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(54) **CDM8 BASED CSI-RS DESIGNS FOR MIMO**

AUF CDM8 BASIERENDE CSI-RS-DESIGNS FÜR MIMO

CONCEPTIONS DE CSI-RS BASÉES CDM8 POUR DES TECHNIQUES MIMO

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Description

TECHNICAL FIELD

[0001] Wireless communications, and in particular to code division multiplexing, CDM, aggregation configurations for reducing performance losses due to channel variations in wireless communications.

BACKGROUND

[0002] Long Term Evolution (LTE) uses Orthogonal Frequency Division Multiplexing (OFDM) in the downlink and Discrete Fourier Transform (DFT)-spread OFDM in the uplink. The basic LTE downlink physical resource can thus be seen as a time-frequency grid as illustrated in FIG. 1, where each resource element corresponds to one OFDM subcarrier during one OFDM symbol interval. Further, as shown in FIG. 2, in the time domain, LTE downlink transmissions are organized into radio frames of 10 ms, each radio frame consisting of ten equally-sized subframes of length Tsubframe = 1 ms.

[0003] Furthermore, the resource allocation in LTE is typically described in terms of resource blocks, where a resource block corresponds to one slot (0.5 ms) in the time domain and 12 contiguous subcarriers in the frequency domain. Resource blocks are numbered in the frequency domain, starting with 0 from one end of the system bandwidth. Downlink transmissions are dynamically scheduled, i.e., in each subframe the network node transmits control information about to which terminals data is transmitted and upon which resource blocks the data is transmitted, in the current downlink subframe. This control signaling is typically transmitted in the first 1, 2, 3 or 4 OFDM symbols in each subframe. A downlink system with 3 OFDM symbols as control is illustrated in FIG 3, which illustrates s downlink subframe.

Codebook-based precoding

[0004] Multi-antenna techniques can significantly increase the data rates and reliability of a wireless communication system. The performance is particularly improved if both the transmitter and the receiver are equipped with multiple antennas, which results in a multiple-input multiple-output (MIMO) communication channel. Such systems and/or related techniques are commonly referred to as MIMO. The LTE standard is currently evolving with enhanced MIMO support. A core component in LTE is the support of MIMO antenna deployments and MIMO related techniques. Currently, LTE-Advanced supports an 8-layer spatial multiplexing mode for 8 Tx antenna ports with channel dependent precoding. LTE-Advanced Pro adds 8-layer spatial multiplexing support for 2D (2 dimensional)/1D (1 dimensional) port layouts with 8/12/16 Tx antenna ports with channel dependent precoding. In LTE Release 14, support for 8-layer spatial multiplexing for 2D/1D port layouts with 20/24/28/32 Tx antenna ports is being specified. The spatial multiplexing mode is aimed for high data rates in favorable channel conditions. An illustration of the spatial multiplexing operation is provided in FIG. 4, which illustrates a transmission structure of precoded spatial multiplexing mode in LTE.

[0005] As seen in FIG. 4, the information carrying symbol vector s is multiplied by an N_T x r precoder matrix $\boldsymbol{W}$, which serves to distribute the transmit energy in a subspace of the N_T (corresponding to N_T antenna ports) dimensional vector space. The precoder matrix is typically selected from a codebook of possible precoder matrices, and typically indicated by means of a precoder matrix indicator (PMI), which specifies a unique precoder matrix in the codebook for a given number of symbol streams. The r symbols in s each correspond to a layer and r is referred to as the transmission rank. In this way, spatial multiplexing is achieved since multiple symbols can be transmitted simultaneously over the same time/frequency resource element (TFRE). The number of symbols r is typically adapted to suit the current channel properties.

[0006] LTE uses OFDM in the downlink (and DFT precoded OFDM in the uplink) and hence the received N_R x 1 vector $\boldsymbol{y}_n$ for a certain TFRE on subcarrier n (or alternatively data TFRE number n) is thus modeled by

$$\boldsymbol{y}_n = \boldsymbol{H}_n \boldsymbol{W} \boldsymbol{s}_n + \boldsymbol{e}_n \qquad \text{Equation 1}$$

where $\boldsymbol{e}_n$ is a noise/interference vector. The precoder $\boldsymbol{W}$ can be a wideband precoder, which is constant over frequency, or frequency selective.

[0007] The precoder matrix is often chosen to match the characteristics of the N_RxN_T MIMO channel matrix $\boldsymbol{H}_n$, resulting in so-called channel dependent precoding. This is also commonly referred to as closed-loop precoding and essentially strives for focusing the transmit energy into a subspace which is strong in the sense of conveying much of the transmitted energy to the UE. In addition, the precoder matrix may also be selected to strive for orthogonalizing the channel, meaning that after proper linear equalization at the UE, the inter-layer interference is reduced.

[0008] The transmission rank, and thus the number of spatially multiplexed layers, is reflected in the number of columns of the precoder. For efficient performance, it is important that a transmission rank that matches the channel properties is selected.

2D antenna arrays

[0009] Developments in Third Generation Partnership Project (3GPP) has led to the discussion of two-dimensional antenna arrays where each antenna element has an independent phase and amplitude control, thereby enabling beamforming in both in the vertical and the horizontal dimensions. Such antenna arrays may be (partly) described by the number of antenna columns corresponding to the horizontal dimension N_h, the number of antenna rows corresponding to the vertical dimension N_v, and the number of dimensions corresponding to different polarizations N_p. The total number of antenna elements is thus $N = N_h N_v N_p$. An example of an antenna where N_h=8 and N_v =4 is illustrated in FIG. 5 below. It furthermore consists of cross-polarized antenna elements meaning that N_p=2. We will denote such an antenna as an 8x4 antenna array with cross-polarized antenna elements.

[0010] However, from a standardization perspective, the actual number of elements in the antenna array is not visible to the wireless device, but rather the antenna ports, where each port corresponds to a CSI (channel state information) reference signal described further below. The wireless device can thus measure the channel from each of these ports. Therefore, a 2D port layout is introduced, described by the number of antenna ports in the horizontal dimension M_h, the number of antenna rows corresponding to the vertical dimension M_v and the number of dimensions corresponding to different polarizations M_p. The total number of antenna ports is thus $M = M_h M_v M_p$. The mapping of these ports on to the N antenna elements is an eNB implementation issue and thus not visible to the wireless device. The wireless device does not even know the value of N; it only knows the value of the number of ports M.

[0011] For LTE Rel-12 wireless device and earlier, only a codebook feedback for a 1D port layout is supported, with 2,4 or 8 antenna ports. Hence, the codebook is designed assuming these ports are arranged on a straight line. In LTE Rel-13, codebooks for 2D port layouts were specified for the case of 8, 12, or 16 antenna ports. In addition, a codebook 1D port layout for the case of 16 antenna ports was also specified in LTE Rel-13. The specified Rel-13 codebooks for the 2D port layouts can be interpreted as a combination of precoders tailored for a horizontal array and a vertical array of antenna ports. This means that (at least part of) the precoder can be described as a function of

$$v_{l,m} = \begin{bmatrix} u_m & e^{j\frac{2\pi l}{O_1 N_1}} u_m & \ldots & e^{j\frac{2\pi l(N_1-1)}{O_1 N_1}} u_m \end{bmatrix}^T \qquad \text{Equation 2}$$

wherein

$$u_m = \begin{bmatrix} 1 & e^{j\frac{2\pi m}{O_2 N_2}} & \ldots & e^{j\frac{2\pi m(N_2-1)}{O_2 N_2}} \end{bmatrix} \qquad \text{Equation 3}$$

[0012] In Equation 2- Equation 3, the parameters N_1 and N_2 denote the number of ports in the 1st dimension and the 2nd dimension, respectively. For 1D port layouts, N_2 = 1 and u_m in equation 3 becomes 1. It should be noted that the 1st dimension could either be the horizontal dimension or the vertical dimension and the 2nd dimension would represent the other dimension. In other words, using the notation of FIG. 5, two possibilities: (1) $N_1 = M_h$ and $N_2 = M_v$, (2) $N_1 = M_v$ and $N_2 = M_h$ could exist, where FIG. 5 illustrates a two-dimensional antenna array of cross-polarized antenna elements (N_P = 2), with N_h = 4 horizontal antenna elements and N_v = 8 vertical antenna elements, and in the right hand side of FIG. 5, the actual port layout with 2 vertical ports and 4 horizontal ports. This could for instance be obtained by virtualizing each port by 4 vertical antenna elements. Hence, assuming cross-polarized ports are present, the wireless device will measure 16 antenna ports in this example.

[0013] The O_1 and O_2 parameters in Equation 2-Equation 3 represent the beam spatial oversampling factors in dimensions 1 and 2, respectively. The values of N_1, N_2, O_1 and O_2 are configured by radio resource control (RRC) signaling. 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 7.2.4-17 of 3GPP TS 36.213 Technical Specification Group Radio Access Network, Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (Release 13); V13.0.1 (2016-01), which is reproduced below in Table 1.

Number of CSI-RS antenna ports	(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,-)
Table 1. Supported configurations of (O_1,O_2) and (N_1,N_2) Table 7.2.4-17 of 3GPP TS 36.213 Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (Release 13); V13.0.1 (2016-01).		

[0014] The details of the LTE Rel-13 codebooks defined using the quantity in Equation 2 can be found in Tables 7.2.4-10, 7.2.4-11, 7.2.4-12, 7.2.4-13, 7.2.4-14, 7.2.4-15, 7.2.4-16, and 7.2.4-17 of 3GPP TS 36.213.

Non-Zero Power Channel State Information Reference Symbols (NZP CSI-RS)

[0015] In LTE Release-10, a new reference symbol sequence was introduced for the intent to estimate channel state information, the NZP CSI-RS. The NZP CSI-RS provides several advantages over basing the CSI feedback on the cell-specific reference symbols (CRS) which were used, for that purpose, in previous releases. Firstly, the NZP CSI-RS is not used for demodulation of the data signal, and thus does not require the same density (i.e., the overhead of the NZP CSI-RS is substantially less). Secondly, NZP CSI-RS provides a much more flexible means to configure CSI feedback measurements (e.g., which NZP CSI-RS resource to measure on can be configured in a wireless device specific manner).

[0016] By measuring on a NZP CSI-RS, a wireless device can estimate the effective channel the NZP CSI-RS is traversing including the radio propagation channel and antenna gains. In more mathematical rigor this implies that if a known NZP CSI-RS signal **X** is transmitted, a wireless device can estimate the coupling between the transmitted signal and the received signal (i.e., the effective channel). Hence if no virtualization is performed in the transmission, the received signal **y** can be expressed as

$$\mathbf{y} = \mathbf{H}\mathbf{x} + \mathbf{e} \qquad \text{Equation 4}$$

and the wireless device can estimate the effective channel **H.** Up to eight NZP CSI-RS ports can be configured for a LTE Rel.11 wireless device, that is, the wireless device can thus estimate the channel from up to eight transmit antenna ports in LTE Rel-11.

[0017] Up to LTE Rel-12, the NZP CSI-RS utilizes an orthogonal cover code (OCC) of length two to overlay two antenna ports on two consecutive REs. A length-2 OCC can be realized by the pair of orthogonal codes [1 1] and [1 - 1]. Throughout this document, OCC is alternatively referred to as code division multiplexing (CDM). A length-N OCC may be either referred to as OCC-N or as CDM-*N* where *N* can take on values of 2, 4, or 8.

[0018] As seen in FIG. 6, many different NZP CSI-RS patterns are available, in which FIG. 6 illustrates resource element grid over an RB pair showing potential positions for UE specific RS (distinguished by respective hatching(s)), CSI-RS (marked with a number corresponding to the CSI-RS antenna port), and CRS (distinguished by respective hatching(s)) as is well known in the art. For the case of 2 CSI-RS antenna ports, there are 20 different patterns within a subframe. The corresponding number of patterns is 10 and 5 for 4 and 8 CSI-RS antenna ports, respectively. For Time Division Duplex (TDD), some additional CSI-RS patterns are available.

[0019] The reference-signal sequence for CSI-RS is defined in Section 6.10.5.1 of 3GPP TS 36.211 Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (Release 13); V13.0.0 (2015-12) as

$$r_{l,n_s}(m) = \frac{1}{\sqrt{2}}\left(1 - 2\cdot c(2m)\right) + j\frac{1}{\sqrt{2}}\left(1 - 2\cdot c(2m+1)\right), \quad m = 0,1,\ldots,N_{\mathrm{RB}}^{\max,\mathrm{DL}} - 1$$

Equation 5

where n_s is the slot number within a radio frame and l is the OFDM symbol number within the slot. The pseudo-random sequence $c(i)$ is generated and initialized according to Sections 7.2 and 6.10.5.1 of [2] 3GPP TS 36.211 Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (Release 13); V13.0.0 (2015-12), respectively. Furthermore, in Equation 5, $N_{\mathrm{RB}}^{\max,\mathrm{DL}} = 110$ is the largest downlink bandwidth configuration supported by specification 3GPP TS 36.211 Technical Specification Group Radio Access Network, Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (Release 13); V13.0.0 (2015-12).

[0020] In LTE Rel-13, the NZP CSI-RS resource is extended to include 12 and 16 ports. Such Rel-13 NZP CSI-RS resource is obtained by aggregating three legacy 4 port CSI-RS resources (to form a 12 port NZP CSI-RS resource) or two legacy 8 port CSI-RS resources (to form a 16 port NZP CSI-RS resource). It should be noted that all NZP CSI-RS resource aggregated together are located in the same subframe. Examples of forming 12 port and 16 port NZP CSI-RS resources are shown in FIG. 7, which illustrates (a) an example of aggregating three 4-port resources to form a 12-port NZP CSI-RS Resource; (b) an example of aggregating two 8-port resources to form a 16-port NZP CSI-RS Resource, each 4-port resource and 8-port being aggregated together is labeled with the same number. In a given subframe, it is possible to have three 12-port resource configurations (i.e., nine out of ten 4-port resources used) and two 16-port resource configurations (i.e., four out of five 8-port resources used). The following port numbering is used for the aggregated NZP CSI-RS resources:

- The aggregated port numbers are 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30 (for 16 NZP CSI-RS ports);
- The aggregated port numbers are 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26 (for 12 NZP CSI-RS ports).

[0021] In addition, Rel-13 NZP CSI-RS design supports two different OCC lengths. It is possible to multiplex antenna ports using OCC lengths two and four for both 12-port and 16-port NZP CSI-RS.

NZP CSI-RS Designs with OCC length 2

[0022] FIG. 8 shows the NZP CSI-RS design for the case of 12 ports with OCC length 2, where different 4-port resources are denoted by the alphabets A-J. In FIG. 8, the different 4-port NZP CSI-RS resources are denoted by the alphabets A-J. For instance, 4-port resources A, F, and J could be aggregated to form a 12-port NZP CSI-RS resource. The length 2 OCC is applied across two REs with the same sub-carrier index and adjacent OFDM symbol indices (for instance, OCC 2 is applied to the REs with OFDM symbol indices 5-6 and sub-carrier index 9 in slot 0).

[0023] FIG. 9 shows the NZP CSI-RS design for the case of 16 ports with OCC length 2, where the different 8 port resources are shown in the legend of FIG. 9, and the resources elements with the same alphabet form one CDM group within each 8 port resource. In FIG. 9, the different 8-port NZP CSI-RS resources are shown in the legend. For instance, 8-port NZP CSI-RS resources 1 and 3 could be aggregated to form a 16-port NZP CSI-RS resource. The length 2 OCC is applied across two REs with the same sub-carrier index and adjacent OFDM symbol indices (for instance, OCC 2 is applied to the REs with OFDM symbol indices 2-3 and sub-carrier index 7 in slot 1).

[0024] For the OCC length 2 case (i.e., when higher layer parameter 'cdmType' is set to cdm2 or when 'cdmType' is not configured by Evolved UMTS Terrestrial Radio Access Network (EUTRAN)), the mapping of the reference signal sequence $r_{l,n_s}(m)$ of Equation 5 to the complex-valued modulation symbols $a_{k,l}^{(p)}$ used as reference symbols on antenna port p is defined as:

$$a_{k,l}^{(p')} = w_{l''} \cdot r_{l,n_s}(m') \qquad \text{Equation 6}$$

where

$$k = k' + 12m + \begin{cases} -0 & \text{for } p' \in \{15,16\}, \text{normal cyclic prefix} \\ -6 & \text{for } p' \in \{17,18\}, \text{normal cyclic prefix} \\ -1 & \text{for } p' \in \{19,20\}, \text{normal cyclic prefix} \\ -7 & \text{for } p' \in \{21,22\}, \text{normal cyclic prefix} \\ -0 & \text{for } p' \in \{15,16\}, \text{extended cyclic prefix} \\ -3 & \text{for } p' \in \{17,18\}, \text{extended cyclic prefix} \\ -6 & \text{for } p' \in \{19,20\}, \text{extended cyclic prefix} \\ -9 & \text{for } p' \in \{21,22\}, \text{extended cyclic prefix} \end{cases}$$

$$l = l' + \begin{cases} l'' & \text{CSI reference signal configurations 0-19, normal cyclic prefix} \\ 2l'' & \text{CSI reference signal configurations 20-31, normal cyclic prefix} \\ l'' & \text{CSI reference signal configurations 0-27, extended cyclic prefix} \end{cases}$$

$$w_{l''} = \begin{cases} 1 & p' \in \{15,17,19,21\} \\ (-1)^{l''} & p' \in \{16,18,20,22\} \end{cases}$$

$$l'' = 0,1$$

$$m = 0,1,\ldots,N_{\mathrm{RB}}^{\mathrm{DL}} - 1$$

$$m' = m + \left\lfloor \frac{N_{\mathrm{RB}}^{\max,\mathrm{DL}} - N_{\mathrm{RB}}^{\mathrm{DL}}}{2} \right\rfloor$$

Equation 7

[0025] In Equation 6-Equation 7, $N_{\mathrm{RB}}^{\mathrm{DL}}$ represents the downlink transmission bandwidth; the indices *k'* and *l'* indicate the subcarrier index (starting from the bottom of each RB) and the OFDM symbol index (starting from the right of each slot). The mapping of different (*k', l'*) pairs to different CSI-RS resource configurations is given in Table 2.

Table 2. Mapping from CSI reference signal configuration to (k',l') for normal cyclic prefix

CSI-RS config.	Number of CSI reference signals configured											
	1 or 2				4				8			
	Normal subframe		Special subframe		Normal subframe		Special subframe		Normal subframe		Special subframe	
	(k',l')	n'_s	(k',l')	n'_s	(k',l')	n'_s	(k',l')	n'_s	(k',l')	n'_s	(k',l')	n'_s
0	(9,5)	0	(9,5)	0	(9,5)	0	(9,5)	0	(9,5)	0	(9,5)	0
1	(11,2)	1	(11,5)	0	(11,2)	1	(11,5)	0	(11,2)	1	(11,5)	0
2	(9,2)	1	(9,2)	1	(9,2)	1	(9,2)	1	(9,2)	1	(9,2)	1
3	(7,2)	1	(7,5)	0	(7,2)	1	(7,5)	0	(7,2)	1	(7,5)	0
4	(9,5)	1			(9,5)	1			(9,5)	1		
5	(8,5)	0	(8,5)	0	(8,5)	0	(8,5)	0				
6	(10,2)	1	(10,5)	0	(10,2)	1	(10,5)	0				
7	(8,2)	1	(8,2)	1	(8,2)	1	(8,2)	1				
8	(6,2)	1	(6,5)	0	(6,2)	1	(6,5)	0				
9	(8,5)	1			(8,5)	1						
10	(3,5)	0	(3,5)	0								
11	(2,5)	0	(2,5)	0								
12	(5,2)	1	(5,5)	0								
13	(4,2)	1	(4,5)	0								
14	(3,2)	1	(3,2)	1								
15	(2,2)	1	(2,2)	1								
16	(1,2)	1	(1,5)	0								
17	(0,2)	1	(0,5)	0								
18	(3,5)	1										
19	(2,5)	1										
20	(11,1)	1			(11,1)	1			(11,1)	1		
21	(9,1)	1			(9,1)	1			(9,1)	1		
22	(7,1)	1			(7,1)	1			(7,1)	1		

(continued)

CSI-RS config.	Number of CSI reference signals configured											
	1 or 2				4				8			
	Normal subframe		Special subframe		Normal subframe		Special subframe		Normal subframe		Special subframe	
	(k',l')	n'_s	(k',l')	n'_s	(k',l')	n'_s	(k',l')	n'_s	(k',l')	n'_s	(k',l')	n'_s
23	(10,1)	1			(10,1)	1						
24	(8,1)	1			(8,1)	1						
25	(6,1)	1			(6,1)	1						
26	(5,1)	1										
27	(4,1)	1										
28	(3,1)	1										
29	(2,1)	1										
30	(1,1)	1										
31	(0,1)	1										

[0026] The quantity *p'* for the case of OCC length 2 is related to the antenna port number *p* as follows:
• $p = p'$ for CSI-RS using up to 8 antenna ports;
• when higher-layer parameter 'cdmType' is set to cdm2 for CSI-RS using more than 8 antenna ports, the following:

$$p = \begin{cases} p' + \frac{N_{\text{ports}}^{\text{CSI}}}{2} i & \text{for } p' \in \left\{15, \ldots, 15 + N_{\text{ports}}^{\text{CSI}}/2 - 1\right\} \\ p' + \frac{N_{\text{ports}}^{\text{CSI}}}{2}\left(i + N_{\text{res}}^{\text{CSI}} - 1\right) & \text{for } p' \in \left\{15 + N_{\text{ports}}^{\text{CSI}}/2, \ldots, 15 + N_{\text{ports}}^{\text{CSI}} - 1\right\} \end{cases} \quad \text{Equation 8}$$

wherein $i \in \{0,1,\ldots, N_{\text{res}}^{\text{CSI}} - 1\}$ is the CSI resource number; $N_{\text{res}}^{\text{CSI}}$ and $N_{\text{ports}}^{\text{CSI}}$ respectively denote the number of aggregated CSI-RS resources and the number of antenna ports per aggregated CSI-RS resource. As stated above, the allowed values of $N_{\text{res}}^{\text{CSI}}$ and $N_{\text{ports}}^{\text{CSI}}$ for the cases of 12 and 16 port NZP CSI-RS design are given in Table 3.

