook-Config			0
1	$01\dots0, N_1-1$	$01\dots0, N_1-1$	$W^{(8)}_{i_{11}, i_{11}+Q_1, i_{11}+2Q_1, i_{11}+3Q_1, i_{12}, i_{12}, i_{12}, i_{12}}$
where $W^{(8)}_{i,j,i',m,m',m''} = \frac{1}{\sqrt{8P}} \begin{bmatrix} v_{i,m} & v_{i,m} & v_{i,m} & v_{i,m} & v_{i,m} & v_{i,m} & v_{i,m} & v_{i,m} \\ v_{i,m} & -v_{i,m} & v_{i,m} & -v_{i,m} & v_{i,m} & -v_{i,m} & v_{i,m} & -v_{i,m} \end{bmatrix}$			

【Figure 94d】

$P=12$				
Value of Codebook-Config	i_{11}	i_{12}	i_2	
			0	
2	$0, 1, \dots, \#N_1 - 1$	$0, 1, \dots, \#N_1 - 1$	$W^{(8)}_{i_{11}, i_{12} + 4, i_{11} + 4, i_{12}, i_{12} + 4, i_{12} + 4}$ if $N_1 > 1$, $N_2 > 1$	
3			$W^{(8)}_{i_{11}, i_{12} + 4, i_{12} + 8, i_{11} + 4, i_{12}, i_{12} + 4, i_{12} + 4}$ if $N_1 \geq N_2$	
	$0, 1, \dots, \#N_1 - 1$	$0, 1, \dots, \#N_1 - 1$	$W^{(8)}_{i_{11}, i_{12}, i_{12} + 4, i_{11} + 4, i_{12}, i_{12} + 4, i_{12} + 8, i_{12} + 4}$ if $N_1 < N_2$	
4			$W^{(8)}_{i_{11}, i_{12} + 4, i_{11} + 8, i_{12}, i_{12}, i_{12} + 4}$ if $N_1 \geq N_2$	
	$0, 1, \dots, \#N_1 - 1$	$0, 1, \dots, \#N_1 - 1$	$W^{(8)}_{i_{11}, i_{12}, i_{12}, i_{11} + 4, i_{12}, i_{12} + 4, i_{12} + 8, i_{12}}$ if $N_1 < N_2$	
$W^{(8)}_{i, i, i, i, i, i, m, m, m} = \frac{1}{\sqrt{8P}} \begin{bmatrix} v_{Q_1, \frac{Q_2}{2}, \frac{Q_3}{2}, \frac{Q_4}{2}, \frac{Q_5}{2}, \frac{Q_6}{2}, m} & v_{Q_1, \frac{Q_2}{2}, \frac{Q_3}{2}, \frac{Q_4}{2}, \frac{Q_5}{2}, \frac{Q_6}{2}, m} & v_{Q_1, \frac{Q_2}{2}, \frac{Q_3}{2}, \frac{Q_4}{2}, \frac{Q_5}{2}, \frac{Q_6}{2}, m} & v_{Q_1, \frac{Q_2}{2}, \frac{Q_3}{2}, \frac{Q_4}{2}, \frac{Q_5}{2}, \frac{Q_6}{2}, m} & v_{Q_1, \frac{Q_2}{2}, \frac{Q_3}{2}, \frac{Q_4}{2}, \frac{Q_5}{2}, \frac{Q_6}{2}, m} & v_{Q_1, \frac{Q_2}{2}, \frac{Q_3}{2}, \frac{Q_4}{2}, \frac{Q_5}{2}, \frac{Q_6}{2}, m} \\ v_{Q_1, \frac{Q_2}{2}, \frac{Q_3}{2}, \frac{Q_4}{2}, \frac{Q_5}{2}, \frac{Q_6}{2}, m} & -v_{Q_1, \frac{Q_2}{2}, \frac{Q_3}{2}, \frac{Q_4}{2}, \frac{Q_5}{2}, \frac{Q_6}{2}, m} & v_{Q_1, \frac{Q_2}{2}, \frac{Q_3}{2}, \frac{Q_4}{2}, \frac{Q_5}{2}, \frac{Q_6}{2}, m} & -v_{Q_1, \frac{Q_2}{2}, \frac{Q_3}{2}, \frac{Q_4}{2}, \frac{Q_5}{2}, \frac{Q_6}{2}, m} & v_{Q_1, \frac{Q_2}{2}, \frac{Q_3}{2}, \frac{Q_4}{2}, \frac{Q_5}{2}, \frac{Q_6}{2}, m} & -v_{Q_1, \frac{Q_2}{2}, \frac{Q_3}{2}, \frac{Q_4}{2}, \frac{Q_5}{2}, \frac{Q_6}{2}, m} \end{bmatrix}$ Where				

【Figure 94e】

$P=16$				
Value of	i_{11}	i_{12}	i_2	
Codebook-Config				
2	$0, 1, \dots, \#N-1$	$0, 1, \dots, \#N-1$	0	
3	$0, 1, \dots, \#N-1$	$0, 1, \dots, \#N-1$	$W_{i_2, i_1}^{(S)}$	$W_{i_2, i_1}^{(S)}$
4	$0, 1, \dots, \#N-1$	$0, 1, \dots, \#N-1$	$W_{i_2, i_1}^{(S)}$	$W_{i_2, i_1}^{(S)}$
Where $W_{i_2, i_1}^{(S)} = \frac{1}{\sqrt{SP}} \begin{bmatrix} v_{Q_i, \frac{Q_i}{2}} v_{Q_i, \frac{Q_i}{2}} & v_{Q_i, \frac{Q_i}{2}} v_{Q_i, \frac{Q_i}{2}} & v_{Q_i, \frac{Q_i}{2}} v_{Q_i, \frac{Q_i}{2}} & v_{Q_i, \frac{Q_i}{2}} v_{Q_i, \frac{Q_i}{2}} \\ v_{Q_i, \frac{Q_i}{2}} v_{Q_i, \frac{Q_i}{2}} & v_{Q_i, \frac{Q_i}{2}} v_{Q_i, \frac{Q_i}{2}} & v_{Q_i, \frac{Q_i}{2}} v_{Q_i, \frac{Q_i}{2}} & v_{Q_i, \frac{Q_i}{2}} v_{Q_i, \frac{Q_i}{2}} \\ v_{Q_i, \frac{Q_i}{2}} v_{Q_i, \frac{Q_i}{2}} & v_{Q_i, \frac{Q_i}{2}} v_{Q_i, \frac{Q_i}{2}} & v_{Q_i, \frac{Q_i}{2}} v_{Q_i, \frac{Q_i}{2}} & v_{Q_i, \frac{Q_i}{2}} v_{Q_i, \frac{Q_i}{2}} \\ v_{Q_i, \frac{Q_i}{2}} v_{Q_i, \frac{Q_i}{2}} & v_{Q_i, \frac{Q_i}{2}} v_{Q_i, \frac{Q_i}{2}} & v_{Q_i, \frac{Q_i}{2}} v_{Q_i, \frac{Q_i}{2}} & v_{Q_i, \frac{Q_i}{2}} v_{Q_i, \frac{Q_i}{2}} \end{bmatrix}$				

