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(54) **Title:** METHODS OF MAPPING MULTIPLE SD-FD BASES PER CSI-RS PORT FOR TYPE II PORT SELECTION CODEBOOK

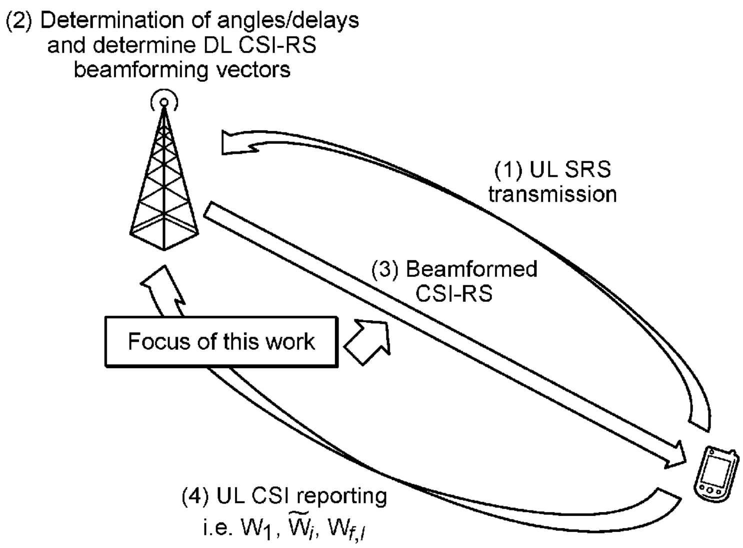

FIG. 3

(57) **Abstract:** A terminal performs Channel State Information (CSI) reporting for type II port selection codebook. The terminal includes a receiver that receives CSI Reference Signal (CSI-RS) resource configurations for CSI measurement by Radio Resource Control (RRC) signaling; and a processor that controls CSI reporting based on density information that comprises new density values in addition to existing density values.

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METHODS OF MAPPING MULTIPLE SD-FD BASES PER CSI-RS PORT FOR TYPE II PORT SELECTION CODEBOOK

TECHNICAL FIELD

[0001] One or more embodiments disclosed herein relate to methods of enhancing Type II port selection codebook for higher rank transmissions.

BACKGROUND

[0002] New Radio (NR) supports Type II channel state information (CSI) feedback for rank 1 and rank 2 (Release 15 of NR).

[0003] One or more new working items relating to NR Multiple Input Multiple Output (MIMO) for Release 17 of NR identify requirements for further enhancing a Type II port selection codebook.

[0004] For example, with regard to enhancement on CSI measurement and reporting it may be evaluated and, if needed, specify CSI reporting for DL multi-TRP and/or multi-panel transmission to enable more dynamic channel/interference hypotheses for NCJT, targeting both FR1 and FR2.

[0005] Further, it may be evaluated and, if needed, specify Type II port selection codebook enhancement (based on Rel. 15/16 Type II port selection) where information related to angle(s) and delay(s) are estimated at the gNode-B (gNB) based on Sounding Reference Signal (SRS) by utilizing downlink (DL)/uplink (UL) reciprocity of angle and delay, and the remaining DL Channel State Information (CSI) is reported by the user equipment (UE), mainly targeting Frequency Division Duplexing (FDD) Frequency Range 1 (FR1) to achieve better trade-off among UE complexity, performance and reporting overhead.

[0006] In other words, discussed herein is how the Type II port selection codebook may be further extended by mapping multiple spatial domain (SD) – frequency domain (FD) base pairs to a CSI-RS port for DL beamforming.

CITATION LIST

NON-PATENT REFERENCE

[0007]

[Non-Patent Reference 1] 3GPP RP 193133, “New WID: Further enhancements on MIMO for NR”, Dec. 2019.

[Non-Patent Reference 2] 3GPP TS 38.214, “NR; Physical layer procedures for data (Release 16).”

[Non-Patent Reference 3] 3GPP TS 38.211, “NR; Physical channels and modulation (Release 16).”

[Non-Patent Reference 4] 3GPP TS 38.331, “NR; Radio Resource Control (RRC); Protocol specification (Release 16).”

SUMMARY

[0008] One of more embodiments provide methods of enhancing Type II port selection codebook for higher rank transmissions.

[0009] In general, in one aspect, embodiments disclosed herein relate to a method for performing CSI reporting for type II port selection codebook that includes adding one or more values of CSI-RS density.

[0010] In general, in one aspect, embodiments disclosed herein relate to a method for performing CSI reporting for type II port selection codebook that includes mapping multiple SD-FD bases to a CSI-RS port based on a configuration for FDM.

[0011] In general, in one aspect, embodiments disclosed herein relate to a method for performing CSI reporting for type II port selection codebook that includes mapping multiple SD-FD bases to a CSI-RS port considering CDM.

[0012] In general, in one aspect, embodiments disclosed herein relate to a method for performing CSI reporting for type II port selection codebook that includes configuring whether to consider FDM and/or CDM based mapping.

[0013] Advantageously, enhancements on CSI measurement and reporting are being discussed in the development of Release 17 of NR. One of such enhancements includes evaluating and, if needed, specifying CSI reporting for Downlink (DL) multi-Transmission Reception Points (TRP) and/or multi-panel transmission to enable more dynamic channel/interference hypotheses for non-coherent joint transmission (NCJT), targeting both Frequency Range 1 (FR1) (i.e., 410 MHz to 7,125 MHz, sub-6 GHz) and Frequency Range 2 (FR2) (i.e., 24,250 MHz to 52,600 MHz, mmWaves). Another of such enhancements includes evaluating and, if needed, specifying Type II port selection codebook enhancements (based on Rel.15/16 Type II port selection) where information related to angle(s) and delay(s) are estimated at a gNB based on Sound Reference Signal (SRS) by utilizing DL/Uplink (UL) reciprocity of angle and delay. The remaining DL CSI is reported by the UE, mainly targeting Frequency Division Duplex (FDD) FR1 to achieve better trade-off among UE complexities, performance, and reporting overhead.

[0014] Other aspects of the disclosure will be apparent from the following description and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. 1 shows an example of a UE selecting a best L CSI-RS ports and reporting the selected beams to a gNB.

[0016] FIG. 2 shows an example of port-pair selection.

[0017] FIG. 3 shows an example of an overall process of Type II port selection.

[0018] FIG. 4 shows an example overview of CSI-RS configuration.

[0019] FIG. 5 shows an example overview of CSI-RS configuration over a bandwidth part (BWP).

[0020] FIG. 6 shows an example of new CSI-RS density values.

[0021] FIG. 7 shows an example of mapping multiple SD-FD bases per CSI-RS port considering frequency division multiplexing.

[0022] FIG. 8 shows an example table of CSI-RS configurations.

[0023] FIG. 9 shows an example of possible partitioning of CSI-RS PRBs.

[0024] FIG. 10 shows an example of CSI-RS PRB partitions.

[0025] FIG. 11 shows an example of configuring CSI-RS PRB partitions.

[0026] FIG. 12 shows an example of mapping multiple SD-FD bases per CSI-RS port considering code division multiplexing.

[0027] FIG. 13 shows an example of mapping multiple SD-FD bases per CSI-RS port considering code division multiplexing.

[0028] FIG. 14 shows an example of a configuration of a wireless communication system according to one or more embodiments.

[0029] FIG. 15 shows an example of a configuration of a BS according to one or more embodiments.

[0030] FIG. 16 shows an example of a configuration of a UE according to one or more embodiments.

DETAILED DESCRIPTION

[0031] Specific embodiments of the invention will now be described in detail with reference to the accompanying figures. Like elements in the various figures are denoted by like reference numerals for consistency.

[0032] In the following detailed description of embodiments of the invention, numerous specific details are set forth in order to provide a more thorough understanding of the invention. However, it will be apparent to one of ordinary skill in the art that the invention may be practiced without these specific details. In other instances, well-known features have not been described in detail to avoid unnecessarily complicating the description.

[0033] Throughout the application, ordinal numbers (e.g., first, second, third, etc.) may be used as an adjective for an element (i.e., any noun in the application). The use of ordinal numbers is not to imply or create any particular ordering of the elements nor to limit any element to being a single element unless expressly disclosed, such as by the use of the terms “before”, “after”, “single”, and other such terminology. Rather, the use of ordinal numbers is to distinguish between the elements. By way of an example, a first element is distinct from a second element, and the first element may encompass more than one element and succeed (or precede) the second element in an ordering of elements.

[0034] One or more embodiments of the invention disclosed herein related to how Type II port selection codebook can be further extended for supporting higher rank transmission especially taking into consideration angle-delay reciprocity of propagation channel.

[0035] At the outset, we discuss an overview of the Rel. 16 Type II Port Selection Codebook (CB) with reference to FIG. 1. Type II port selection CB does not require a UE to derive spatial domain (SD) beams considering 2D-DFT basis as in a regular Type II CB.

[0036] Instead, a gNB transmits K beamformed CSI-RS ports considering set of SD beams. In this example, a UE has to identify $L(\leq K)$ best CSI-RS ports (*e.g.*, corresponding to beams) and report their indices within $\mathbf{W}_1$.

[0037] SB-wise precoding vector generation for layer $l \in \{1, 2, 3, 4\}$ [2] is defined by $\boldsymbol{W}_l(\boldsymbol{N_t} \times \boldsymbol{N}_3) = \mathbf{Q}\boldsymbol{W}_{\mathbf{1}}\widetilde{\mathbf{W}}_l\mathbf{W}_{f,l}^{\mathrm{H}}$ equation (1) with parameters defined as follows:

[0038] $\mathbf{Q}(N_\mathrm{t} \times K)$: K SD beams used for CSI-RS beamforming

[0039] $\mathbf{W}_1(K \times 2L)$: Block diagonal matrix

[0040] $\widetilde{\mathbf{W}}_l(2L \times M)$: Linear combination (LC) coefficient matrix

[0041] $\mathbf{W}_{\mathrm{f},l}(\boldsymbol{N}_{\mathbf{3}} \times M)$:DFT basis vectors (FD bases)

[0042] N_3: Number of sub-bands

[0043] M: Number of FD basis vectors

[0044] In this example, a number of CSI-RS ports, K, is configured by higher layers such as in accordance with $P_{CSI-RS} \in \{4, 8, 12, 16, 24, 32\}$. $\mathbf{W}_1$ consists of column vectors from an identity matrix. The column vectors correspond to selected beams. A number of ports (*i.e.*, beams) to be selected, L , is higher layer configured in accordance with $L \in \{2, 3, 4\}$ when $P_{CSI-RS} > 4$. SD beams within $\mathbf{Q}$ are selected transparent to the UE. In addition, the SD beams can be determined based on sounding reference signals (SRS) or UL Demodulation Reference Signal (DMRS) transmission.

[0045] Turning to FIG. 2, reporting of $\mathbf{W_1}$based on Selected Beams is discussed in accordance with one or more embodiments. Parameter d is configured by the gNB and determines the sampling granularity of port groups. For example, in Rel. 16, d is configured as, $d \in \{1,2,3,4\}$ and $d \leq L$. Further, a UE reports $i_{1,1}$ as part of PMI to select L beams [2] where $i_{l,l} \in \{0, 1, K, \left\lceil \frac{P_{CSI-RS}}{2d} \right\rceil - 1\}$.

[0046] For example, in FIG. 2 it may be assumed $K=8$ and $L=2$. Thus, in Case 1 shown in FIG. 2, $d=2$ and $i_{1,1} = \{0,1\}$. Under Case 1, available port-pairs for selection are {B1,B2}, {B3,B4}. In Case 2 of the examples shown in FIG. 2, $d=1$ and $i_{1,1} = \{0,1,2,3\}$. Under Case 2, available port-pairs for selection are {B1, B2}, {B2, B3}, {B3, B4}, {B4, B1}.