Total number of antenna ports $N_{\text{res}}^{\text{CSI}} N_{\text{ports}}^{\text{CSI}}$	**Number of antenna ports per resources** $N_{\text{ports}}^{\text{CSI}}$	**Number of CSI-RS resources** $N_{\text{res}}^{\text{CSI}}$
12	4	3
16	8	2

NZP CSI-RS Designs with OCC length 4

[0027] FIG. 10 shows the NZP CSI-RS design for the case of 12 ports with OCC length 4, where 4-port resources are denoted by the alphabets A-J. In FIG. 10, the different 4-port NZP CSI-RS resources are denoted by the alphabets A-J. For instance, 4-port resources A, F, and J could be aggregated to form a 12-port NZP CSI-RS resource. A length 4 OCC is applied within a CDM group where a CDM group consists of the 4 resource elements used for mapping legacy 4-port CSI-RS. That is, the resource elements labeled with the same alphabet in FIG. 10 comprise one CDM group. A length-4 OCC is given in Equation 9.

$$W_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix} \quad \text{Equation 9}$$

[0028] FIG. 11 shows the NZP CSI-RS design for the case of 16 ports with OCC length 4, where different 8-port resources are shown in the legend, the resource elements with the same alphabet form one CDM group within an 8-port CSI-RS resource. In FIG. 11, the different 8-port NZP CSI-RS resources are shown in the legend. For instance, 8-port NZP CSI-RS resources 1 and 3 could be aggregated to form a 16-port NZP CSI-RS resource. Each 8-port resource is further partitioned into two groups of 4 adjacent REs and each of these groups comprises a CDM group. In FIG. 11, the REs with labels A and B form one legacy 8-port resource where A and B are the CDM groups within this resource. An OCC with length 4 is applied within each CDM group. In the rest of the document, the CDM groups corresponding to REs with labels A and B within each 8-port NZP CSI-RS resource configuration are referred to as CDM groups i and ii, respectively.

[0029] For the OCC length 4 case (i.e., when higher layer parameter 'cdmType' is set to cdm4), the mapping of the reference signal sequence $r_{l,n_s}(m)$ of Equation 5 to the complex-valued modulation symbols $a_{k,l}^{(p)}$ used as reference symbols on antenna port p are defined as:

$$a_{k,l}^{(p')} = w_{p'}(i) \cdot r_{l,n_s}(m') \quad \text{Equation 10}$$

where

$$k = k' + 12m - \begin{cases} k'' & \text{for } p' \in \{15,16,19,20\}, \text{normal cyclic prefix}, N_{\text{ports}}^{\text{CSI}} = 8 \\ k''+6 & \text{for } p' \in \{17,18,21,22\}, \text{normal cyclic prefix}, N_{\text{ports}}^{\text{CSI}} = 8 \\ 6k'' & \text{for } p' \in \{15,16,17,18\}, \text{normal cyclic prefix}, N_{\text{ports}}^{\text{CSI}} = 4 \end{cases}$$

$$l = l' + \begin{cases} l'' & \text{CSI reference signal configurations 0 - 19, normal cyclic prefix} \\ 2l'' & \text{CSI reference signal configurations 20 - 31, normal cyclic prefix} \end{cases}$$

$$l'' = 0,1$$

$$k'' = 0,1$$

$$i = 2k'' + l''$$

$$m = 0,1,\ldots,N_{\text{RB}}^{\text{DL}} - 1$$

$$m' = m + \left\lfloor \frac{N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{DL}}}{2} \right\rfloor$$

Equation 11

[0030] In Equation 10 - Equation 11, $N_{\text{RB}}^{\text{DL}}$ represents the downlink transmission bandwidth; $N_{\text{ports}}^{\text{CSI}}$ denotes the number of antenna ports per aggregated CSI-RS resource; the indices *k'* and *l'* indicate the subcarrier index (starting from the bottom of each RB) and the OFDM symbol index (starting from the right of each slot). The mapping of different (*k', l'*) pairs to different CSI-RS resource configurations is given in Table 2. Furthermore, $w_{p'}(i)$ in Equation 10 is given by Table 4, where Table 4 illustrates the sequence $w_{p'}(i)$ for CDM4.

p'		$[w_{p'}(0)\ w_{p'}(1)\ w_{p'}(2)\ w_{p'}(3)]$
$N_{\text{ports}}^{\text{CSI}} = 4$	$N_{\text{ports}}^{\text{CSI}} = 8$	
15	15,17	[1 1 1 1]
16	16,18	[1 -1 1 -1]
17	19,21	[1 1 -1 -1]
18	20,22	[1 -1 -1 1]

[0031] When higher-layer parameter 'cdmType' is set to cdm4 for CSI-RS using more than 8 antenna ports, antenna port number

$$p = iN_{\text{ports}}^{\text{CSI}} + p' \qquad \text{Equation 12}$$

where $p' \in \{15,16,\ldots,15+N_{\text{ports}}^{\text{CSI}}-1\}$ for CSI-RS resource number $i \in \{0,1,\ldots,N_{\text{res}}^{\text{CSI}}-1\}$.

[0032] Non-patent disclosure Ericsson: "CSI-RS Design for Class A FD-MIMO", 3GPP draft, R1-157204, vol. RAN WG1, 9 November 2015, XP051022786, discloses details for 12 and 16 port CSI-RS construction for CDM-2 and CDM-4, the details including mechanisms used to aggregate REs to form of the 12 and 16 port CSI-RS resource, if CDM-4 is mapped on 2 or 4 OFDM symbols ('FDM/TDM' or 'TDM'), and port numbering. As CSI-RS pattern options for CDM-4, it is disclosed that three possibilities to group 4 REs with a length 4 cover code are (a) CDM-4 across 4 OFDM symbols, (b) 2D CDM-4, where 2 adjacent OFDM symbols and 2 adjacent REs in the symbols are covered by the OCC, and (c) 2D CDM-4, where 2 adjacent OFDM symbols and REs belonging to the 4 port Rel-12 CSI-RS in the symbols are covered by the OCC.

SUMMARY

[0033] According to aspects of the present disclosure, methods, a network node and a wireless device according to the independent claims are provided. Preferred embodiments are recited in the dependent claims.

[0034] The invention is defined by the appended claims. The embodiments that do not fully fall under the scope of the claims have to be interpreted as examples useful for understanding the invention. Some examples of the present disclosure advantageously provide a method and system for code division multiplexing, CDM, aggregation configurations for reducing performance losses due to channel variations in wireless communications.

[0035] Disadvantages of one approach in CDM-8 design include that (1) it will suffer performance losses if the channel varies significantly over 9 OFDM symbols due to loss of orthogonality in the CDM-8 group, and (2) it has higher CSI-RS overhead than required. Other disadvantages of other CDM-8 approaches include (1) the scheme does not prevent performance losses if the channel varies significantly over 9 OFDM symbols due to loss of orthogonality in the CDM-8 group, and (2) the scheme is not suitable for 24 ports. For 24-ports, if CDM-4 aggregation is done arbitrarily (as discussed above) to form a CDM-8 group, this can still result in performance losses if the channel varies significantly over 9 OFDM symbols due to loss of orthogonality in the CDM-8 group as illustrated in the example of FIG. 15.

[0036] Certain examples of the present disclosure may provide solutions to these or other problems. In a first solution, the length 8 orthogonal cover code is achieved by aggregating two length 4 orthogonal cover code groups belonging to a pair of legacy LTE CSI-RS resources where the pair of legacy resources are chosen from a constrained set of pairs that are chosen to minimize loss of orthogonality of the length 8 cover code due to channel variations in time domain. In this solution, the network node signals to the wireless device pairs of legacy CSI-RS resources that are selected during the aggregation of length 4 orthogonal cover code groups or indices that represent pairs of legacy CSI-RS resources that are selected during the aggregation of length 4 orthogonal cover code groups.

[0037] In a second solution, the length 8 orthogonal cover code is achieved by aggregating two length 4 orthogonal cover code groups belonging to a pair of legacy LTE CSI-RS resources where the pair of legacy resources and which length 4 orthogonal cover code groups are selected from a constrained set of pairs that are chosen to minimize loss of orthogonality of the length 8 cover code due to channel variations in time and frequency domains. In this solution, where the network node signals to the wireless device one or more 8-port CSI-RS configuration and CDM-4 group combination pairs that are chosen during the aggregation of length 4 orthogonal cover code groups or one or more indices that represent 8-port CSI-RS configuration and CDM-4 group combination pairs that are chosen during the aggregation of length 4 orthogonal cover code groups.

[0038] In one example of the disclosure, a method of increasing the energy in a reference signal while limiting its bandwidth, the method comprising at least one of:

a) Selecting a first and a second reference signal configuration, where at least one of the following are met:

i) the first and the second reference signal configurations are selected from a predefined set of reference signal configurations
ii) each reference signal configuration identifies a set of frequency and time locations of resource elements
iii) each resource element is associated with an element of a reference sequence
iv) a maximum time separation of the time locations in the first and second reference signal configurations is a first maximum separation
v) the largest maximum time separation of the time locations over all possible pairs of reference signal configurations in the predefined set is a largest maximum separation, and
vi) the largest maximum time separation is greater than the first maximum separation;

b) forming a reference signal by applying a first cover sequence to a first and a second set of reference signal sequences, where at least one of the following are met:

i) the first reference signal sequence corresponds to a first subset of reference elements of the first reference signal configuration
ii) the second reference signal sequence corresponds to a second subset of reference elements of the second reference signal configuration
iii) the first cover sequence is associated with an antenna port,
iv) the first cover sequence is selected from a set of cover sequences,
v) and each cover sequence is orthogonal to every other cover sequence in the set; and

c) transmitting the reference signal in the first and second subsets of reference elements.
According to one variant of this example, at least one of the following are met: a maximum frequency separation of

the frequency locations in the first and second subsets is a second maximum separation, the largest maximum frequency separation of the frequency locations over all possible pairs of reference elements in the first and second reference signal configurations is a largest maximum separation and the largest maximum frequency separation is greater than the second maximum separation.
According to one variant of this example,
d) Transmitting N distinct reference signals in the first and second subsets of resource elements, wherein at least one of the following are met:

i) each reference signal is associated with an antenna port number, thereby creating a set of antenna port numbers for the N distinct reference signals
ii) the antenna port numbers are consecutive, such that any antenna port number in the set n_1 is related to another antenna port n_2 in the set according to:

$$n_1 = n_2 + 1 \text{ or } n_1 = n_2 - 1 .$$

[0039] According to another example of the disclosure, a method of transmitting CSI-RS ports in multiple aggregated legacy LTE CSI-RS resources using a length 8 orthogonal cover code. According to one or more examples of the disclosure, the length 8 orthogonal cover code is achieved by aggregating two length 4 orthogonal cover code groups belonging to a pair of legacy LTE CSI-RS resources where the pair of legacy resources are chosen from a constrained set of pairs that are chosen to minimize loss of orthogonality of the length 8 cover code due to channel variations in time domain. According to one variant of this example, a network node signals to a wireless device the pairs of legacy CSI-RS resources that are chosen during the aggregation of length 4 orthogonal cover code groups or one or more indices that represent the pairs of legacy CSI-RS resources that are chosen during the aggregation of length 4 orthogonal cover code groups.
[0040] According to one or more examples of the disclosure, the length 8 orthogonal cover code is achieved by aggregating two length 4 orthogonal cover code groups belonging to a pair of legacy LTE CSI-RS resources where the pair of legacy resources and which length 4 orthogonal cover code groups are chosen from a constrained set of pairs that are chosen to minimize loss of orthogonality of the length 8 cover code due to channel variations in time and frequency domains. According to one variant of this example, the network node signals to the wireless device one or more 8-port CSI-RS configuration and CDM-4 group combination pairs that are chosen during the aggregation of length 4 orthogonal cover code groups or one or more indices that represent one or more 8-port CSI-RS configuration and CDM-4 group combination pairs that are chosen during the aggregation of length 4 orthogonal cover code groups.
[0041] According to one or more examples of the disclosure, the aggregation of length 4 orthogonal cover codes with the same group number in a pair of 8-port CSI-RS configurations is allowed. According to one or more examples of the disclosure, the aggregation of length 4 orthogonal cover code groups within the same 8-port CSI-RS configuration is allowed in combination with the aggregation of length 4 orthogonal cover codes between a pair of 8-port CSI-RS configurations.
[0042] According to one example of the disclosure, a network node is provided. The network node includes processing circuitry configured to: select a first set and second set of reference signal resources in a subframe, and aggregate the first set and second set of reference signal resources to the subframe to form a code division multiplexing, CDM, aggregation configuration. The first set and second set of reference signal resources in the subframe satisfies a temporal criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum time separation of six OFDM symbols. The first set and second set of reference signal resources in the subframe satisfies a frequency criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum frequency separation of six subcarriers.
[0043] According to one variant of this example, the first set of reference signal resources corresponds to a first portion of a first reference signal configuration. The second set of reference signal resources corresponds to a second portion of a second reference signal configuration. According to one variant of this example, the first reference signal configuration is at least a first channel state information-reference signal, CSI-RS, configuration. The second reference signal configuration is at least a second CSI-RS configuration different from the at least first CSI-RS configuration. According to one variant of this example, the first set of reference signal resources in the subframe includes a subset of resources from an eight port CSI-RS resource configuration. The second set of reference signal resources in the subframe includes a subset of resources in a different eight port CSI-RS resource configuration different from the eight port CSI-RS resource configuration corresponding to the first set of reference signal resources. The CDM aggregation configuration has an orthogonal cover code of length eight. According to one variant of this example, processing circuitry is further configured to communicate the CDM aggregation configuration to a wireless device.

[0044] According to another example of the disclosure, a method is provided. A first set and second set of reference signal resources. The first set and second set of reference signal resources are aggregated to the subframe to form a code division multiplexing, CDM, aggregation configuration. The first set and second set of reference signal resources in the subframe satisfy a temporal criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum time separation of six OFDM symbols. The first set and second set of reference signal resources in the subframe satisfy a frequency criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum frequency separation of six subcarriers.

[0045] According to one variant of this example, the first set of reference signal resources corresponds to a first portion of a first reference signal configuration. The second set of reference signal resources corresponds to a second portion of a second reference signal configuration. According to one variant of this example, the first reference signal configuration is at least a first channel state information-reference signal, CSI-RS, configuration. The second reference signal configuration is at least a second CSI-RS configuration different from the at least first CSI-RS configuration. According to one variant of this example, the first set of reference signal resources in the subframe includes a subset of resources from an eight port CSI-RS resource configuration. The second set of reference signal resources in the subframe includes a subset of resources in a different eight port CSI-RS resource configuration different from the eight port CSI-RS resource configuration corresponding to the first set of reference signal resources. The CDM aggregation configuration has an orthogonal cover code of length eight.

[0046] According to another example of the disclosure, a wireless device is provided. The wireless device includes processing circuitry configured to receive a CDM aggregation configuration corresponding to an aggregated first set and second set of reference signal resources in a subframe. The processing circuitry is further configured to perform channel estimation based on the CDM aggregation configuration. The first set and second set of reference signal resources in the subframe satisfy a temporal criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum time separation of six OFDM symbols. The first set and second set of reference signal resources in the subframe satisfy a frequency criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum frequency separation of six subcarriers.

[0047] According to one variant of this example, the first set of reference signal resources corresponds to a first portion of a first reference signal configuration. The second set of reference signal resources corresponds to a second portion of a second reference signal configuration. According to one variant of this example, the first reference signal configuration is at least a first channel state information-reference signal, CSI-RS, configuration. The second reference signal configuration is at least a second CSI-RS configuration different from the at least first CSI-RS configuration. According to one variant of this example, the first set of reference signal resources in the subframe includes a subset of resources from an eight port CSI-RS resource configuration. The second set of reference signal resources in the subframe includes a subset of resources in a different eight port CSI-RS resource configuration different from the eight port CSI-RS resource configuration corresponding to the first set of reference signal resources. The CDM aggregation configuration has an orthogonal cover code of length eight. According to one variant of this example, the processing circuitry is further configured to map the selected first set and second set of reference signal resources in the subframe to a plurality of antenna ports.

[0048] According to another example of the disclosure, a method for a wireless device is provided. A CDM aggregation configuration corresponding to an aggregated first set and second set of reference signal resources in a subframe is received. Channel estimation is performed based on the CDM aggregation configuration. The first set and second set of reference signal resources in the subframe satisfy a temporal criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum time separation of six OFDM symbols. The first set and second set of reference signal resources in the subframe satisfy a frequency criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum frequency separation of six subcarriers.

[0049] According to one variant of this example, the first set of reference signal resources corresponds to a first portion of a first reference signal configuration. The second set of reference signal resources corresponds to a second portion of a second reference signal configuration. According to one variant of this example, the first reference signal configuration is at least a first channel state information-reference signal, CSI-RS, configuration. The second reference signal configuration is at least a second CSI-RS configuration different from the at least first CSI-RS configuration. According to one variant of this example, the first set of reference signal resources in the subframe includes a subset of resources from an eight port CSI-RS resource configuration. The second set of reference signal resources in the subframe includes a subset of resources in a different eight port CSI-RS resource configuration different from the eight port CSI-RS resource configuration corresponding to the first set of reference signal resources. The CDM aggregation configuration has an orthogonal cover code of length eight. According to one variant of this example, the selected first set and second set of reference signal resources in the subframe are mapped to a plurality of antenna ports.

[0050] According to another example of the disclosure, a network node is provided. The network node includes an aggregation processing module configured to select a first set and second set of reference signal resources in a subframe, aggregate the first set and second set of reference signal resources to the subframe to form a code division multiplexing, CDM, aggregation configuration. The first set and second set of reference signal resources in the subframe satisfy a temporal criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum time separation of six OFDM symbols. The first set and second set of reference signal resources in the subframe satisfy a frequency criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum frequency separation of six subcarriers.

[0051] According to another example of the disclosure, a wireless device is provided. The wireless device includes a channel processing module configured to receive a CDM aggregation configuration corresponding to an aggregated first set and second set of reference signal resources in a subframe. The channel processing module is further configured to perform channel estimation based on the CDM aggregation configuration. The first set and second set of reference signal resources in the subframe satisfies a temporal criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum time separation of six OFDM symbols. The first set and second set of reference signal resources in the subframe satisfies a frequency criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum frequency separation of six subcarriers.

[0052] According to one example of the disclosure, a network node is provided. The network node includes processing circuitry configured to: select a first set and second set of reference signal resources in a subframe and aggregate the first set and second set of reference signal resources in the subframe to form a code division multiplexing, CDM, aggregation configuration. The first set and second set of reference signal resources in the subframe satisfy a temporal criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum time separation of six OFDM symbols. The first set and second set of reference signal resources in the subframe satisfy a frequency criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum frequency separation of six subcarriers.

[0053] According to one variant of this example, the first set of reference signal resources corresponds to a first portion of a first reference signal configuration. The second set of reference signal resources corresponds to a second portion of a second reference signal configuration. According to one variant of this example, the first reference signal configuration is at least a first channel state information-reference signal, CSI-RS, configuration. The second reference signal configuration is at least a second CSI-RS configuration different from the at least first CSI-RS configuration.

[0054] According to one variant of this example, the first set of reference signal resources in the subframe includes a subset of resources from an eight port CSI-RS resource configuration. The second set of reference signal resources in the subframe includes a subset of resources in a different eight port CSI-RS resource configuration different from the eight port CSI-RS resource configuration corresponding to the first set of reference signal resources. The CDM aggregation configuration has an orthogonal cover code of length eight. According to one variant of this example, the processing circuitry is further configured to communicate the CDM aggregation configuration to a wireless device. According to one variant of this example, the CDM aggregation configuration is an aggregation of two CDM-4 groups.

[0055] According to another example of the disclosure, a method is provided. A first set and second set of reference signal resources in a subframe are selected. The first set and second set of reference signal resources are aggregated to the subframe to form a code division multiplexing, CDM, aggregation configuration. The first set and second set of reference signal resources in the subframe satisfy a temporal criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum time separation of six OFDM symbols. The first set and second set of reference signal resources in the subframe satisfy a frequency criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum frequency separation of six subcarriers.

[0056] According to one variant of this example, the first set of reference signal resources corresponds to a first portion of a first reference signal configuration. The second set of reference signal resources corresponds to a second portion of a second reference signal configuration. According to one variant of this example, the first reference signal configuration is at least a first channel state information-reference signal, CSI-RS, configuration. The second reference signal configuration is at least a second CSI-RS configuration different from the at least first CSI-RS configuration. According to one variant of this example, the first set of reference signal resources in the subframe includes a subset of resources from an eight port CSI-RS resource configuration. The second set of reference signal resources in the subframe includes a subset of resources in a different eight port CSI-RS resource configuration different from the eight port CSI-RS resource configuration corresponding to the first set of reference signal resources. The CDM aggregation configuration having an orthogonal cover code of length eight.

[0057] According to one variant of this example, the CDM aggregation configuration is communicated to a wireless device. According to one variant of this example, the CDM aggregation configuration is an aggregation of two CDM-4 groups.

[0058] According to another example of the disclosure, a wireless device is provided. The wireless device includes processing circuitry configured to receive a CDM aggregation configuration corresponding to an aggregated first set and second set of reference signal resources in a subframe and perform channel estimation based on the CDM aggregation configuration. The first set and second set of reference signal resources satisfy a temporal criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum time separation of six OFDM symbols. The first set and second set of reference signal resources satisfy a frequency criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum frequency separation of six subcarriers.

[0059] According to one variant of this example, the first set of reference signal resources corresponds to a first portion of a first reference signal configuration. The second set of reference signal resources corresponds to a second portion of a second reference signal configuration. According to one variant of this example, the first reference signal configuration is at least a first channel state information-reference signal, CSI-RS, configuration. The second reference signal configuration is at least a second CSI-RS configuration different from the at least first CSI-RS configuration.

[0060] According to one variant of this example, the first set of reference signal resources in the subframe includes a subset of resources from an eight port CSI-RS resource configuration. The second set of reference signal resources in the subframe includes a subset of resources in a different eight port CSI-RS resource configuration different from the eight port CSI-RS resource configuration corresponding to the first set of reference signal resources. The CDM aggregation configuration having an orthogonal cover code of length eight. According to one variant of this example, the processing circuitry is further configured to map the selected first set and second set of reference signal resources in the subframe to a plurality of antenna ports. According to one variant of this example, the CDM aggregation configuration is an aggregation of two CDM-4 groups.

[0061] According to another example of the disclosure, a method for a wireless device is provided. A CDM aggregation configuration corresponding to an aggregated first set and second set of reference signal resources in a subframe is received. The first set and second set of reference signal resources. Channel estimation is performed based on the CDM aggregation configuration. The first set and second set of reference signal resources satisfy a temporal criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum time separation of six OFDM symbols. The first set and second set of reference signal resources satisfy a frequency criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum frequency separation of six subcarriers.

[0062] According to one variant of this example, the first set of reference signal resources corresponds to a first portion of a first reference signal configuration. The second set of reference signal resources corresponds to a second portion of a second reference signal configuration. According to one variant of this example, the first reference signal configuration is at least a first channel state information-reference signal, CSI-RS, configuration. The second reference signal configuration is at least a second CSI-RS configuration different from the at least first CSI-RS configuration.

[0063] According to one variant of this example, the first set of reference signal resources in the subframe includes a subset of resources from an eight port CSI-RS resource configuration. The second set of reference signal resources in the subframe includes a subset of resources in a different eight port CSI-RS resource configuration different from the eight port CSI-RS resource configuration corresponding to the first set of reference signal resources. The CDM aggregation configuration has an orthogonal cover code of length eight.

[0064] According to one variant of this example, the CDM aggregation configuration is an aggregation of two CDM-4 groups. According to one variant of this example, the selected first set and second set of reference signal resources in the subframe are mapped to a plurality of antenna ports.

