subset restriction would be signaled with a conventional bitmap, $N = N_H \cdot N_V = 64$ bits would be used.

"Similar rows embodiment"

In one embodiment, by using compressing of the CSR signalling, a scheme is designed taking into consideration the hypothesis that precoders (k, l) with adjacent l-indices (i.e. $(k, l_0 - 1), (k, l_0)$ and $(k, l_0 + 1)$) are likely to have the same restriction setting, meaning that if (k, l_0) is restricted, $(k, l_0 + 1)$ is likely to be restricted as well and vice versa. The scheme works as follows:

First, a bitmap of N_H bits are sent, indicating the codebook subset restriction for the "row" of precoders where $l = 0$ (c.f. Figure 4), i.e the precoders $(k, l) = (0,0), (1,0), \ldots, (N_H - 1,0)$.

Then, the codebook subset restriction for the second "row" of precoders, where $l = 1$ is sent. If the restriction is the same as for the previous row of precoders, a '1' is sent. If the restriction for this row differs from the restriction of the previous row, a '0' is sent, followed by a bitmap indicating the restriction for this row.

The previous step is then repeated for each of the N_V "rows" of precoders.

This embodiment is illustrated with an example, considering the codebook subset restriction setting illustrated in Figure 4, i.e. the restriction of precoders with indices $(k, l) = (0,4), (3,5), (4,5), (7,4)$ should be signaled.

For $l = 0$:

No precoders with l-index 0 should be restricted, therefore the bitmap '00000000' is sent.

For $l = 1$:

The restriction of this row is identical to the restriction of the previous row, the bit '1' is sent.

For $l = 2$:

The restriction of this row is identical to the restriction of the previous row, the bit '1' is sent.

For $l = 3$:

The restriction of this row is identical to the restriction of the previous row, the bit '1' is sent.

For $l = 4$:

The restriction of this row is not identical to the restriction of the previous row, therefore the bit '0' is sent. The bitmap indicating the restriction for this row should now be sent. Precoders $(0,4)$ and $(7,4)$ should be restricted. Therefore, the bitmap '10000001' is sent.

For $l = 5$:

The restriction of this row is not identical to the restriction of the previous row, therefore the bit '0' is sent. The bitmap indicating the restriction for this row should now be sent. Precoders $(3,5)$ and $(4,5)$ should be restricted. Therefore, the bitmap '00011000' is sent.

For $l = 6$:

The restriction of this row is not identical to the restriction of the previous row, therefore the bit '0' is sent. The bitmap indicating the restriction for this row should now be sent. No precoder should be restricted. Therefore, the bitmap '00000000' is sent.

For $l = 7$:

The restriction of this row is identical to the restriction of the previous row, the bit '1' is sent.

The string of bits to be signaled is thus '0000000001110100000010000110000000000001', consisting of 39 bits. Generally, the number of bits required with this scheme is

$$N_{bits} = M \cdot N_H + N_V - 1$$

Where M is the number of times the rows change and a bitmap for a row has to be transmitted, $M = 4$ in the example. Analyzing the above expression, we note that $1 \leq M \leq N_V$. This means that for some of the $2^N = 2^{N_H \cdot N_V}$ possible codebook subset restrictions, the number of bits required to signal the codebook subset restriction with this scheme is smaller than N, while for others, such as when $M = N_V$, the number of bits required is larger than N.

It should be noted that this is a small example for the sake of illustrating the embodiment. If a larger codebook is used, say $N_H = N_V = 30$, and $M = 4$ the number of bits required with this scheme would be $N_{bits} = M \cdot N_H + N_V - 1 = 149$ compared to $N = N_H \cdot N_V = 900$ in the case of just transmitting the entire bitmap; this is hence a substantial reduction in the number of required bits.

Finally, it is pointed out that all possible codebook subset restriction configurations can be represented by this encoding/decoding scheme, thereby providing full flexibility.

"Similar columns" embodiment

In another embodiment, the scheme discussed in the previous embodiment is modified by instead taking into consideration the hypothesis that precoders (k, l) with adjacent k-indices (i.e. $(k_0 - 1, l), (k_0, l)$ and $(k_0 + 1, l)$) are likely to have the same restriction setting, meaning that if (k_0, l) is restricted, $(k_0 + 1, l)$ is likely to be restricted as well and vice versa. The construction of the string of bits to be signaled would then work similarly as in the previously discussed embodiment, except that the precoders "columns" k will be used instead.