[0047] In the examples in accordance with FIG. 2, parameters are defined by the following formulas:

[0048] $$\mathrm{W}_1 = \begin{bmatrix} \mathrm{E} & 0 \\ 0 & \mathrm{E} \end{bmatrix}$$

[0049] $$\mathrm{E} = \left[\mathrm{e}_{\mathrm{mod}(\mathrm{i}_{1,1}\mathrm{d},\ \mathrm{k}/2)}^{\mathrm{K}/2} \quad \mathrm{e}_{\mathrm{mod}(\mathrm{i}_{1,1}\mathrm{d}+1,\ \mathrm{k}/2)}^{\mathrm{K}/2} \right]$$

[0050] $\boldsymbol{e}_l^{K/2}$: A $(K/\mathbf{2} \times 1)$ vector with all zeros except 1 at l^{th} location

[0051] One or more embodiments relating to Type II Port Selection (PS) Codebook Structures will now be discussed. A general structure for SB-wise precoder generation for Rel. 17 port selection (PS) codebook considering l-th layer can be given as follows in equation (2):

[0052] $\mathrm{W_l(N_t \times N_3) = QW_{1,l}\widetilde{W}_l\left(SW_{f,l}\right)^H}$

[0053] $= \mathbf{Q}(\mathbf{W_{1,l}}\widetilde{\mathbf{W}}_l\mathbf{W}_{f,l}^{H})\mathbf{S}^{H}$

[0054] Where parameters are defined as:

[0055] $\mathrm{Q = [b_1 b_2 \cdots b_K]}$

[0056] $\mathrm{S = [f_1\ f_2\ \cdots f_{K'}]}$

[0057] $\mathbf{Q}(N_t \times K)$: K beamformed ports for SD beam selection

[0058] Note: $\boldsymbol{b_i}, i \in \{1,2,\cdots K\}$: i-th SD basis vector

[0059] $\mathbf{S}(N_3 \times K')$: K' beamformed ports for FD basis selection

[0060] Note: $\boldsymbol{f_j}, j \in \{1,2,\cdots K'\}$: $\boldsymbol{j}$-th FD basis vector

[0061] $\mathbf{W}_{1,l}$ $(K \times 2L_l)$: Block diagonal matrix where each matrix block consisting of L_l columns from an $(K \times K)$ identity matrix

[0062] $\mathbf{W}_{f,l}$ $(K' \times M_l)$: A matrix consisting of columns from an $(K' \times K')$ identity matrix

[0063] $\widetilde{\mathbf{W}}_l$ $(2L_l \times M_l)$: Linear combination coefficient matrix

[0064] It is noted that compared to Rel. 16 PS codebook in (2), CSI-RS beamforming is done both in SD and FD domains. FD bases for beamforming can be determined considering delay reciprocity.

[0065] In this example, a gNB transmits $(K \times K')$ beamformed SD and FD ports. Selection of K SD beams and K' FD bases for DL beamforming is transparent to UE. A UE selects L_l ports out of K SD beams and M_l ports out of K' FD bases for l-th layer and report them back to the gNB as part of PMI ($\mathbf{W}_1$ and $\mathbf{W}_{f,l}$ capture selected SD and FD bases). In addition, the UE reports LC coefficients in $\widetilde{\mathbf{W}}_l$ as well.

[0066] One or more embodiments of Type II Port Selection Codebook will now be discussed from the perspective of the UE.

[0067] Note that, equation (2) captures the final precoder generated at the network (NW) side considering reported port selection matrices $\mathbf{W}_{1,l}$ and $\mathbf{W}_{f,l}$ by the UE. However, from the UE's perspective, since $\mathbf{Q}$ and $\mathbf{S}$ are not known to the UE, the final SB-wise precoder for l-th layer looks as follows:

[0068] Equation (3) $\boldsymbol{W}_l(\boldsymbol{N_t} \times \boldsymbol{N_3}) = \boldsymbol{W}_{\mathbf{1},l}\widetilde{\mathbf{W}}_l\mathbf{W}_{f,l}^{H}$

[0069] Note that, equation (3) captures precoder generation when separate SD beams and FD bases selection is configured.

[0070] Further, it is possible to support a codebook structure without allowing the UE to select SD and FD bases separately (hence joint SD-FD selection). This can be explicitly given as:

[0071] Equation (4) $\mathrm{W_l(N_t \times N_3) = W_{1,l}W_2}$

[0072] Equation (4) captures precoder generation when Joint SD-FD bases selection is configured.

[0073] Here, $\mathbf{W}_{1,l}$ is a block diagonal matrix with each matrix block consisting of L_l columns from an $(K \times K)$ identity matrix (considering polarization common/specific selection). It is noted that the number of SD-FD bases pairs available for DL beamforming may not be the same as available CSI-RS ports within the configured CSI-RS resource. Hence, embodiments discussed herein contemplate how to map multiple SD-FD bases to a CSI-RS port considering frequency/code division multiplexing techniques

[0074] FIG. 3 shows an example of an overall process of Type II port selection. That is, how to potentially map multiple SD-FD bases to a CSI-RS port for DL beamforming. In FIG. 3, a terminal performs UL SRS transmission to a node, a determination of angles/delays and a determination of DL CSI-RS beamforming vectors is made, a beamformed CSI-RS is transmitted to the terminal from the node, and the terminal reports to the node UL CSI reporting such as $\mathbf{W}_1$, $\widetilde{\mathbf{W}}_l$, $\mathbf{W}_{\mathrm{f},l}$.

[0075] Turning to a discussion overviewing CSI-RS configurations, consider a 12 ports CSI-RS resource to understand necessary configurations. In particular, CSI-RS resource configuration for 12 ports CSI-RS resource within an RB is given by the *Row 10* of Table 7.4.1.5.3-1 in [3] as shown in FIG. 4.

[0076] Within an RB:

[0077] The time-domain locations $l_0 \in \{0,1, \ldots, 13\}$ and $l_1 \in \{2, 3, \ldots, 12\}$ are provided by the higher-layer parameters, such as *firstOFDMSymbolInTimeDomain,* and *firstOFDMSymbolInTimeDomain2* [3];

[0078] in this example, $\mathrm{l}_0 = 3$; and

[0079] the frequency-domain location is given by a bitmap provided by the higher-layer parameter.

[0080] For the example, a bitmap of size 6 is configured as shown by the vector displayed in FIG. 4.

[0081] The indices k' and l' index resource elements within a CDM group (referring to the Table in FIG. 4) [3].

[0082] Antenna port numbers are associated with 12 ports [3]: *3000*, *3001*, *3002*, *3003*, *3004*, *3005*, *3006*, *3007*, *3008*, *3009*, *3010*, *3011*.

[0083] Additionally, across RBs allocated for CSI-RS are described as follows.

[0084] It is noted that resource elements identified as discussed previously for CSI-RS mapping within a PRB is then repeated across every $\lceil 1/\rho \rceil$ where ρ is the density of the PRBs configured for CSI-RS reception by the UE. Additionally, all 12 ports use following two PN-sequences:

[0085] PN-Seq. for 3rd OFDM symbol -> $r_{3,n_{s,f}} = [r_3(0), r_3(1), \cdots]$

[0086] PN-Seq. for 4th OFDM symbol -> $r_{4,n_{s,f}} = [r_4(0), r_4(1), \cdots]$

[0087] Where $r_l(m)$ is the m-th element of the PN-sequence associated with l-th OFDM symbol [3].

[0088] Turning to CSI-RS resource configuration over a bandwidth part (BWP) as described by example in FIG. 5, consider an example to understand how CSI-RS resource(s) can be configured over a given BWP. In particular, consider the density, $\rho = 0.5$, and 12 ports CSI-RS resource considered previously in FIG. 4.

[0089] Configuration of *density*, ρ using RRC signalling [4] is shown in the information element displayed in FIG. 5. Additionally, along with the density ρ, the RRC parameter *freqBand* determines the RBs transmitting CSI-RS within BWP as shown in the corresponding parameter shown in FIG. 5.

[0090] It is noted that the 'sub-band' in the example shown in FIG. 5 can be identified as a physical resource group (PRG) as well.

[0091] One or more embodiments relate to introducing new CSI-RS density values. Further discussion of the one or more embodiments is provided with reference to FIG. 6.

[0092] That is, in addition to the existing values defined for density ρ, consideration is provided to add additional values such as, for example, $\rho \in \{0.125, 0.25, 0.5, 1, 2, 3\}$. Note that, other values for ρ are not precluded and those skilled in the art will appreciate the range of possible values for ρ.

[0093] Further, for the newly introduced density values, using higher layer signaling or DCI, a RB level comb offset indication should be done to inform which RBs are occupied by CSI-RS. For example, for density $\rho = 0.25$, x=2-bits are included as indication for RB level comb offset to inform which RBs are occupied by CSI-RS.

[0094] It is noted that with smaller ρ, a higher number of SRS resources can be accommodated within a given BWP. It is further noted that mapping between SD-FD bases to CSI-RS port is one-to-one.

[0095] One or more embodiments relate to mapping multiple SD-FD bases per CSI-RS port considering frequency division multiplexing (FDM). Further discussion of the one or more embodiments is provided with reference to FIG. 7.

[0096] That is, consideration is provided for FDM based mapping for assigning multiple SD-FD bases pairs to a single CSI-RS port (*i.e.*, many-to-one mapping). For example, let $\rho = 0.5$. Additionally, consider that available PRBs for CSI-RS within a BWP are divided in to two sets, *i.e.*, CSI-RS 1 and CSI-RS 2.

[0097] Now, with reference to FIG. 7, SD-FD pairs mapped to CSI-RS ports in PRBs in one set (same color) are the same. However, the SD-FD bases mapped to CSI-RS ports of PRBs in different sets (different colors) are different. Consider 4 CSI-RS ports within CDM group 0 as, P_0, P_1, P_2, P_3:

[0098] SD-FD bases mapped to these 4 ports in PRBs in CSI-RS 1 set are, $P_{1,0}^{\mathrm{SD-FD}}$, $P_{1,1}^{\mathrm{SD-FD}}$, $P_{1,2}^{\mathrm{SD-FD}}$, $P_{1,3}^{\mathrm{SD-FD}}$

[0099] SD-FD bases mapped to these 4 ports in PRBs in CSI-RS 2 set are, $P_{2,0}^{\mathrm{SD-FD}}$, $P_{2,1}^{\mathrm{SD-FD}}$, $P_{2,2}^{\mathrm{SD-FD}}$, $P_{2,3}^{\mathrm{SD-FD}}$

[00100] Note that, $P_{1,i}^{\mathrm{SD-FD}} \neq P_{2,j}^{\mathrm{SD-FD}}$ where $i, j \in \{0,\ 1,\ 2,\ 3\}$.

[00101] Further note that compared to the above one or more embodiments, with the following one or more embodiments, it is possible to map a higher number of SD-FD bases than the available ports in a given CSI-RS resource.

[00102] One or more embodiments in accordance with an alternative of the above one or more embodiments relate to mapping multiple SD-FD bases per CSI-RS port considering frequency division multiplexing (FDM). Further discussion of the one or more embodiments is provided with reference to FIG. 8.

[00103] That is, consideration is provided for a number of frequency partitions/sets/ /SD-FD bases per CSI-RS port, O_f, to consider within available PRBs for CSI-RS transmission is configured using higher-layer signaling or DCI.

[00104] In this example, the total number of SD-FD pairs identified for beamforming in the DL is $\mathrm{P_{SD-FD}}$. Further, total number of available CSI-RS ports is $\mathrm{P_{CSI-RS}}$. Then, considering O_f, the relation between $\mathrm{P_{SD-FD}}$ and $\mathrm{P_{CSI-RS}}$ can be given as equation (5):

[00105] $\mathrm{P_{SD-FD}} = O_f \times \mathrm{P_{CSI-RS}}$

[00106] In an option in accordance with the above one or more embodiments, a set of values for O_f is defined in the specification(s) and using higher layer signaling or x-bit(s) in DCI, a value for O_f is selected. For example, let possible values for O_f defined in the specification(s) be, $\{1,\ 2\}$. Then using 1 bit in DCI, one value is selected for O_f.

[00107] In an option in accordance with the above one or more embodiments, a value of O_f is configured using higher layer signaling or x-bit(s) in DCI. For example, using 2 bits in DCI, a value for O_f is configured. Note that it is possible to configure one value out of $\{1,\ 2,\ 3\}$ for O_f using 2 bits.