[Figure 95a]

Value of Codebook-Config	i_{11}	i_{12}	i_2		
			0	1	2
1	$0, 1, \dots, O_1 N_1 - 1$	$0, 1, \dots, O_2 N_2 - 1$	$W_{i_{11}/i_{12}, 0}^{(1)}$	$W_{i_{11}/i_{12}, 1}^{(1)}$	$W_{i_{11}/i_{12}, 2}^{(1)}$
where $W_{i_{11}/i_{12}, n}^{(1)} = \frac{1}{\sqrt{P}} \begin{bmatrix} v_{i_{11}, n} \\ \varphi_n v_{i_{12}, n} \end{bmatrix}$, if $N_1 \geq N_2$ $W_{i_{11}/i_{12}, n}^{(1)} = \frac{1}{\sqrt{P}} \begin{bmatrix} v_{i_{11}, n} \\ \varphi_n v_{i_{12}, n} \end{bmatrix}$, if $N_1 < N_2$					
					$W_{i_{11}/i_{12}, 3}^{(1)}$

【Figure 95b】

Value of Codebook-Config	i_{11}	i_{12}	i_2	1	2	3
2	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2i_1, 2i_2, 0}^{(1)}$	$W_{2i_1, 2i_2, 1}^{(1)}$	$W_{2i_1, 2i_2, 2}^{(1)}$	$W_{2i_1, 2i_2, 3}^{(1)}$
Value of Codebook-Config	i_{11}	i_{12}	i_2	4	5	6
2	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2i_1+1, 2i_2, 0}^{(1)}$	$W_{2i_1+1, 2i_2, 1}^{(1)}$	$W_{2i_1+1, 2i_2, 2}^{(1)}$	$W_{2i_1+1, 2i_2, 3}^{(1)}$
Value of Codebook-Config	i_{11}	i_{12}	i_2	8	9	10
2	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2i_1, 2i_2+1, 0}^{(1)}$	$W_{2i_1, 2i_2+1, 1}^{(1)}$	$W_{2i_1, 2i_2+1, 2}^{(1)}$	$W_{2i_1, 2i_2+1, 3}^{(1)}$
Value of Codebook-Config	i_{11}	i_{12}	i_2	12	13	14
2	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2i_1+1, 2i_2+1, 0}^{(1)}$	$W_{2i_1+1, 2i_2+1, 1}^{(1)}$	$W_{2i_1+1, 2i_2+1, 2}^{(1)}$	$W_{2i_1+1, 2i_2+1, 3}^{(1)}$
where $W_{l,m,n}^{(1)} = \frac{1}{\sqrt{P}} \begin{bmatrix} v_{l,m} \\ \varphi_n v_{l,m} \end{bmatrix}$, if $N_1 \geq N_2$ $W_{l,m,n}^{(1)} = \frac{1}{\sqrt{P}} \begin{bmatrix} v_{m,l} \\ \varphi_n v_{m,l} \end{bmatrix}$, if $N_1 < N_2$						

【Figure 95c】

Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	i_2	i_2	i_2	i_2
3	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2i_1+2i_2,0}^{(1)}$	$W_{2i_1+2i_2,1}^{(1)}$	$W_{2i_1+2i_2,2}^{(1)}$	$W_{2i_1+2i_2,3}^{(1)}$
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	i_2	i_2	i_2	i_2
3	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2i_1+2i_2,0}^{(1)}$	$W_{2i_1+2i_2,1}^{(1)}$	$W_{2i_1+2i_2,2}^{(1)}$	$W_{2i_1+2i_2,3}^{(1)}$
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	i_2	i_2	i_2	i_2
3	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2i_1+2i_2,0}^{(1)}$	$W_{2i_1+2i_2,1}^{(1)}$	$W_{2i_1+2i_2,2}^{(1)}$	$W_{2i_1+2i_2,3}^{(1)}$
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	i_2	i_2	i_2	i_2
3	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2i_1+2i_2,0}^{(1)}$	$W_{2i_1+2i_2,1}^{(1)}$	$W_{2i_1+2i_2,2}^{(1)}$	$W_{2i_1+2i_2,3}^{(1)}$
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	i_2	i_2	i_2	i_2
3	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2i_1+2i_2,0}^{(1)}$	$W_{2i_1+2i_2,1}^{(1)}$	$W_{2i_1+2i_2,2}^{(1)}$	$W_{2i_1+2i_2,3}^{(1)}$
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	i_2	i_2	i_2	i_2
3	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2i_1+2i_2,0}^{(1)}$	$W_{2i_1+2i_2,1}^{(1)}$	$W_{2i_1+2i_2,2}^{(1)}$	$W_{2i_1+2i_2,3}^{(1)}$

where $W_{l,m,n}^{(1)} = \frac{1}{\sqrt{P}} \begin{bmatrix} v_{l,m} \\ \phi_n v_{l,m} \end{bmatrix}$, if $N_1 \geq N_2$

$W_{l,m,n}^{(1)} = \frac{1}{\sqrt{P}} \begin{bmatrix} v_{m,l} \\ \phi_n v_{m,l} \end{bmatrix}$, if $N_1 < N_2$

【Figure 95d】

Value	i_{l1}	i_{l2}	i_2	i_1	i_2	i_3
Codebook-Config						
4	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2i_1, 2i_2, 0}^{(1)}$	$W_{2i_1, 2i_2, 1}^{(1)}$	$W_{2i_1, 2i_2, 2}^{(1)}$	$W_{2i_1, 2i_2, 3}^{(1)}$
Value	i_{l1}	i_{l2}	i_2	i_1	i_2	i_3
Codebook-Config						
4	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2i_1, 2i_2, 0}^{(1)}$	$W_{2i_1, 2i_2, 1}^{(1)}$	$W_{2i_1, 2i_2, 2}^{(1)}$	$W_{2i_1, 2i_2, 3}^{(1)}$
Value	i_{l1}	i_{l2}	i_2	i_1	i_2	i_3
Codebook-Config						
4	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2i_1, 2i_2, 0}^{(1)}$	$W_{2i_1, 2i_2, 1}^{(1)}$	$W_{2i_1, 2i_2, 2}^{(1)}$	$W_{2i_1, 2i_2, 3}^{(1)}$
Value	i_{l1}	i_{l2}	i_2	i_1	i_2	i_3
Codebook-Config						
4	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2i_1, 2i_2, 0}^{(1)}$	$W_{2i_1, 2i_2, 1}^{(1)}$	$W_{2i_1, 2i_2, 2}^{(1)}$	$W_{2i_1, 2i_2, 3}^{(1)}$
Value	i_{l1}	i_{l2}	i_2	i_1	i_2	i_3
Codebook-Config						
4	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{2i_1, 2i_2, 0}^{(1)}$	$W_{2i_1, 2i_2, 1}^{(1)}$	$W_{2i_1, 2i_2, 2}^{(1)}$	$W_{2i_1, 2i_2, 3}^{(1)}$

where $W_{l,m,n}^{(1)} = \frac{1}{\sqrt{P}} \begin{bmatrix} v_{l,m} \\ \varphi_n v_{l,m} \end{bmatrix}$, if $N_1 \geq N_2$