In another embodiment an extra initial bit is inserted where '1' indicates that encoding is done under the assumption that precoders (k, l) with adjacent l-indices (i.e. $(k, l_0 - 1), (k, l_0)$ and $(k, l_0 + 1)$) are likely to have the same restriction, hence the encoding is done row wise, whereas a '0' indicates that precoders (k, l) with adjacent k-indices (i.e. $(k_0 -$

$1, l)$, (k_0, l) and $(k_0 + 1, l)$) are likely to have the same restriction setting, hence encoding is done column wise.

In another embodiment an initial bit is inserted where '1' indicates that no precoders are restricted, a '0' indicates that some precoders are restricted and the '0' is followed by a number of bits representing the codebook subset restriction.

Accordingly, different "compression" techniques (whether based on similar rows, columns, or otherwise) may be adopted for different groups of precoders in the same codebook, where the particular technique is indicated to the device so that the device can decode the signaling. Alternatively, the same "compression" technique may be adopted for each of the groups of precoders, but the network evaluates different possible techniques to identify the one that provides the best compression and then adopts that approach (and indicates it to the device).

Of course, the embodiments shown in Figure 2, and variations thereof, may be used for signaling a restricted subset of precoders in any given codebook, whether Kronecker structured or not. Moreover, the signaling may be rank-specific, meaning that different signaling restricts different rank-specific codebooks.

According to other embodiments shown in Figure 5, a method is implemented in a network node 10 (e.g., a base station) for signaling to a wireless communication device 14 which precoders in a codebook are restricted from being used (e.g., which Kronecker product precoders are restricted). As shown, the method includes generating codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group, e.g., with a single signaling bit (Block 210). In at least some embodiments, this signaling (i) is rank-agnostic so as to restrict precoders irrespective of their transmission rank; and/or (ii) jointly restricts a group of precoders by restricting a certain component that those precoders (i.e., the precoders in the group) have in common. Regardless, the method then includes sending the generated signaling to the wireless communication device 14 (Block 220).

Consider embodiments that jointly restrict a group of precoders by restricting a certain component that those precoders (i.e., the precoders in the group) have in common. Precoders have a certain component in common if the precoders are derived from or are otherwise a function of that same component. In one embodiment, for example, a group of precoders $W(b)$ that have a certain component b in common are jointly restricted by restricting that component b. Restriction of this component b may be signaled for instance in terms of one or more indices for the component (e.g., m where the component is indexed as b_m or (k, l) where the component is indexed as $b_{k,l}$, with m, k, and l being indices for a Kronecker-structured codebook as described above).

Note that embodiments herein contemplate a precoder having one or more different "components" at any level of granularity (e.g., component(s) at a high level of precoder

factorability and/or component(s) at a lower level of precoder factorability). For example, a precoder may comprise one or more different components b at one level of granularity. At a finer level of granularity, though, each of these components b may in turn be derived from or otherwise be a function of multiple sub-components x_H and x_V such that $b(x_H,x_V)$. In this case, a group of precoders $W(x_H,x_V)$ that have a certain component x_H or x_V in common may be jointly restricted by restricting that component x_H or x_V. Restriction of this component x_H or x_V may be signaled for instance in terms of an index for the component (e.g., k or l where the component x_H is indexed as x_H^k and the component x_V is indexed as x_V^l, with x_H and x_V being horizontal and vertical beamforming vectors, respectively, and with k and l being indices for a Kronecker-structured codebook as described above).

In some embodiments, a precoder at one level of granularity consists of one or more different components that are referred to as one or more so-called "beam precoders". Each precoder W in this regard consists of one or more beamforming vectors $b_0, b_1, \ldots, b_X$ that are referred to as beam precoders. One or more embodiments herein jointly restrict a group of precoders W that have a certain beam precoder in common, by restricting that beam precoder With restriction of precoders W as a whole founded on restriction of one or more of their constituting beam precoders, these embodiments advantageously generate the CSR signaling in terms of beam-specific restrictions (i.e., restrictions of certain beam precoders), rather than in terms of precoder-specific restrictions (i.e., restrictions on precoders W as a whole). In some embodiments, the device 14 shall assume that a precoder W is restricted if one or more of its beam precoders are restricted. In other embodiments, each beam precoder must be restricted for the device 14 to assume that the total precoder W is restricted.