[00108] In an option in accordance with the above one or more embodiments, a value of O_f is pre-defined in the specification(s). For example, O_f is pre-defined as 2 in the specification(s). Alternatively in this option, a set of values for O_f is pre-defined in the specification(s) along with a one-to-one mapping with another parameter. For example, O_f is related to $\mathrm{P_{CSI-RS}}$ as shown in FIG. 8.

[00109] One or more embodiments in accordance with the above examples are described with reference to FIG. 9 showing examples of possible partitioning of CSI-RS PRBs when $O_f = 2$. In this example, let $\rho = 0.5$. Then, available CSI-RS PRBs can be divided into two sets, *i.e.*, CSI-RS 1 and CSI-RS 2, as shown in FIG. 9.

[00110] It is noted that case 1 and case 2 are two examples for PRB partitioning. Those skilled in the art will appreciate that there can be other ways to group PRBs for achieving different partitions. Additionally, CSI-RS ports within a particular frequency partition may be mapped with the same set of SD-FD pairs. Further, CSI-RS ports

between different frequency partitions may be mapped with different sets of SD-FD pairs.

[00111] One or more embodiments relate to configuring CSI-RS PRB partitions. Further discussion of the one or more embodiments is provided with reference to FIG. 10.

[00112] As discussed above, it is possible to group CSI-RS PRBs in different ways to generate partitions. However, it is important that the UE is aware of the specific PRB grouping considered for determining partitions. As such, a CSI-RS PRB grouping rule for generating different frequency partitions may be pre-defined in the specification(s). For example, a rule could be after assigning a PRB for a particular group, the next PRB for the same group is assigned only after all the other groups are allocated with at least one PRB.

[00113] In this example, Let $\rho = 1$. Also, assume a number of partitions, $O_f = 4$, for CSI-RS 1/2/3/4. Then, based on the above rule example, the UE assumes CSI-RS PRB allocation for different groups as shown in FIG. 10.

[00114] An option in accordance with the one or more embodiments is discussed with reference to FIG. 11. In this option, CSI-RS PRB grouping is associated with the number of configured frequency partitions, O_f. For example, let $\rho = 1$ as shown in FIG. 11, PRB grouping when $O_f = 2$ is different than that for $O_f = 4$.

[00115] As an alternative of the one or more embodiments , CSI-RS PRB allocation for different groups is indicated using higher-layer signaling or DCI considering a bitmap(s). For example, let $O_f = 2$ and there are 10 CSI-RS PRBs within the BWP. Then, using 1's in the following bitmap the NW indicates to the UE the PRBs associated with CSI-RS 1 group: 1000100010.

[00116] Note that if $O_f > 2$, multiple bitmaps associated with different PRB groups may need to be configured.

[00117] An option in accordance with the above discussion of the one or more embodiments and alternatives relates to configuring CSI-RS PRB partitions. Consider with combinatorial signaling, that the NW indicates CSI-RS PRB allocation for different groups using higher layer signaling or DCI. For example, using $\left\lceil \log_2 \binom{N_{\mathrm{CSI-RS}}}{N_{\mathrm{PRB}}^{\mathrm{G}}} \right\rceil$ bits, where $N_{\mathrm{CSI-RS}}$ is the number of CSI-RS PRBs and $N_{\mathrm{PRB}}^{\mathrm{G}}$ is the number of CSI-RS PRBs per group, the NW indicates PRB allocation for each group separately.

[00118] It is noted that $N_{\mathrm{PRB}}^{\mathrm{G}}$ can be equal to $\frac{N_{\mathrm{CSI-RS}}}{O_f}$. It is also possible that $N_{\mathrm{PRB}}^{\mathrm{G}}$ is configured separately.

[00119] It is further noted that with the one or more embodiments , CSI-RS PRB grouping follows a certain pattern, i.e., grouping consecutive PRBs, grouping every other PRB etc. However, with the one or more embodiments alternative, CSI-RS PRB grouping does not need to follow any pattern and it is possible to select any CSI-RS PRB within given BWP for a certain group.

[00120] One or more embodiments relate to mapping multiple SD-FD bases per CSI-RS port considering code division multiplexing (CDM). Further discussion of the one or more embodiments is provided with reference to FIG. 12.

[00121] That is, consideration is provided for CDM based mapping for assigning multiple SD-FD bases pairs to a single CSI-RS port (i.e., many-to-one mapping). For example, Let $\rho = 1$ and consider 12 ports CSI-RS resource. Then, considering CDM, two sets of CSI-RS resources ($O_f = 2$), i.e., CSI-RS 1 and CSI-RS 2, can be generated as shown in FIG. 12.

[00122] It is noted that O_f number of separate codes are generated to map O_f SD-FD bases to a CSI-RS port with CDM. It is further noted that unlike in the case with FDM based approach discussed previously, with CDM based approach, SD-FD bases pairs can occupy all CSI-RS PRBs.

[00123] As an alternative of the one or more embodiments , it is possible that with higher-layer signaling or DCI, the NW initializes or configures codes associated with different CSI-RS sets.

[00124] An option in accordance with the above discussion of the four one or more embodiments and alternatives relates to code configurations being associated with configured O_f value.

[00125] As another alternative of the one or more embodiments , it is possible that configurations associated with codes for CDM-based mapping of SD-FD bases to a CSI-RS port are pre-defined in the specification(s).

[00126] As another alternative of the one or more embodiments , it is possible that CDM-based mapping of multiple SD-FD bases pairs to a single CSI-RS port can be applied only to a subset of available CSI-RS ports. For example, let $\rho = 1$ and consider 12 ports CSI-RS resource. Then, considering CDM, only a subset of available CSI-RS ports are mapped with two SD-FD bases ($O_f = 2$) as shown in FIG. 13.

[00127] One or more embodiments in accordance with the one or more embodiments relate to configuration of FDM and/or CDM based SD-FD bases to CSI-RS port mapping considering number of SD-FD bases for DL beamforming.

[00128] That is, consideration is provided a UE being configured with FDM and/or CDM based multiple SD-FD bases to CSI-RS port mapping based on a number of SD-FD bases or any other rule.

[00129] As an option in accordance with the one or more embodiments , the UE may be configured, based on a configured O_f value, with FDM and/or CDM based multiple SD-FD bases to CSI-RS port mapping. For example:

[00130] If $\mathrm{O_f} \leq 2$: CDM based mapping

[00131] Else, FDM based mapping.

[00132] As an alternative of the one or more embodiments , it is possible that a specific CSI-RS port multiplexing rule is pre-defined in the specification(s).

[00133] As an alternative of the one or more embodiments , it is possible that a specific CSI-RS port multiplexing rule is configured using higher-layer signaling or DCI.

[00134] **Wireless Communication System**

[00135] FIG. 14 is a wireless communications system 1 according to one or more embodiments of the present invention. The wireless communication system 1 includes a UE 10, a BS 20, and a core network 30. The wireless communication system 1 may be a NR system. The wireless communication system 1 is not limited to the specific configurations described herein and may be any type of wireless communication system such as an LTE/LTE-Advanced (LTE-A) system.

[00136] The BS 20 may communicate uplink (UL) and downlink (DL) signals with the UE 10 in a cell of the BS 20. The DL and UL signals may include control information and user data. The BS 20 may communicate DL and UL signals with the core network 30 through backhaul links 31. The BS 20 may be gNodeB (gNB). The BS 20 may be referred to as a network (NW) 20. For example, the BS 20 may transmit DL signals such as a CSI-RS and DCI.

[00137] The BS 20 includes antennas, a communication interface to communicate with an adjacent BS 20 (for example, X2 interface), a communication interface to communicate with the core network 30 (for example, S1 interface), and a CPU (Central Processing Unit) such as a processor or a circuit to process transmitted and received signals with the UE 10. Operations of the BS 20 may be implemented by the processor processing or executing data and programs stored in a memory. However, the BS 20 is not limited to the hardware configuration set forth above and may be realized by other appropriate hardware configurations as understood by those of ordinary skill in the art. Numerous BSs 20 may be disposed so as to cover a broader service area of the wireless communication system 1.

[00138] The UE 10 may communicate DL and UL signals that include control information and user data with the BS 20 using Multi Input Multi Output (MIMO) technology. The UE 10 may be a mobile station, a smartphone, a cellular phone, a tablet, a mobile router, or information processing apparatus having a radio communication function such as a wearable device. The wireless communication system 1 may include

one or more UEs 10. For example, the UE 10 may transmit UL signals such as an SRS and CSI report.

[00139] The UE 10 includes a CPU such as a processor, a RAM (Random Access Memory), a flash memory, and a radio communication device to transmit/receive radio signals to/from the BS 20 and the UE 10. For example, operations of the UE 10 described below may be implemented by the CPU processing or executing data and programs stored in a memory. However, the UE 10 is not limited to the hardware configuration set forth above and may be configured with, e.g., a circuit to achieve the processing described below.

[00140] **Configuration of BS**

[00141] The BS 20 according to embodiments of the present invention will be described below with reference to FIG. 15. FIG. 15 is a diagram illustrating a schematic configuration of the BS 20 according to embodiments of the present invention. The BS 20 may include a plurality of antennas (antenna element group) 201, amplifier 202, transceiver (transmitter/receiver) 203, a baseband signal processor 204, a call processor 205 and a transmission path interface 206.

[00142] User data that is transmitted on the DL from the BS 20 to the UE 20 is input from the core network, through the transmission path interface 206, into the baseband signal processor 204.

[00143] In the baseband signal processor 204, signals are subjected to Packet Data Convergence Protocol (PDCP) layer processing, Radio Link Control (RLC) layer transmission processing such as division and coupling of user data and RLC retransmission control transmission processing, Medium Access Control (MAC) retransmission control, including, for example, HARQ transmission processing, scheduling, transport format selection, channel coding, inverse fast Fourier transform (IFFT) processing, and precoding processing. Then, the resultant signals are transferred to each transceiver 203. As for signals of the DL control channel, transmission processing is performed, including channel coding and inverse fast Fourier transform, and the resultant signals are transmitted to each transceiver 203.

[00144] The baseband signal processor 204 notifies each UE 10 of control information (system information) for communication in the cell by higher layer signaling (e.g., Radio Resource Control (RRC) signaling and broadcast channel). Information for communication in the cell includes, for example, UL or DL system bandwidth.

[00145] In each transceiver 203, baseband signals that are precoded per antenna and output from the baseband signal processor 204 are subjected to frequency conversion processing into a radio frequency band. The amplifier 202 amplifies the radio frequency signals having been subjected to frequency conversion, and the resultant signals are transmitted from the antennas 201.

[00146] As for data to be transmitted on the UL from the UE 10 to the BS 20, radio frequency signals are received in each antennas 201, amplified in the amplifier 202, subjected to frequency conversion and converted into baseband signals in the transceiver 203, and are input to the baseband signal processor 204.

[00147] The baseband signal processor 204 performs FFT processing, IDFT processing, error correction decoding, MAC retransmission control reception processing, and RLC layer and PDCP layer reception processing on the user data included in the received baseband signals. Then, the resultant signals are transferred to the core network through the transmission path interface 206. The call processor 205 performs call processing such as setting up and releasing a communication channel, manages the state of the BS 20, and manages the radio resources.

[00148] **Configuration of UE**

[00149] The UE 10 according to embodiments of the present invention will be described below with reference to FIG. 16. FIG. 16 is a schematic configuration of the UE 10 according to embodiments of the present invention. The UE 10 has a plurality of UE antenna S101, amplifiers 102, the circuit 103 comprising transceiver (transmitter/receiver) 1031, the controller 104, and an application 105.

[00150] As for DL, radio frequency signals received in the UE antenna S101 are amplified in the respective amplifiers 102, and subjected to frequency conversion into baseband signals in the transceiver 1031. These baseband signals are subjected to reception processing such as FFT processing, error correction decoding and retransmission control and so on, in the controller 104. The DL user data is transferred to the application 105. The application 105 performs processing related to higher layers above the physical layer and the MAC layer. In the downlink data, broadcast information is also transferred to the application 105.