$W_{l,m,n}^{(1)} = \frac{1}{\sqrt{P}} \begin{bmatrix} v_{m,l} \\ \varphi_n v_{m,l} \end{bmatrix}$, if $N_1 < N_2$

【Figure 96b】

Value of Codebook-Config	i_{l1}	i_{l2}	i_2	1	2	3
2	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{i_{l1}, i_{l2}, i_2}^{(2)}$	$W_{i_{l1}, i_{l2}, i_2}^{(2)}$	$W_{i_{l1}, i_{l2}, i_2}^{(2)}$	$W_{i_{l1}, i_{l2}, i_2}^{(2)}$
Value of Codebook-Config	i_{l1}	i_{l2}	i_2	5	6	7
2	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{i_{l1}, i_{l2}, i_2}^{(2)}$	$W_{i_{l1}, i_{l2}, i_2}^{(2)}$	$W_{i_{l1}, i_{l2}, i_2}^{(2)}$	$W_{i_{l1}, i_{l2}, i_2}^{(2)}$
Value of Codebook-Config	i_{l1}	i_{l2}	i_2	9	10	11
2	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{i_{l1}, i_{l2}, i_2}^{(2)}$	$W_{i_{l1}, i_{l2}, i_2}^{(2)}$	$W_{i_{l1}, i_{l2}, i_2}^{(2)}$	$W_{i_{l1}, i_{l2}, i_2}^{(2)}$
Value of Codebook-Config	i_{l1}	i_{l2}	i_2	13	14	15
2	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W_{i_{l1}, i_{l2}, i_2}^{(2)}$	$W_{i_{l1}, i_{l2}, i_2}^{(2)}$	$W_{i_{l1}, i_{l2}, i_2}^{(2)}$	$W_{i_{l1}, i_{l2}, i_2}^{(2)}$
$W_{i, l, m, m', n}^{(2)} = \frac{1}{\sqrt{2P}} \begin{bmatrix} v_{l, m} & v_{l, m'} \\ \varphi_n v_{l, m} & -\varphi_n v_{l, m'} \end{bmatrix}, \text{ if } N_1 \geq N_2$ $W_{i, l, m, m', n}^{(2)} = \frac{1}{\sqrt{2P}} \begin{bmatrix} v_{m, l} & v_{m, l'} \\ \varphi_n v_{m, l} & -\varphi_n v_{m, l'} \end{bmatrix}, \text{ if } N_1 < N_2$ If $N_1 < N_2$, then $p_1 = 0$ and $p_2 = 1$, otherwise $p_1 = 1$ and $p_2 = 0$.						

【Figure 96c】

Value of Codebook-Config	i_{11}	i_{12}	i_2	1	2	3
3	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W^{(2)}_{i_1 i_2}$	$W^{(2)}_{i_1 i_2}$	$W^{(2)}_{i_1 i_2}$	$W^{(2)}_{i_1 i_2}$
Value of Codebook-Config	i_{11}	i_{12}	i_2	5	6	7
3	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W^{(2)}_{i_1 i_2}$	$W^{(2)}_{i_1 i_2}$	$W^{(2)}_{i_1 i_2}$	$W^{(2)}_{i_1 i_2}$
Value of Codebook-Config	i_{11}	i_{12}	i_2	9	10	11
3	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W^{(2)}_{i_1 i_2}$	$W^{(2)}_{i_1 i_2}$	$W^{(2)}_{i_1 i_2}$	$W^{(2)}_{i_1 i_2}$
Value of Codebook-Config	i_{11}	i_{12}	i_2	13	14	15
3	$0, 1, \dots, \frac{N_1 Q_1}{2} - 1$	$0, 1, \dots, \frac{N_2 Q_2}{2} - 1$	$W^{(2)}_{i_1 i_2}$	$W^{(2)}_{i_1 i_2}$	$W^{(2)}_{i_1 i_2}$	$W^{(2)}_{i_1 i_2}$
$W^{(2)}_{i, l', m, i, n} = \frac{1}{\sqrt{2P}} \begin{bmatrix} v_{l, m} & v_{l, m} \\ \varphi_n v_{l, m} & -\varphi_n v_{l, m} \end{bmatrix}, \text{ if } N_1 \geq N_2$						
$W^{(2)}_{i, l', m, i, n} = \frac{1}{\sqrt{2P}} \begin{bmatrix} v_{m, l} & v_{m, l} \\ \varphi_n v_{m, l} & -\varphi_n v_{m, l} \end{bmatrix}, \text{ if } N_1 < N_2$						

[Figure 96d]

【Figure 97a】

Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	(δ_1, δ_2)	i_2	
				0	1
1	$0, 1, \dots, O_2 N_2 - 1$	$0, 1, \dots, O_2 N_2 - 1$	$(O_1, 0), (0, O_2)$ if $N_1, N_2 > 1$ $(O_1, 0), (2O_1, 0), (3O_1, 0)$ if $N_1 = 1$ $(0, O_2), (0, 2O_2), (0, 3O_2)$ if $N_2 = 1$	$W_{i_{1,1}, i_{1,2} + \delta_1, i_{1,2} + \delta_2}^{(3)}$	$\tilde{W}_{i_{1,1}, i_{1,1} + \delta_1, i_{1,2} + \delta_2}^{(3)}$
where $W_{i,f,m,m'}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{i,m} & v_{i,m} & v_{i,m} \\ v_{i,m} & -v_{i,m} & -v_{i,m} \end{bmatrix}$ and $\tilde{W}_{i,f,m,m'}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{i,m} & v_{i,m} & v_{i,m} \\ v_{i,m} & v_{i,m} & -v_{i,m} \end{bmatrix}$, if $N_1 \geq N_2$ $W_{i,f,m,m'}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{m,f} & v_{m,f} & v_{m,f} \\ v_{m,f} & -v_{m,f} & -v_{m,f} \end{bmatrix}$ and $\tilde{W}_{i,f,m,m'}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{m,f} & v_{m,f} & v_{m,f} \\ v_{m,f} & v_{m,f} & -v_{m,f} \end{bmatrix}$, if $N_1 < N_2$					