[0065] According to another example of the disclosure, a network node is provided. The network node includes an aggregation processing module configured to: select a first set and second set of reference signal resources in a subframe and aggregate the first set and second set of reference signal resources to the subframe to form a code division multiplexing, CDM, aggregation configuration. The first set and second set of reference signal resources in the subframe satisfy a temporal criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum time separation of six OFDM symbols. The first set and second set of reference signal resources in the subframe satisfy a frequency criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum frequency separation of six subcarriers.

[0066] According to one example of the disclosure, a wireless device is provided. The wireless device includes a channel processing module configured to: receive a CDM aggregation configuration corresponding to an aggregated first set and second set of reference signal resources in a subframe, and perform channel estimation based on the CDM aggregation configuration. The first set and second set of reference signal resources satisfy a temporal criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum time separation of six OFDM symbols. The first set and second set of reference signal resources satisfy a frequency criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum frequency separation of six subcarriers.

[0067] According to one variant of this example, the channel processing module is further configured to communicate the CDM aggregation configuration to a wireless device. According to one variant of this example, the CDM aggregation configuration is communicated to a wireless device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0068] A more complete understanding of the present embodiments, and the attendant advantages and features thereof, will be more readily understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

FIG. 1 illustrates a basic LTE downlink physical resource;
FIG. 2 illustrates an LTE time-domain structure;
FIG. 3 illustrates a physical resource block within a downlink subframe;
FIG. 4 illustrates a transmission structure of precoded spatial multiplexing mode in LTE;
FIG. 5 illustrates a two-dimensional antenna array elements;
FIG. 6 illustrates a resource element grid;
FIG. 7a-b illustrate an example of aggregating three 4-port resources to form a 12-port NZP CSI-RS Resource, and an example of aggregating two 8-port resources to form a 16-port NZP CSI-RS Resource, each 4-port resource and 8-port being aggregated together is labeled with the same number;
FIG. 8 illustrates NZP CSI-RS design for the case of 12 ports with OCC length 2, where different 4-port resources are denoted by the alphabets A-J;
FIG. 9 illustrates NZP CSI-RS design for the case of 16 ports with OCC length 2, where the different 8 port resources;
FIG. 10 illustrates NZP CSI-RS design for the case of 12 ports with OCC length 4, where 4-port resources are denoted by the alphabets A-J;
FIG. 11 illustrates NZP CSI-RS design for the case of 16 ports with OCC length 4, where different 8-port resources are shown in the legend, the resource elements with the same alphabet form one CDM group within an 8-port CSI-RS resource;
FIG. 12 illustrates a CDM-8 pattern design;
FIG. 13 illustrates a 32-port example;
FIG. 14 illustrates CDM-8 group patterns;
FIG. 15 illustrates a 24-port, CDM-4 aggregation performed in an arbitrary way;
FIG. 16 is a block diagram of a system for code division multiplexing, CDM, aggregation configurations for wireless communications in accordance with the principles of some embodiments of the present disclosure;
FIG. 17 is a flow diagram of one exemplary embodiment of the aggregation process of aggregation code in accordance with the principles of some embodiments of the disclosure;
FIG. 18 is a diagram of CDM-8 groups formed by aggregating CDM-4 groups in accordance with the principles of some embodiments of the disclosure;
FIG. 19 is a diagram of aggregating CDM-4 groups that could result in performance losses;
FIG. 20 is a diagram of CDM-4 aggregation within 8-port CSI-RS resource combined with CDM-4 aggregation across a pair of 8-port CSI-RS resources in accordance with the principles of some embodiments of the disclosure;
FIG. 21 is a flow diagram of one exemplary embodiment of the channel process of channel code 24 in accordance with the principles of the disclosure; and
FIG. 22 is an example of antenna port numbering with CDM8 and 32 ports with {k_0,k_1,k_2,k_3}={0,4,1,3}.

DETAILED DESCRIPTION

Number of NZP CSI-RS Configurations

[0069] The number of different 12 port and 16 port CSI-RS configurations in a subframe in the LTE Release 13 NZP CSI-RS designs are three and two, respectively. That is, for the 12 port case, three different CSI-RS configurations can be formed where each configuration is formed by aggregating three legacy 4-port CSI-RS configurations. This will consume 36 CSI-RS REs of the 40 CSI-RS REs available for CSI-RS within a physical resource block (PRB). For the 16 port case, two different CSI-RS configurations can be formed where each configuration is formed by aggregating two legacy 8-port CSI-RS configurations. This will consume 32 CSI-RS REs of the 40 CSI-RS REs available for CSI-RS within a resource block (RB).

NZP CSI-RS for 24 and 32 ports and CDM-8 in LTE Release 14

[0070] In LTE Release 14, a NZP CSI-RS configuration with 24 and 32 ports is achieved by aggregating three and four legacy 8-port CSI-RS resources. For instance, in the case of 24 ports three out of the five legacy 8-port resources shown in FIG. 9 and FIG. 11 are aggregated together. Both CDM-2 (i.e., OCC length-2 code) and CDM-4 (i.e., OCC length-4 code) are supported for 24 and 32 ports in Release 14.

[0071] In addition, CDM-8 will also be supported in LTE Release 14 for NZP CSI-RS with 24 and 32 ports. A CDM-8 can be defined using a length-8 OCC given by Equation 13. The main motivation for introducing CDM-8 in Release-14 is to support full power utilization for NZP CSI-RS transmission.

$$W_8 = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \end{bmatrix} \qquad \text{Equation 13}$$

[0072] A CDM-8 pattern design is proposed in R1-166341, "CSI-RS design for {20,24,28,32} ports", China Academy of Telecommunications Technology (CATT), 3GPP TSG RAN WG1 Meeting #86, August 22-26, 2016, Gothenburg, Sweden, which is reproduced in FIG. 12. The REs with the same letter in Figure 12 represent a Code Division Multiplexing (CDM)-8 group. The major drawbacks of this design are as follows:

- Each CDM-8 group is spread across 9 OFDM symbols (i.e., from symbol 5 in the first slot to symbol 6 in the second slot). In this design, the orthogonality of the length-8 OCC depends on the flatness of the channel in the time domain. That is, the channel should not vary significantly over the 9 OFDM symbols over which each CDM-8 group is spread. However, in practice, the channel can vary over 9 OFDM symbols due to wireless device mobility and phase drift. Hence, when the channel varies over 9 OFDM symbols due to wireless device mobility or phase drift, the orthogonality of these CDM-8 groups may be destroyed.
- The CDM-8 design has extra CSI-RS overhead. For instance, for a 32 port NZP CSI-RS design, this design will use all the CSI-RS REs labeled A-D. Noting that these CSI-RS REs are distributed over all 5 legacy 8-port CSI-RS resources (i.e., resources 0-1 indicated in FIG. 12), then these 5 legacy 8-port CSI-RS resources cannot be used for other wireless devices and legacy wireless devices always have to perform Physical Downlink Shared Channel (PDSCH) rate matching around all 40 CSI-RS REs in these resources. This will result in higher CSI-RS overhead than needed (i.e. a CSI-RS RE overhead increase of $1 - \frac{40}{32} = 25\%$ in a subframe carrying CSI-RS transmission). The problem is even worse for 24 port NZP CSI-RS design since all 40 CSI-RS REs cannot be used for other wireless devices (i.e., a CSI-RS RE overhead increase of $1 - \frac{40}{24} = 67\%$ in a subframe carrying CSI-RS transmission).

[0073] A CDM-8 approach is proposed in the following references: R1-166519, "Performance comparison of CDM-4 and CDM-8 for CSI-RS", Intel Corporation, 3GPP TSG RAN WG1 Meeting #86, August 22-26, 2016, Gothenburg, Sweden and R1-167996, "WF on CDM aggregation for NP CSI-RS", Samsung, Xinwei, Ericsson, 3GPP TSG RAN WG1 Meeting #86, August 22-26, 2016, Gothenburg, Sweden, where the CDM-8 group is attained by aggregating two CDM-4 groups in two different legacy 8-port CSI-RS resources. A 32-port example is shown in FIG. 13, where the CDM-8 group denoted by A is formed by aggregating a CDM-4 group from legacy 8-port CSI-RS resource 0 and a CDM-4 group from legacy 8-port CSI-RS resource 2. It is further proposed that the aggregation of the CDM-4 groups is done in the order of the CSI-RS configuration index. For instance, if the four legacy 8-port CSI-RS resources being aggregated together are signaled by the network node to the wireless device as {0, 1, 2, 4}, then legacy 8-port CSI-RS resources 0, 1, 2, and 4 correspond to CSI-RS resource numbers $i = 0$, $i = 1$, $i = 2$, and $i = 3$, respectively (note the CSI-RS resource number i is defined as in Equation 12). Then according to the aggregation criterion in R1-167996, "WF on CDM aggregation for NP CSI-RS", Samsung, Xinwei, Ericsson, 3GPP TSG RAN WG1 Meeting #86, August 22-26, 2016, Gothenburg, Sweden, CDM-4 groups in legacy 8-port CSI-RS resources 0 and 1 (which correspond to i=0 and i=1) are aggregated together to form a CDM-8 group. Similarly, CDM-4 groups in legacy 8-port CSI-RS resources 2 and 4 (which correspond to i=2 and i=3) are aggregated together to form a CDM-8 group. This results in the CDM-8 group patterns shown in FIG. 13.

[0074] However, according to the CDM-8 aggregation criterion in R1-167996, "WF on CDM aggregation for NP CSI-RS", Samsung, Xinwei, Ericsson, 3GPP TSG RAN WG1 Meeting #86, August 22-26, 2016, Gothenburg, Sweden, if the four legacy 8-port CSI-RS resources being aggregated together are signaled by the network node to the wireless device as {0, 4, 1, 2}, then legacy 8-port CSI-RS resources 0, 4, 1, and 2 correspond to CSI-RS resource numbers $i = 0$, $i = 1$, $i = 2$, and $i = 3$, respectively (note the CSI-RS resource number i is defined as in Equation 12). Then according to this aggregation criterion, CDM-4 groups in legacy 8-port CSI-RS resources 0 and 4 (which correspond to i=0 and i=1) are aggregated together to form a CDM-8 group. Similarly, CDM-4 groups in legacy 8-port CSI-RS resources 1 and 2 (which correspond to i=2 and i=3) are aggregated together to form a CDM-8 group. This results in the CDM-8 group patterns shown in FIG. 14. A disadvantage with this CDM-8 grouping is that CDM-8 groups denoted by A and D in FIG. 14 are spread across 9 OFDM symbols. Hence, when the channel varies over 9 OFDM symbols due to wireless device mobility or phase drift, the orthogonality of these CDM-8 groups may be destroyed.

[0075] A second disadvantage of the approaches described above is how to support the CDM-8 aggregation for 24 ports. Since there are an odd number (i.e., 3) of legacy 8-port CSI-RS resources being aggregated together to form a 24-port NZP CSI-RS configuration, the approach of aggregating CDM-4 groups in legacy 8-port CSI-RS resources with consecutive CSI-RS resource numbers does not apply. This is due to the lack of a fourth legacy 8-port CSI-RS resource which would otherwise be used for CDM-4 aggregation with the third legacy 8-port CSI-RS resource.

[0076] It is possible to perform CDM-4 aggregation in an arbitrary fashion in the case of 24-ports as shown in FIG. 15. However, the resulting CDM-8 group C in FIG. 15 is spread across 9 OFDM symbols. Hence, when the channel varies over 9 OFDM symbols due to wireless device mobility or phase drift, the orthogonality of this CDM-8 group may be destroyed.

[0077] Some embodiments of the disclosure aim to solve at least some of the problems with existing systems at least in part by providing for CDM-8 designs via CDM-4 aggregation while minimizing the performance losses due to channel variations in the time and frequency directions. Some embodiments of the disclosure may provide for CDM-8 designs that does not involve any increase in CSI-RS overhead (i.e., 32 CSI-RS REs per PRB will be used for 32 port NZP CSI-RS).

[0078] Note that although terminology from 3GPP LTE has been used in this disclosure, this should not be seen as limiting the scope of the disclosure to only the aforementioned system. Other wireless systems, including New Radio (NR), Wide Band Code Division Multiple Access (WCDMA), WiMax, Ultra-Mobile Broadband (UMB) and Global Systems for Mobile communications (GSM), may also benefit from exploiting the ideas covered within this disclosure. Also note that terminology such as network node and wireless device should be considering non-limiting and does in particular not imply a certain hierarchical relation between the two; in general "eNodeB" could be considered as device 1 and "wireless device" device 2, and these two devices communicate with each other over some radio channel. Herein, we also focus on wireless transmissions in the downlink, but some embodiments of the disclosure are equally applicable in the uplink.

[0079] Before describing in detail exemplary embodiments, it is noted that the embodiments reside primarily in combinations of apparatus components and processing steps related to CDM aggregation configurations for wireless communications. Accordingly, components have been represented where appropriate by conventional symbols in the drawings, showing only those specific details that are pertinent to understanding the embodiments so as not to obscure the disclosure with details that will be readily apparent to those of ordinary skill in the art having the benefit of the description herein.

[0080] As used herein, relational terms, such as "first" and "second," "top" and "bottom," and the like, may be used solely to distinguish one entity or element from another entity or element without necessarily requiring or implying any physical or logical relationship or order between such entities or elements.

[0081] The term wireless device used herein may refer to any type of wireless device communicating with a network node and/or with another wireless device in a cellular or mobile communication system. Examples of a wireless device are user equipment (UE), target device, device to device (D2D) wireless device, machine type wireless device or wireless device capable of machine to machine (M2M) communication, PDA, iPAD, Tablet, mobile terminals, smart phone, laptop embedded equipped (LEE), laptop mounted equipment (LME), USB dongles etc.

[0082] The term "network node" used herein may refer to a radio network node or another network node, e.g., a core network node, Mobile Switching Center (MSC), Mobility Management Entity (MME), Operations and Maintenance (O&M), Operations System Support (OSS), SON, positioning node (e.g. (Evolved Serving Mobile Location Center (E-SMLC)), Minimization Drive Test (MDT) node, etc.

[0083] The term "network node" or "radio network node" used herein can be any kind of network node comprised in a radio network which may further comprise any of base station (BS), radio base station, base transceiver station (BTS), base station controller (BSC), radio network controller (RNC), evolved Node B (eNB or eNodeB), Node B, multi-standard radio (MSR) radio node such as MSR BS, relay node, donor node controlling relay, radio access point (AP), transmission points, transmission nodes, Remote Radio Unit (RRU) Remote Radio Head (RRH), nodes in distributed antenna system (DAS) etc.

[0084] Note further, that functions described herein as being performed by a wireless device or a network node may be distributed over a plurality of wireless devices and/or network nodes. In other words, it is contemplated that the functions of the network node and wireless device described herein are not limited to performance by a single physical device and, in fact, can be distributed among several physical devices.

[0085] Referring now to drawing figures in which like reference designators refer to like elements there is shown in FIG. 16 an exemplary system for code division multiplexing, CDM, aggregation configurations for wireless communications in accordance with the principles of some embodiments of the present disclosure and designated generally as "10." System 10 includes one or more wireless devices 12a-12n (collectively referred to as wireless device 12) and one or more network nodes 14a-14n (collectively referred to as network node 14), in communication with each other via one or more communication networks using one or more communication protocols, where wireless device 12 and/or network node 14 are configured to perform the processes described herein.

[0086] Wireless device 12 includes one or more communication interfaces 16 for communicating with one or more other wireless devices 12, network nodes 14, and/or other elements in system 10. In one or more embodiments, communication interface 16 includes one or more transmitters and/or one or more receivers. Wireless device 12 includes processing circuitry 18. Processing circuitry 18 includes processor 20 and memory 22. In addition to a traditional processor and memory, processing circuitry 18 may comprise integrated circuitry for processing and/or control, e.g., one or more processors and/or processor cores and/or FPGAs (Field Programmable Gate Array) and/or ASICs (Application Specific Integrated Circuitry). Processor 20 may be configured to access (e.g., write to and/or reading from) memory 22, which may comprise any kind of volatile and/or nonvolatile memory, e.g., cache and/or buffer memory and/or RAM (Random Access Memory) and/or ROM (Read-Only Memory) and/or optical memory and/or EPROM (Erasable Programmable Read-Only Memory). Such memory 22 may be configured to store code executable by processor 20 and/or other data, e.g., data pertaining to communication, e.g., configuration and/or address data of nodes, etc.

[0087] Processing circuitry 18 may be configured to control any of the methods and/or processes described herein and/or to cause such methods and/or processes to be performed, e.g., by wireless device 12. Processor 20 corresponds to one or more processors 20 for performing wireless device 12 functions described herein. Wireless device 12 includes memory 22 that is configured to store data, programmatic software code and/or other information described herein. In one or more embodiments, memory 22 is configured to store Channel code 24. For example, channel code 24 includes instructions that, when executed by processor 20, causes processor 20 to perform the process discussed in detail with respect to FIG. 21 and embodiments discussed herein.

[0088] Network node 14 includes one or more communication interfaces 26 for communicating with one or more other network nodes 14, wireless device 12, and/or other elements in system 10. In one or more embodiments, communication interface 26 includes one or more transmitters and/or one or more receivers. Network node 14 includes processing circuitry 28. Processing circuitry 28 includes processor 30 and memory 32. In addition to a traditional processor and memory, processing circuitry 28 may comprise integrated circuitry for processing and/or control, e.g., one or more processors and/or processor cores and/or FPGAs (Field Programmable Gate Array) and/or ASICs (Application Specific Integrated Circuitry). Processor 30 may be configured to access (e.g., write to and/or reading from) memory 32, which may comprise any kind of volatile and/or nonvolatile memory, e.g., cache and/or buffer memory and/or RAM (Random Access Memory) and/or ROM (Read-Only Memory) and/or optical memory and/or EPROM (Erasable Programmable Read-Only Memory). Such memory 32 may be configured to store code executable by processor 30 and/or other data, e.g., data pertaining to communication, e.g., configuration and/or address data of nodes, etc.

[0089] Processing circuitry 28 may be configured to control any of the methods and/or processes described herein and/or to cause such methods and/or processes to be performed, e.g., by network node 14. Processor 30 corresponds to one or more processors 30 for performing network node 14 functions described herein. Network node 14 includes memory 32 that is configured to store data, programmatic software code and/or other information described herein. In one or more embodiments, memory 32 is configured to store aggregation code 34. For example, aggregation code 34 includes instructions that, when executed by processor 30, causes processor 30 to perform the process discussed in detail with respect to FIG. 17 and embodiments discussed herein.

[0090] FIG. 17 is a flow diagram of one exemplary embodiment of the aggregation process of aggregation code 34 in accordance with the principles of some embodiments of the disclosure. Processing circuitry 28 selects a first set and second set of reference signal resources in a subframe, the first set and second set of reference signal resources satisfies a temporal criterion and a frequency criterion for separation between resource elements (Block S100). Processing circuitry 28 is further configured to aggregate the first set and second set of reference signal resources to the subframe to form a CDM aggregation configuration (Block S102). In one or more embodiments, processing circuitry 28 communicates CDM aggregation configuration to a wireless device 12.

[0091] In one or more embodiments (collectively referred to as Embodiment A), to minimize the risk of performance losses due to channel variations across OFDM symbols, some constraints are introduced on which pair of legacy 8-port CSI-RS resources can be used to perform CDM-4 aggregation. The pair of legacy 8-port CSI-RS resources are chosen such that the largest time separation between CSI-RS REs in the two legacy 8-port CSI-RS resources is limited to less than 6 OFDM symbols. For instance, the CSI-RS REs in legacy 8-port CSI-RS resources 0 and 2 have a maximum separation of 6 OFDM symbols (i.e., referring to FIG. 11, CSI-RS REs of legacy 8-port CSI-RS resource 0 in OFDM symbol 5 of the first slot are separated by 6 OFDM symbols from the CSI-RS REs of legacy 8-port CSI-RS resource 2 in OFDM symbol 3). This can help reduce the performance losses due to channel variations in time, as this approach only requires the channel to be invariant over a maximum of 6 OFDM symbols to ensure orthogonality within the resulting CDM-8 groups. The list of allowed pairs of legacy 8-port CSI-RS resources over which CDM-4 aggregation can be performed to obtain a CDM-8 group is given in Table 5 that illustrates a list of 8-port CSI-RS configuration pairings for CDM-4 aggregation.

CDM-4 Aggregation Configurations	**Pair of 8 port CSI-RS Configurations**	
0	0	1
1	0	2
2	0	3
3	1	2
4	1	3
5	1	4
6	2	3
7	2	4
8	3	4

[0092] Table 5. List of Allowed 8-port CSI-RS Configuration Pairings for CDM-4 Aggregation

[0093] Table 5 indicates the pair of 8-port CSI-RS configurations that can be in any order. For instance the pair (3,4) corresponding to the last row of Table 5 applies to both the following cases:

- The first 8-port CSI-RS configuration is 3 and the second 8-port CSI-RS configuration is 4;
- The first 8-port CSI-RS configuration is 4 and the second 8-port CSI-RS configuration is 3.

[0094] The exact order of the 8-port CSI-RS configurations is determined by the CSI-RS resource number i defined in Equation 12. In some embodiments, one or more CDM-4 aggregation configuration indices (which represents the pair of 8-port CSI-RS configurations) is signaled to the wireless device by the network node via higher layer signaling.

[0095] An example of CDM-8 design using embodiment is given as follows. The network node configures the wireless device with 32 NZP CSI-RS ports by aggregating legacy 8-port CSI-RS resources in the order 4, 0, 2, 1 where resource 4 corresponds to CSI-RS resource number i = 0 and resource 1 corresponds to CSI-RS resource number i = 3 (note that CSI-RS resource number i is defined as in Equation 12). As a next step, the network node forms CDM-8 groups by aggregating CDM-4 groups across the allowed pairs of legacy 8-port CSI-RS resources given in Table 5. For instance, the network node can aggregate the CDM-4 groups across legacy 8-port resource pairs (2,4) and (0,1) which correspond to CDM-4 aggregation configurations 7 and 0 in Table 5. The resulting CDM-8 groups are shown in FIG. 18. In FIG. 18, CDM-8 groups indicated by A and B are a result of aggregating CDM-4 groups across 8-port CSI-RS resources pairs (2,4); CDM-8 groups indicated by C and D are a result of aggregating CDM-4 groups across 8-port CSI-RS resources pairs (0,1). Note that the resource elements of all 4 CDM-8 groups have a maximum time separation ΔT=6 symbols, as highlighted in FIG. 18 for Group C. Furthermore, groups are not formed from with configurations with maximum time separations of ΔT=9 symbols, as illustrated in example in FIG. 18. In one or more embodiments, network node 14 then indicates CDM-4 aggregation configuration indices 7 and 0 to wireless device 12 via higher layer signaling. The wireless device uses this signal to know the CDM-8 groups being used for NZP CSI-RS transmission and performs channel estimation.