In one embodiment, a beam precoder is the beamforming vector used to transmit on a particular layer, where different scaled versions of that beamforming vector are transmitted on different polarizations. Different layers are transmitted on different beam precoders. A precoder W in this case can be expressed as:

$$W = \alpha \cdot \begin{bmatrix} b_0 & b_1 & \cdots & b_{L-1} \\ \varphi_0 b_0 & \varphi_1 b_1 & \cdots & \varphi_{L-1} b_{L-1} \end{bmatrix}$$

Here, W is a $N \times L$ precoder matrix, where N is the number of transmit antenna ports, L the transmission rank (i.e. the number of transmitted spatial streams), $b_0, b_1, \ldots, b_{L-1}$ are $\frac{N}{2} \times 1$ beamforming vectors (denoted beam precoders), $\varphi_0, \varphi_1, \ldots, \varphi_{L-1}$ and α are arbitrary complex numbers. Another precoder W of the same codebook as W above can be expressed as:

$$W = \alpha \cdot \begin{bmatrix} b_1 & b_2 & \cdots & b_L \\ \varphi_1 b_1 & \varphi_2 b_2 & \cdots & \varphi_L b_L \end{bmatrix}.$$

For example, by signaling b_0, only the former precoder is restricted and by signaling b_1 both precoders will be restricted.

In some embodiments, the first $\frac{N}{2}$ antenna ports are mapped to antennas with one polarization while the latter $\frac{N}{2}$ antenna ports are mapped to antennas with the same positions as the first antennas, but with an orthogonal polarization. In such embodiments, for each column of W (i.e. the precoder for each spatial layer), a beam precoder b is transmitted on one polarization and a scaled version of the same beam precoder φb is transmitted on a second polarization. Such scaling may impact the phase, amplitude, or both the phase and amplitude of the beam precoder.

In another embodiment, a beam precoder is the beamforming vector used to transmit on multiple different layers, where the layers are sent on orthogonal polarizations. In this case, a precoder W can be expressed as:

$$W = \alpha \cdot \begin{bmatrix} b_0 & b_0 & \cdots & b_0 \\ \varphi_0 b_0 & \varphi_1 b_0 & \cdots & \varphi_{L-1} b_0 \end{bmatrix}$$

Accordingly, it should be noted that the beam precoders for each spatial layer $b_0, b_1, \ldots, b_{L-1}$ may be different beam precoders, or, some subsets of the beam precoders may be identical, for example b_0 may be equal to b_1.

In yet another embodiment, a beam precoder is the beamforming vector used to transmit on a particular layer and on a particular polarization. That is, a beam precoder may be defined in a slightly different way than the definition above. The definition of a beam precoder may for example allow different beam precoders to be transmitted on the different polarizations of the same layer, such as

$$W = \alpha \cdot \begin{bmatrix} b_0 & b_2 & \cdots & b_{2L-2} \\ \varphi_0 b_1 & \varphi_1 b_3 & \cdots & \varphi_{L-1} b_{2L-1} \end{bmatrix}.$$

In still another embodiment, the beam precoders may be defined by disregarding the polarization as

$$W = \alpha \cdot [b_0 \quad b_1 \quad \ldots \quad b_{L-1}].$$

Note that the beam precoders $b_0, b_1, \ldots, b_{L-1}$ may be chosen explicitly from a set of beam precoders (a codebook) or they may be implicitly chosen when selecting the (total) precoder W from a codebook $\boldsymbol{X}$. It should be noted that the selection of the (total) precoder W may be made with one or several PMIs. In the case where selection of the total precoder W is made with several PMIs, the resulting beam precoders for each layer may be a function of only a subset of the PMIs or they may be a function of all PMIs.