【Figure 97b】

Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	(δ_1, δ_2)	i_2	1	2	3
2	$0, 1, \dots, 2N_1 - 1$	$0, 1, \dots, 2N_2 - 1$	$(0, 1), (0, 0, 2)$	$W_{\delta_1, \delta_2}^{(3)}$ $\delta_1, \delta_2 = 0, 1, 2$	$W_{\delta_1, \delta_2}^{(3)}$ $\delta_1, \delta_2 = 0, 1, 2$	$W_{\delta_1, \delta_2}^{(3)}$ $\delta_1, \delta_2 = 0, 1, 2$	$W_{\delta_1, \delta_2}^{(3)}$ $\delta_1, \delta_2 = 0, 1, 2$
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	(δ_1, δ_2)	i_2	5	6	7
2	$0, 1, \dots, 2N_1 - 1$	$0, 1, \dots, 2N_2 - 1$	$(0, 1), (0, 0, 2)$	$W_{\delta_1, \delta_2}^{(3)}$ $\delta_1, \delta_2 = 0, 1, 2$	$W_{\delta_1, \delta_2}^{(3)}$ $\delta_1, \delta_2 = 0, 1, 2$	$W_{\delta_1, \delta_2}^{(3)}$ $\delta_1, \delta_2 = 0, 1, 2$	$W_{\delta_1, \delta_2}^{(3)}$ $\delta_1, \delta_2 = 0, 1, 2$
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	(δ_1, δ_2)	i_2	9	10	11
2	$0, 1, \dots, 2N_1 - 1$	$0, 1, \dots, 2N_2 - 1$	$(0, 1), (0, 0, 2)$	$W_{\delta_1, \delta_2}^{(3)}$ $\delta_1, \delta_2 = 0, 1, 2$	$W_{\delta_1, \delta_2}^{(3)}$ $\delta_1, \delta_2 = 0, 1, 2$	$W_{\delta_1, \delta_2}^{(3)}$ $\delta_1, \delta_2 = 0, 1, 2$	$W_{\delta_1, \delta_2}^{(3)}$ $\delta_1, \delta_2 = 0, 1, 2$
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	(δ_1, δ_2)	i_2	13	14	15
2	$0, 1, \dots, 2N_1 - 1$	$0, 1, \dots, 2N_2 - 1$	$(0, 1), (0, 0, 2)$	$W_{\delta_1, \delta_2}^{(3)}$ $\delta_1, \delta_2 = 0, 1, 2$	$W_{\delta_1, \delta_2}^{(3)}$ $\delta_1, \delta_2 = 0, 1, 2$	$W_{\delta_1, \delta_2}^{(3)}$ $\delta_1, \delta_2 = 0, 1, 2$	$W_{\delta_1, \delta_2}^{(3)}$ $\delta_1, \delta_2 = 0, 1, 2$
where $W_{i, j, m, m}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{i, m} & v_{i, m} & v_{i, m} \\ v_{i, m} & -v_{i, m} & -v_{i, m} \end{bmatrix}$ and $\tilde{W}_{i, j, m, m}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{i, m} & v_{i, m} & v_{i, m} \\ v_{i, m} & v_{i, m} & -v_{i, m} \end{bmatrix}$, if $N_1 \geq N_2$ $W_{i, j, m, m}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{m, j} & v_{m, j} & v_{m, j} \\ v_{m, j} & -v_{m, j} & -v_{m, j} \end{bmatrix}$ and $\tilde{W}_{i, j, m, m}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{m, j} & v_{m, j} & v_{m, j} \\ v_{m, j} & v_{m, j} & -v_{m, j} \end{bmatrix}$, if $N_1 < N_2$ $(s_1, s_2) = (\frac{\rho_1^2}{2}, \frac{\rho_2^2}{2})$ and $(\rho_1, \rho_2) = (\frac{\rho_1^2}{4}, \frac{\rho_2^2}{4})$.							

【Figure 97c】

Value of Codebook-Config	i_{11}	i_{12}	(δ_1, δ_2)	i_2	1	2	3
3	$0, 1, \dots, N_1 - 1$	$0, 1, \dots, 2N_2 - 1$	$(O_1, 0), (0, O_2)$	$\tilde{W}_{\frac{N_1}{2}, i_2}^{(3)}$	$\tilde{W}_{\frac{N_1}{2}, i_2}^{(3)}$	$\tilde{W}_{\frac{N_1}{2}, i_2}^{(3)}$	$\tilde{W}_{\frac{N_1}{2}, i_2}^{(3)}$
Value of Codebook-Config	i_{11}	i_{12}	(δ_1, δ_2)	i_2	5	6	7
3	$0, 1, \dots, N_1 - 1$	$0, 1, \dots, 2N_2 - 1$	$(O_1, 0), (0, O_2)$	$\tilde{W}_{\frac{N_1}{2}, i_2}^{(3)}$	$\tilde{W}_{\frac{N_1}{2}, i_2}^{(3)}$	$\tilde{W}_{\frac{N_1}{2}, i_2}^{(3)}$	$\tilde{W}_{\frac{N_1}{2}, i_2}^{(3)}$
Value of Codebook-Config	i_{11}	i_{12}	(δ_1, δ_2)	i_2	9	10	11
3	$0, 1, \dots, N_1 - 1$	$0, 1, \dots, 2N_2 - 1$	$(O_1, 0), (0, O_2)$	$\tilde{W}_{\frac{N_1}{2}, i_2}^{(3)}$	$\tilde{W}_{\frac{N_1}{2}, i_2}^{(3)}$	$\tilde{W}_{\frac{N_1}{2}, i_2}^{(3)}$	$\tilde{W}_{\frac{N_1}{2}, i_2}^{(3)}$
Value of Codebook-Config	i_{11}	i_{12}	(δ_1, δ_2)	i_2	13	14	15
3	$0, 1, \dots, N_1 - 1$	$0, 1, \dots, 2N_2 - 1$	$(O_1, 0), (0, O_2)$	$\tilde{W}_{\frac{N_1}{2}, i_2}^{(3)}$	$\tilde{W}_{\frac{N_1}{2}, i_2}^{(3)}$	$\tilde{W}_{\frac{N_1}{2}, i_2}^{(3)}$	$\tilde{W}_{\frac{N_1}{2}, i_2}^{(3)}$
where $\tilde{W}_{l, j, m, m'}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{l, m} & v_{l, m} & v_{l, m} & v_{l, m} \\ v_{l, m} & -v_{l, m} & -v_{l, m} & -v_{l, m} \end{bmatrix}$ and $\tilde{W}_{l, j, m, m'}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{l, m} & v_{l, m} & v_{l, m} & v_{l, m} \\ v_{l, m} & v_{l, m} & -v_{l, m} & -v_{l, m} \end{bmatrix}$, if $N_1 \geq N_2$ $\tilde{W}_{l, j, m, m'}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{m, l} & v_{m, l} & v_{m, l} & v_{m, l} \\ v_{m, l} & -v_{m, l} & -v_{m, l} & -v_{m, l} \end{bmatrix}$ and $\tilde{W}_{l, j, m, m'}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{m, l} & v_{m, l} & v_{m, l} & v_{m, l} \\ v_{m, l} & v_{m, l} & -v_{m, l} & -v_{m, l} \end{bmatrix}$, if $N_1 < N_2$ $(s_1, s_2) = (O_1, \frac{O_2}{2})$ and $(p_1, p_2) = (\frac{O_1}{4}, \frac{O_2}{4})$.							