[00151] On the other hand, UL user data is input from the application 105 to the controller 104. In the controller 104, retransmission control (Hybrid ARQ) transmission processing, channel coding, precoding, DFT processing, IFFT processing and so on are performed, and the resultant signals are transferred to each transceiver 1031. In the transceiver 1031, the baseband signals output from the controller 104 are converted into a radio frequency band. After that, the frequency-converted radio frequency signals are amplified in the amplifier 102, and then, transmitted from the antenna 101.

[00152] **Variation**

[00153] The information, signals, and/or others described in this specification may be represented by using any of a variety of different technologies. For example, data, instructions, commands, information, signals, bits, symbols, chips, and so on, all of which may be referenced throughout the herein-contained description, may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or photons, or any combination of these.

[00154] Also, information, signals, and so on can be output from higher layers to lower layers and/or from lower layers to higher layers. Information, signals, and so on may be input and/or output via a plurality of network nodes.

[00155] The information, signals, and so on that are input and/or output may be stored in a specific location (for example, a memory) or may be managed by using a management table. The information, signals, and so on to be input and/or output can be overwritten, updated, or appended. The information, signals, and so on that are

output may be deleted. The information, signals, and so on that are input may be transmitted to another apparatus.

[00156] Reporting of information is by no means limited to the aspects/present embodiments described in this specification, and other methods may be used as well. For example, reporting of information may be implemented by using physical layer signaling (for example, downlink control information (DCI), uplink control information (UCI), higher layer signaling (for example, RRC (Radio Resource Control) signaling, broadcast information (master information block (MIB), system information blocks (SIBs), and so on), MAC (Medium Access Control) signaling and so on), and other signals and/or combinations of these.

[00157] Software, whether referred to as “software,” “firmware,” “middleware,” “microcode,” or “hardware description language,” or called by other terms, should be interpreted broadly to mean instructions, instruction sets, code, code segments, program codes, programs, subprograms, software modules, applications, software applications, software packages, routines, subroutines, objects, executable files, execution threads, procedures, functions, and so on.

[00158] Also, software, commands, information, and so on may be transmitted and received via communication media. For example, when software is transmitted from a website, a server, or other remote sources by using wired technologies (coaxial cables, optical fiber cables, twisted-pair cables, digital subscriber lines (DSL), and so on) and/or wireless technologies (infrared radiation, microwaves, and so on), these wired technologies and/or wireless technologies are also included in the definition of communication media.

[00159] The terms “system” and “network” as used in this specification are used interchangeably.

[00160] In the present specification, the terms “base station (BS),” “radio base station,” “eNB,” “gNB,” “cell,” “sector,” “cell group,” “carrier,” and “component carrier” may be used interchangeably. A base station may be referred to as a “fixed

station," "NodeB," "eNodeB (eNB)," "access point," "transmission point," "receiving point," "femto cell," "small cell" and so on.

[00161] A base station can accommodate one or a plurality of (for example, three) cells (also referred to as "sectors"). When a base station accommodates a plurality of cells, the entire coverage area of the base station can be partitioned into multiple smaller areas, and each smaller area can provide communication services through base station subsystems (for example, indoor small base stations (RRHs (Remote Radio Heads))). The term "cell" or "sector" refers to part of or the entire coverage area of a base station and/or a base station subsystem that provides communication services within this coverage.

[00162] In the present specification, the terms "mobile station (MS)," "user terminal," "user equipment (UE)," and "terminal" may be used interchangeably.

[00163] A mobile station may be referred to as, by a person skilled in the art, a "subscriber station," "mobile unit," "subscriber unit," "wireless unit," "remote unit," "mobile device," "wireless device," "wireless communication device," "remote device," "mobile subscriber station," "access terminal," "mobile terminal," "wireless terminal," "remote terminal," "handset," "user agent," "mobile client," "client," or some other appropriate terms in some cases.

[00164] Furthermore, the radio base stations in this specification may be interpreted as user terminals. For example, each aspect/present embodiment of the present disclosure may be applied to a configuration in which communication between a radio base station and a user terminal is replaced with communication among a plurality of user terminals (D2D (Device-to-Device)). In this case, the user terminals 20 may have the functions of the radio base stations 10 described above. In addition, wording such as "uplink" and "downlink" may be interpreted as "side." For example, an uplink channel may be interpreted as a side channel.

[00165] Likewise, the user terminals in this specification may be interpreted as radio base stations. In this case, the radio base stations may have the functions of the user terminals described above.

[00166] Actions which have been described in this specification to be performed by a base station may, in some cases, be performed by upper nodes. In a network including one or a plurality of network nodes with base stations, it is clear that various operations that are performed to communicate with terminals can be performed by base stations, one or more network nodes (for example, MMEs (Mobility Management Entities), S-GW (Serving-Gateways), and so on may be possible, but these are not limiting) other than base stations, or combinations of these.

[00167] One or more embodiments illustrated in this specification may be used individually or in combinations, which may be switched depending on the mode of implementation. The order of processes, sequences, flowcharts, and so on that have been used to describe the aspects/present embodiments herein may be re-ordered as long as inconsistencies do not arise. For example, although various methods have been illustrated in this specification with various components of steps in exemplary orders, the specific orders that are illustrated herein are by no means limiting.

[00168] One or more embodiments illustrated in the present disclosure may be applied to LTE (Long Term Evolution), LTE-A (LTE-Advanced), LTE-B (LTE-Beyond), SUPER 3G, IMT-Advanced, 4G (4th generation mobile communication system), 5G (5th generation mobile communication system), FRA (Future Radio Access), New-RAT (Radio Access Technology), NR(New Radio), NX (New radio access), FX (Future generation radio access), GSM (registered trademark) (Global System for Mobile communications), CDMA 2000, UMB (Ultra Mobile Broadband), IEEE 802.11 (Wi-Fi (registered trademark)), IEEE 802.16 (WiMAX (registered trademark)), IEEE 802.20, UWB (Ultra-WideBand), Bluetooth (registered trademark), systems that use other adequate radio communication methods and/or next-generation systems that are enhanced based on these.

[00169] The phrase “based on” (or “on the basis of”) as used in this specification does not mean “based only on” (or “only on the basis of”), unless otherwise specified. In other words, the phrase “based on” (or “on the basis of”) means both “based only on” and “based at least on” (“only on the basis of” and “at least on the basis of”).

[00170] Reference to elements with designations such as "first," "second" and so on as used herein does not generally limit the quantity or order of these elements. These designations may be used herein only for convenience, as a method for distinguishing between two or more elements. Thus, reference to the first and second elements does not imply that only two elements may be employed, or that the first element must precede the second element in some way.

[00171] The term "judging (determining)" as used herein may encompass a wide variety of actions. For example, "judging (determining)" may be interpreted to mean making "judgments (determinations)" about calculating, computing, processing, deriving, investigating, looking up (for example, searching a table, a database, or some other data structures), ascertaining, and so on. Furthermore, "judging (determining)" may be interpreted to mean making "judgments (determinations)" about receiving (for example, receiving information), transmitting (for example, transmitting information), input, output, accessing (for example, accessing data in a memory), and so on. In addition, "judging (determining)" as used herein may be interpreted to mean making "judgments (determinations)" about resolving, selecting, choosing, assuming, establishing, comparing, and so on. In other words, "judging (determining)" may be interpreted to mean making "judgments (determinations)" about some action.

[00172] The terms "connected" and "coupled," or any variation of these terms as used herein mean all direct or indirect connections or coupling between two or more elements, and may include the presence of one or more intermediate elements between two elements that are "connected" or "coupled" to each other. The coupling or connection between the elements may be physical, logical, or a combination thereof. For example, "connection" may be interpreted as "access."

[00173] In this specification, when two elements are connected, the two elements may be considered "connected" or "coupled" to each other by using one or more electrical wires, cables and/or printed electrical connections, and, as some non-limiting and non-inclusive examples, by using electromagnetic energy having wavelengths in radio frequency regions, microwave regions, (both visible and invisible) optical regions, or the like.

[00174] In this specification, the phrase “A and B are different” may mean that “A and B are different from each other.” The terms “separate,” “be coupled” and so on may be interpreted similarly.

[00175] Furthermore, the term "or" as used in this specification or in claims is intended to be not an exclusive disjunction.

[00176] Now, although the present invention has been described in detail above, it should be obvious to a person skilled in the art that the present invention is by no means limited to the embodiments described in this specification. The present invention can be implemented with various corrections and in various modifications, without departing from the spirit and scope of the invention defined by the recitations of claims. Consequently, the description in this specification is provided only for the purpose of explaining examples, and should by no means be construed to limit the invention according to the present invention in any way.

[00177] **Alternative Examples**

[00178] The above examples and modified examples may be combined with each other, and various features of these examples can be combined with each other in various combinations. The invention is not limited to the specific combinations disclosed herein.

[00179] Although the disclosure has been described with respect to only a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that various other embodiments may be devised without departing from the scope of the present invention. Accordingly, the scope of the invention should be limited only by the attached claims.

CLAIMS

What is claimed is:

1. A terminal that performs Channel State Information (CSI) reporting for type II port selection codebook, the terminal comprising:
   a receiver that receives CSI Reference Signal (CSI-RS) resource configurations for CSI measurement by Radio Resource Control (RRC) signaling; and
   a processor that controls CSI reporting based on density information that comprises new density values in addition to existing density values.

2. The terminal of claim 1, wherein a resource block (RB) level offset indication is performed to inform which RBs are occupied by CSI-RS through higher layer signaling or downlink control information (DCI) for the new density values.

3. The terminal of claim 1, wherein the terminal maps spatial domain (SD) – frequency domain (FD) bases to CSI-RS reports one-to-one.

4. The terminal of claim 1, wherein the terminal maps multiple SD-FD bases to a single CSI-RS port in a frequency division multiplexing (FDM) based mapping.

5. The terminal of claim 4, wherein the processor configures partitioning of a CSI-RS physical resource block (PRB) for FDM based mapping.

6. The terminal of claim 5, wherein CSI-RS ports within a particular frequency partition are mapped with a same set of SD-FD parts.

7. The terminal of claim 5, wherein after assigning the CSI-RS PRB for a group, the terminal assigns a next PRB for the same group only after all other groups are already allocated with at least one CSI-RS PRB.

8. The terminal of claim 5, wherein CSI-RS PRB allocation is indicated using higher-layer signaling or DCI considering a bitmap using a number of bits.

9. The terminal of claim 8, wherein the number of bits is determined based on a number of CSI-RS PRBs and a number of CSI-RS PRBs per group.

10. The terminal of claim 4, wherein the mapping is performed using code division multiplexing (CDM).

11. The terminal of claim 10, wherein a network initializes and configures predetermined codes for CDM associated with different CSI-RS sets using higher layer signaling or DCI.

12. The terminal of claim 4, wherein the mapping is only applied to a subset of available CSI-RS ports.

13. The terminal of claim 1, wherein the terminal determines whether to consider FDM or CDM based mapping based on a configured value.

14. A method for a terminal performing Channel State Information (CSI) reporting for type II port selection codebook, the method comprising:

receiving beamformed CSI reference signal (RS) ports comprising spatial domain (SD) beams and frequency domain (FD) bases; and

controlling the CSI reporting based on density information that comprises new density values in addition to existing density values.

