CLAIMS

What is claimed is:

1. A method, comprising:

determining a precoding matrix indicator by a user equipment (110), comprising:

determining an intermediate set of vectors from a frequency-domain codebook;

forming a subset of the intermediate set of vectors, wherein there are 2M vectors in the intermediate set of vectors, wherein forming the subset of the intermediate set of vectors further comprises:

selecting the subset of M vectors from the intermediate set of 2M vectors;

mapping the subset of vectors to a combinatorial indicator, wherein mapping the subset of M vectors to the combinatorial indicator comprises:

applying a first map to nonzero indices $n_{3,l}^{(f)}$ of the M vectors inside the intermediate set to obtain first intermediate indices $n_l^{(f)}$ defined between one and 2M-1, wherein applying the first map comprises separating the nonzero indices $n_{3,l}^{(f)}$ of the M vectors inside the intermediate set into first and second groups depending on the initial value of the intermediate set and subtracting a first preconfigured quantity from the indices of the second group, according to the following function:

$$n_l^{(f)} = \begin{cases} n_{3,l}^{(f)} & n_{3,l}^{(f)} \leq M_{initial} + 2M - 1 \\ n_{3,l}^{(f)} - (N_3 - 2M) & n_{3,l}^{(f)} > M_{initial} + N_3 - 1 \end{cases},$$

wherein $n_{3,l}^{(f)}$ are the nonzero indices of the M vectors for layer l, for $f = 1,2,\dots,M-1$, and where the nonzero values of $n_{3,l}^{(f)}$ are selected from a value set $\{1,2,\dots,N_3 - 1\}$ associated to the vectors of the frequency-domain codebook;

applying a second map to the first intermediate indices $n_l^{(f)}$ to obtain second intermediate indices $x_l^{(f)}$ defined between zero and 2M-2,

wherein applying the second map comprises inverting a sign of the first intermediate indices $n_l^{(f)}$ and adding a second preconfigured quantity, according to the following function:

$x_l^{(f)} = 2M - 1 - n_l^{(f)}$,

for first intermediate indices $n_l^{(f)}$ for $f = 1,2, \dots M-1$, second intermediate indices $x_l^{(f)}$ and for layer l;

using the second intermediate indices $x_l^{(f)}$ as an argument in a calculation of combinatorial coefficients $C(x, y)$ to calculate the combinatorial indicator i_l, wherein using the second intermediate indices as an argument in a calculation of combinatorial coefficients to calculate the combinatorial indicator comprises using the second intermediate indices as a first argument of combinatorial coefficients to calculate the combinatorial indicator associated with the vectors of nonzero indices $n_{3,l}^{(f)}$, according to the following function:

$i_l = \sum_{f=1}^{M-1} C\left(x_l^{(f)}, M - f\right)$, wherein $C(x,y) = \begin{cases} \binom{x}{y} & x \geq y \\ 0 & x < y \end{cases}$; and

forming the precoding matrix indicator at least from the combinatorial indicator i_l and an indicator i_{init} of the initial value $M_{initial}$, such that the precoding matrix indicator includes the combinatorial indicator i_l, and the indicator i_{init} of the initial value $M_{initial}$.

2. The method of claim 1, wherein the vectors with nonzero indices $n_{3,l}^{(f)}$ are identified by the indicator i_{init} of the initial value $M_{initial}$ and the combinatorial indicator i_l.

3. The method of any of claims 1 and 2, further comprising sending by the user equipment (110) the precoding matrix indicator toward a RAN node.

4. The method of any one of claims 1 to 3, wherein determining the precoding matrix indicator comprises using reference signals obtained from the RAN node.

5. The method of any one of claims 1 or to 4, wherein the initial value of the intermediate set is common for all reported layers, whereas the combinatorial indicator is specific for each reported layer.

6. The method of any one of the claims above, further comprising receiving by the user equipment and from the RAN node data that has had one or more codebook elements applied to the data based on the sent precoding matrix indicator.

7. The method of claim 1, wherein:
determining the intermediate set of vectors comprises:
selecting the intermediate set of vectors based on an initial value, $M_{initial}$, where $M_{initial}$ is selected from a set of nonpositive values $\{-2M+1, -2M+2, \dots, 0\}$, , wherein the indices of the intermediate set of vectors are defined as $IntS = \{(M_{initial} + i)\ mod\ N_3, i = 0,1, \dots, 2M-1\}$, where N_3 is a size of the frequency-domain codebook of vectors.