Irrespective of the particular way a beam precoder is defined, though, one or more embodiments herein jointly restrict a group of precoders W that have a certain beam precoder in common, by restricting that beam precoder. That is, in some embodiments, codebook subset restriction (CSR) may be signalled based on the set of possible beam precoders b, instead of CSR signalled on the set of possible (total) precoders W. In some such embodiments, the device 14 shall assume that a precoder W is restricted if one or more of the beam precoders

$b_0, b_1, \ldots, b_{L-1}$ of each layer are restricted. In other such embodiments, each layers' beam precoder must be restricted for the device 14 to assume that the total precoder W is restricted

Consider a specific example for an 8TX codebook with transmission rank 2. In some embodiments, this codebook is defined as shown in Figure 6. Defined in this way, each precoder W is formed in part from a beam precoder v_m (note the notation shift from $b_0, b_1, \ldots, b_{L-1}$ to v_m). The beam precoder index m is the same for some precoders W, including for instance precoders whose subcodebook index i_2 is equal to 0, 1, 8, 9, 12 or 13 (since for those precoders $m = 2i_1$). This means that those precoders W have the same beam precoder v_m in common. Accordingly, some embodiments herein jointly restrict a group of precoders W that have a particular beam precoder v_m in common, by restricting that beam precoder v_m, e.g., with a single bit. Restriction of this beam precoder v_m may be signaled for instance in terms of index m (e.g., beam precoders indexed with a particular value of m are restricted). Signaling in this case may constitute a bitmap, with different bits in the bitmap respectively dedicated to indicating whether or not different beam precoders are restricted from being used. For example, signaling may constitute a bitmap of m values, with different bits in the bitmap respectively dedicated to indicating whether or not beam precoders indexed with different of m values are restricted from use.

In alternative embodiments not shown in Figure 6, the beam precoder v_m is replaced by beam precoder $v_{k,l}$, which is a Kronecker product of a vertical beamforming vector x_V with index k and a horizontal beamforming vector x_H with index l. For example, as noted above, these beamforming vectors may comprise DFT vectors. Regardless, restriction of beam precoder $v_{k,l}$ may be signaled in terms of the index pair (k, l). Signaling in this case may constitute a bitmap of (k, l) value pairs, with different bits in the bitmap respectively dedicated to indicating whether or not beam precoders indexed with different (k, l) value pairs are restricted from use.

Instead of such a bitmap, restriction of one or more beam precoders $v_{k,l}$ in some embodiments is jointly signaled in terms of a "rectangle" defined by two (k, l) value pairs: namely, (k_0, l_0) and (k_1, l_1). In this case, beam precoders $v_{k,l}$ with indides $k_0 < k < k_1$ and $l_0 < l < l_1$ are restricted.

As yet another alternative, restriction of one or more beam precoders $v_{k,l}$ in some embodiments is signaled in terms of a bitmap of k values and/or a bitmap of l values. If signaled as only a bitmap of k values, the device in some embodiments assumes that any beam precoders $v_{k,l}$ with certain k values are restricted, irrespective of those precoders' l values. If signaled as only a bitmap of l values, the device in some embodiments assumes that any beam precoders $v_{k,l}$ with certain l values are restricted, irrespective of those precoders' k values. If signaled as both a bitmap of k values and a bitmap of l values, the device in some embodiments assumes that only beam precoders $v_{k,l}$ with certain (k, l) value pairs as collectively defined by those bitmaps are restricted.

That said, restrictions specified in term of k and/or l values may in some sense be deemed as restrictions at a finer level of granularity than even the beam precoders themselves. Indeed, as noted above, each beam precoder $v_{k,l}$, is in some embodiments a Kronecker product of a vertical beamforming vector x_V with index k and a horizontal beamforming vector x_H with index l. Accordingly, signaling the restriction as k and/or l values effectively amounts to restricting (sub)components x_H or x_V.

Consider an example of these finer-granularity embodiments where codebook subset restriction is to be applied to beam precoders with l values of 3 or 4. If this configuration of codebook subset restriction would be signaled with a conventional bitmap, $N = N_H \cdot N_V = 64$ bits would be used. By contrast, the scheme in these finer-granularity embodiments consider restriction of entire precoder "rows", i.e all precoders that are formed from beam precoders with the same l-index is either turned on or off. To signal the codebook subset restriction in this example, therefore, the bitmap '00011000' of l values, consisting of $N_V = 8$ bits, may be sent. With this scheme, a large reduction of the number of bits required to signal the codebook subset restriction is seen. However, not all of the 2^N possible codebook subset restrictions may be signaled.