[0096] In one or more other embodiments (collectively referred to as Embodiment B), according to the list of allowed 8-port CSI-RS configuration pairings in Table 5, the aggregation of CDM-4 groups across 8-port CSI-RS resource configurations 1 and 4 are allowed. However, if the CDM-4 aggregation across 8-port CSI-RS resource configurations 1 and 4 are done as shown in FIG. 19, where the CDM-4 aggregation or resulting CDM-8 group (denoted by CSI-RS REs with A) can suffer from channel variations in the frequency domain. The two CDM-4 groups being aggregated together in FIG. 19 are separated 8 subcarriers. In order for the orthogonality of the CDM-8 group to hold, the channel needs to be invariant over 8 subcarriers, and under deployment scenarios with high delay spread, this condition is not easily met. Hence, in addition to minimizing the risk of performance losses due to channel variations across symbols (as done in Embodiment A), it is also important to limit the performance losses due to channel variations in the frequency domain (i.e., across subcarriers).

[0097] In Embodiment A, additional constraints are introduced on which CDM-4 groups within a pair of legacy 8-port resource configurations can be aggregated together. The two CDM-4 groups within a pair of legacy 8-port resource configurations being aggregated together are selected such that frequency separation between the two groups is no more than 6 subcarriers. The 6 subcarrier maximum separation is selected here since the OCC length 4 code in the case of 12 port NZP CSI-RS designs of LTE Release 13 are also separated by 6 subcarriers (see FIG. 10). The list of allowed CDM-4 aggregations within pairs of legacy 8-port CSI-RS resources to obtain a CDM-8 group is given in Table 6.

Table 6. List of Allowed CDM-4 Aggregations within a pair of 8-port CSI-RS configurations

CDM-4 Aggregation Configurations	**8 port CSI-RS Configuration and CDM-4 group combination pairs**			
	First 8-port CSI-RS resource Configuration	First CDM-4 Group	Second 8-port CSI-RS resource Configuration	Second CDM-4 Group
0	0	i	1	i
1	0	i	1	ii
2	0	ii	1	ii
3	0	i	2	i
4	0	i	2	ii
5	0	ii	2	i
6	0	ii	2	ii
7	0	i	3	i
8	0	ii	3	i
9	0	ii	3	ii
10	1	i	2	i
11	1	ii	2	i
12	1	ii	2	ii
13	1	i	3	i
14	1	ii	3	i
15	1	ii	3	ii
16	1	i	4	i
17	1	ii	4	i
18	1	ii	4	ii
19	2	i	3	i
20	2	ii	3	i
21	2	ii	3	ii
22	2	i	4	i
23	2	i	4	ii
24	2	ii	4	i
25	2	ii	4	ii
26	3	i	4	i
27	3	i	4	ii
28	3	ii	4	ii

[0098] In Table 6, i and ii represent the first and second CDM-4 groups within a legacy 8-port CSI-RS resource respectively.

[0099] It should be noted that Table 6 indicates 8-port CSI-RS configuration and CDM-4 group combination pairs that can be in any order. For instance the combination pairs (3,ii) and (4,ii) corresponding to the last row of Table 6 applies to both the following cases:

- The first 8-port CSI-RS configuration is 3 and the second 8-port CSI-RS configuration is 4;
- The first 8-port CSI-RS configuration is 4 and the second 8-port CSI-RS configuration is 3.

[0100] The exact order of the 8-port CSI-RS configurations is determined by the CSI-RS resource number i defined in Equation 12. In some embodiments, one or more CDM-4 aggregation configuration indices (which represents the 8 port CSI-RS Configuration and CDM-4 group combination pairs) is signaled to the wireless device by network node via higher layer signaling. In an alternate embodiment, only the 1st CDM-4 groups between pairs of 8-port CSI-RS configurations are allowed to be aggregated and similarly only the 2nd CDM-4 groups between pairs of 8-port CSI-RS configurations are allowed to be aggregated.

[0101] An alternative list of allowed CDM-4 aggregations within pairs of legacy 8-port CSI-RS resources to obtain a CDM-8 group is given in Table 7.

Table 7. An Alternative List of Allowed CDM-4 Aggregations within a pair of 8-port CSI-RS configurations

CDM-4 Aggregation Configurations	**8 port CSI-RS Configuration and CDM-4 group combination pairs**			
	First 8-port CSI-RS resource Configuration	First CDM-4 Group	Second 8-port CSI-RS resource Configuration	Second CDM-4 Group
0	0	i	1	i
1	0	ii	1	ii
2	0	i	2	i
3	0	ii	2	ii
4	0	i	3	i
5	0	ii	3	ii
6	1	i	2	i
7	1	ii	2	i
8	1	ii	2	ii
9	1	i	3	i
10	1	ii	3	i
11	1	ii	3	ii
12	1	i	4	i
13	1	ii	4	ii
14	2	i	3	i
15	2	ii	3	i
16	2	ii	3	ii
17	2	i	4	i
18	2	ii	4	ii
19	3	i	4	i
20	3	ii	4	ii

[0102] In Table 7, only the 1st CDM-4 groups between pairs of 8-port CSI-RS configurations are allowed to be aggregated and similarly only the 2nd CDM-4 groups between pairs of 8-port CSI-RS configurations are allowed to be aggregated with the exception of three rows (rows 7, 10 and 15). The reason for choosing the combination pairs listed in rows 7, 10, and 15 is that these combination pairs are located in the same two OFDM symbols (i.e., OFDM symbols 2-3 in the second slot) and have a maximum frequency separation of 6 subcarriers.

[0103] In a further alternative embodiment, CDM-4 group aggregation within the same 8-port CSI-RS configuration is also allowed. In some cases, CDM-4 aggregation within the same 8-port CSI-RS configuration may be combined with CDM-4 aggregation across pairs of 8-port CSI-RS configurations. An example showing CDM-4 aggregation within 8-port CSI-RS resource combined with CDM-4 aggregation across a pair of 8-port CSI-RS resources in shown in FIG. 20. In FIG. 20, the CDM-8 group indicated by C is formed by CDM-4 group aggregation within the same 8-port CSI-RS configuration.

Antenna Port Numbering

[0104] For CSI reference signals transmitted on 24 and 32 antenna ports, the antenna ports will be p = 15,...,38 and p = 15,...,46, respectively. When aggregating multiple legacy CSI-RS resources of 8 ports to form a CSI-RS resource for 24 or 28 ports, mapping between each antenna port to a CSI-RS RE needs to be defined in order for a wireless device to measure the channel of each antenna port correctly. A number of solutions by using 24 and 32 ports as examples are discussed below.

[0105] For CSI reference signals using 24 or 32 antenna ports, $N_{\text{res}}^{\text{CSI}}$ CSI-RS resource configurations in the same subframe, numbered from 0 to $N_{\text{res}}^{\text{CSI}}-1$, are aggregated to obtain $N_{\text{res}}^{\text{CSI}}N_{\text{ports}}^{\text{CSI}}$ antenna ports in total. Each CSI-RS resource configuration in such an aggregation corresponds to $N_{\text{ports}}^{\text{CSI}}=8$ antenna ports and one of the CSI-RS configurations in Table 2. $N_{\text{res}}^{\text{CSI}}$ and $N_{\text{ports}}^{\text{CSI}}$ respectively denote the number of aggregated CSI-RS resources and the number of antenna ports per aggregated CSI-RS resource configuration. The values of $N_{\text{res}}^{\text{CSI}}$ and $N_{\text{ports}}^{\text{CSI}}$ for the cases of 24 and 32 port NZP CSI-RS design are given in Table 8.

Table 8: Aggregation of CSI-RS configurations for 24 and 32 ports

Total number of antenna ports $N_{\text{res}}^{\text{CSI}}N_{\text{ports}}^{\text{CSI}}$	**Number of antenna ports per CSI-RS configuration** $N_{\text{ports}}^{\text{CSI}}$	**Number of CSI-RS configurations** $N_{\text{res}}^{\text{CSI}}$
24	8	3
32	8	4

[0106] A solution by using 32 ports as an example is discussed, where a UE is signaled with a list of four 8 ports CSI-RS resources, i.e. $\{k_0,k_1,k_2,k_3\}$ and $k_i \in \{0,1,2,3,4\}$ is one of the 8 ports CSI-RS resource configurations in Table 2. For the case of OCC8, i.e., when higher layer parameter 'cdmType' is set to cdm8, and a list of $N_{\text{res}}^{\text{CSI}}=4$ CSI-RS resource configurations $\{k_0,k_1,k_2,k_3\}$, the list is reordered to a new list $\{m_0,m_1,m_2,m_3\}$ such that $m_0 = k_0$ and m_1 corresponds to the first entry in $\{k_1, k_2, k_3\}$ that the pair of CSI-RS resources $\{m_0, m_1\}$ meet the constraints discussed in Embodiment A. Similarly, $\{m_2, m_3\}$ are the second pair of CSI-RS resources with $m_3 = k_i$ and $m_4 = k_j$ ($i,j \in \{1,2,3\}$) such that $j > i$; .

[0107] The mapping of the reference signal sequence $r_{l,n_s}(m)$ of Equation 5 to the complex-valued modulation symbols $a_{k,l}^{(p)}$ used as reference symbols on antenna port p are defined as:

$$a_{k,l}^{(p')} = w_{p'}(i) \cdot r_{l,n_s}(m')$$

where

$$k = k_q' + 12m - \begin{cases} k'' & \text{for } p' \in \{15,...,22\}, \text{normal cyclic prefix}, N_{\text{ports}}^{\text{CSI}} = 8 \\ k''+6 & \text{for } p' \in \{23,...,30\}, \text{normal cyclic prefix}, N_{\text{ports}}^{\text{CSI}} = 8 \end{cases}$$

$$l = l_q' + \begin{cases} l'' & \text{CSI reference signal configurations } 0\text{-}19, \text{normal cyclic prefix} \\ 2l'' & \text{CSI reference signal configurations } 20\text{-}31, \text{normal cyclic prefix} \end{cases}$$

q = 0,1
l''=0,1
k''=0,1

$$i = 4q + 2k'' + l''$$

m

$$m = 0,1,..., N_{\text{RB}}^{\text{DL}} - 1$$

$$m' = m + \left\lfloor \frac{N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{DL}}}{2} \right\rfloor$$

and where $w_{p'}(i)$ is given by Table 9.

Table 9

p'	$[w_{p'}(0) w_{p'}(1) w_{p'}(2) w_{p'}(3) w_{p'}(4) w_{p'}(5) w_{p'}(6) w_{p'}(7)]$
15,23	[1 1 1 1 1 1 1 1]
16,24	[1 -1 1 -1 1 -1 1 -1]
19,25	[1 1 -1 -1 1 1 -1 -1]
20,26	[1 -1 -1 1 1 -1 -1 1]
15,27	[1 1 1 1 -1 -1 -1 -11
16,28	[1 -1 1 -1 -1 1 -1 1]
19,29	[1 1 -1 -1 -1 -1 1 1]
20,30	[1 -1 -1 1 -1 1 1 -1]

[0108] The quantity (k_q', l_q') corresponds to (k', l') given in Table 2 of a CSI-RS resource configuration n_q (q = 0,1) and $\{n_0, n_1\}$ is a pair of CSI-RS configurations used for CDM8. $(n_0,n_1) = (m_0,m_1)$ or $(n_0,n_1) = (m_2,m_3)$. The quantity (k', l') and the necessary conditions on n_s are given by Table 2. Let i be the ith pair of CSI-RS resources, i.e. (m_{2i}, m_{2i+1}), the relation between the antenna port number p and the quantity p' can be described as

$$p = i2N_{\text{ports}}^{\text{CSI}} + p' \qquad \text{Equation 14}$$

where $p' \in \{15,16,..,15+2N_{\text{ports}}^{\text{CSI}} - 1\}$ for the ith pair of CSI-RS resources (m_{2i}, m_{2i+1}) and $i \in \{0,1\}$, $N_{\text{ports}}^{\text{CSI}} = 8$.

[0109] FIG. 21 is a flow diagram of one exemplary embodiment of the channel process of channel code 24 in accordance with the principles of the disclosure. Processing circuitry 18 receives a CDM aggregation configuration corresponding to an aggregated first set and second set of reference signal resources in a subframe, the first set and second set of reference signal resources satisfying a temporal criterion and a frequency criterion for separation between resource elements (Block S104). The selected first set and second set of reference signal resources in the subframe configured to reduce performance losses due to at least one channel variation across a plurality of symbols in the subframe. Processing circuitry 18 performs channel estimation based on the CDM aggregation configuration (Block S106).

[0110] FIG. 22 shows an example of antenna port numbering with CDM8 and 32 ports with $\{k_0,k_1,k_2,k_3\}$ = {0, 4,1, 3}. To satisfy the constraints discussed in Embodiment A, the CSI-RS resource configurations are re-ordered as $\{m_0,m_1,m_2,m_3\}$ = {0,1,4,3}. Then the first CSI-RS resource pair is $\{n_0,n_1\}$ = (0,1) and the second pair is $\{n_0,n_1\}$ = (4,3). For the first pair of resources $\{n_0,n_1\}$ = (0,1), the CDM8 cover code $w_{p'}(0),...,w_{p'}(3)$ are mapped to the CSI-RS REs of config 0 while $w_{p'}(4),...,w_{p'}(7)$ are mapped to the CSI-RS REs of config 1. Similarly, for the second pair of resources $\{n_0,n_1\}$ = (4,3), the CDM8 cover code $w_{p'}(0),...,w_{p'}(3)$ are mapped to the CSI-RS REs of config 4 while $w_{p'}(4),...,w_{p'}(7)$ are mapped to the CSI-RS REs of config 3. Note that the subscription *p'* of w'_p is omitted in the figure for simplicity. The antenna port *p* can be derived according to $\{m_0,m_1,m_2,m_3\}$ = {0,1, 4, 3} and, where the first 16 ports p={15,...,30} are mapped to REs associated with the first CSI-RS resource pair $\{m_0,m_1\}$ = {0,1} and the next 16 ports p={31,...,46} are mapped to REs associated with the second CSI-RS resource pair $\{m_2,m_3\}$ = {4,3}.

[0111] In one or more embodiments, network node 14 includes aggregation processing module. Aggregation processing module is configured to select a first set and second set of reference signal resources in a subframe. The aggregation processing module is further configured to aggregate the first set and second set of reference signal resources to the subframe to form a code division multiplexing, CDM, aggregation configuration. The first set and second set of reference signal resources in the subframe satisfy a temporal criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum time separation of six OFDM symbols. The first set and second set of reference signal resources in the subframe satisfy a frequency criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum frequency separation of six subcarriers.

[0112] In one or more embodiments, a wireless device 14 includes a channel processing module configured to receive a CDM aggregation configuration corresponding to an aggregated first set and second set of reference signal resources in a subframe. The CDM aggregation configuration configured to perform channel estimation based on the CDM aggregation configuration. The first set and second set of reference signal resources in the subframe satisfy a temporal criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum time separation of six OFDM symbols. The first set and second set of reference signal resources in the subframe satisfy a frequency criterion such that any two resource elements in the first set and second set of reference signal resources have up to a maximum frequency separation of six subcarriers.

[0113] As will be appreciated by one of skill in the art, the concepts described herein may be embodied as a method, data processing system, and/or computer program product. Accordingly, the concepts described herein may take the form of an entirely hardware embodiment, an entirely software embodiment or an embodiment combining software and hardware aspects all generally referred to herein as a "circuit" or "module." Furthermore, the disclosure may take the form of a computer program product on a tangible computer usable storage medium having computer program code embodied in the medium that can be executed by a computer. Any suitable tangible computer readable medium may be utilized including hard disks, CD-ROMs, electronic storage devices, optical storage devices, or magnetic storage devices.

[0114] Some embodiments are described herein with reference to flowchart illustrations and/or block diagrams of methods, systems and computer program products. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

[0115] These computer program instructions may also be stored in a computer readable memory or storage medium that can direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer readable memory produce an article of manufacture including instruction means which implement the function/act specified in the flowchart and/or block diagram block or blocks.

[0116] The computer program instructions may also be loaded onto a computer or other programmable data processing apparatus to cause a series of operational steps to be performed on the computer or other programmable apparatus to produce a computer implemented process such that the instructions which execute on the computer or other programmable apparatus provide steps for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

[0117] It is to be understood that the functions/acts noted in the blocks may occur out of the order noted in the operational illustrations. For example, two blocks shown in succession may in fact be executed substantially concurrently or the blocks may sometimes be executed in the reverse order, depending upon the functionality/acts involved. Although some of the diagrams include arrows on communication paths to show a primary direction of communication, it is to be understood that communication may occur in the opposite direction to the depicted arrows.

[0118] Computer program code for carrying out operations of the concepts described herein may be written in an object oriented programming language such as Java® or C++. However, the computer program code for carrying out operations of the disclosure may also be written in conventional procedural programming languages, such as the "C" programming language. The program code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer. In the latter scenario, the remote computer may be connected to the user's computer through a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

Claims

1. A network node (14), comprising:
processing circuitry (18) configured to:

    select a first set and second set of reference signal resource elements in a subframe; and
    aggregate the first set and second set of reference signal resource elements in the subframe to form a code division multiplexing, CDM, configuration for a CDM-8 design for at least twenty four Channel System Information-Reference Signal, CSI-RS, antenna ports;
    wherein the first set and second set of reference signal resource elements in the subframe satisfy a temporal criterion such that any two resource elements in the first set and second set of reference signal resource elements have up to a maximum time separation of six Orthogonal Frequency Division Multiplexing, OFDM, symbols; and
    wherein the first set and second set of reference signal resource elements in the subframe satisfy a frequency criterion such that any two resource elements in the first set and second set of reference signal resource elements have up to a maximum frequency separation of six subcarriers.

2. The network node (14) of Claim 1, wherein the first set of reference signal resource elements corresponds to a first portion of a first reference signal configuration; and
the second set of reference signal resource elements corresponds to a second portion of a second reference signal configuration;
and, optionally:

    wherein the first reference signal configuration is at least a first CSI-RS configuration; and
    the second reference signal configuration is at least a second CSI-RS configuration different from the at least first CSI-RS configuration.

3. The network node (14) of Claim 1 or 2, wherein the first set of reference signal resource elements in the subframe includes a subset of resource elements from an eight port CSI-RS resource configuration;
the second set of reference signal resource elements in the subframe includes a subset of resource elements in a different eight port CSI-RS resource configuration different from the eight port CSI-RS resource configuration corresponding to the first set of reference signal resource elements; and
the CDM configuration having an orthogonal cover code of length eight; and/or
wherein the processing circuitry (28) is further configured to communicate the CDM configuration to a wireless device (12);
and/or
wherein the CDM configuration is an aggregation of two CDM-4 groups; and/or
wherein the network node (14) is a base station.

4. A method, comprising:

    selecting (S100) a first set and second set of reference signal resource elements in a subframe;
    aggregating (S102) the first set and second set of reference signal resource elements to the subframe to form a code division multiplexing, CDM, configuration for a CDM-8 design for at least twenty four Channel System

Information-Reference Signal, CSI-RS, antenna ports;
wherein the first set and second set of reference signal resource elements in the subframe satisfy a temporal criterion such that any two resource elements in the first set and second set of reference signal resource elements have up to a maximum time separation of six Orthogonal Frequency Division Multiplexing, OFDM, symbols; and
wherein the first set and second set of reference signal resource elements in the subframe satisfy a frequency criterion such that any two resource elements in the first set and second set of reference signal resource elements have up to a maximum frequency separation of six subcarriers.

5. The method of Claim 4, wherein the first set of reference signal resource elements corresponds to a first portion of a first reference signal configuration; and
the second set of reference signal resource elements corresponds to a second portion of a second reference signal configuration;
and, optionally:

wherein the first reference signal configuration is at least a first CSI-RS configuration; and
the second reference signal configuration is at least a second CSI-RS configuration different from the at least first CSI-RS configuration.

6. The method of Claim 4 or 5, wherein the first set of reference signal resource elements in the subframe includes a subset of resource elements from an eight port CSI-RS resource configuration;
the second set of reference signal resource elements in the subframe includes a subset of resource elements in a different eight port CSI-RS resource configuration different from the eight port CSI-RS resource configuration corresponding to the first set of reference signal resource elements; and
the CDM configuration having an orthogonal cover code of length eight; and/or
further comprising communicating the CDM configuration to a wireless device (12);
and/or
wherein the CDM configuration is an aggregation of two CDM-4 groups; and/or
wherein the method is performed by a base station (14).

7. A wireless device (12), comprising:
processing circuitry (28) configured to:

receive a code division multiplexing, CDM, configuration for a CDM-8 design for at least twenty four Channel System Information-Reference Signal, CSI-RS, antenna ports, the CDM configuration corresponding to an aggregated first set and second set of reference signal resource elements in a subframe;
perform channel measurements based on the CDM configuration;
wherein the first set and second set of reference signal resource elements satisfy a temporal criterion such that any two resource elements in the first set and second set of reference signal resource elements have up to a maximum time separation of six Orthogonal Frequency Division Multiplexing, OFDM, symbols; and
wherein the first set and second set of reference signal resource elements satisfy a frequency criterion such that any two resource elements in the first set and second set of reference signal resource elements have up to a maximum frequency separation of six subcarriers.

8. The wireless device (12) of Claim 7, wherein the first set of reference signal resource elements corresponds to a first portion of a first reference signal configuration; and
the second set of reference signal resource elements corresponds to a second portion of a second reference signal configuration;
and, optionally:

wherein the first reference signal configuration is at least a first CSI-RS configuration; and
the second reference signal configuration is at least a second CSI-RS configuration different from the at least first CSI-RS configuration.

9. The wireless device (12) of Claim 7 or 8, wherein the first set of reference signal resource elements in the subframe includes a subset of resource elements from an eight port CSI-RS resource configuration;
the second set of reference signal resource elements in the subframe includes a subset of resource elements in a different eight port CSI-RS resource configuration different from the eight port CSI-RS resource configuration corresponding to the first set of reference signal resource elements; and

the CDM configuration having an orthogonal cover code of length eight; and/or
wherein the processing circuitry (28) is further configured to map the selected first set and second set of reference signal resource elements in the subframe to a plurality of antenna ports;
and/or
wherein the CDM configuration is an aggregation of two CDM-4 groups; and/or
wherein the wireless device (12) is a user equipment.

10. The wireless device (12) of any of Claims 7 to 9, wherein the processing circuitry (28) is further configured to use a mapping to determine antenna ports on which reference signal resources to be used for performing channel measurements are transmitted.

11. A method for a wireless device (12), the method comprising:

receiving (S104) a code division multiplexing, CDM, configuration for a CDM-8 design for at least twenty four Channel System Information-Reference Signal, CSI-RS, antenna ports, the CDM configuration corresponding to an aggregated first set and second set of reference signal resource elements in a subframe;
performing (S106) channel measurements based on the CDM configuration;
wherein the first set and second set of reference signal resource elements satisfy a temporal criterion such that any two resource elements in the first set and second set of reference signal resource elements have up to a maximum time separation of six Orthogonal Frequency Division Multiplexing, OFDM, symbols; and
wherein the first set and second set of reference signal resource elements satisfy a frequency criterion such that any two resource elements in the first set and second set of reference signal resource elements have up to a maximum frequency separation of six subcarriers.

12. The method of Claim 11, wherein the first set of reference signal resource elements corresponds to a first portion of a first reference signal configuration; and
the second set of reference signal resource elements corresponds to a second portion of a second reference signal configuration;
and, optionally:

wherein the first reference signal configuration is at least a first CSI-RS configuration; and
the second reference signal configuration is at least a second CSI-RS configuration different from the at least first CSI-RS configuration.