[Figure 97d]

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Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	(δ_1, δ_2)	i_2			
				0	1	2	3
4	$01 \dots N_1 - 1$	$01 \dots N_1 - 1$	$(O_1, 0), (0, O_2)$ if $N_1, N_2 > 1$ $(O_1, 0), (2O_1, 0), (3O_1, 0)$ if $N_1 = 1$ $(0, O_2), (0, 2O_2), (0, 3O_2)$ if $N_2 = 1$	$W^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$	$W^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$	$\tilde{W}^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$	$\tilde{W}^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$
				$W^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$	$W^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$	$\tilde{W}^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$	$\tilde{W}^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	(δ_1, δ_2)	i_2			
				4	5	6	7
4	$01 \dots N_1 - 1$	$01 \dots N_1 - 1$	$(O_1, 0), (0, O_2)$ if $N_1, N_2 > 1$ $(O_1, 0), (2O_1, 0), (3O_1, 0)$ if $N_1 = 1$ $(0, O_2), (0, 2O_2), (0, 3O_2)$ if $N_2 = 1$	$W^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$	$W^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$	$\tilde{W}^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$	$\tilde{W}^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$
				$W^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$	$W^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$	$\tilde{W}^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$	$\tilde{W}^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	(δ_1, δ_2)	i_2			
				8	9	10	11
4	$01 \dots N_1 - 1$	$01 \dots N_1 - 1$	(δ_1, δ_2)	$W^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$	$W^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$	$\tilde{W}^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$	$\tilde{W}^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$
				$W^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$	$W^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$	$\tilde{W}^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$	$\tilde{W}^{(3)}_{\delta_1, \delta_2, i_{1,1} + \delta_1, i_{1,2} + \delta_2}$

【Figure 97e】

[illegible]

【Figure 97f】

4	$0, 1, \dots, N_1 - 1$	$0, 1, \dots, N_1 - 1$	$(O_1, 0), (0, O_2)$ if $N_1 N_2 > 1$ $(O_1, 0), (2O_1, 0), (3O_1, 0)$ if $N_1 = 1$ $(0, O_2), (0, 2O_2), (0, 3O_2)$ if $N_2 = 1$	$W_{s_{l,i}^{(3)} s_{m,i}^{(3)}}^{(3)}$	$W_{s_{l,i}^{(0)} s_{m,i}^{(0)}}^{(0)}$	$\widetilde{W}_{s_{l,i}^{(3)} s_{m,i}^{(3)}}^{(3)}$	$\widetilde{W}_{s_{l,i}^{(3)} s_{m,i}^{(3)}}^{(3)}$
where $W_{l,i',m,i'}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l,m'} \\ v_{l,m} & -v_{l,m} & -v_{l,m'} \end{bmatrix}$ and $\widetilde{W}_{l,i',m,i'}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l,m'} \\ v_{l,m} & v_{l,m} & -v_{l,m'} \end{bmatrix}$, if $N_1 \geq N_2$ $W_{l,i',m,i'}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{m,l} & v_{m,l} & v_{m,i'} \\ v_{m,l} & -v_{m,l} & -v_{m,i'} \end{bmatrix}$ and $\widetilde{W}_{l,i',m,i'}^{(3)} = \frac{1}{\sqrt{3P}} \begin{bmatrix} v_{m,l} & v_{m,l} & v_{m,i'} \\ v_{m,l} & v_{m,l} & -v_{m,i'} \end{bmatrix}$, if $N_1 < N_2$ $(s_1, s_2) = (O_1, \frac{O_2}{3})$ and $(p_1, p_2) = (\frac{O_1}{3}, -)$.							

【Figure 98a】

Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	(δ_1, δ_2)	i_2	
				0	1
1	$0, 1, \dots, O_1 N_1 - 1$	$0, 1, \dots, O_2 N_2 - 1$	$(O_1, 0), (0, O_2)$ if $N_1, N_2 > 1$ $(O_1, 0), (2O_1, 0), (3O_1, 0)$ if $N_1 = 1$ $(0, O_2), (0, 2O_2), (0, 3O_2)$ if $N_2 = 1$	$W_{i_{1,1}, i_{1,1} + \delta_1, i_{1,2}, i_{1,2} + \delta_2, 1}^{(4)}$	$W_{i_{1,1}, i_{1,1} + \delta_1, i_{1,2}, i_{1,2} + \delta_2, 1}^{(4)}$
where $W_{l,i,m,n}^{(4)} = \frac{1}{\sqrt{4P}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l,m} & v_{l,m} \\ \varphi_n v_{l,m} & \varphi_n v_{l,m} & -\varphi_n v_{l,m} & -\varphi_n v_{l,m} \end{bmatrix}$, if $N_1 \geq N_2$ $W_{l,i,m,n}^{(4)} = \frac{1}{\sqrt{4P}} \begin{bmatrix} v_{m,l} & v_{m,l} & v_{m,l} & v_{m,l} \\ \varphi_n v_{m,l} & \varphi_n v_{m,l} & -\varphi_n v_{m,l} & -\varphi_n v_{m,l} \end{bmatrix}$, if $N_1 < N_2$					

【Figure 98b】

Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	(δ_1, δ_2)	i_2
2	$0, 1, \dots, 2N_1 - 1$	$0, 1, \dots, 2N_2 - 1$	$(O_1, 0), (0, O_2)$	0
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	(δ_1, δ_2)	i_2
2	$0, 1, \dots, 2N_1 - 1$	$0, 1, \dots, 2N_2 - 1$	$(O_1, 0), (0, O_2)$	2
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	(δ_1, δ_2)	i_2
2	$0, 1, \dots, 2N_1 - 1$	$0, 1, \dots, 2N_2 - 1$	$(O_1, 0), (0, O_2)$	4
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	(δ_1, δ_2)	i_2
2	$0, 1, \dots, 2N_1 - 1$	$0, 1, \dots, 2N_2 - 1$	$(O_1, 0), (0, O_2)$	6
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	(δ_1, δ_2)	i_2
2	$0, 1, \dots, 2N_1 - 1$	$0, 1, \dots, 2N_2 - 1$	$(O_1, 0), (0, O_2)$	8

where $W_{l,l',m,m',n}^{(4)} = \frac{1}{\sqrt{4P}} \begin{bmatrix} v_{l,m} & v_{l',m} \\ \varphi_n v_{l,m} & \varphi_n v_{l',m} \end{bmatrix}$, if $N_1 \geq N_2$	$W_{l,l',m,m',n}^{(4)} = \frac{1}{\sqrt{4P}} \begin{bmatrix} v_{l,m} & v_{m',j} \\ \varphi_n v_{l,m} & \varphi_n v_{m',j} \end{bmatrix}$, if $N_1 < N_2$
$(s_1, s_2) = (\frac{\rho_1}{2}, \frac{\rho_2}{2})$ and $(p_1, p_2) = (\frac{\rho_1}{4}, \frac{\rho_2}{4})$.	