15. A system that performs Channel State Information (CSI) reporting for type II port selection codebook, the system comprising:

a terminal that comprises:

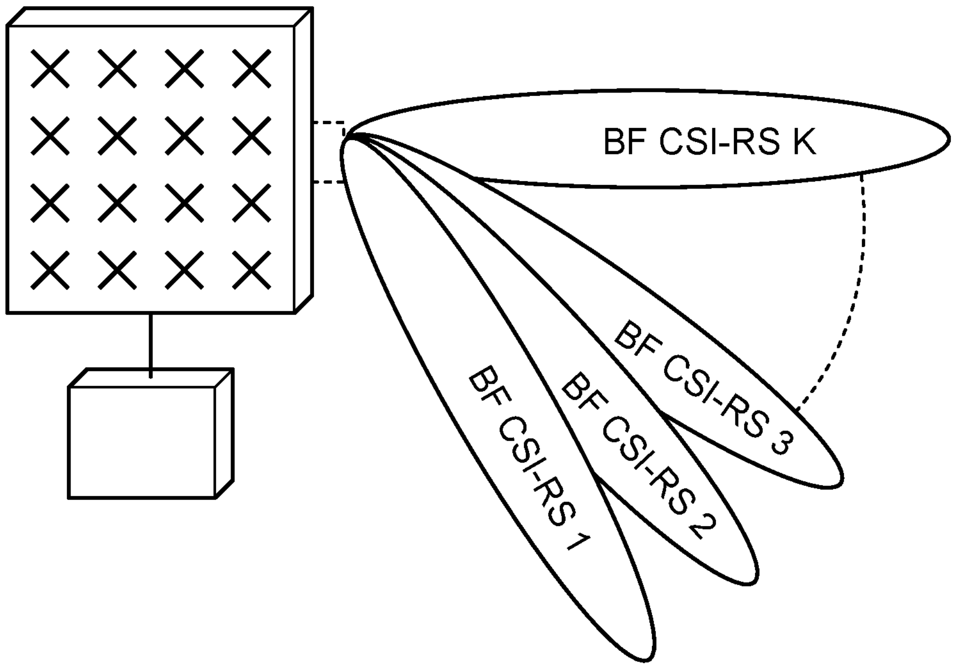
a receiver that receives CSI Reference Signal (CSI-RS) resource configurations for CSI measurement by Radio Resource Control (RRC) signaling; and

a first processor that controls CSI reporting based on density information that comprises new density values in addition to existing density values.

a base station that comprises:

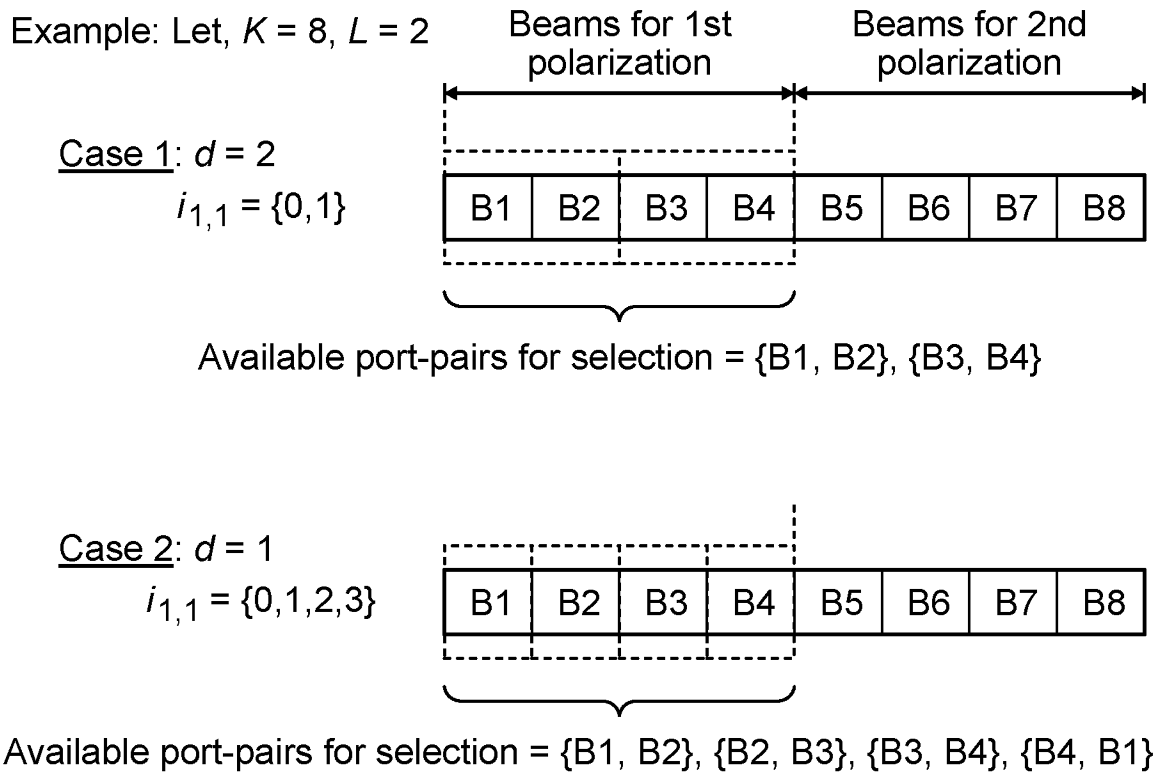
a transmitter that transmits the CSI-RS resource configurations; and

a second processor that controls transmission of the density information.



UE selects best *L* CSI-RS ports and reports those selected beams to gNB

FIG. 1



$$\mathbf{W}_1 = \begin{bmatrix} \mathbf{E} & \mathbf{0} \\ \mathbf{0} & \mathbf{E} \end{bmatrix}$$

$$\mathbf{E} = \begin{bmatrix} e^{K/2}_{\mathrm{mod}(i_{1,1}d, k/2)} & e^{K/2}_{\mathrm{mod}(i_{1,1}d+1, k/2)} \end{bmatrix}$$

$e_l^{K/2}$: A ($K/2$ x 1) vector with all zeros except 1 at l^{th} location

FIG. 2

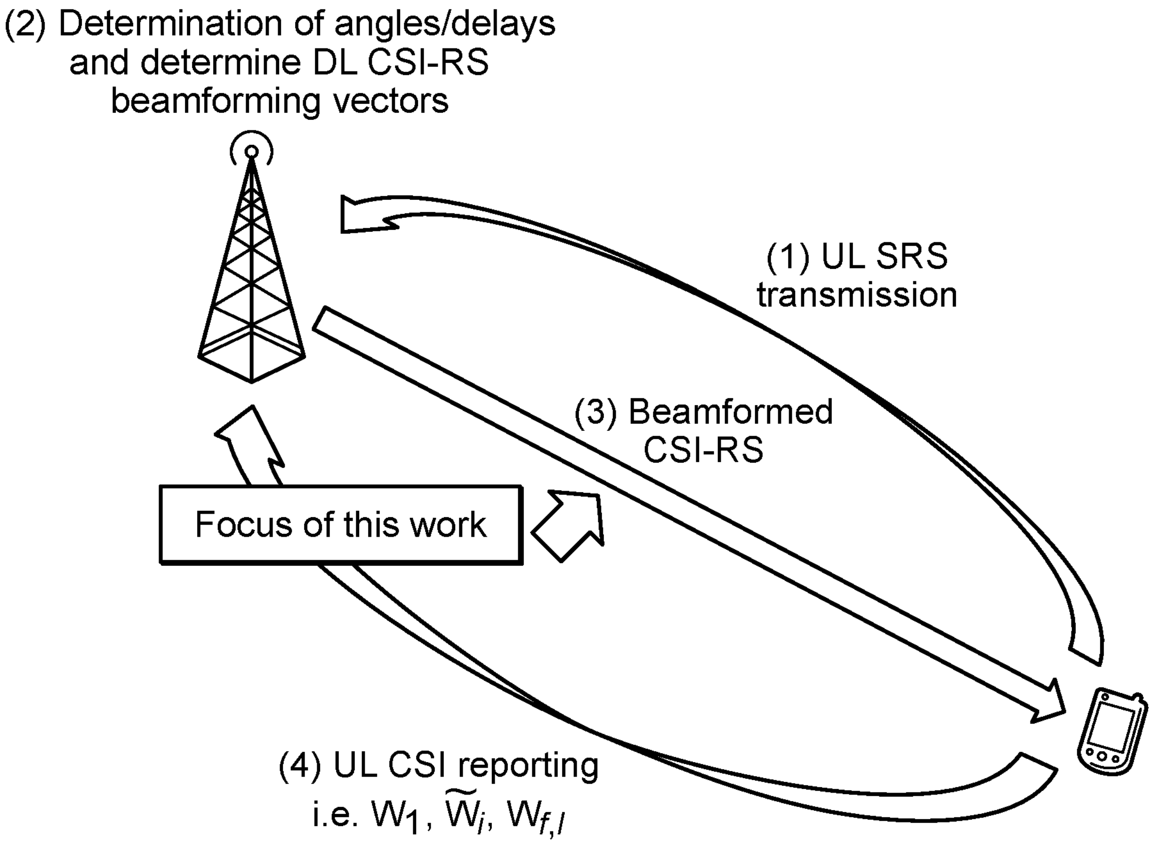
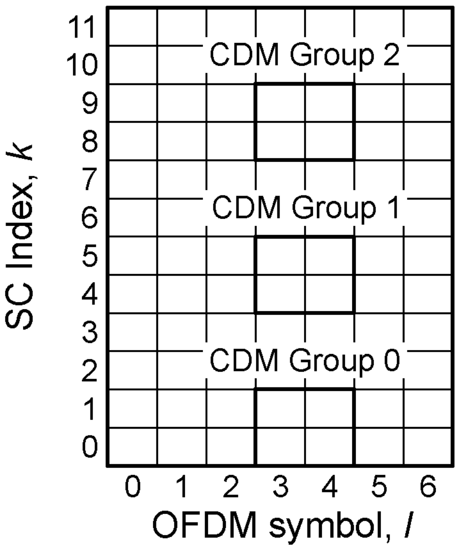
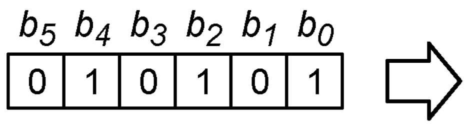

(2) Determination of angles/delays and determine DL CSI-RS beamforming vectors
(1) UL SRS transmission
(3) Beamformed CSI-RS
Focus of this work
(4) UL CSI reporting i.e. W1, W̃i, Wf,l

FIG. 3

Row	Ports X	Density ρ	cdm-Type	$(\bar{k},\bar{l})$	cdm group index j	k'	l'
10	12	1	cdm4-FD2 -TD2	(k_0, l_0), (k_1, l_0), (k_2, l_0),	0,1,2	0,1	0,1



Here, $k_0 = 0; k_1 = 4, k_2 = 8$, $l_0 = 3$



f(i): Bit number of the *i*-th in the bitmap set to one

$k_{i-1} = 2f(i)[3]$

$k_0 = 2f(1) = 2x0 = 0$

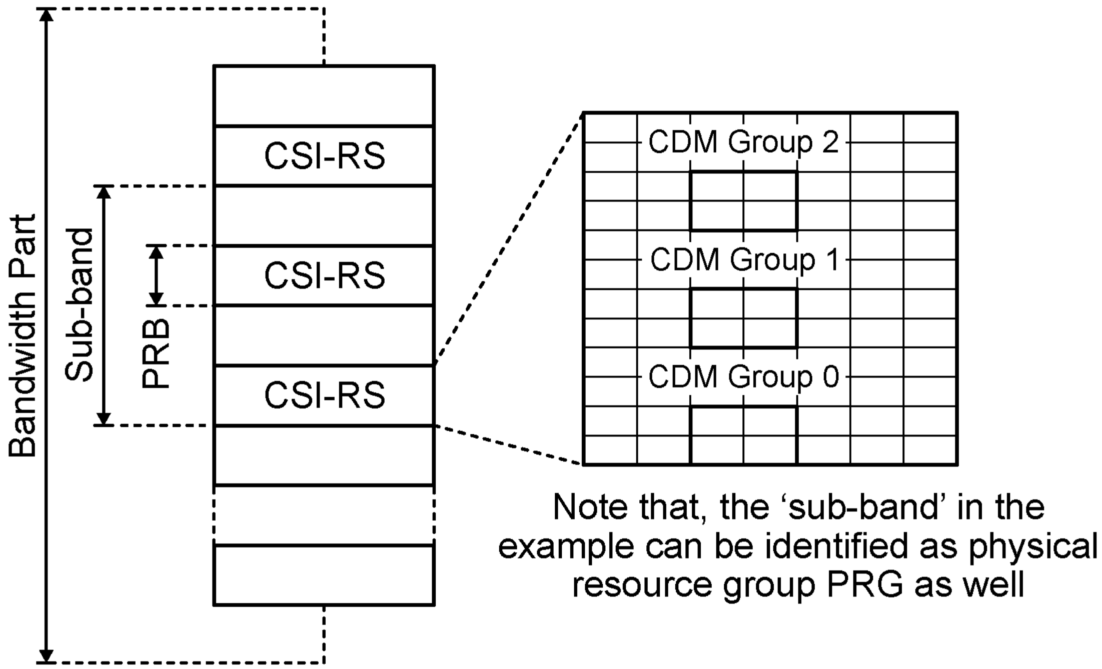
$k_1 = 2f(2) = 2x2 = 4$

$k_2 = 2f(3) = 2x4 = 8$

FIG. 4

Configuration of *density*, ρ using RRC signaling [4]:

```
density             CHOICE {
    dot5                ENUMERATED {evenPRBs, oddPRBs}
    one                 NULL,
    three               NULL,
    spare               NULL
},                  },
```




```
freqBand    CSI-Frequencyoccupation,
```

```
CSI-Frequencyoccupation ::= SEQUENCE {
   startingRB   INTEGER (0..maxNrofPhysicalResourceBlocks-1),
   nrofRBs      INTEGER (24..maxNrofPhysicalResourceBlocksPlus1),
   ...
}
```