13. The method of Claim 11 or 12, wherein the first set of reference signal resource elements in the subframe includes a subset of resource elements from an eight port CSI-RS resource configuration;
the second set of reference signal resource elements in the subframe includes a subset of resource elements in a different eight port CSI-RS resource configuration different from the eight port CSI-RS resource configuration corresponding to the first set of reference signal resource elements; and
the CDM configuration having an orthogonal cover code of length eight; and/or
wherein the CDM configuration is an aggregation of two CDM-4 groups; and/or
further comprising mapping the selected first set and second set of reference signal resource elements in the subframe to a plurality of antenna ports;
and/or
wherein the wireless device (12) is a user equipment.

14. The method of any of Claims 11 to 13, further comprising using a mapping to determine antenna ports on which reference signal resources to be used for performing channel measurements are transmitted.

Patentansprüche

1. Netzwerkknoten (14), umfassend:
eine Verarbeitungsschaltung (28), die eingerichtet ist zum:

Auswählen einer ersten Menge und einer zweiten Menge von Referenzsignalressourcenelementen in einem Unterrahmen; und
Aggregieren der ersten Menge und der zweiten Menge von Referenzsignalressourcenelementen in dem Un-

terrahmen, um eine Code Division Multiplexing-, CDM-, Konfiguration für ein CDM-8-Design für mindestens vierundzwanzig Channel System Information-Reference Signal-, CSI-RS-, Antennenports zu bilden;
wobei die erste Menge und die zweite Menge von Referenzsignalressourcenelementen in dem Unterrahmen ein zeitliches Kriterium erfüllen, so dass zwei beliebige Ressourcenelemente in der ersten Menge und der zweiten Menge von Referenzsignalressourcenelementen eine maximale zeitliche Trennung von bis zu sechs Orthogonal Frequency Division Multiplexing-, OFDM-, Symbolen aufweisen; und
wobei die erste Menge und die zweite Menge von Referenzsignalressourcenelementen in dem Unterrahmen ein Frequenzkriterium erfüllen, so dass zwei beliebige Ressourcenelemente in der ersten Menge und der zweiten Menge von Referenzsignalressourcenelementen eine maximale Frequenztrennung von bis zu sechs Unterträgern aufweisen.

2. Netzwerknoten (14) nach Anspruch 1, wobei die erste Menge von Referenzsignalressourcenelementen einem ersten Abschnitt einer ersten Referenzsignalkonfiguration entspricht; und
die zweite Menge von Referenzsignalressourcenelementen einem zweiten Abschnitt einer zweiten Referenzsignalkonfiguration entspricht;
und, optional:

wobei die erste Referenzsignalkonfiguration wenigstens eine erste CSI-RS-Konfiguration ist; und
die zweite Referenzsignalkonfiguration wenigstens eine zweite CSI-RS-Konfiguration ist, die von der wenigstens einen ersten CSI-RS-Konfiguration verschieden ist.

3. Netzwerknoten (14) nach Anspruch 1 oder 2, wobei die erste Menge von Referenzsignalressourcenelementen in dem Unterrahmen eine Teilmenge von Ressourcenelementen von einer 8-Port-CSI-RS-Ressourcenkonfiguration umfasst;
die zweite Menge von Referenzsignalressourcenelementen in dem Unterrahmen eine Teilmenge von Ressourcenelementen in einer anderen 8-Port-CSI-RS-Ressourcenkonfiguration umfasst, die von der 8-Port-CSI-RS-Ressourcenkonfiguration, die der ersten Menge von Referenzsignalressourcenelementen entspricht, verschieden ist; und die CDM-Konfiguration einen orthogonalen Deckungscode der Länge acht aufweist;
und/oder
wobei die Verarbeitungsschaltung (28) ferner dazu eingerichtet ist, um die CDM-Konfiguration an ein drahtloses Gerät (12) zu übermitteln;
und/oder
wobei die CDM-Konfiguration eine Aggregation von zwei CDM-4-Gruppen ist; und/oder
wobei der Netzwerknoten (14) eine Basisstation ist.

4. Verfahren, umfassend:

Auswählen (S100) einer ersten Menge und einer zweiten Menge von Referenzsignalressourcenelementen in einem Unterrahmen;
Aggregieren (S102) der ersten Menge und der zweiten Menge von Referenzsignalressourcenelementen in dem Unterrahmen, um eine Code Division Multiplexing-, CDM-, Konfiguration für ein CDM-8-Design für mindestens vierundzwanzig Channel System Information-Reference Signal-, CSI-RS-, Antennenports zu bilden;
wobei die erste Menge und die zweite Menge von Referenzsignalressourcenelementen in dem Unterrahmen ein zeitliches Kriterium erfüllen, so dass zwei beliebige Ressourcenelemente in der ersten Menge und der zweiten Menge von Referenzsignalressourcenelementen eine maximale zeitliche Trennung von bis zu sechs Orthogonal Frequency Division Multiplexing-, OFDM-, Symbolen aufweisen; und
wobei die erste Menge und die zweite Menge von Referenzsignalressourcenelementen in dem Unterrahmen ein Frequenzkriterium erfüllen, so dass zwei beliebige Ressourcenelemente in der ersten Menge und der zweiten Menge von Referenzsignalressourcenelementen eine maximale Frequenztrennung von bis zu sechs Unterträgern aufweisen.

5. Verfahren nach Anspruch 4, wobei die erste Menge von Referenzsignalressourcenelementen einem ersten Abschnitt einer ersten Referenzsignalkonfiguration entspricht; und
die zweite Menge von Referenzsignalressourcenelementen einem zweiten Abschnitt einer zweiten Referenzsignalkonfiguration entspricht;
und, optional:

wobei die erste Referenzsignalkonfiguration wenigstens eine erste CSI-RS-Konfiguration ist; und die zweite Referenzsignalkonfiguration wenigstens eine zweite CSI-RS-Konfiguration ist, die von der wenigstens einen ersten CSI-RS-Konfiguration verschieden ist.

6. Verfahren nach Anspruch 4 oder 5, wobei die erste Menge von Referenzsignalressourcenelementen in dem Unterrahmen eine Teilmenge von Ressourcenelementen von einer 8-Port-CSI-RS-Ressourcenkonfiguration umfasst;
die zweite Menge von Referenzsignalressourcenelementen in dem Unterrahmen eine Teilmenge von Ressourcenelementen in einer anderen 8-Port-CSI-RS-Ressourcenkonfiguration umfasst, die von der 8-Port-CSI-RS-Ressourcenkonfiguration, die der ersten Menge von Referenzsignalressourcenelementen entspricht, verschieden ist; und die CDM-Konfiguration einen orthogonalen Deckungscode der Länge acht aufweist;
und/oder
ferner umfassend ein Übermitteln der CDM-Konfiguration an ein drahtloses Gerät (12);
und/oder
wobei die CDM-Konfiguration eine Aggregation von zwei CDM-4-Gruppen ist; und/oder
wobei das Verfahren von einer Basisstation (14) ausgeführt wird.

7. Drahtloses Gerät (12), umfassend:
eine Verarbeitungsschaltung (28), die eingerichtet ist zum:

Empfangen einer Code Division Multiplexing-, CDM-, Konfiguration für ein CDM-8-Design für mindestens vierundzwanzig Channel System Information-Reference Signal-, CSI-RS-, Antennenports, wobei die CDM-Konfiguration einer aggregierten ersten Menge und zweiten Menge von Referenzsignalressourcenelementen in einem Unterrahmen entspricht;
Durchführen von Kanalmessungen basierend auf der CDM-Konfiguration;
wobei die erste Menge und die zweite Menge von Referenzsignalressourcenelementen ein zeitliches Kriterium erfüllen, so dass zwei beliebige Ressourcenelemente in der ersten Menge und der zweiten Menge von Referenzsignalressourcenelementen eine maximale zeitliche Trennung von bis zu sechs Orthogonal Frequency Division Multiplexing-, OFDM-, Symbolen aufweisen; und
wobei die erste Menge und die zweite Menge von Referenzsignalressourcenelementen ein Frequenzkriterium erfüllen, so dass zwei beliebige Ressourcenelemente in der ersten Menge und der zweiten Menge von Referenzsignalressourcenelementen eine maximale Frequenztrennung von bis zu sechs Unterträgern aufweisen.

8. Drahtloses Gerät (12) nach Anspruch 7, wobei die erste Menge von Referenzsignalressourcenelementen einem ersten Abschnitt einer ersten Referenzsignalkonfiguration entspricht; und
die zweite Menge von Referenzsignalressourcenelementen einem zweiten Abschnitt einer zweiten Referenzsignalkonfiguration entspricht;
und, optional:

wobei die erste Referenzsignalkonfiguration wenigstens eine erste CSI-RS-Konfiguration ist; und
die zweite Referenzsignalkonfiguration wenigstens eine zweite CSI-RS-Konfiguration ist, die von der wenigstens einen ersten CSI-RS-Konfiguration verschieden ist.

9. Drahtloses Gerät (12) nach Anspruch 7 oder 8, wobei die erste Menge von Referenzsignalressourcenelementen in dem Unterrahmen eine Teilmenge von Ressourcenelementen von einer 8-Port-CSI-RS-Ressourcenkonfiguration umfasst;
die zweite Menge von Referenzsignalressourcenelementen in dem Unterrahmen eine Teilmenge von Ressourcenelementen in einer anderen 8-Port-CSI-RS-Ressourcenkonfiguration umfasst, die von der 8-Port-CSI-RS-Ressourcenkonfiguration, die der ersten Menge von Referenzsignalressourcenelementen entspricht, verschieden ist; und die CDM-Konfiguration einen orthogonalen Deckungscode der Länge acht aufweist;
und/oder
wobei die Verarbeitungsschaltung (28) ferner dazu eingerichtet ist, um die ausgewählte erste Menge und zweite Menge von Referenzsignalressourcenelementen in dem Unterrahmen einer Vielzahl von Antennenports zuzuordnen;
und/oder
wobei die CDM-Konfiguration eine Aggregation von zwei CDM-4-Gruppen ist; und/oder
wobei das drahtlose Gerät (12) ein Benutzerendgerät ist.

10. Drahtloses Gerät (12) nach einem der Ansprüche 7 bis 9, wobei die Verarbeitungsschaltung (28) ferner dazu eingerichtet ist, eine Zuordnung zu verwenden, um Antennenports zu bestimmen, auf denen Referenzsignalressourcen

übertragen werden, die zum Durchführen von Kanalmessungen zu verwenden sind.

11. Verfahren für ein drahtloses Gerät (12), wobei das Verfahren umfasst:

Empfangen (S104) einer Code Division Multiplexing-, CDM-, Konfiguration für ein CDM-8-Design für mindestens vierundzwanzig Channel System Information-Reference Signal-, CSI-RS-, Antennenports, wobei die CDM-Konfiguration einer aggregierten ersten Menge und zweiten Menge von Referenzsignalressourcenelementen in einem Unterrahmen entspricht;
Durchführen (S106) von Kanalmessungen basierend auf der CDM-Konfiguration;
wobei die erste Menge und die zweite Menge von Referenzsignalressourcenelementen ein zeitliches Kriterium erfüllen, so dass zwei beliebige Ressourcenelemente in der ersten Menge und der zweiten Menge von Referenzsignalressourcenelementen eine maximale zeitliche Trennung von bis zu sechs Orthogonal Frequency Division Multiplexing-, OFDM-, Symbolen aufweisen; und
wobei die erste Menge und die zweite Menge von Referenzsignalressourcenelementen ein Frequenzkriterium erfüllen, so dass zwei beliebige Ressourcenelemente in der ersten Menge und der zweiten Menge von Referenzsignalressourcenelementen eine maximale Frequenztrennung von bis zu sechs Unterträgern aufweisen.

12. Verfahren nach Anspruch 11, wobei die erste Menge von Referenzsignalressourcenelementen einem ersten Abschnitt einer ersten Referenzsignalkonfiguration entspricht; und
die zweite Menge von Referenzsignalressourcenelementen einem zweiten Abschnitt einer zweiten Referenzsignalkonfiguration entspricht;
und, optional:

wobei die erste Referenzsignalkonfiguration wenigstens eine erste CSI-RS-Konfiguration ist; und
die zweite Referenzsignalkonfiguration wenigstens eine zweite CSI-RS-Konfiguration ist, die von der wenigstens einen ersten CSI-RS-Konfiguration verschieden ist.

13. Verfahren nach Anspruch 11 oder 12, wobei die erste Menge von Referenzsignalressourcenelementen in dem Unterrahmen eine Teilmenge von Ressourcenelementen von einer 8-Port-CSI-RS-Ressourcenkonfiguration umfasst;
die zweite Menge von Referenzsignalressourcenelementen in dem Unterrahmen eine Teilmenge von Ressourcenelementen in einer anderen 8-Port-CSI-RS-Ressourcenkonfiguration umfasst, die von der 8-Port-CSI-RS-Ressourcenkonfiguration, die der ersten Menge von Referenzsignalressourcenelementen entspricht, verschieden ist; und
die CDM-Konfiguration einen orthogonalen Deckungscode der Länge acht aufweist;
und/oder
wobei die CDM-Konfiguration eine Aggregation von zwei CDM-4-Gruppen ist; und/oder
ferner umfassend eine Zuordnung der ausgewählten ersten Menge und zweiten Menge von Referenzsignalressourcenelementen in dem Unterrahmen zu einer Vielzahl von Antennenports;
und/oder
wobei das drahtlose Gerät (12) ein Benutzerendgerät ist.

14. Verfahren nach einem der Ansprüche 11 bis 13, ferner umfassend eine Verwendung einer Zuordnung, um Antennenports zu bestimmen, auf denen Referenzsignalressourcen übertragen werden, die zum Durchführen von Kanalmessungen zu verwenden sind.

Revendications

1. Nœud (14) de réseau, comprenant :
un ensemble (18) de circuits de traitement configuré pour :

sélectionner un premier ensemble et un deuxième ensemble d'éléments de ressources de signaux de référence dans une sous-trame ; et
agréger le premier ensemble et le deuxième ensemble d'éléments de ressources de signaux de référence dans la sous-trame pour former une configuration de multiplexage par répartition en code, CDM, pour une conception CDM-8 pour au moins vingt-quatre ports d'antenne pour signaux de référence d'information sur l'état des canaux, CSI-RS ;
dans lequel le premier ensemble et le deuxième ensemble d'éléments de ressources de signaux de référence

dans la sous-trame satisfont à un critère temporel tel que deux éléments de ressources quelconques dans le premier ensemble et le deuxième ensemble d'éléments de ressources de signaux de référence ont jusqu'à une séparation temporelle maximum de six symboles de multiplexage par répartition orthogonale de la fréquence, OFDM ; et

dans lequel le premier ensemble et le deuxième ensemble d'éléments de ressources de signaux de référence dans la sous-trame satisfont à un critère fréquentiel tel que deux éléments de ressources quelconques dans le premier ensemble et le deuxième ensemble d'éléments de ressources de signaux de référence ont jusqu'à une séparation fréquentielle maximum de six sous-porteuses.

2. Nœud (14) de réseau selon la revendication 1, dans lequel le premier ensemble d'éléments de ressources de signaux de référence correspond à une première partie d'une première configuration de signaux de référence ; et le deuxième ensemble d'éléments de ressources de signaux de référence correspond à une deuxième partie d'une deuxième configuration de signaux de référence ;
et, facultativement, :

dans lequel la première configuration de signaux de référence est au moins une première configuration CSI-RS ; et

la deuxième configuration de signaux de référence est au moins une deuxième configuration CSI-RS différente de l'au moins une première configuration CSI-RS.

3. Nœud (14) de réseau selon la revendication 1 ou 2, dans lequel le premier ensemble d'éléments de ressources de signaux de référence dans la sous-trame inclut un sous-ensemble d'éléments de ressources d'une configuration de ressources CSI-RS huit ports ;
le deuxième ensemble d'éléments de ressources de signaux de référence dans la sous-trame inclut un sous-ensemble d'éléments de ressources dans une configuration différente de ressources CSI-RS huit ports différente de la configuration de ressources CSI-RS huit ports correspondant au premier ensemble d'éléments de ressources de signaux de référence ; et
la configuration CDM ayant un code de couverture orthogonal de longueur huit ;
et/ou
dans lequel l'ensemble (28) de circuits de traitement est en outre configuré pour communiquer la configuration CDM à un dispositif sans fil (12) ;
et/ou
dans lequel la configuration CDM est une agrégation de deux groupes CDM-4 ; et/ou
dans lequel le nœud (14) de réseau est une station de base.

4. Procédé, comprenant :

la sélection (S100) d'un premier ensemble et d'un deuxième ensemble d'éléments de ressources de signaux de référence dans une sous-trame ;

l'agrégation (S102) du premier ensemble et du deuxième ensemble d'éléments de ressources de signaux de référence dans la sous-trame pour former une configuration de multiplexage par répartition en code, CDM, pour une conception CDM-8 pour au moins vingt-quatre ports d'antenne pour signaux de référence d'information sur l'état des canaux, CSI-RS ;

dans lequel le premier ensemble et le deuxième ensemble d'éléments de ressources de signaux de référence dans la sous-trame satisfont à un critère temporel tel que deux éléments de ressources quelconques dans le premier ensemble et le deuxième ensemble d'éléments de ressources de signaux de référence ont jusqu'à une séparation temporelle maximum de six symboles de multiplexage par répartition orthogonale de la fréquence, OFDM ; et

dans lequel le premier ensemble et le deuxième ensemble d'éléments de ressources de signaux de référence dans la sous-trame satisfont à un critère fréquentiel tel que deux éléments de ressources quelconques dans le premier ensemble et le deuxième ensemble d'éléments de ressources de signaux de référence ont jusqu'à une séparation fréquentielle maximum de six sous-porteuses.

5. Procédé selon la revendication 4, dans lequel le premier ensemble d'éléments de ressources de signaux de référence correspond à une première partie d'une première configuration de signaux de référence ; et
le deuxième ensemble d'éléments de ressources de signaux de référence correspond à une deuxième partie d'une deuxième configuration de signaux de référence ;
et, facultativement, :

dans lequel la première configuration de signaux de référence est au moins une première configuration CSI-RS ; et
la deuxième configuration de signaux de référence est au moins une deuxième configuration CSI-RS différente de l'au moins une première configuration CSI-RS.

6. Procédé selon la revendication 4 ou 5, dans lequel le premier ensemble d'éléments de ressources de signaux de référence dans la sous-trame inclut un sous-ensemble d'éléments de ressources d'une configuration de ressources CSI-RS huit ports ;
le deuxième ensemble d'éléments de ressources de signaux de référence dans la sous-trame inclut un sous-ensemble d'éléments de ressources dans une configuration différente de ressources CSI-RS huit ports différente de la configuration de ressources CSI-RS huit ports correspondant au premier ensemble d'éléments de ressources de signaux de référence ; et
la configuration CDM ayant un code de couverture orthogonal de longueur huit ;
et/ou
comprenant en outre la communication de la configuration CDM à un dispositif sans fil (12) ;
et/ou
dans lequel la configuration CDM est une agrégation de deux groupes CDM-4 ; et/ou
dans lequel le procédé est mis en œuvre par une station de base (14).

7. Dispositif sans fil (12), comprenant :
un ensemble (28) de circuits de traitement configuré pour :

recevoir une configuration de multiplexage par répartition en code, CDM, pour une conception CDM-8 pour au moins vingt-quatre ports d'antenne pour signaux de référence d'information sur l'état des canaux, CSI-RS, la configuration CDM correspondant à un premier ensemble et un deuxième ensemble agrégés d'éléments de ressources de signaux de référence dans une sous-trame ;
exécuter des mesures de canal sur la base de la configuration CDM ;
dans lequel le premier ensemble et le deuxième ensemble d'éléments de ressources de signaux de référence satisfont à un critère temporel tel que deux éléments de ressources quelconques dans le premier ensemble et le deuxième ensemble d'éléments de ressources de signaux de référence ont jusqu'à une séparation temporelle maximum de six symboles de multiplexage par répartition orthogonale de la fréquence, OFDM ; et
dans lequel le premier ensemble et le deuxième ensemble d'éléments de ressources de signaux de référence satisfont à un critère fréquentiel tel que deux éléments de ressources quelconques dans le premier ensemble et le deuxième ensemble d'éléments de ressources de signaux de référence ont jusqu'à une séparation fréquentielle maximum de six sous-porteuses.

8. Dispositif sans fil (12) selon la revendication 7, dans lequel le premier ensemble d'éléments de ressources de signaux de référence correspond à une première partie d'une première configuration de signaux de référence ; et le deuxième ensemble d'éléments de ressources de signaux de référence correspond à une deuxième partie d'une deuxième configuration de signaux de référence ;
et, facultativement, :

dans lequel la première configuration de signaux de référence est au moins une première configuration CSI-RS ; et
la deuxième configuration de signaux de référence est au moins une deuxième configuration CSI-RS différente de l'au moins une première configuration CSI-RS.

9. Dispositif sans fil (12) selon la revendication 7 ou 8, dans lequel le premier ensemble d'éléments de ressources de signaux de référence dans la sous-trame inclut un sous-ensemble d'éléments de ressources d'une configuration de ressources CSI-RS huit ports ;
le deuxième ensemble d'éléments de ressources de signaux de référence dans la sous-trame inclut un sous-ensemble d'éléments de ressources dans une configuration différente de ressources CSI-RS huit ports différente de la configuration de ressources CSI-RS huit ports correspondant au premier ensemble d'éléments de ressources de signaux de référence ; et
la configuration CDM ayant un code de couverture orthogonal de longueur huit ;
et/ou
dans lequel l'ensemble (28) de circuits de traitement est en outre configuré pour mapper le premier ensemble et le deuxième ensemble sélectionnés d'éléments de ressources de signaux de référence dans la sous-trame sur une

pluralité de ports d'antenne ;
et/ou
dans lequel la configuration CDM est une agrégation de deux groupes CDM-4 ; et/ou
dans lequel le dispositif sans fil (12) est un équipement utilisateur.

10. Dispositif sans fil (12) selon l'une quelconque des revendications 7 à 9, dans lequel l'ensemble (28) de circuits de traitement est en outre configuré pour utiliser un mappage pour déterminer des ports d'antenne sur lesquels des ressources de signaux de référence destinées à être utilisées pour exécuter des mesures de canal sont transmises.

11. Procédé pour un dispositif sans fil (12), le procédé comprenant :

la réception (S104) d'une configuration de multiplexage par répartition en code, CDM, pour une conception CDM-8 pour au moins vingt-quatre ports d'antenne pour signaux de référence d'information sur l'état des canaux, CSI-RS, la configuration CDM correspondant à un premier ensemble et un deuxième ensemble agrégés d'éléments de ressources de signaux de référence dans une sous-trame ;
l'exécution (S106) de mesures de canal sur la base de la configuration CDM ;
dans lequel le premier ensemble et le deuxième ensemble d'éléments de ressources de signaux de référence satisfont à un critère temporel tel que deux éléments de ressources quelconques dans le premier ensemble et le deuxième ensemble d'éléments de ressources de signaux de référence ont jusqu'à une séparation temporelle maximum de six symboles de multiplexage par répartition orthogonale de la fréquence, OFDM ; et
dans lequel le premier ensemble et le deuxième ensemble d'éléments de ressources de signaux de référence satisfont à un critère fréquentiel tel que deux éléments de ressources quelconques dans le premier ensemble et le deuxième ensemble d'éléments de ressources de signaux de référence ont jusqu'à une séparation fréquentielle maximum de six sous-porteuses.