【Figure 98d】

Value of Codebook-Config	i_{11}	i_{12}	(g, δ_i)	i_2	i_2
4	$0, 1, \dots, N_1 - 1$	$0, 1, \dots, 4N_1 - 1$	$(O_1, 0), (0, O_2)$ if $N_1, N_2 > 1$ $(O_1, 0), (2O_1, 0), (3O_1, 0)$ if $N_1 = 1$ $(0, O_2), (0, 2O_2), (0, 3O_2)$ if $N_2 = 1$	0	1
				$W_{s_{i_{1,1}}, s_{i_{1,1}} + \delta_1, s_{i_{2,2}} + \delta_2, 0}^{(4)}$	$W_{s_{i_{1,1}}, s_{i_{1,1}} + \delta_1, s_{i_{2,2}} + \delta_2, 1}^{(4)}$
4	$0, 1, \dots, N_1 - 1$	$0, 1, \dots, 4N_1 - 1$	$(O_1, 0), (0, O_2)$ if $N_1, N_2 > 1$ $(O_1, 0), (2O_1, 0), (3O_1, 0)$ if $N_1 = 1$ $(0, O_2), (0, 2O_2), (0, 3O_2)$ if $N_2 = 1$	2	3
				$W_{s_{i_{1,1}} + p_1, s_{i_{1,1}} + p_1 + \delta_1, s_{i_{2,2}} + \delta_2, 0}^{(4)}$	$W_{s_{i_{1,1}} + p_1, s_{i_{1,1}} + p_1 + \delta_1, s_{i_{2,2}} + \delta_2, 1}^{(4)}$
Value of Codebook-Config	i_{11}	i_{12}	(g, δ_i)	i_2	i_2
				4	5

[Figure 98e]

4	$0,1,\dots,N_1-1$	$0,1,\dots,4N_1-1$	$(O_1,0),(0,O_2)$ if $N_1,N_2 > 1$ $(O_1,0),(2O_1,0),(3O_1,0)$ if $N_1 = 1$ $(0,O_2),(0,2O_2),(0,3O_2)$ if $N_2 = 1$	$W^{(4)}_{s_{i_1,1}+2p_1-s_{i_1,1}+2p_1+\delta_1-s_{i_1,2}-s_{i_1,3}+\delta_2,0}$	$W^{(4)}_{s_{i_1,1}+2p_1-s_{i_1,1}+2p_1+\delta_1-s_{i_1,2}-s_{i_1,3}+\delta_2,1}$
Value of Codebook-Config, s	$i_{1,1}$	$i_{1,2}$	(δ_1,δ_2)	i_2	
				6	7

【Figure 98f】

4	$q_{1,\dots,N_1-1}$	$0_{1,\dots,N_1-1}$	$(O_1, 0)_i (0, O_2)$ if N_1, N_2 > 1 $(O_1, 0)_i (2O_1, 0)_i (3O_1, 0)$ $)$ if $N_1 = 1$ $(0, O_2)_i (0, 2O_2)_i (0, 3O_2)$ $)$ if $N_2 = 1$	$W^{(4)}_{s_{i,1}+3p_1, s_{i,1}+3p_1+\delta_1, s_{i,2}, s_{i,2}+\delta_2, 1}$ $W^{(4)}_{s_{i,1}+3p_1, s_{i,1}+3p_1+\delta_1, s_{i,2}, s_{i,2}+\delta_2, 0}$	
where $W^{(4)}_{l,i,m,n} = \frac{1}{\sqrt{4P}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l,m} & v_{l,m} \\ \varphi_n v_{l,m} & \varphi_n v_{l,m} & -\varphi_n v_{l,m} & -\varphi_n v_{l,m} \end{bmatrix}, \text{ if } N_1 \geq N_2$ $W^{(4)}_{l,i,m,n} = \frac{1}{\sqrt{4P}} \begin{bmatrix} v_{m,i} & v_{m,i} & v_{m,i} & v_{m,i} \\ \varphi_n v_{m,i} & \varphi_n v_{m,i} & -\varphi_n v_{m,i} & -\varphi_n v_{m,i} \end{bmatrix}, \text{ if } N_1 < N_2$ $(s_1, s_2) = (O_1, \frac{O_2}{4})$ and $(p_1, p_2) = (\frac{O_1}{4}, -)$.					

【Figure 100b】

4		$0, 1, \dots, AN_1 - 1$	$0, 1, \dots, AN_1 - 1$	$W_{h_1, h_2}^{(6)} = \frac{1}{\sqrt{6Q}} \begin{bmatrix} V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} \\ V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} \\ V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} \\ V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} \\ V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} \end{bmatrix} \text{ if } N_1 \geq N_2$ $W_{h_1, h_2}^{(6)} = \frac{1}{\sqrt{6Q}} \begin{bmatrix} V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} \\ V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} \\ V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} \\ V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} \\ V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} & -V_{s, h_{1,1}+s, h_{1,2}} & V_{s, h_{1,1}+s, h_{1,2}} \end{bmatrix} \text{ if } N_1 < N_2$
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【Figure 101a】