8. An apparatus, comprising:

means for determining a precoding matrix indicator by a user equipment, comprising:
determining an intermediate set of vectors from a frequency-domain codebook, wherein the means for determining the intermediate set of vectors comprises:
means for selecting the intermediate set of vectors based on an initial value, $M_{initial}$, wherein $M_{initial}$ is selected from a set of nonpositive values $\{-2M+1, -2M+2, \dots, 0\}$, wherein the indices of the intermediate set of vectors are defined as $IntS = \{(M_{initial} + i)\ mod\ N_3, i = 0,1, \dots, 2M-1\}$, wherein N_3 is a size of the frequency-domain codebook of vectors;
means for forming a subset of the intermediate set of vectors, wherein there are 2M vectors in the intermediate set of vectors, wherein the means for forming the subset of the intermediate set of vectors further comprise:

means for selecting the subset of M vectors from the intermediate set of 2M vectors;

mapping the subset of vectors to a combinatorial indicator, wherein the means for mapping the subset of vectors to the combinatorial indicator comprise:

means for applying a first map to nonzero indices $n_{3,l}^{(f)}$ of the M vectors inside the intermediate set to obtain first intermediate indices $n_l^{(f)}$ defined between one and 2M-1; wherein applying the first map comprises separating the nonzero indices $n_{3,l}^{(f)}$ of the M vectors inside the intermediate set into first and second groups depending on the initial value of the intermediate set and subtracting a first preconfigured quantity from the indices of the second group, according to the following function:

$$n_l^{(f)} = \begin{cases} n_{3,l}^{(f)} & n_{3,l}^{(f)} \leq M_{initial} + 2M - 1 \\ n_{3,l}^{(f)} - (N_3 - 2M) & n_{3,l}^{(f)} > M_{initial} + N_3 - 1 \end{cases},$$

wherein $n_{3,l}^{(f)}$ are the nonzero indices of the M vectors for layer l, for $f = 1,2, \dots, M-1$, and wherein the nonzero values of $n_{3,l}^{(f)}$ are selected from a value set $\{1,2, \dots, N_3 - 1\}$ associated to the vectors of the frequency-domain codebook;

means for applying a second map to the first intermediate indices $n_l^{(f)}$ to obtain second intermediate indices $x_l^{(f)}$ defined between zero and 2M-2, wherein applying the second map comprises inverting a sign of the first intermediate indices $n_l^{(f)}$ and adding a second preconfigured quantity, according to the following function:

$$x_l^{(f)} = 2M - 1 - n_l^{(f)},$$

for first intermediate indices $n_l^{(f)}$ for $f = 1,2, \dots M-1$, second intermediate indices $x_l^{(f)}$ and for layer l;

means for using the second intermediate indices $x_l^{(f)}$ as an argument in a calculation of combinatorial coefficients $C(x, y)$ to calculate the combinatorial indicator i_l, wherein using the second intermediate indices

as an argument in a calculation of combinatorial coefficients to calculate the combinatorial indicator comprises using the second intermediate indices as a first argument of combinatorial coefficients to calculate the combinatorial indicator associated with the vectors of nonzero indices $n_{3,l}^{(f)}$, according to the following function:

$i_l = \sum_{f=1}^{M-1} C\left(x_l^{(f)}, M - f\right)$, wherein $C(x,y) = \begin{cases} \binom{x}{y} & x \geq y \\ 0 & x < y \end{cases}$; and

means for forming the precoding matrix indicator at least from the combinatorial indicator indicator i_l and an indicator i_{init} of the initial value $M_{initial}$, such that the precoding matrix indicator includes the combinatorial indicator i_l, and the indicator i_{init} of the initial value $M_{initial}$.

9. The apparatus of claim 8, wherein

vectors with nonzero indices $n_{3,l}^{(f)}$ are identified by the indicator $i_{init}$of the initial value $M_{initial}$ and the combinatorial indicator i_l.

10. The apparatus of any of claims 8 and 9, further comprising means for sending by the user equipment (110) the precoding matrix indicator toward a RAN node.

11. The apparatus of any of claims 8 to 10, wherein determining the precoding matrix indicator comprises using reference signals obtained from the RAN node.

12. The apparatus of any one of claims 8 to 11, wherein the initial value of the intermediate set is common for all reported layers, whereas the combinatorial indicator is specific for each reported layer.

13. The apparatus of any one of claims 8 to 12, further comprising means for receiving by the user equipment and from the RAN node data that has had one or more codebook elements applied to the data based on the sent precoding matrix indicator.

14. An apparatus, comprising:

means for receiving, at a base station, a precoding matrix indicator from a user equipment, the precoding matrix indicator comprising a combinatorial indicator i_l that maps to a subset of vectors from a frequency-domain codebook; and

means for determining, using at least the received precoding matrix indicator, information from at least the frequency-domain codebook to apply to data for transmission toward the user equipment, wherein the means for determining comprise:

means for obtaining first and second intermediate indices, wherein the second intermediate indices, $x_l^{(f)}$, for $f = 1,2, \ldots M-1$, and for layer l, are obtained by performing an unranking procedure on the combinatorial indicator i_l, and wherein the first intermediate indices, $n_l^{(f)}$, for $f = 1,2, \ldots M-1$, and for layer l, are obtained from their respective second intermediate indices $x_l^{(f)}$ by inverting the following function:

$x_l^{(f)} = 2M - 1 - n_l^{(f)}$, and

means for obtaining nonzero indices of vectors $n_{3,l}^{(f)}$, for $f = 1,2, \ldots M-1$, and for layer l, from their respective first intermediate indices $n_l^{(f)}$ by inverting the following function:

$$n_l^{(f)} = \begin{cases} n_{3,l}^{(f)} & n_{3,l}^{(f)} \leq M_{initial} + 2M - 1 \\ n_{3,l}^{(f)} - (N_3 - 2M) & n_{3,l}^{(f)} > M_{initial} + N_3 - 1 \end{cases},$$

wherein $n_{3,l}^{(f)}$ are associated to the vectors of the frequency-domain codebook, wherein the precoding matrix indicator comprises an indicator i_{init} of an initial value $M_{initial}$, and wherein $M_{initial}$ is obtained from the indicator i_{init} of the initial value $M_{initial}$..