12. Procédé selon la revendication 11, dans lequel le premier ensemble d'éléments de ressources de signaux de référence correspond à une première partie d'une première configuration de signaux de référence ; et
le deuxième ensemble d'éléments de ressources de signaux de référence correspond à une deuxième partie d'une deuxième configuration de signaux de référence ;
et, facultativement, :

dans lequel la première configuration de signaux de référence est au moins une première configuration CSI-RS ; et
la deuxième configuration de signaux de référence est au moins une deuxième configuration CSI-RS différente de l'au moins une première configuration CSI-RS.

13. Procédé selon la revendication 11 ou 12, dans lequel le premier ensemble d'éléments de ressources de signaux de référence dans la sous-trame inclut un sous-ensemble d'éléments de ressources d'une configuration de ressources CSI-RS huit ports ;
le deuxième ensemble d'éléments de ressources de signaux de référence dans la sous-trame inclut un sous-ensemble d'éléments de ressources dans une configuration différente de ressources CSI-RS huit ports différente de la configuration de ressources CSI-RS huit ports correspondant au premier ensemble d'éléments de ressources de signaux de référence ; et
la configuration CDM ayant un code de couverture orthogonal de longueur huit ;
et/ou
dans lequel la configuration CDM est une agrégation de deux groupes CDM-4 ; et/ou
comprenant en outre le mappage du premier ensemble et du deuxième ensemble sélectionnés d'éléments de ressources de signaux de référence dans la sous-trame sur une pluralité de ports d'antenne ;
et/ou
dans lequel le dispositif sans fil (12) est un équipement utilisateur.

14. Procédé selon l'une quelconque des revendications 11 à 13, comprenant en outre l'utilisation d'un mappage pour déterminer des ports d'antenne sur lesquels des ressources de signaux de référence destinées à être utilisées pour exécuter des mesures de canal sont transmises.

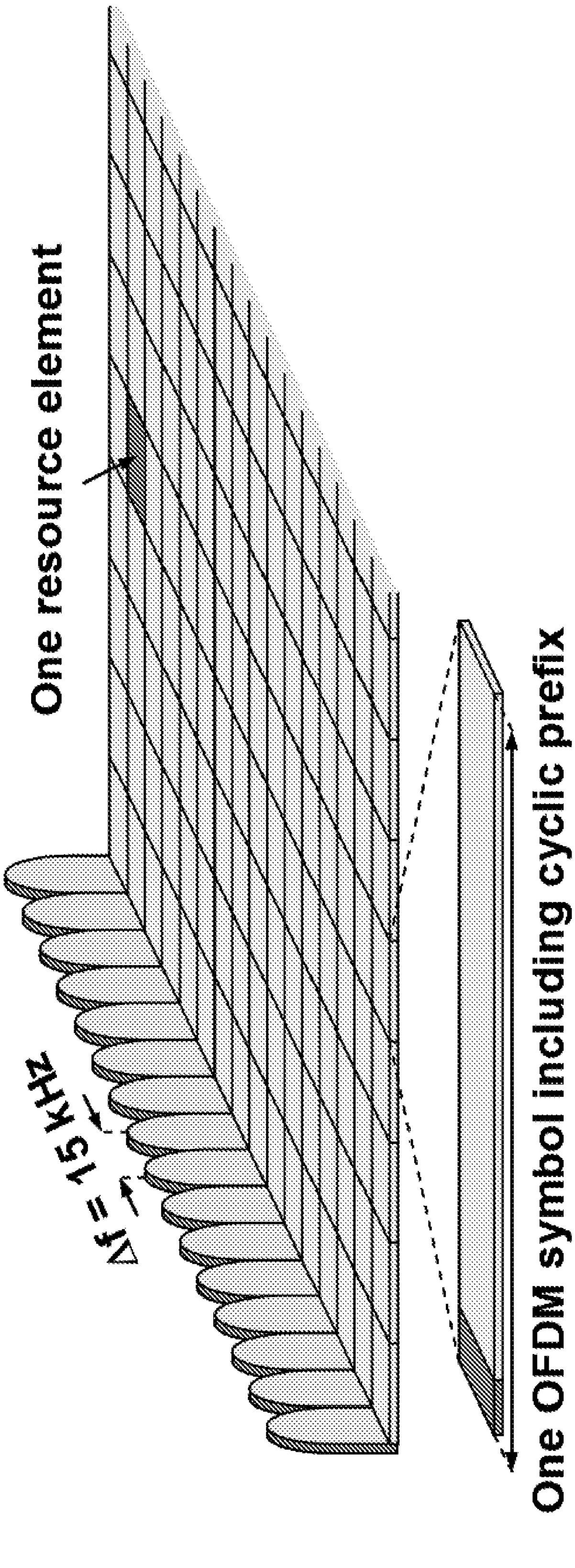

One resource element
Δf = 15 kHz
One OFDM symbol including cyclic prefix

FIG. 1

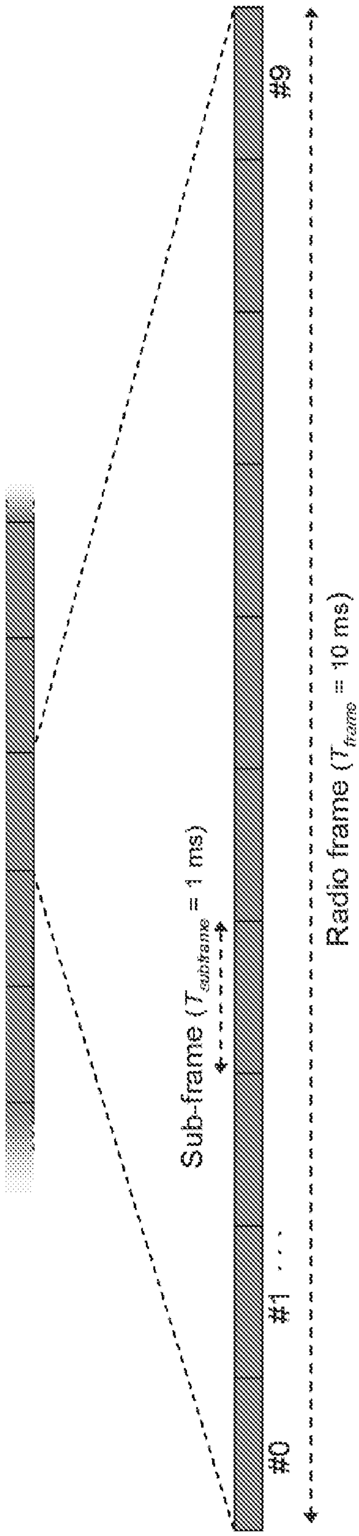


FIG. 2

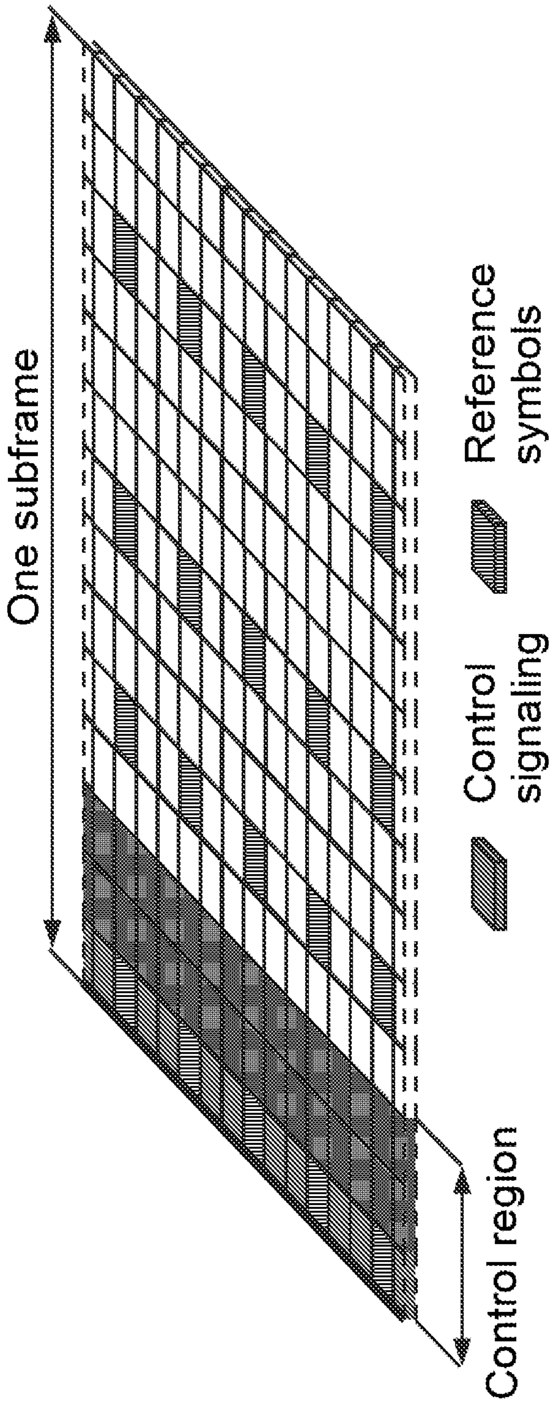

One subframe
Control region
Control signaling
Reference symbols

FIG. 3

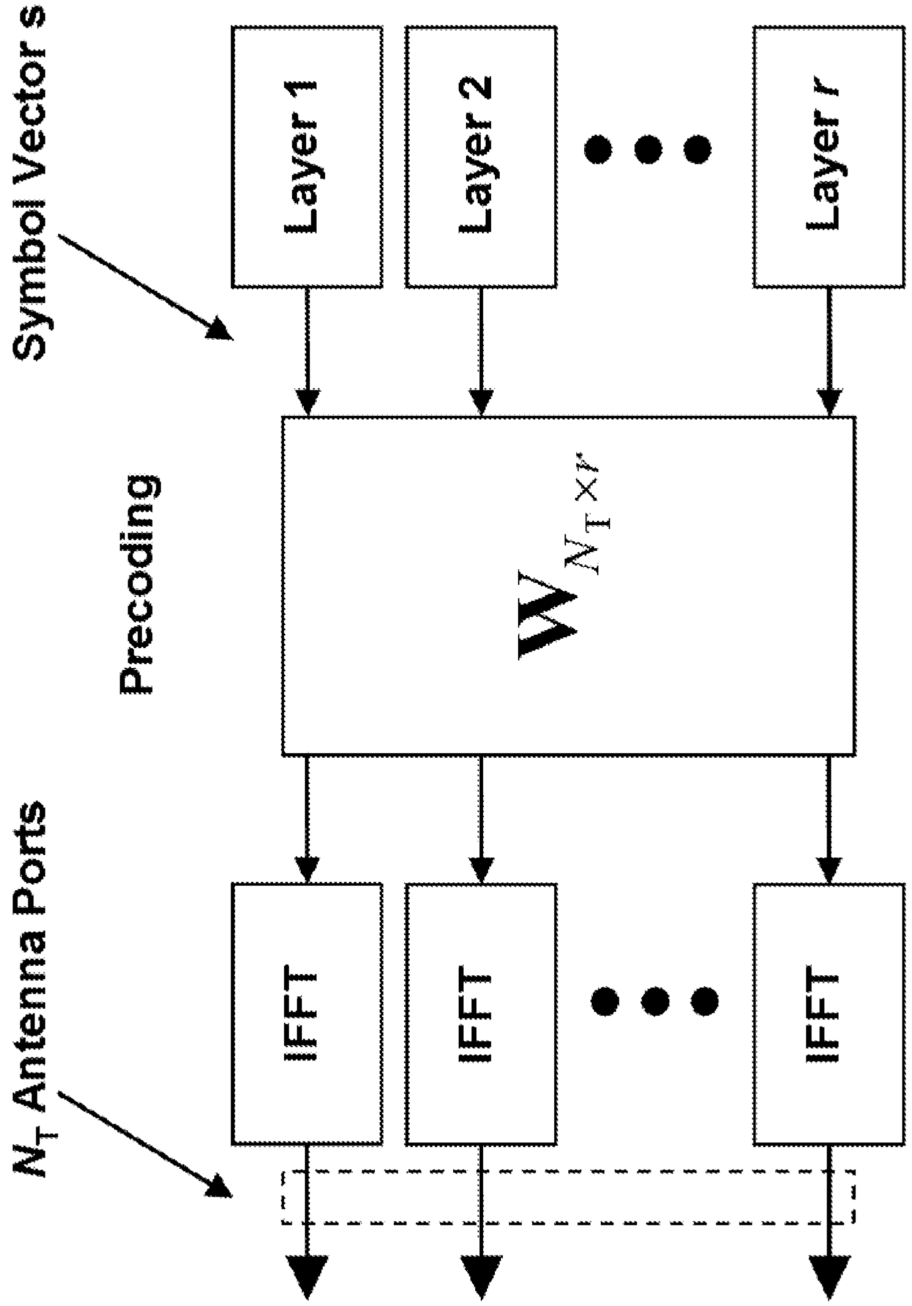

Symbol Vector s
Layer 1
Layer 2
Layer r
Precoding
$\mathbf{W}_{N_T \times r}$
N_T Antenna Ports
IFFT
IFFT
IFFT

FIG. 4

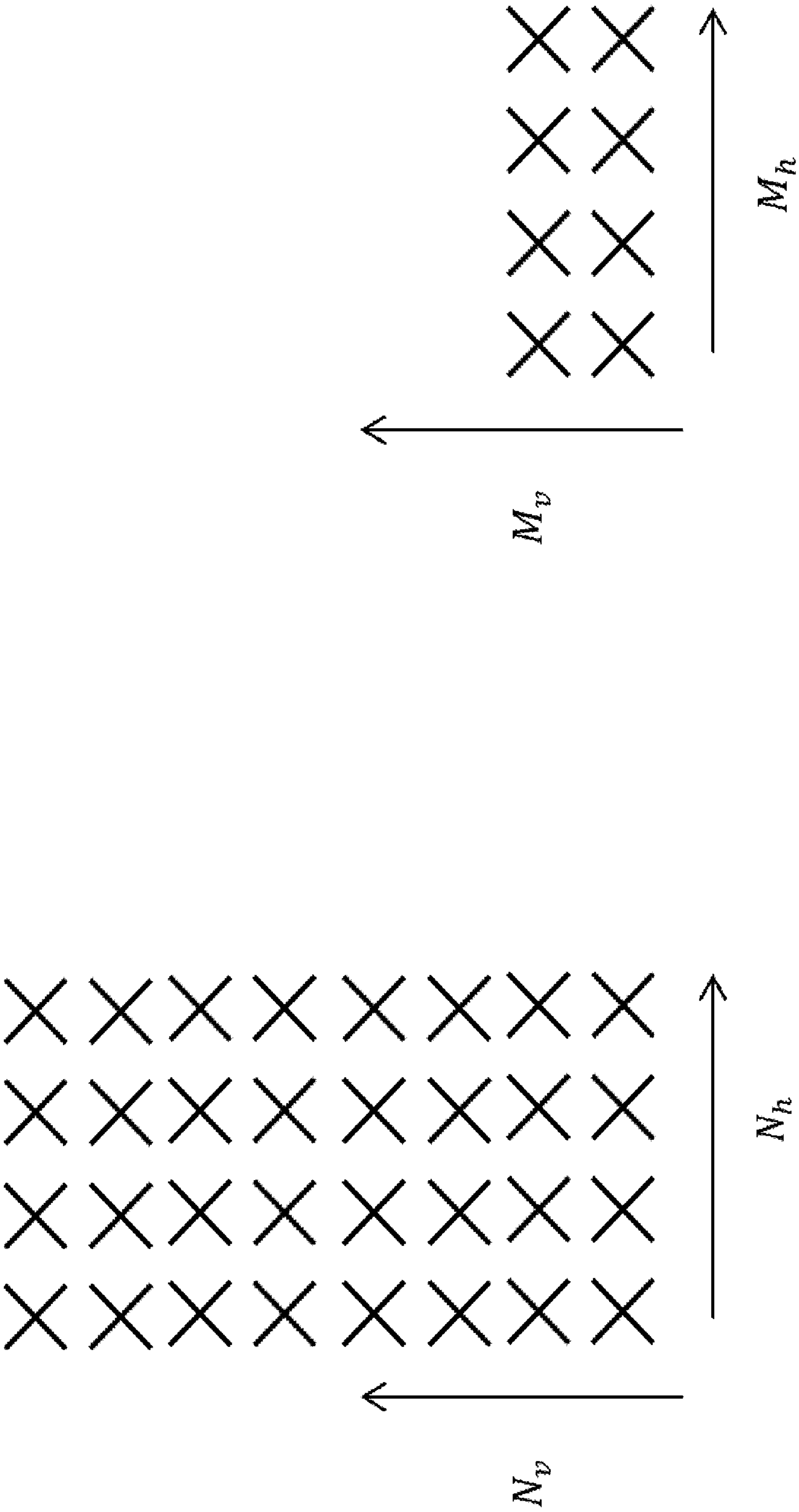


FIG. 5

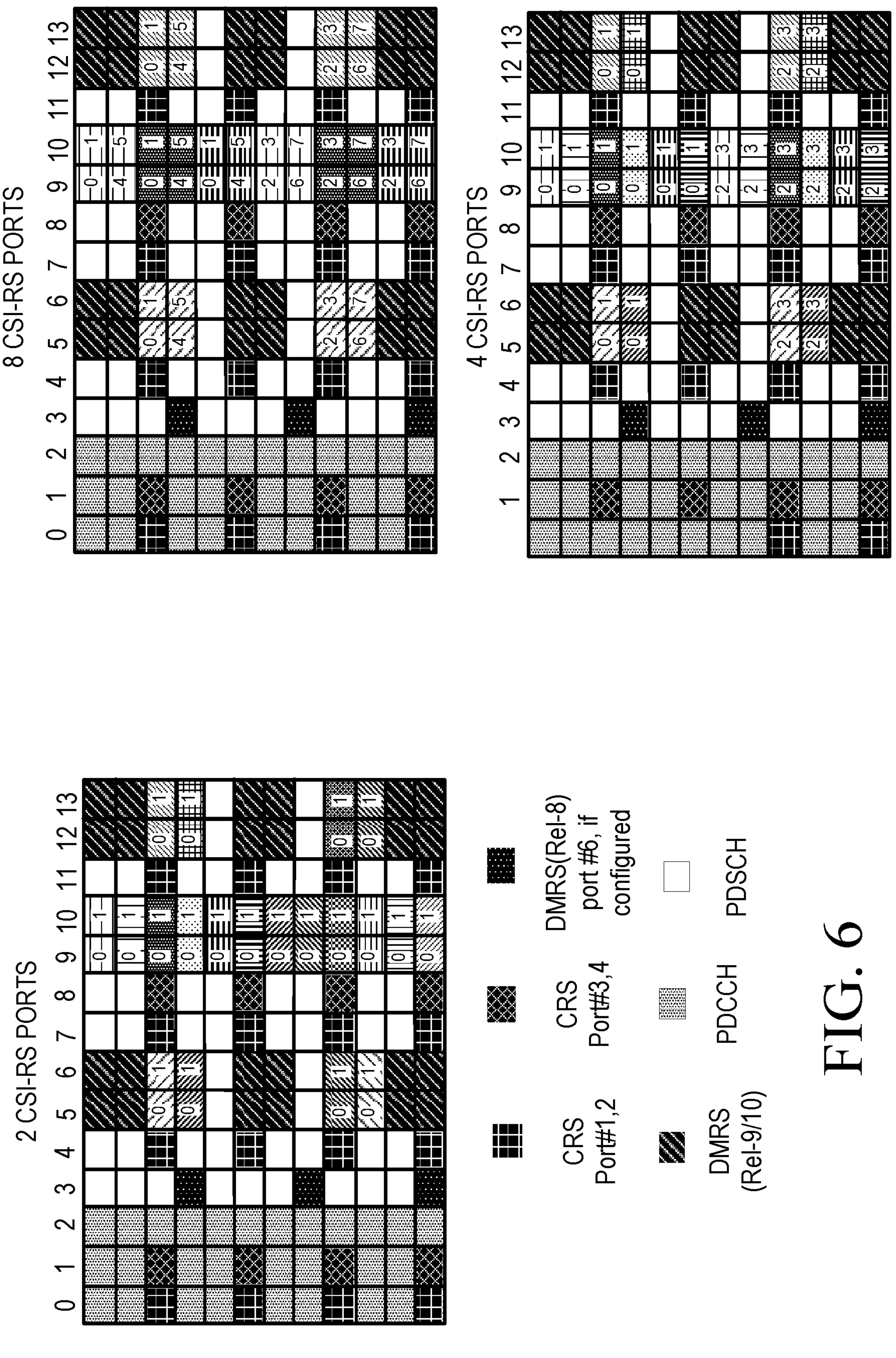

8 CSI-RS PORTS
4 CSI-RS PORTS
2 CSI-RS PORTS
CRS Port#1,2
CRS Port#3,4
DMRS(Rel-8) port #6, if configured
DMRS (Rel-9/10)
PDCCH
PDSCH