FIG. 5

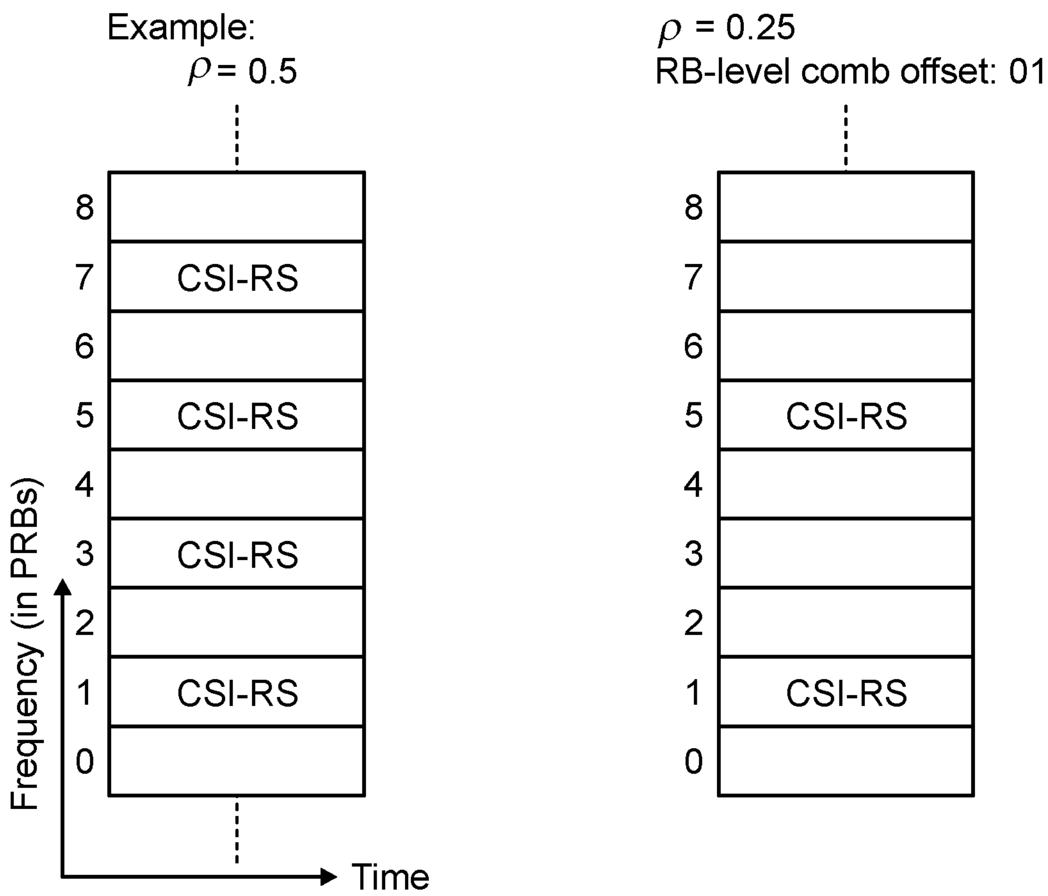

Example:
ρ = 0.5
ρ = 0.25
RB-level comb offset: 01
8
7
6
5
4
3
2
1
0
CSI-RS
CSI-RS
CSI-RS
CSI-RS
Frequency (in PRBs)
Time
CSI-RS
CSI-RS

FIG. 6

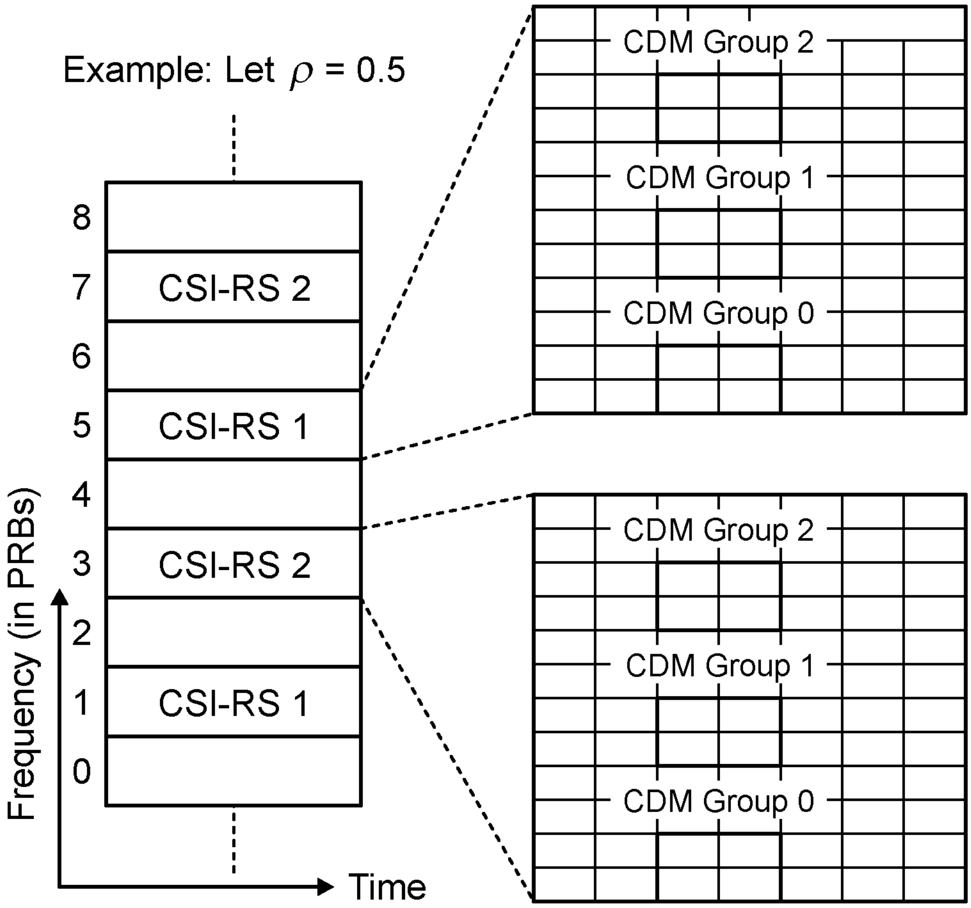

Example: Let ρ = 0.5
8
7
CSI-RS 2
6
5
CSI-RS 1
4
3
CSI-RS 2
2
1
CSI-RS 1
0
Frequency (in PRBs)
Time
CDM Group 2
CDM Group 1
CDM Group 0
CDM Group 2
CDM Group 1
CDM Group 0

FIG. 7

NW configures P_{CSI-RS} and based on that associated O_f is selected from the table

P_{CSI-RS}	O_f
4	4
8	4
16	2
32	1

FIG. 8

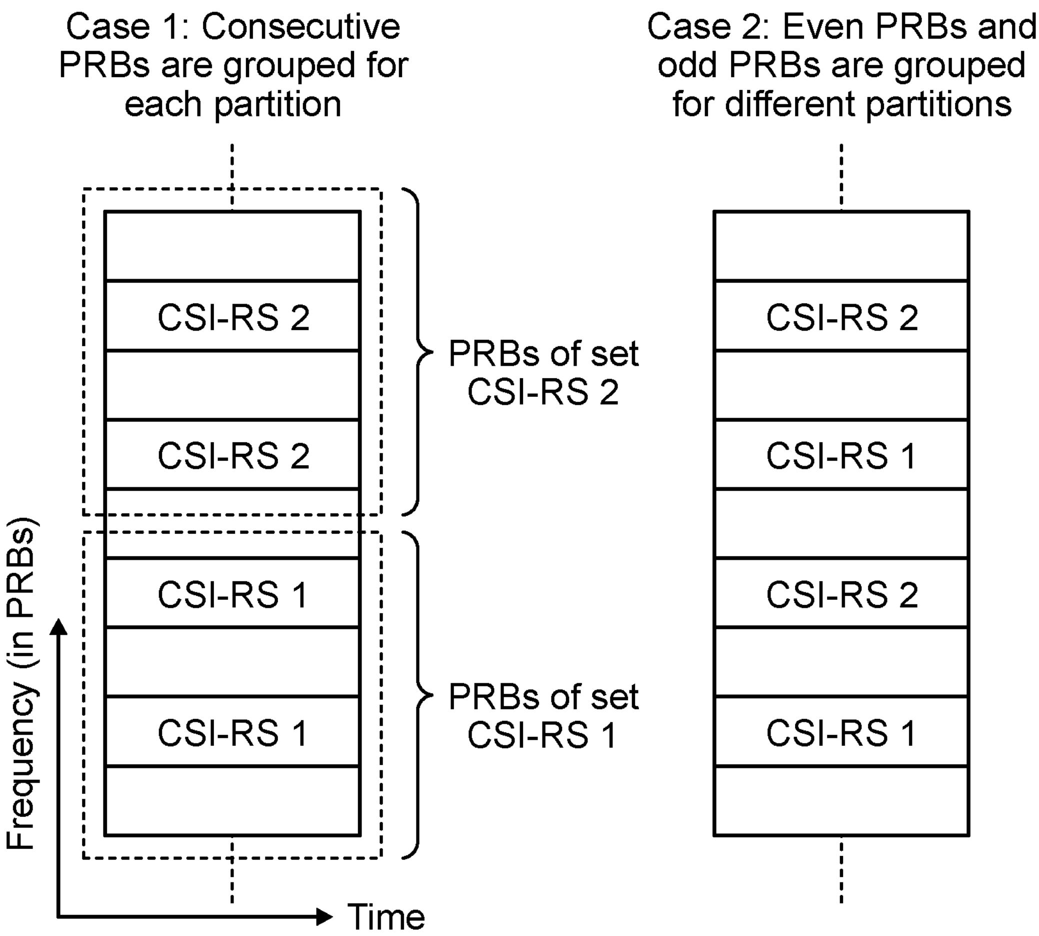

Case 1: Consecutive PRBs are grouped for each partition
Case 2: Even PRBs and odd PRBs are grouped for different partitions
CSI-RS 2
CSI-RS 2
CSI-RS 1
CSI-RS 1
PRBs of set CSI-RS 2
PRBs of set CSI-RS 1
CSI-RS 2
CSI-RS 1
CSI-RS 2
CSI-RS 1
Frequency (in PRBs)
Time