Value of Codebook-Config	i_{11}	i_{12}	i_2
1	$0, 1, \dots, O_1 N_1 - 1$	i_{12}	0
			$p_{h,1,1,2}^{(D)} = \frac{1}{\sqrt{Q}} \begin{bmatrix} V_{1,1,1,2} + \alpha_{1,1,2} & V_{1,1,1,2} - \alpha_{1,1,2} & V_{1,1,1,2} + \alpha_{1,1,2} & V_{1,1,1,2} - \alpha_{1,1,2} \\ V_{1,1,1,2} - \alpha_{1,1,2} & V_{1,1,1,2} + \alpha_{1,1,2} & V_{1,1,1,2} - \alpha_{1,1,2} & V_{1,1,1,2} + \alpha_{1,1,2} \\ V_{1,1,1,2} + \alpha_{1,1,2} & V_{1,1,1,2} - \alpha_{1,1,2} & V_{1,1,1,2} + \alpha_{1,1,2} & V_{1,1,1,2} - \alpha_{1,1,2} \\ V_{1,1,1,2} - \alpha_{1,1,2} & V_{1,1,1,2} + \alpha_{1,1,2} & V_{1,1,1,2} - \alpha_{1,1,2} & V_{1,1,1,2} + \alpha_{1,1,2} \end{bmatrix} \quad \text{if } N_1 \geq N_2$ $p_{h,1,1,2}^{(D)} = \frac{1}{\sqrt{Q}} \begin{bmatrix} V_{1,1,1,2} + \alpha_{1,1,2} & V_{1,1,1,2} - \alpha_{1,1,2} & V_{1,1,1,2} + \alpha_{1,1,2} & V_{1,1,1,2} - \alpha_{1,1,2} \\ V_{1,1,1,2} - \alpha_{1,1,2} & V_{1,1,1,2} + \alpha_{1,1,2} & V_{1,1,1,2} - \alpha_{1,1,2} & V_{1,1,1,2} + \alpha_{1,1,2} \\ V_{1,1,1,2} + \alpha_{1,1,2} & V_{1,1,1,2} - \alpha_{1,1,2} & V_{1,1,1,2} + \alpha_{1,1,2} & V_{1,1,1,2} - \alpha_{1,1,2} \\ V_{1,1,1,2} - \alpha_{1,1,2} & V_{1,1,1,2} + \alpha_{1,1,2} & V_{1,1,1,2} - \alpha_{1,1,2} & V_{1,1,1,2} + \alpha_{1,1,2} \end{bmatrix} \quad \text{if } N_1 < N_2$

[Figure 101b]

Value of Codebook-Config	i_{11}	i_{12}	i_2
2	$0, 1, \dots, 4N_1 - 1$	$0, 1, \dots, 4N_1 - 1$	0
	$W_{k,1,2}^{(0)} = \frac{1}{\sqrt{Q}} \begin{bmatrix} v_{1,1,1,1,1,1} & v_{1,1,1,1,1,2} & v_{1,1,1,1,1,3} & v_{1,1,1,1,1,4} & v_{1,1,1,1,1,5} & v_{1,1,1,1,1,6} \\ v_{1,1,1,1,2,1} & v_{1,1,1,1,2,2} & v_{1,1,1,1,2,3} & v_{1,1,1,1,2,4} & v_{1,1,1,1,2,5} & v_{1,1,1,1,2,6} \\ v_{1,1,1,1,3,1} & v_{1,1,1,1,3,2} & v_{1,1,1,1,3,3} & v_{1,1,1,1,3,4} & v_{1,1,1,1,3,5} & v_{1,1,1,1,3,6} \\ v_{1,1,1,1,4,1} & v_{1,1,1,1,4,2} & v_{1,1,1,1,4,3} & v_{1,1,1,1,4,4} & v_{1,1,1,1,4,5} & v_{1,1,1,1,4,6} \\ v_{1,1,1,1,5,1} & v_{1,1,1,1,5,2} & v_{1,1,1,1,5,3} & v_{1,1,1,1,5,4} & v_{1,1,1,1,5,5} & v_{1,1,1,1,5,6} \\ v_{1,1,1,1,6,1} & v_{1,1,1,1,6,2} & v_{1,1,1,1,6,3} & v_{1,1,1,1,6,4} & v_{1,1,1,1,6,5} & v_{1,1,1,1,6,6} \end{bmatrix} \quad \text{if } N_1 \geq N_2$ $W_{k,1,2}^{(0)} = \frac{1}{\sqrt{Q}} \begin{bmatrix} v_{1,1,1,1,1,1} & v_{1,1,1,1,1,2} & v_{1,1,1,1,1,3} & v_{1,1,1,1,1,4} & v_{1,1,1,1,1,5} & v_{1,1,1,1,1,6} \\ v_{1,1,1,1,2,1} & v_{1,1,1,1,2,2} & v_{1,1,1,1,2,3} & v_{1,1,1,1,2,4} & v_{1,1,1,1,2,5} & v_{1,1,1,1,2,6} \\ v_{1,1,1,1,3,1} & v_{1,1,1,1,3,2} & v_{1,1,1,1,3,3} & v_{1,1,1,1,3,4} & v_{1,1,1,1,3,5} & v_{1,1,1,1,3,6} \\ v_{1,1,1,1,4,1} & v_{1,1,1,1,4,2} & v_{1,1,1,1,4,3} & v_{1,1,1,1,4,4} & v_{1,1,1,1,4,5} & v_{1,1,1,1,4,6} \\ v_{1,1,1,1,5,1} & v_{1,1,1,1,5,2} & v_{1,1,1,1,5,3} & v_{1,1,1,1,5,4} & v_{1,1,1,1,5,5} & v_{1,1,1,1,5,6} \\ v_{1,1,1,1,6,1} & v_{1,1,1,1,6,2} & v_{1,1,1,1,6,3} & v_{1,1,1,1,6,4} & v_{1,1,1,1,6,5} & v_{1,1,1,1,6,6} \end{bmatrix} \quad \text{if } N_1 < N_2$		

Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	i_2
1	$0, 1, \dots, Q_1 N_1 - 1$	$0, 1, \dots, Q_2 N_2 - 1$	0
			$W_{i_{1,1}, i_{1,2}}^{(0)} = \frac{1}{\sqrt{8Q}} \begin{bmatrix} V_{2i_{1,1}, 2i_{1,2}} & V_{2i_{1,1}, 2i_{1,2}+1} & V_{2i_{1,1}, 2i_{1,2}+2} & V_{2i_{1,1}, 2i_{1,2}+3} \\ V_{2i_{1,1}, 2i_{1,2}+4} & -V_{2i_{1,1}, 2i_{1,2}+5} & V_{2i_{1,1}, 2i_{1,2}+6} & -V_{2i_{1,1}, 2i_{1,2}+7} \\ V_{2i_{1,1}, 2i_{1,2}+8} & -V_{2i_{1,1}, 2i_{1,2}+9} & V_{2i_{1,1}, 2i_{1,2}+10} & -V_{2i_{1,1}, 2i_{1,2}+11} \\ V_{2i_{1,1}, 2i_{1,2}+12} & -V_{2i_{1,1}, 2i_{1,2}+13} & V_{2i_{1,1}, 2i_{1,2}+14} & -V_{2i_{1,1}, 2i_{1,2}+15} \end{bmatrix}$
			$N_1 \geq N_2$
			$W_{i_{1,1}, i_{1,2}}^{(0)} = \frac{1}{\sqrt{8Q}} \begin{bmatrix} V_{2i_{1,1}, 2i_{1,2}} & V_{2i_{1,1}, 2i_{1,2}+1} & V_{2i_{1,1}, 2i_{1,2}+2} & V_{2i_{1,1}, 2i_{1,2}+3} \\ V_{2i_{1,1}, 2i_{1,2}+4} & -V_{2i_{1,1}, 2i_{1,2}+5} & V_{2i_{1,1}, 2i_{1,2}+6} & -V_{2i_{1,1}, 2i_{1,2}+7} \\ V_{2i_{1,1}, 2i_{1,2}+8} & -V_{2i_{1,1}, 2i_{1,2}+9} & V_{2i_{1,1}, 2i_{1,2}+10} & -V_{2i_{1,1}, 2i_{1,2}+11} \\ V_{2i_{1,1}, 2i_{1,2}+12} & -V_{2i_{1,1}, 2i_{1,2}+13} & V_{2i_{1,1}, 2i_{1,2}+14} & -V_{2i_{1,1}, 2i_{1,2}+15} \end{bmatrix}$
			$N_1 < N_2$