FIG. 6

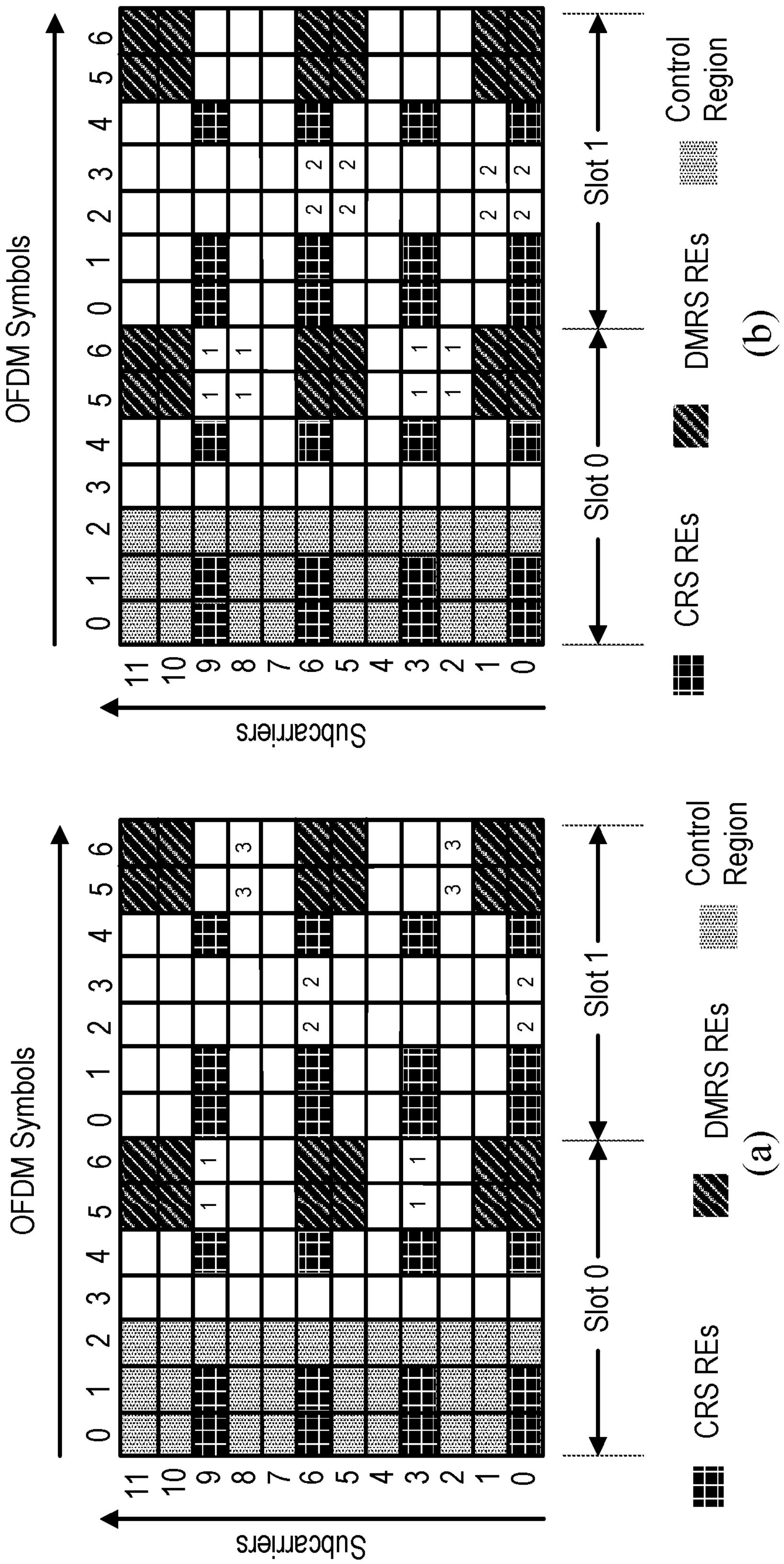

OFDM Symbols
Subcarriers
Slot 0
Slot 1
CRS REs
DMRS REs
Control Region
(a)
(b)

FIG. 7

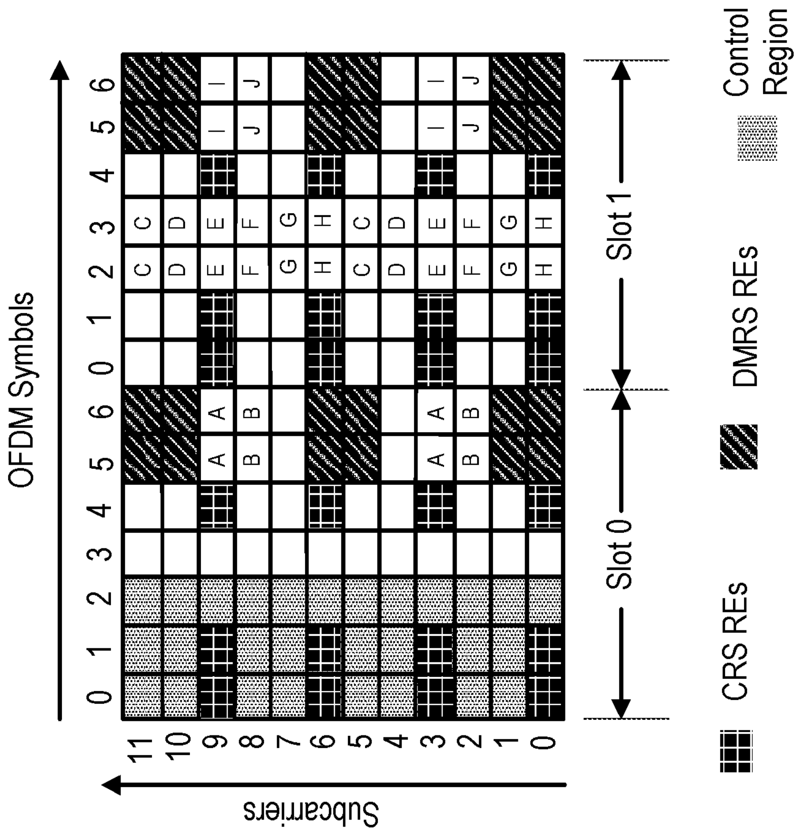
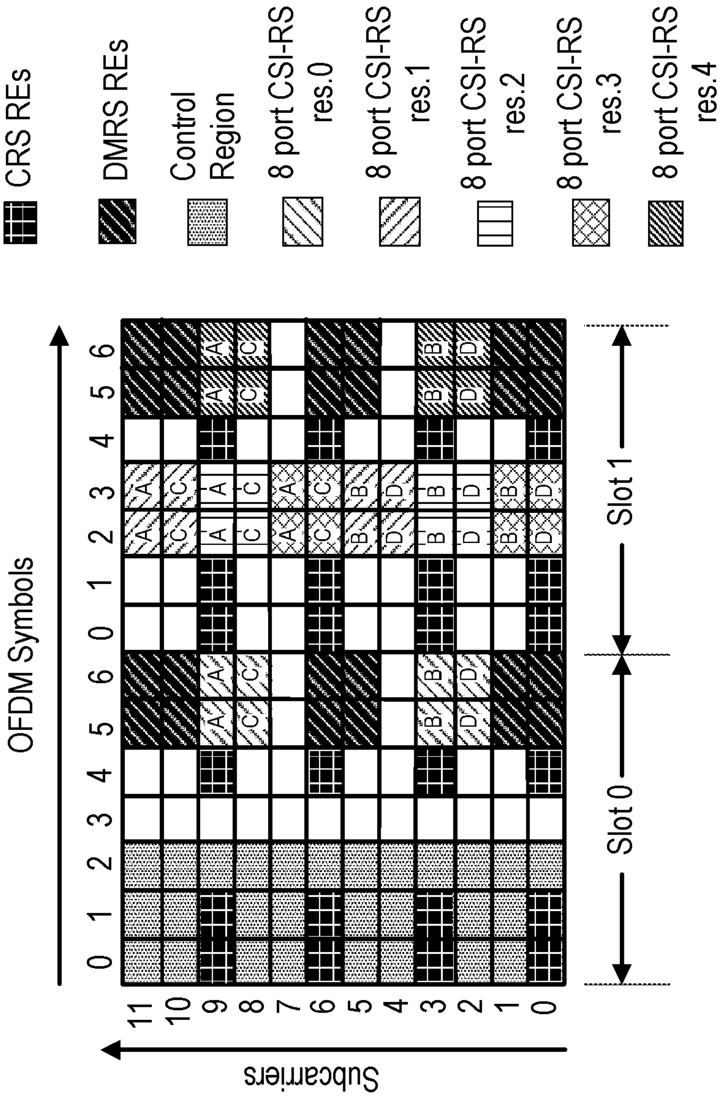

OFDM Symbols
Subcarriers
Slot 0
Slot 1
CRS REs
DMRS REs
Control Region

FIG. 8



CRS REs
DMRS REs
Control Region
8 port CSI-RS res.0
8 port CSI-RS res.1
8 port CSI-RS res.2
8 port CSI-RS res.3
8 port CSI-RS res.4
OFDM Symbols
Subcarriers
Slot 0
Slot 1

FIG. 9

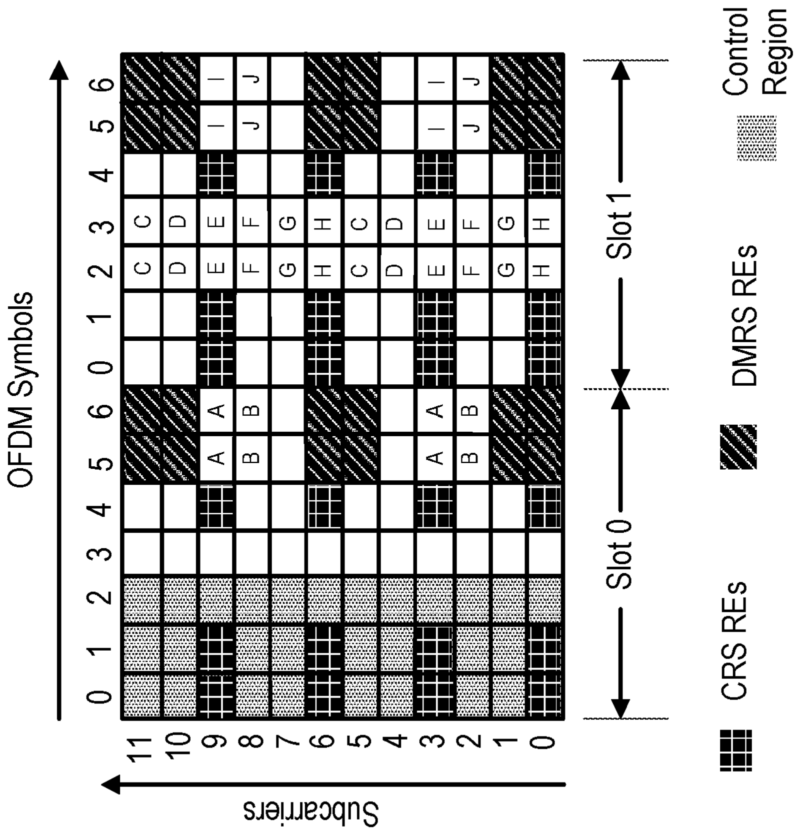
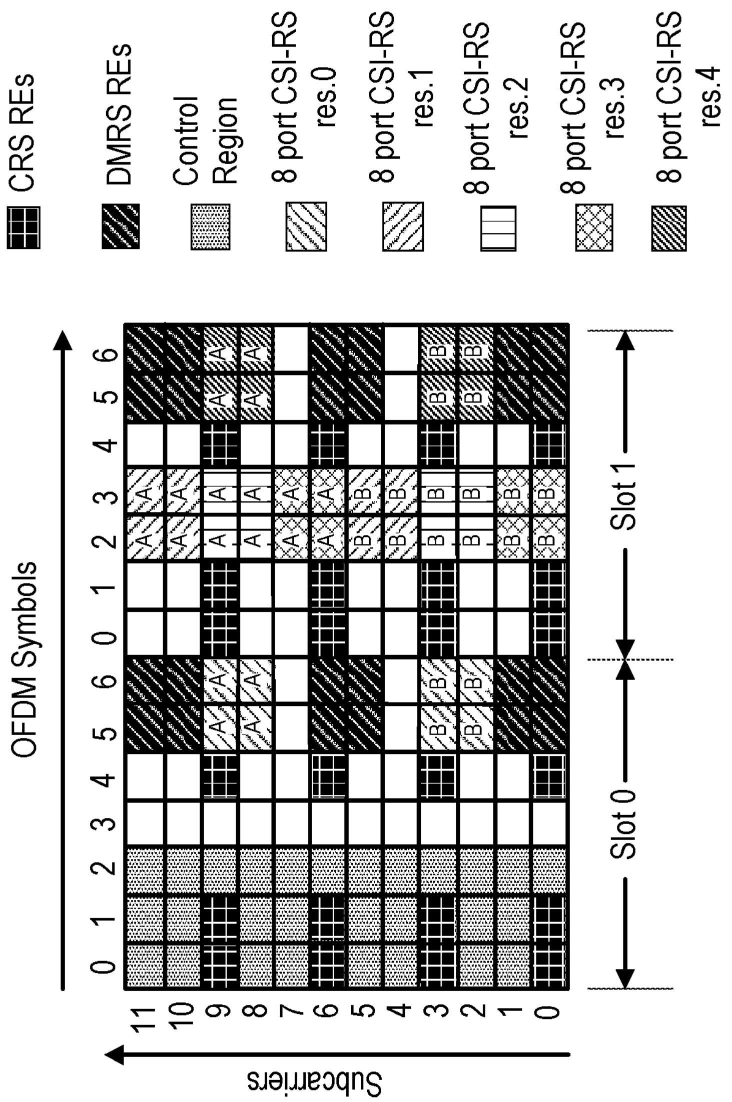

OFDM Symbols
Subcarriers
Slot 0
Slot 1
CRS REs
DMRS REs
Control Region

FIG. 10



CRS REs
DMRS REs
Control Region
8 port CSI-RS res.0
8 port CSI-RS res.1
8 port CSI-RS res.2
8 port CSI-RS res.3
8 port CSI-RS res.4
OFDM Symbols
Subcarriers
Slot 0
Slot 1
A
B

FIG. 11

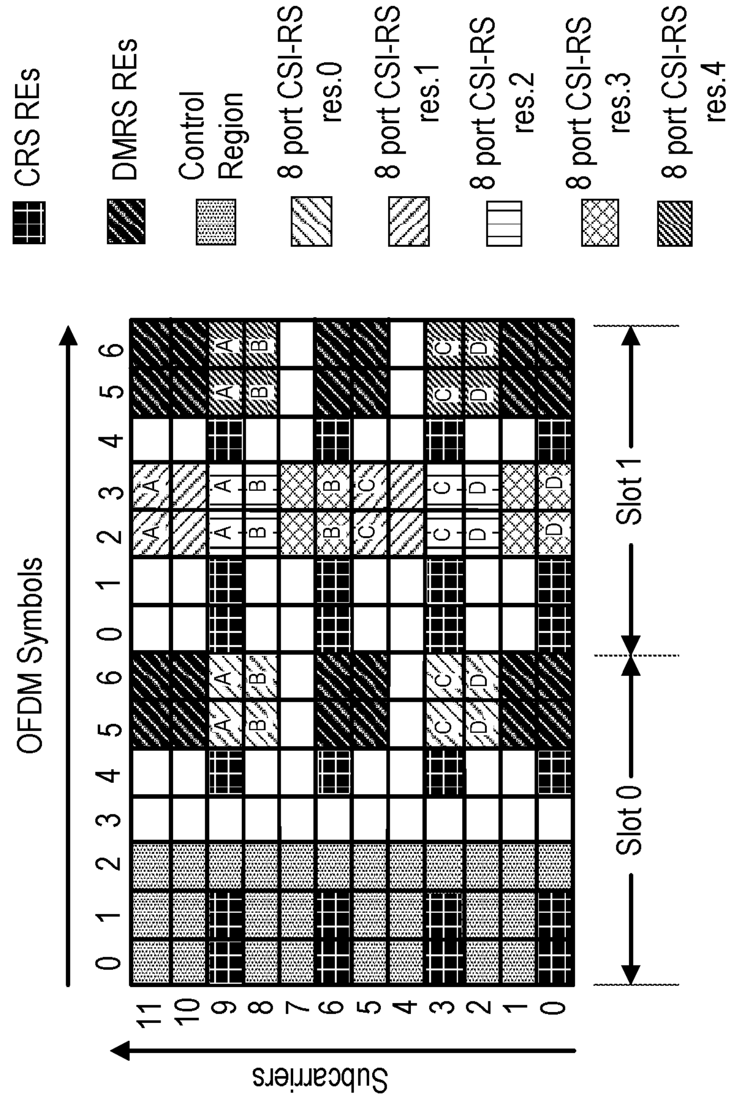

OFDM Symbols
Subcarriers
Slot 0
Slot 1
CRS REs
DMRS REs
Control Region
8 port CSI-RS res.0
8 port CSI-RS res.1
8 port CSI-RS res.2
8 port CSI-RS res.3
8 port CSI-RS res.4

FIG. 12

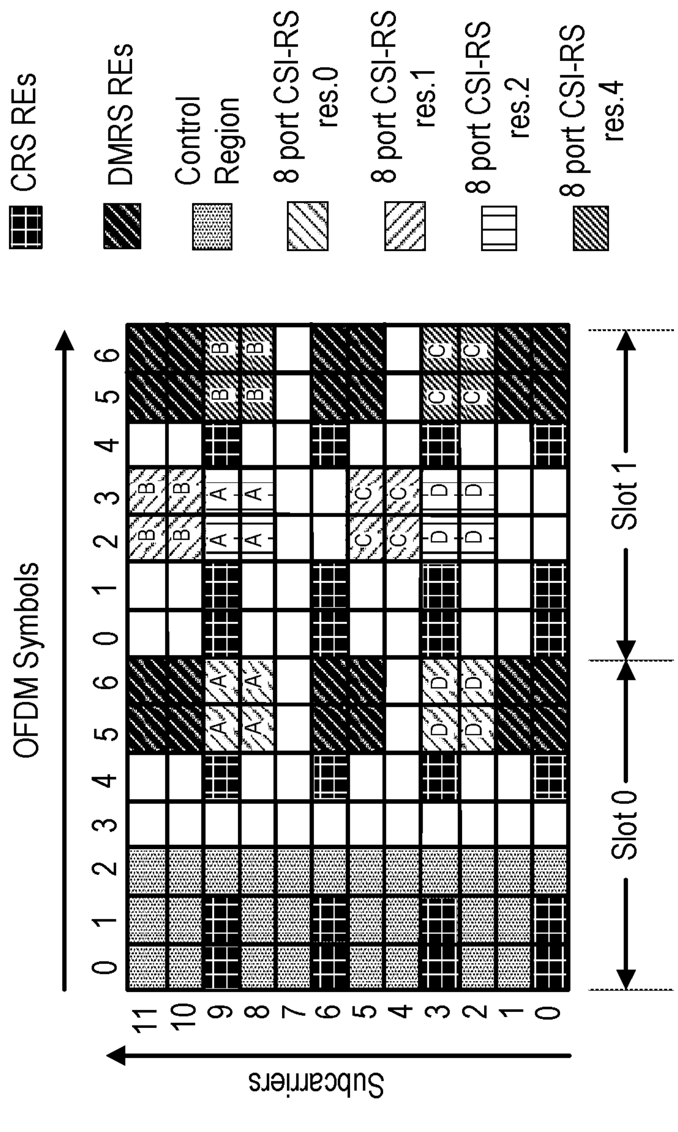

CRS REs
DMRS REs
Control Region
8 port CSI-RS res.0
8 port CSI-RS res.1
8 port CSI-RS res.2
8 port CSI-RS res.4
OFDM Symbols
Subcarriers
Slot 0
Slot 1

FIG. 13

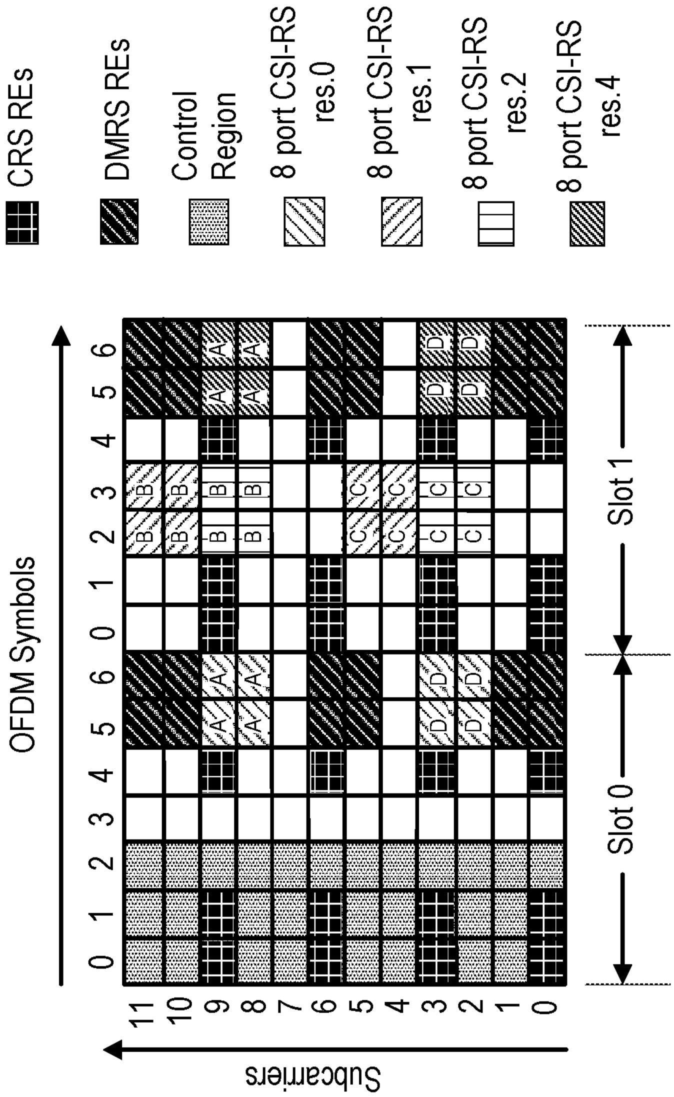

CRS REs
DMRS REs
Control Region
8 port CSI-RS res.0
8 port CSI-RS res.1
8 port CSI-RS res.2
8 port CSI-RS res.4
OFDM Symbols
Subcarriers
Slot 0
Slot 1

FIG. 14

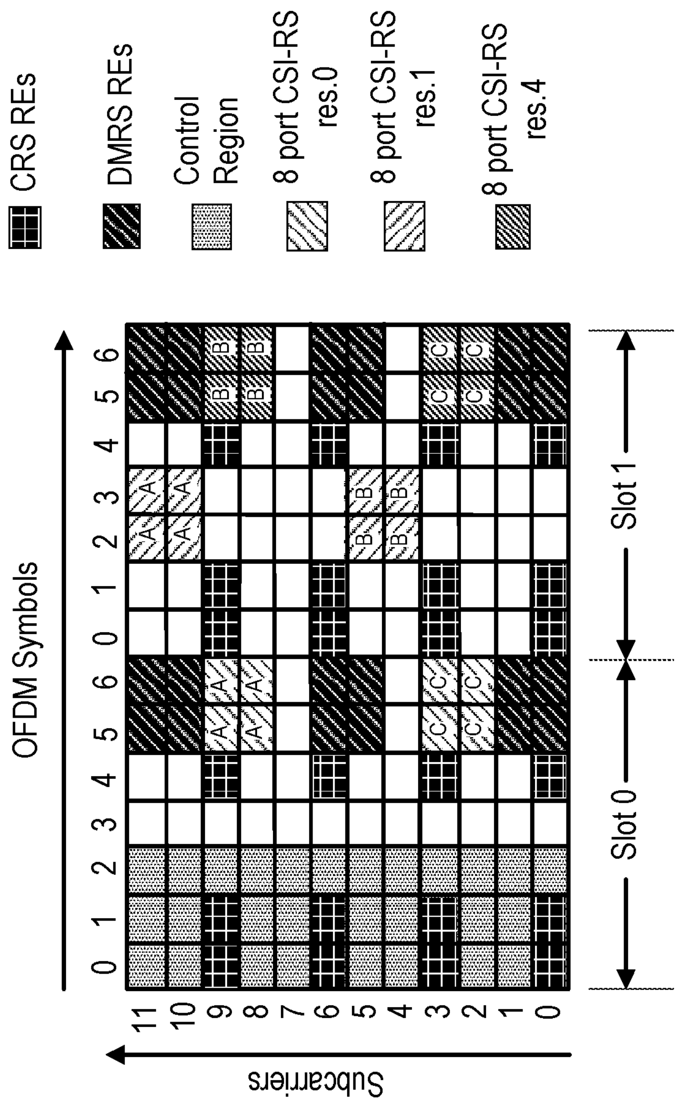

CRS REs
DMRS REs
Control Region
8 port CSI-RS res.0
8 port CSI-RS res.1
8 port CSI-RS res.4
OFDM Symbols
0 1 2 3 4 5 6 0 1 2 3 4 5 6
Subcarriers
11 10 9 8 7 6 5 4 3 2 1 0
A
B
C
Slot 0
Slot 1