FIG. 9

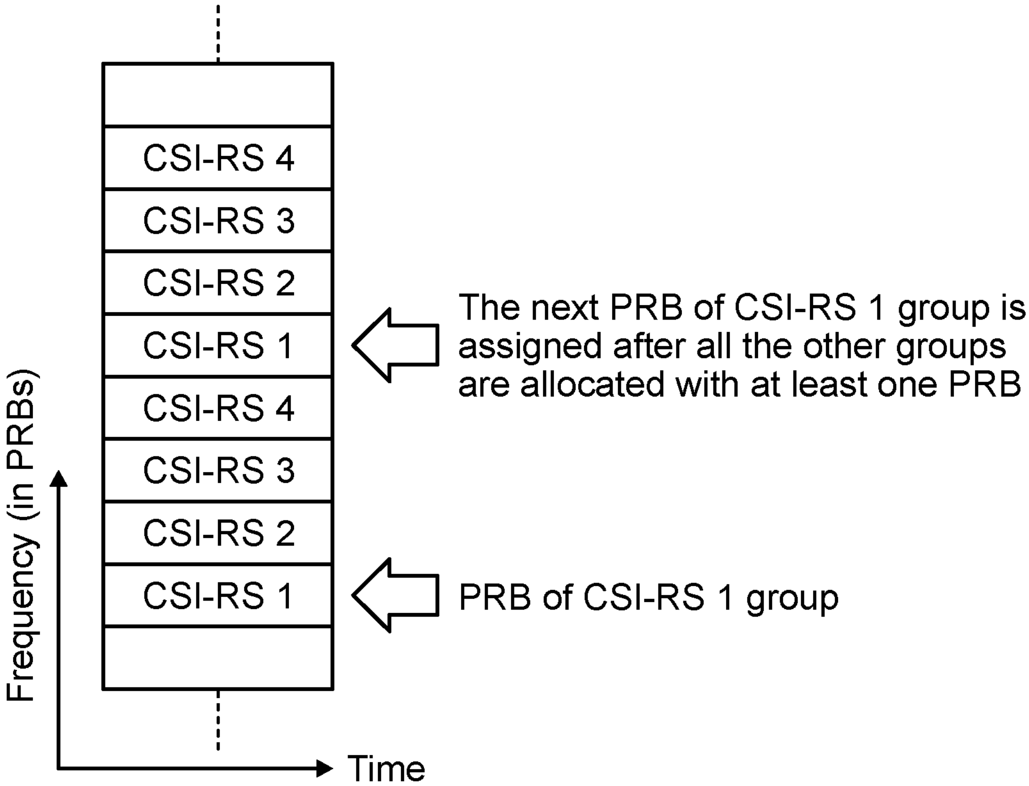

CSI-RS 4
CSI-RS 3
CSI-RS 2
CSI-RS 1
CSI-RS 4
CSI-RS 3
CSI-RS 2
CSI-RS 1
The next PRB of CSI-RS 1 group is assigned after all the other groups are allocated with at least one PRB
PRB of CSI-RS 1 group
Frequency (in PRBs)
Time

FIG. 10

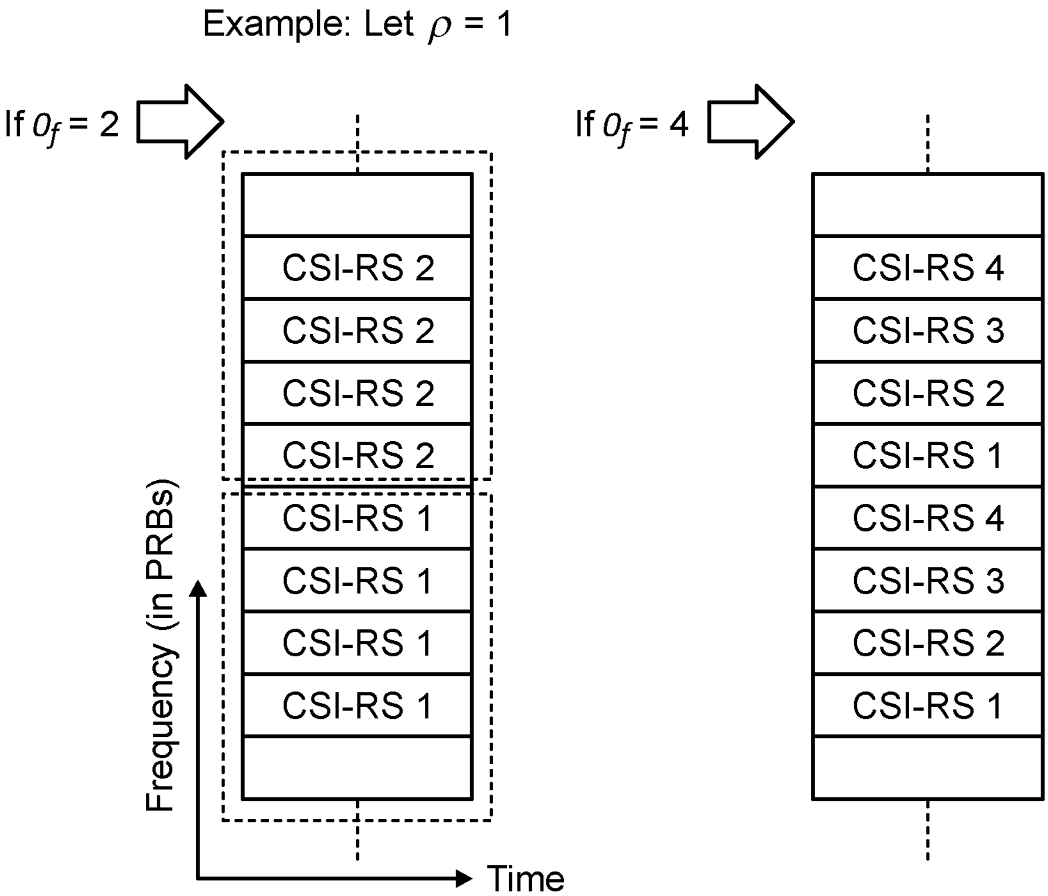
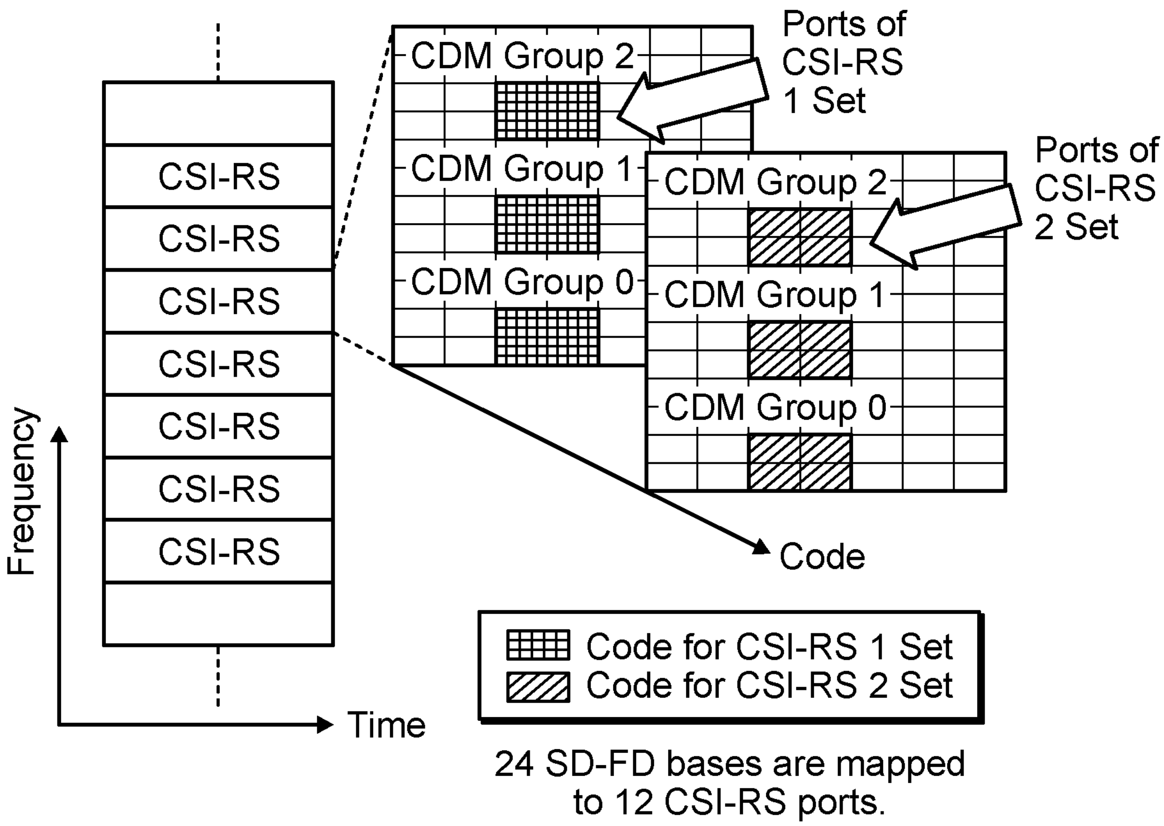

Example: Let ρ = 1
If O_f = 2
If O_f = 4
CSI-RS 2
CSI-RS 2
CSI-RS 2
CSI-RS 2
CSI-RS 1
CSI-RS 1
CSI-RS 1
CSI-RS 1
Frequency (in PRBs)
Time
CSI-RS 4
CSI-RS 3
CSI-RS 2
CSI-RS 1
CSI-RS 4
CSI-RS 3
CSI-RS 2
CSI-RS 1

FIG. 11



Ports of CSI-RS 1 Set
CDM Group 2
CDM Group 1
CDM Group 0
Ports of CSI-RS 2 Set
CDM Group 2
CDM Group 1
CDM Group 0
CSI-RS
CSI-RS
CSI-RS
CSI-RS
CSI-RS
CSI-RS
CSI-RS
Frequency
Time
Code
Code for CSI-RS 1 Set
Code for CSI-RS 2 Set
24 SD-FD bases are mapped to 12 CSI-RS ports.

FIG. 12

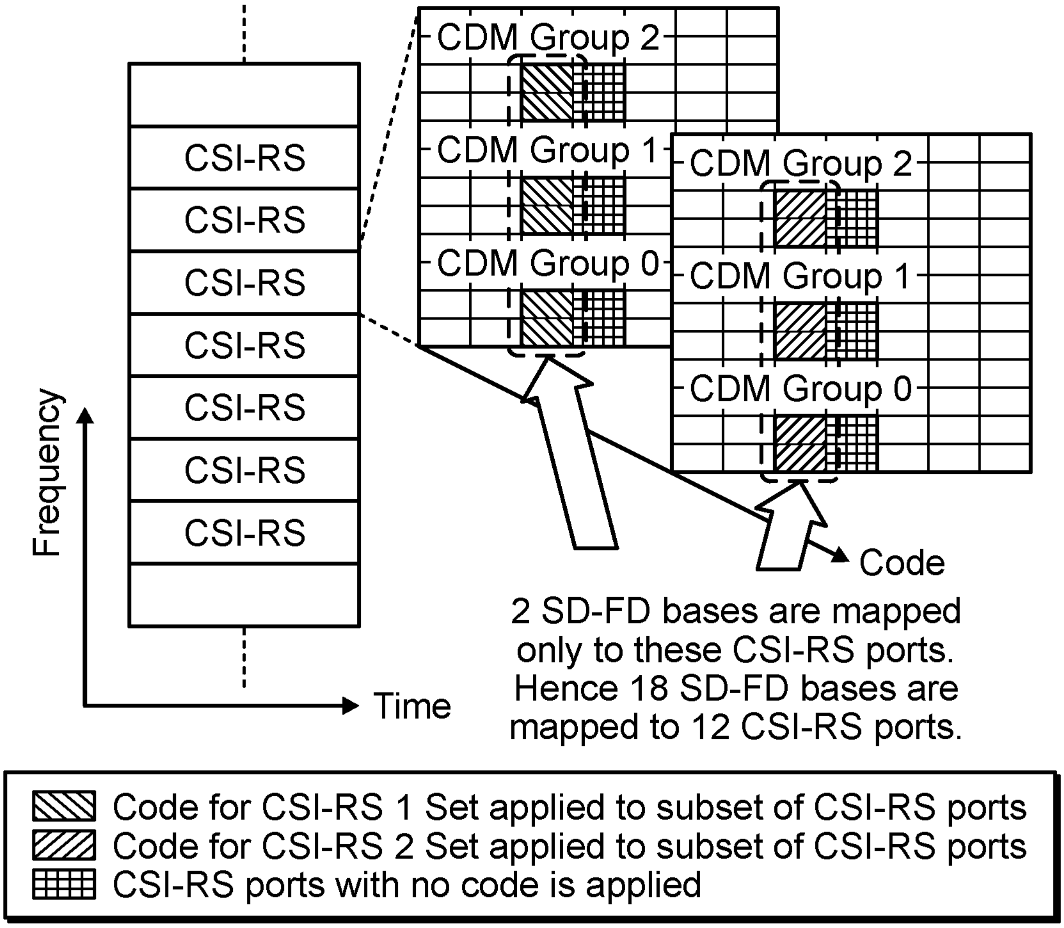

CSI-RS
CSI-RS
CSI-RS
CSI-RS
CSI-RS
CSI-RS
CSI-RS
Frequency
Time
CDM Group 2
CDM Group 1
CDM Group 0
CDM Group 2
CDM Group 1
CDM Group 0
Code
2 SD-FD bases are mapped only to these CSI-RS ports. Hence 18 SD-FD bases are mapped to 12 CSI-RS ports.
Code for CSI-RS 1 Set applied to subset of CSI-RS ports
Code for CSI-RS 2 Set applied to subset of CSI-RS ports
CSI-RS ports with no code is applied