[Figure 102c]

Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	i_2
3			0
$PP_{k,i}^{(D)} = \frac{1}{\sqrt{SQ}} \begin{bmatrix} V_{4k,1} \cdot \pi_{4k,1} & V_{4k,2} \cdot \pi_{4k,2} & V_{4k,3} \cdot \pi_{4k,3} & V_{4k,4} \cdot \pi_{4k,4} \\ V_{4k,5} \cdot \pi_{4k,5} & -V_{4k,6} \cdot \pi_{4k,6} & -V_{4k,7} \cdot \pi_{4k,7} & -V_{4k,8} \cdot \pi_{4k,8} \\ V_{4k,9} \cdot \pi_{4k,9} & -V_{4k,10} \cdot \pi_{4k,10} & V_{4k,11} \cdot \pi_{4k,11} & V_{4k,12} \cdot \pi_{4k,12} \\ V_{4k,13} \cdot \pi_{4k,13} & -V_{4k,14} \cdot \pi_{4k,14} & -V_{4k,15} \cdot \pi_{4k,15} & -V_{4k,16} \cdot \pi_{4k,16} \end{bmatrix}$ $N_1 \geq N_2$ and 12 port configuration $PP_{k,i}^{(D)} = \frac{1}{\sqrt{SQ}} \begin{bmatrix} V_{2k,1} \cdot \pi_{2k,1} & V_{2k,2} \cdot \pi_{2k,2} & V_{2k,3} \cdot \pi_{2k,3} & V_{2k,4} \cdot \pi_{2k,4} \\ V_{2k,5} \cdot \pi_{2k,5} & -V_{2k,6} \cdot \pi_{2k,6} & -V_{2k,7} \cdot \pi_{2k,7} & -V_{2k,8} \cdot \pi_{2k,8} \\ V_{2k,9} \cdot \pi_{2k,9} & -V_{2k,10} \cdot \pi_{2k,10} & V_{2k,11} \cdot \pi_{2k,11} & V_{2k,12} \cdot \pi_{2k,12} \\ V_{2k,13} \cdot \pi_{2k,13} & -V_{2k,14} \cdot \pi_{2k,14} & -V_{2k,15} \cdot \pi_{2k,15} & -V_{2k,16} \cdot \pi_{2k,16} \end{bmatrix}$ $N_1 < N_2$ and 12 port configuration $PP_{k,i}^{(D)} = \frac{1}{\sqrt{SQ}} \begin{bmatrix} V_{4k,1} \cdot \pi_{4k,1} & V_{4k,2} \cdot \pi_{4k,2} & V_{4k,3} \cdot \pi_{4k,3} & V_{4k,4} \cdot \pi_{4k,4} \\ V_{4k,5} \cdot \pi_{4k,5} & -V_{4k,6} \cdot \pi_{4k,6} & -V_{4k,7} \cdot \pi_{4k,7} & -V_{4k,8} \cdot \pi_{4k,8} \\ V_{4k,9} \cdot \pi_{4k,9} & -V_{4k,10} \cdot \pi_{4k,10} & V_{4k,11} \cdot \pi_{4k,11} & V_{4k,12} \cdot \pi_{4k,12} \\ V_{4k,13} \cdot \pi_{4k,13} & -V_{4k,14} \cdot \pi_{4k,14} & -V_{4k,15} \cdot \pi_{4k,15} & -V_{4k,16} \cdot \pi_{4k,16} \end{bmatrix}$ $N_1 \geq N_2$ and 16 port configuration $PP_{k,i}^{(D)} = \frac{1}{\sqrt{SQ}} \begin{bmatrix} V_{4k,1} \cdot \pi_{4k,1} & V_{4k,2} \cdot \pi_{4k,2} & V_{4k,3} \cdot \pi_{4k,3} & V_{4k,4} \cdot \pi_{4k,4} \\ V_{4k,5} \cdot \pi_{4k,5} & -V_{4k,6} \cdot \pi_{4k,6} & -V_{4k,7} \cdot \pi_{4k,7} & -V_{4k,8} \cdot \pi_{4k,8} \\ V_{4k,9} \cdot \pi_{4k,9} & -V_{4k,10} \cdot \pi_{4k,10} & V_{4k,11} \cdot \pi_{4k,11} & V_{4k,12} \cdot \pi_{4k,12} \\ V_{4k,13} \cdot \pi_{4k,13} & -V_{4k,14} \cdot \pi_{4k,14} & -V_{4k,15} \cdot \pi_{4k,15} & -V_{4k,16} \cdot \pi_{4k,16} \end{bmatrix}$ if $N_1 < N_2$ and 16 port configuration			

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2016/007961**A. CLASSIFICATION OF SUBJECT MATTER****H04B 7/06(2006.01)i, H04B 7/04(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04B 7/06; H04L 5/00; H04B 7/04

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: precoder codebook parameter, quantities of antenna ports, dimension, oversampling factor, codebook configuration information

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SAMSUNG, `Specification impacts and evaluation results with linear-combination codebook enhancements`, R1-153407, 3GPP TSG RAN WG1 Meeting #81, Fukuoka, Japan, 01 June 2015 See sections 2-3.	1-15
A	ERICSSON, `Comparing non-precoded and beamformed CSI-RS enhancements`, R1-153166, 3GPP TSG-RAN WG1#81, Fukuoka, Japan, 16 May 2015 See sections 2-3.	1-15
A	ALCATEL-LUCENT SHANGHAI BELL et al., `3D Codebook Design for 3D MIMO`, R1-152661, 3GPP TSG RAN WG1 Meeting #81, Fukuoka, Japan, 16 May 2015 See section 2.	1-15
A	US 2013-0308715 A1 (SAMSUNG ELECTRONICS CO., LTD.) 21 November 2013 See paragraphs [0077]-[0078], [0145]-[0152]; and figures 10-11.	1-15
A	US 2014-0369279 A1 (SAMSUNG ELECTRONICS CO., LTD.) 18 December 2014 See paragraphs [0030]-[0031], [0140]-[0144]; and figure 7.	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR2016/007961

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