15. The apparatus of claim 14, wherein the means for determining comprises means for obtaining at least from the vectors of the frequency-domain codebook corresponding to

nonzero indices $n_{3,l}^{(f)}$, for $f = 1,2, \ldots M-1$, and for layer l, precoding weights to apply to the data for transmission towards the user equipment.

16. The apparatus of any one of claims 14 and 15, wherein the apparatus further comprises means for: transmitting by the base station the data, having the information from at least the frequency-domain codebook applied, toward the user equipment.

17. A computer program product comprising a computer-readable storage medium bearing computer program code embodied therein for use with a computer, the computer program code comprising:

code for determining a precoding matrix indicator by a user equipment, comprising:

determining an intermediate set of vectors from a frequency-domain codebook, wherein determining the intermediate set of vectors comprises:

selecting the intermediate set of vectors based on an initial value, $M_{initial}$,

wherein $M_{initial}$ is selected from a set of nonpositive values $\{-2M+1, -2M+2, \ldots, 0\}$, wherein there are 2M vectors in the intermediate set of vectors, wherein the indices of the intermediate set of vectors are defined as $IntS = \{(M_{initial} + i) \; mod \; N_3, i = 0,1, \ldots, 2M-1\}$, wherein N_3 is a size of the frequency-domain codebook of vectors;

forming a subset of the intermediate set of vectors, wherein there are 2M vectors in the intermediate set of vectors, wherein forming the subset of the intermediate set of vectors further comprises:

selecting the subset of M vectors from the intermediate set of 2M vectors;

mapping the subset of vectors to a combinatorial indicator, wherein mapping the subset of M vectors to the combinatorial indicator comprises:

applying a first map to nonzero indices $n_{3,l}^{(f)}$ of the M vectors inside the intermediate set to obtain first intermediate indices $n_l^{(f)}$ defined between one and 2M-1, wherein applying the first map comprises separating the nonzero indices $n_{3,l}^{(f)}$ of the M vectors inside the intermediate set into first and second groups depending on the initial value

of the intermediate set and subtracting a first preconfigured quantity from the indices of the second group, according to the following function:

$$n_l^{(f)} = \begin{cases} n_{3,l}^{(f)} & n_{3,l}^{(f)} \leq M_{initial} + 2M - 1 \\ n_{3,l}^{(f)} - (N_3 - 2M) & n_{3,l}^{(f)} > M_{initial} + N_3 - 1 \end{cases},$$

wherein $n_{3,l}^{(f)}$ are the nonzero indices of the M vectors for layer l, for $f = 1,2, \ldots, M-1$, and where the nonzero values of $n_{3,l}^{(f)}$ are selected from a value set $\{1,2, \ldots, N_3 - 1\}$ associated to the vectors of the frequency-domain codebook;

applying a second map to the first intermediate indices $n_l^{(f)}$ to obtain second intermediate indices $x_l^{(f)}$ defined between zero and 2M-2, wherein applying the second map comprises inverting a sign of the first intermediate indices $n_l^{(f)}$ and adding a second preconfigured quantity, according to the following function:

$x_l^{(f)} = 2M - 1 - n_l^{(f)}$,

for first intermediate indices $n_l^{(f)}$ for $f = 1,2, \ldots M-1$, second intermediate indices $x_l^{(f)}$ and for layer l;

using the second intermediate indices $x_l^{(f)}$ as an argument in a calculation of combinatorial coefficients $C(x, y)$ to calculate the combinatorial indicator i_l, wherein using the second intermediate indices as an argument in a calculation of combinatorial coefficients to calculate the combinatorial indicator comprises using the second intermediate indices as a first argument of combinatorial coefficients to calculate the combinatorial indicator associated with the vectors of nonzero indices $n_{3,l}^{(f)}$, according to the following function:

$i_l = \sum_{f=1}^{M-1} C\left(x_l^{(f)}, M - f\right)$, wherein $C(x, y) = \begin{cases} \binom{x}{y} & x \geq y \\ 0 & x < y \end{cases}$; and

forming the precoding matrix indicator at least from the combinatorial indicator i_l and an indicator i_{init} of the initial value $M_{initial}$, such that the precoding

matrix indicator includes the combinatorial indicator i_l, and the indicator i_{init} of the initial value $M_{initial}$

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