FIG. 13

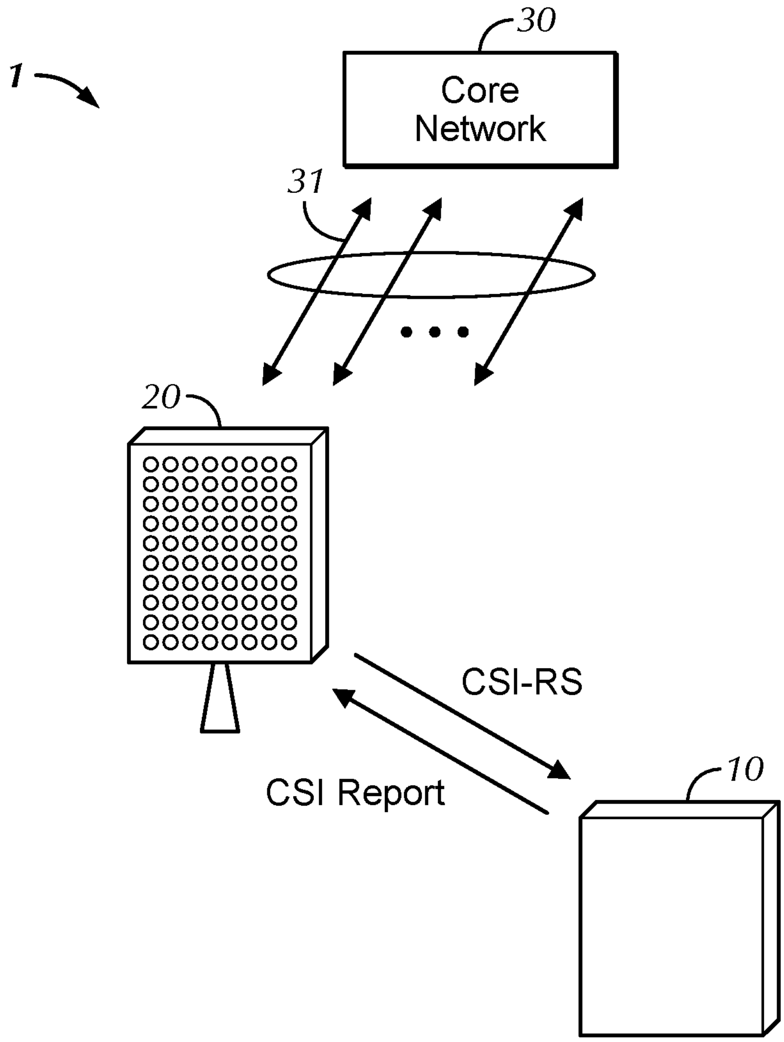


FIG. 14

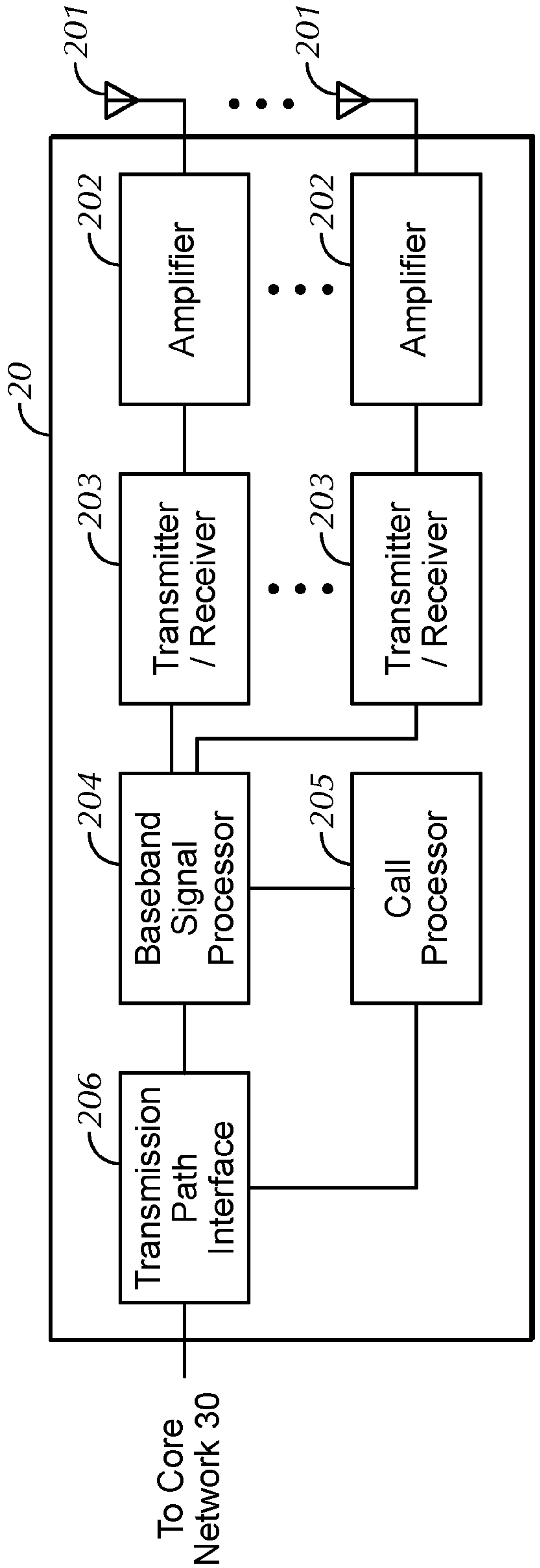

201
201
20
202
Amplifier
202
Amplifier
203
Transmitter / Receiver
203
Transmitter / Receiver
204
Baseband Signal Processor
205
Call Processor
206
Transmission Path Interface
To Core Network 30

FIG. 15

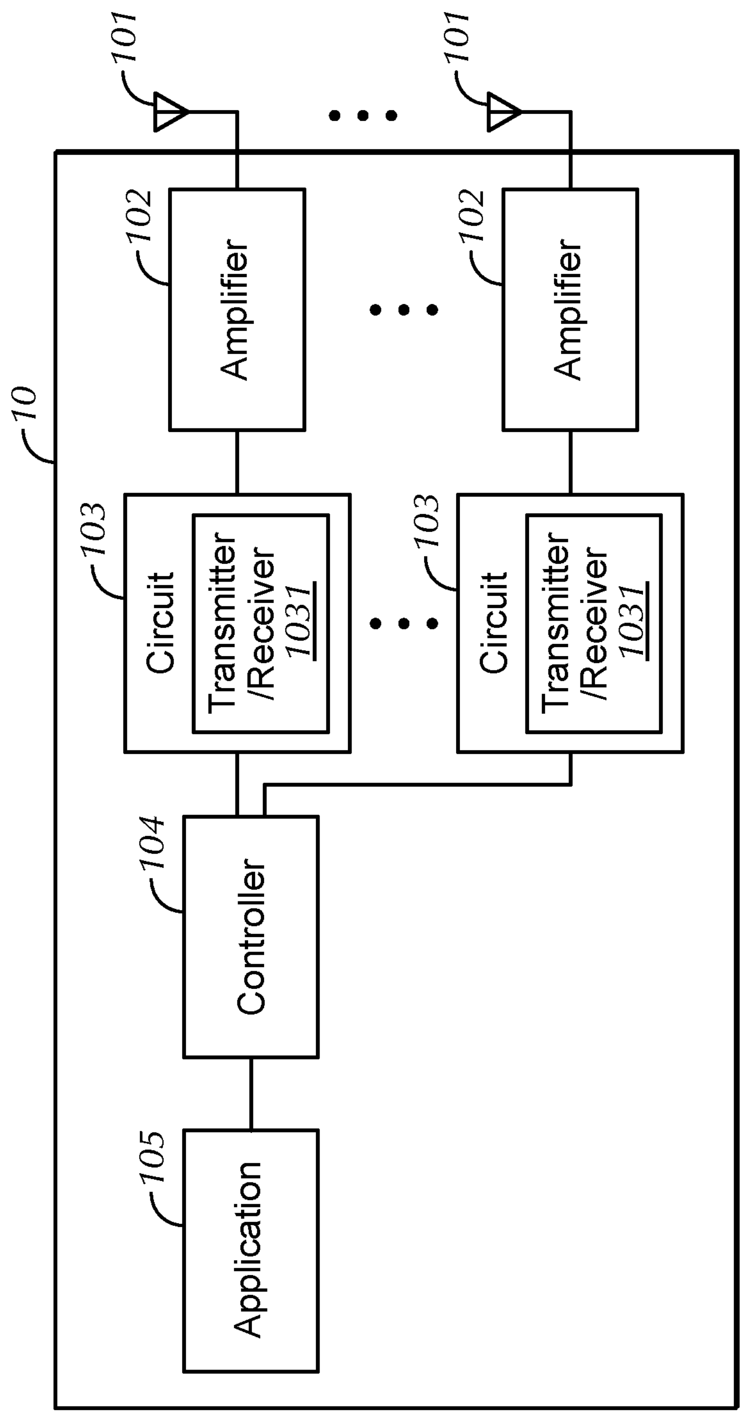

101
101
102
Amplifier
102
Amplifier
10
103
Circuit
Transmitter /Receiver 1031
103
Circuit
Transmitter /Receiver 1031
104
Controller
105
Application

FIG. 16

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2022/011449

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B7/0456
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04B

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	HUAWEI ET AL: "Summary of Phase 3 Email discussion for Rel-17 CSI enhancements", 3GPP DRAFT; R1-2009759, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. E-meeting; 20201026 - 20201113 13 November 2020 (2020-11-13), XP051954412, Retrieved from the Internet: URL:https://ftp.3gpp.org/tsg_ran/WG1_RL1/TSGR1_103-e/Docs/R1-2009759.zip R1-2009759 Summary of Phase 3 Email discussion for Rel-17 CSI enhancements_V34_Mod.docx [retrieved on 2020-11-13]	14
Y	page 2	1-13,15

-/--

[X] Further documents are listed in the continuation of Box C.

[ ] See patent family annex.

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 April 2022	09/05/2022

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Sieben, Stefan

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	page 5 -----	
Y	"3rd Generation Partnership Project; Technical Specification Group Radio Access Network; NR; Radio Resource Control (RRC) protocol specification (Release 16)", 3GPP STANDARD; TECHNICAL SPECIFICATION; 3GPP TS 38.331, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG2, no. V16.2.0 7 October 2020 (2020-10-07), pages 1-921, XP051961610, Retrieved from the Internet: URL:ftp://ftp.3gpp.org/Specs/archive/38_series/38.331/38331-g20.zip 38331-g20.docx [retrieved on 2020-10-07] cited in the application	1-13,15
A	page 126 page 410 -----	14

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