FIG. 15

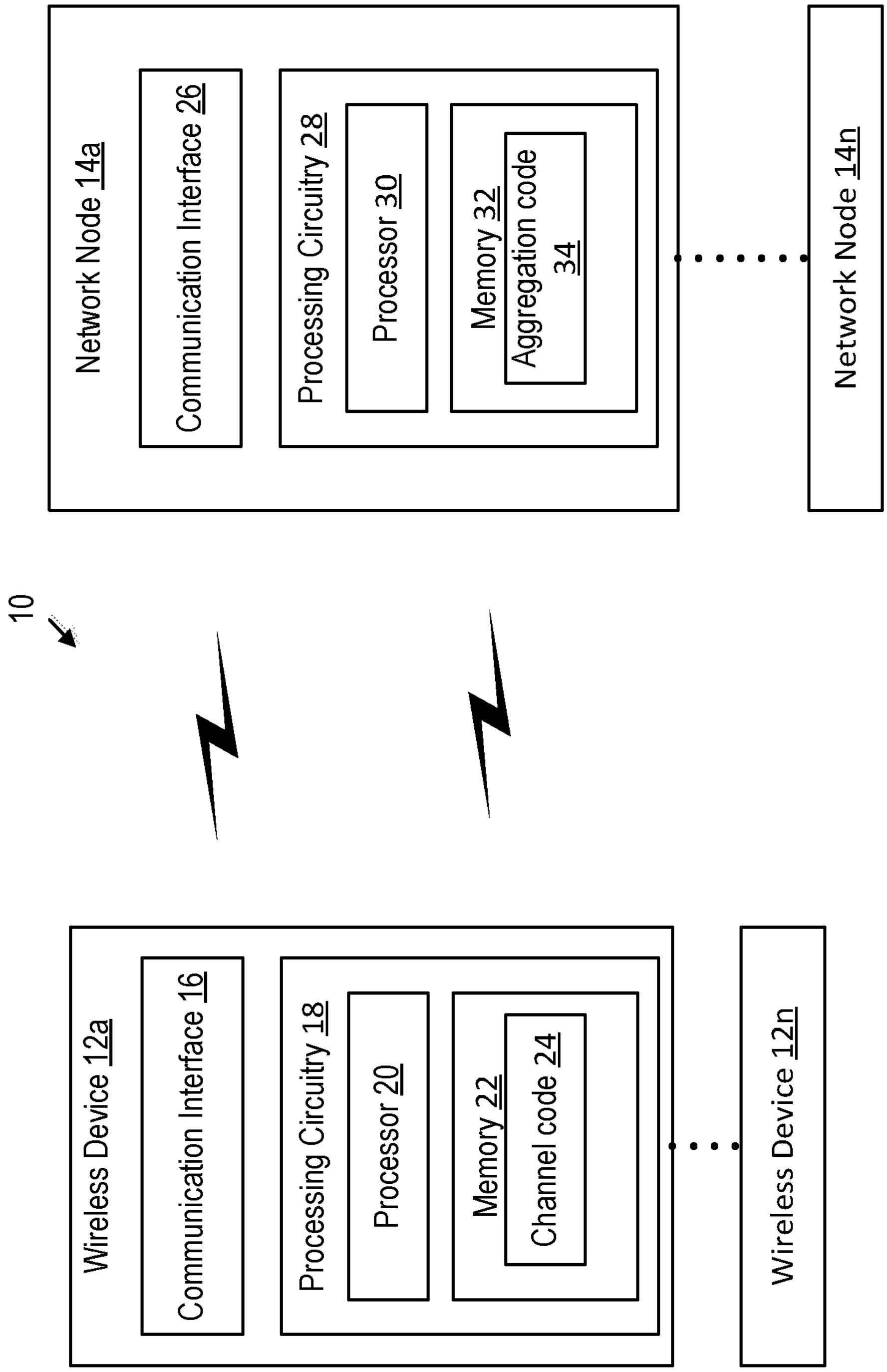

10
Network Node 14a
Communication Interface 26
Processing Circuitry 28
Processor 30
Memory 32
Aggregation code 34
Network Node 14n
Wireless Device 12a
Communication Interface 16
Processing Circuitry 18
Processor 20
Memory 22
Channel code 24
Wireless Device 12n

FIG. 16

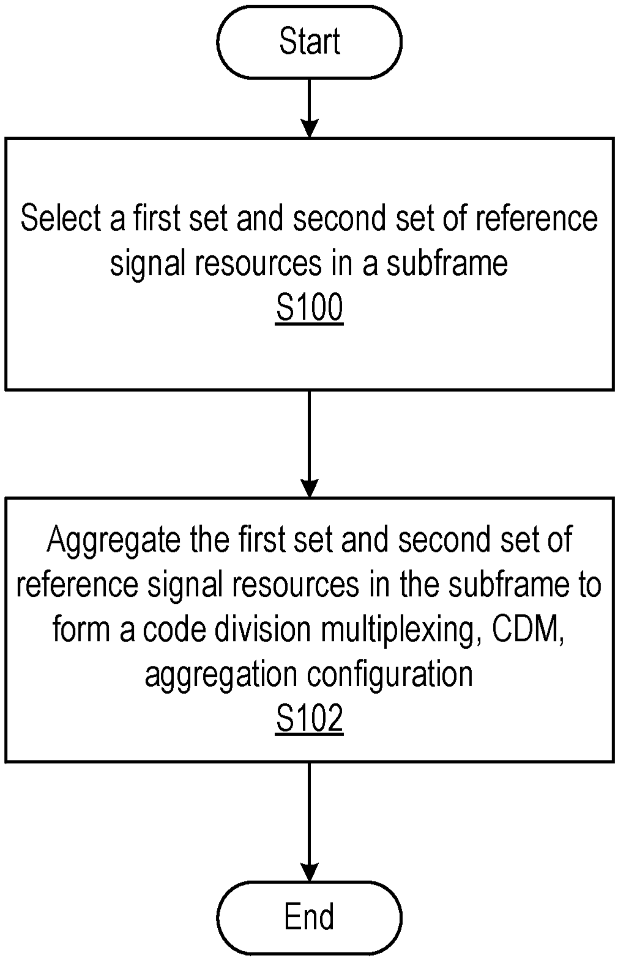

Start
Select a first set and second set of reference signal resources in a subframe
S100
Aggregate the first set and second set of reference signal resources in the subframe to form a code division multiplexing, CDM, aggregation configuration
S102
End

FIG. 17

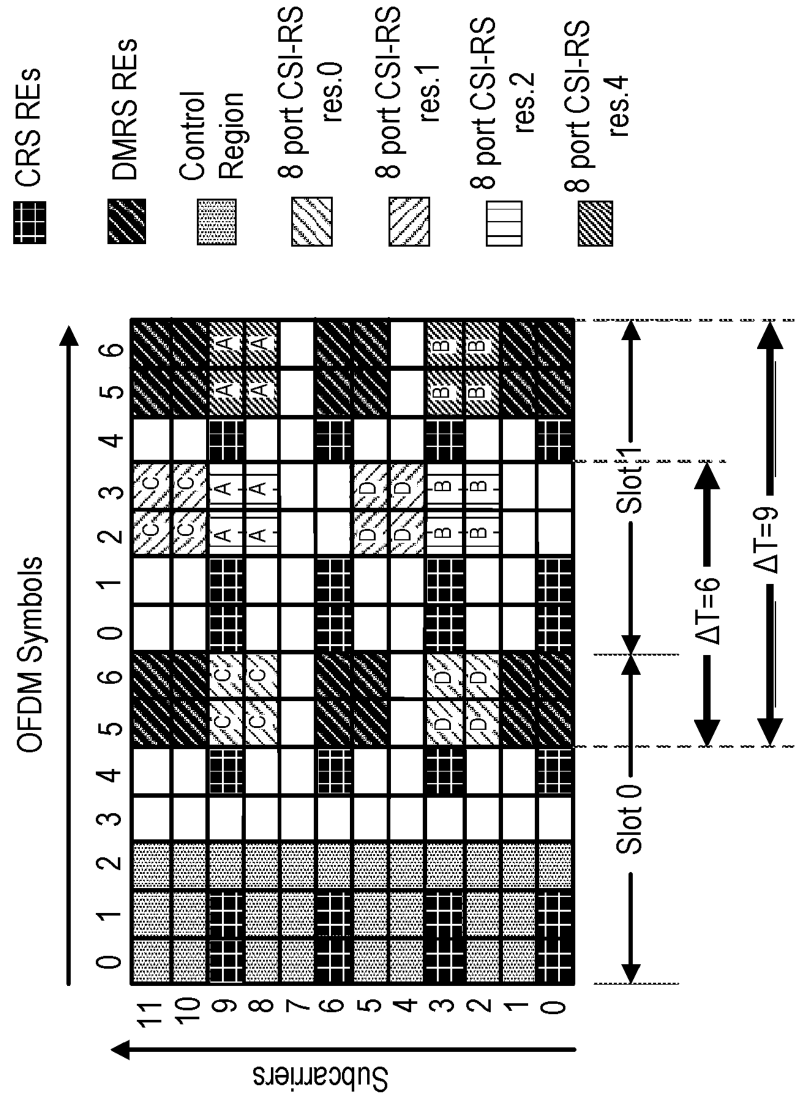
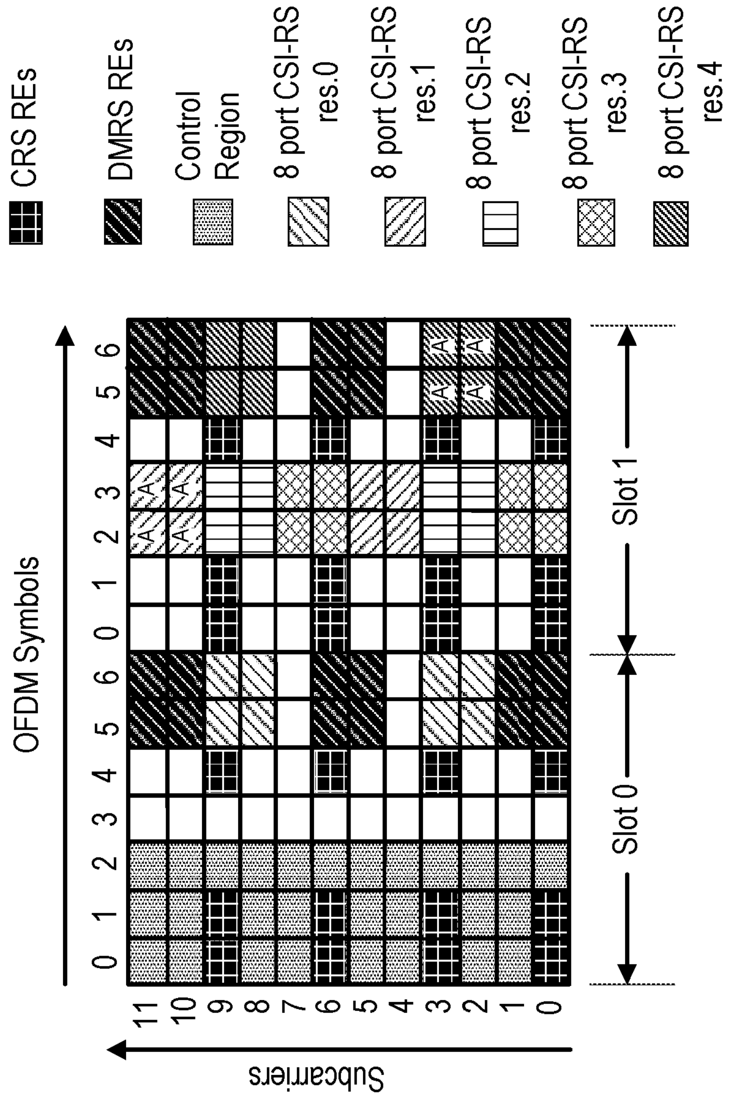

CRS REs
DMRS REs
Control Region
8 port CSI-RS res.0
8 port CSI-RS res.1
8 port CSI-RS res.2
8 port CSI-RS res.4
OFDM Symbols
Subcarriers
0 1 2 3 4 5 6 0 1 2 3 4 5 6
11 10 9 8 7 6 5 4 3 2 1 0
A
B
C
D
Slot 0
Slot 1
ΔT=6
ΔT=9

FIG. 18



CRS REs
DMRS REs
Control Region
8 port CSI-RS res.0
8 port CSI-RS res.1
8 port CSI-RS res.2
8 port CSI-RS res.3
8 port CSI-RS res.4
OFDM Symbols
Subcarriers
Slot 0
Slot 1
A

FIG. 19

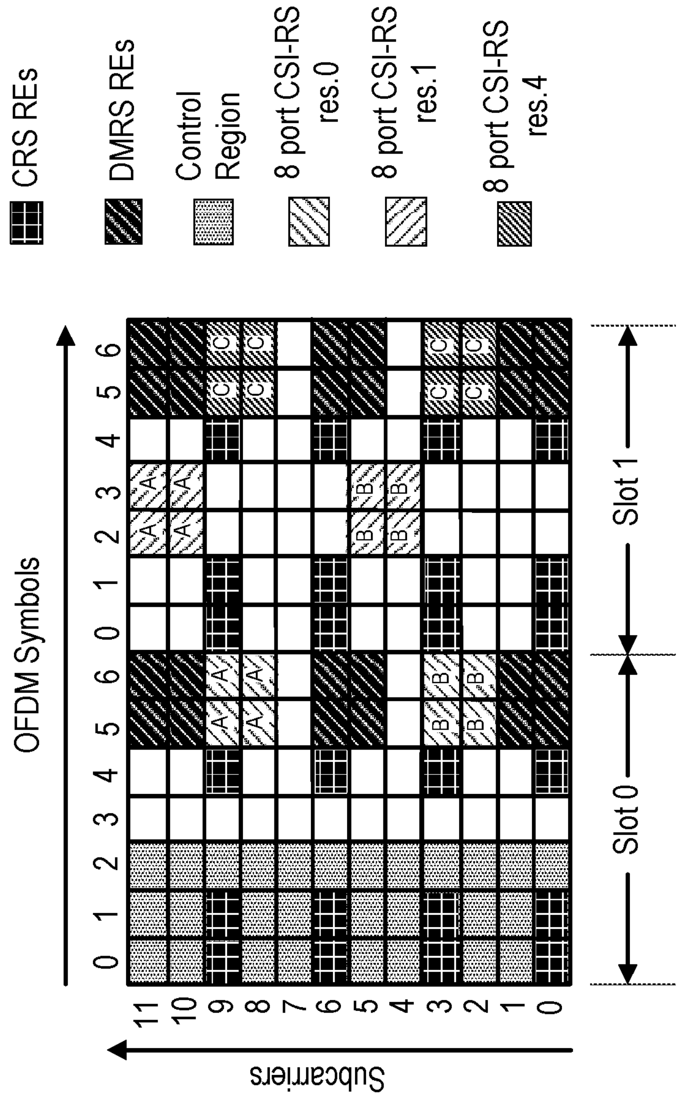

CRS REs
DMRS REs
Control Region
8 port CSI-RS res.0
8 port CSI-RS res.1
8 port CSI-RS res.4
OFDM Symbols
Subcarriers
Slot 0
Slot 1

FIG. 20

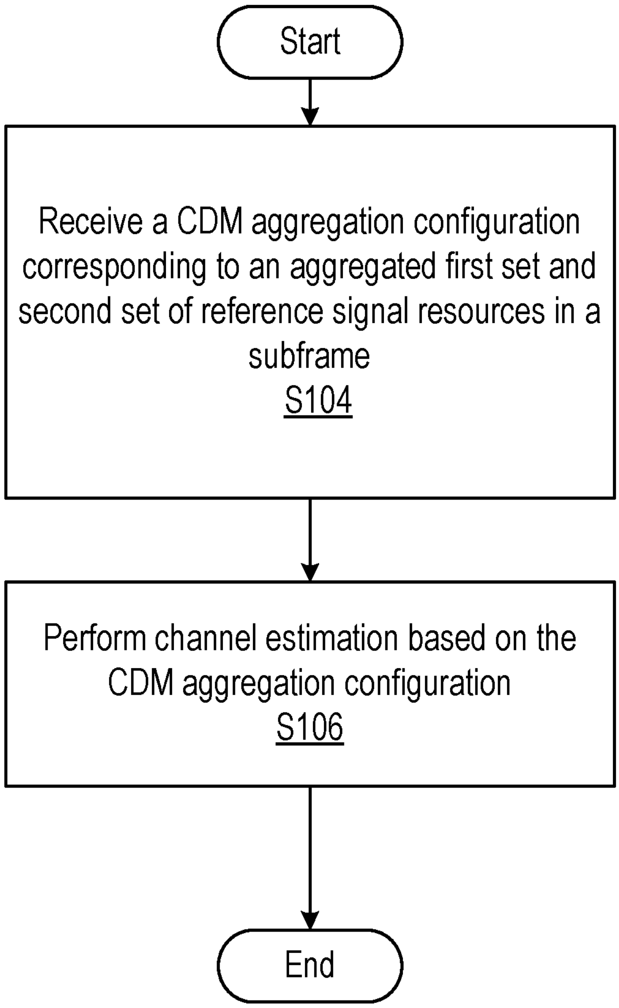

Start
Receive a CDM aggregation configuration corresponding to an aggregated first set and second set of reference signal resources in a subframe
S104
Perform channel estimation based on the CDM aggregation configuration
S106
End

FIG. 21

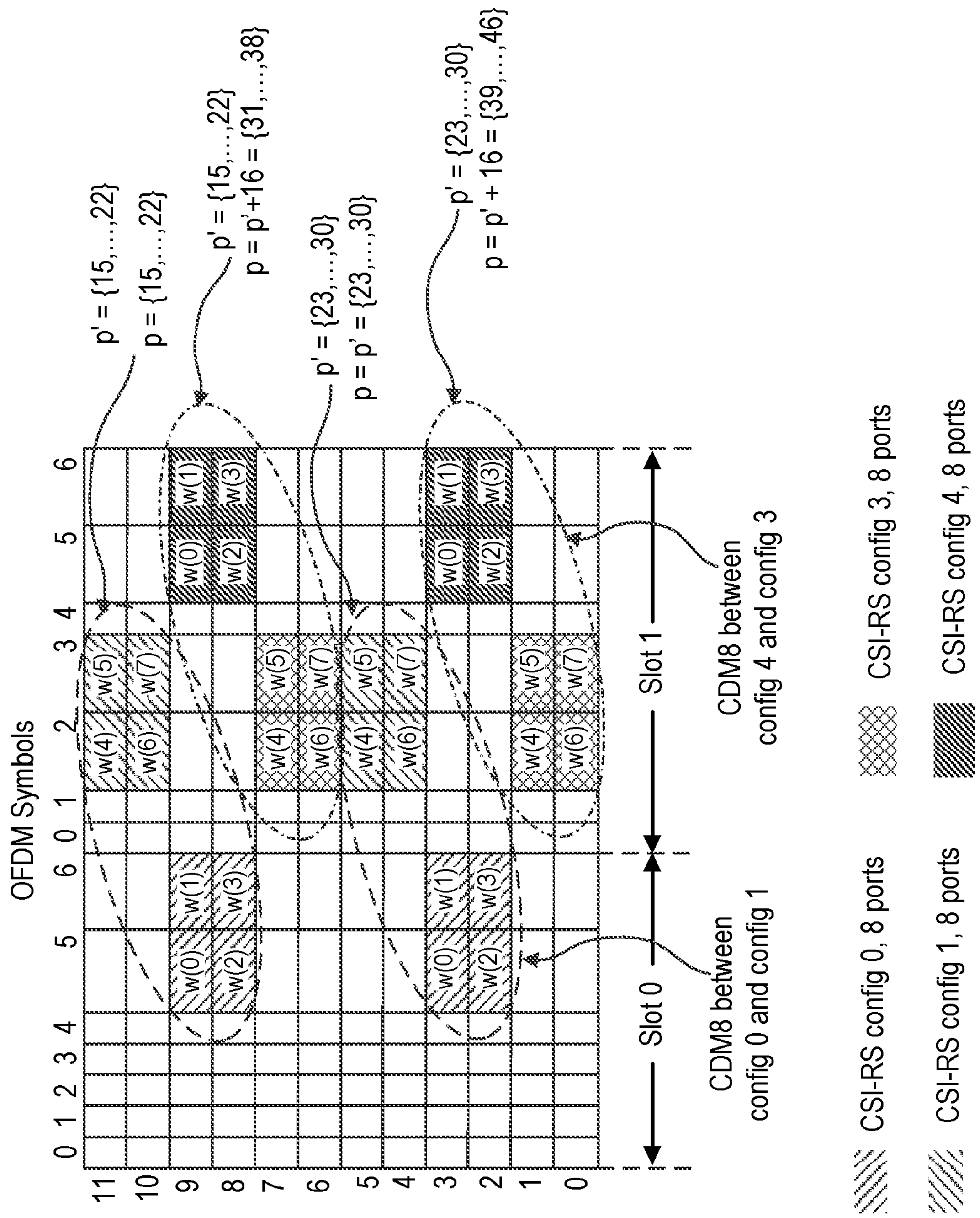

OFDM Symbols
One RB (subcarriers)
0 1 2 3 4 5 6 0 1 2 3 4 5 6
11 10 9 8 7 6 5 4 3 2 1 0
w(0) w(1) w(2) w(3) w(4) w(5) w(6) w(7)
p' = {15,...,22}
p = {15,...,22}
p' = {15,...,22}
p = p'+16 = {31,...,38}
p' = {23,...,30}
p = p' = {23,...,30}
p' = {23,...,30}
p = p' + 16 = {39,...,46}
Slot 0
Slot 1
CDM8 between config 0 and config 1
CDM8 between config 4 and config 3
CSI-RS config 0, 8 ports
CSI-RS config 1, 8 ports
CSI-RS config 3, 8 ports
CSI-RS config 4, 8 ports

FIG. 22

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Non-patent literature cited in the description

- Technical Specification Group Radio Access Network, Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (Release 13); V13.0.1. *3GPP TS 36.213,* January 2016 **[0013]**
- Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (Release 13); V13.0.1. *3GPP TS 36.213,* January 2016 **[0013]**
- *3GPP TS 36.213* **[0014]**
- Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (Release 13); V13.0.0. *3GPP TS 36.211,* December 2015 **[0019]**
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- **ERICSSON.** CSI-RS Design for Class A FD-MIMO. *3GPP draft, R1-157204,* 09 November 2015 **[0032]**
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