In a similar embodiment, the restriction is applied on the precoder "columns" k and the codebook subset restriction is signaled with a N_H bit long bitmap, indicating restrictions of entire precoder "columns".

In another embodiment an extra initial bit is inserted where '1' indicates that encoding is done as above "row wise", whereas a '0' indicates is done "column wise".

In yet another embodiment, the device 14 shall assume that a precoder W is restricted if both the vertical and the horizontal precoder in the Kronecker structure are restricted. If only one of the vertical and horizontal precoders are restricted, then the device 14 shall not assume that the resulting precoder after Kronecker operation is restricted.

Thus, one or more embodiments herein advantageously exploit a codebook's Kronecker structure to generate the signaling of Figure 5 in terms of indices k, l, and/or m. In some embodiments, for example, the signaling is generated to jointly restrict, e.g., with a single bit, a group of precoders that either (i) have the same value of index k; (ii) have the same value of index l; or (iii) have the same pair of values for indices (k, l).

In some embodiments, signaling that jointly restricts a group of precoders by restricting a certain component (e.g., beam precoder) that those precoders have in common is rank-agnostic. That is, the signaling jointly restricts the group of precoders regardless of the precoders' transmission rank (i.e., regardless of which rank-specific codebook they belong to). For example, embodiments that restrict a single beam precoder b_0 can be extended so that all precoders across all ranks that contain the restricted beam precoder b_0 are restricted. Hence, all precoders across all ranks that contain a certain beam precoder b_0 is a precoder group that can be restricted jointly. According to some embodiments, therefore, an advantage of signaling

CSR based on beam precoders is that one does not need to signal a separate CSR for precoders with different rank (precoders with different rank are restricted with the same CSR). This reduces signaling overhead.

Signaling that jointly restricts a group of precoders by restricting a certain component that those precoders have in common also proves effective for restricting precoders that transmit in whole or in part towards certain angular pointing directions. Indeed, according to some embodiments herein, the network node 10 jointly restricts a group of precoders that transmit at least in part towards a certain angular pointing direction, by restricting a certain component (e.g., beam precoder) which has that angular pointing direction. In this way, the network node 10 avoids transmitting energy in a certain direction, by signaling to the device 14 by means of CSR that the device 14 shall not compute feedback for that particular direction.

More specifically in this regard, when each precoder W is formed from multiple beam precoders, the precoder W in some sense has multiple angular pointing directions corresponding to the angular pointing directions of its constituent beam precoders (where each beam precoder has its own azimuth and zenith angular pointing direction for example). In another sense, though, the precoder W has an overall angular pointing direction that is a combination (e.g., average) of its beam precoders' respective directions. By restricting beam precoders that have certain angular pointing directions, embodiments herein effectively restrict precoders that transmit at least in part in those directions, and do so with reduced signaling overhead.

As an example, a set of rank-1 precoders with the same angular pointing direction but with different polarization properties, such as the whole set of rank-1 precoders

$$\begin{bmatrix} b_0 \\ e^{j\omega_0} b_0 \end{bmatrix}, \begin{bmatrix} b_0 \\ e^{j\omega_1} b_0 \end{bmatrix}, \begin{bmatrix} b_0 \\ e^{j\omega_2} b_0 \end{bmatrix},$$

may be restricted by restriction signaling of a single beam precoder b_0. That is, when a restriction is signaled for a certain beam precoder, the restriction applies implicitly to all polarization phases of the signaled beam. Hence, the group of rank-1 precoders exemplified above is associated with a single CSR bit and is thus jointly restricted. This reduces device complexity and CSR signaling overhead, since only the beam direction needs to be signaled.

In another example, the set of rank-1 precoders

$$\begin{bmatrix} b_0 \\ e^{j\omega_0} b_1 \end{bmatrix}, \begin{bmatrix} b_2 \\ e^{j\omega_1} b_0 \end{bmatrix}, \begin{bmatrix} b_0 \\ e^{j\omega_2} b_2 \end{bmatrix},$$

may be jointly restricted by restriction signaling of a single beam precoder b_0. Hence, the group of rank-1 precoders exemplified above is associated with a single CSR bit and is thus jointly restricted.

Restriction of precoders with certain angular pointing directions can also be accomplished by specifying restrictions in terms of certain k and/or l values. This is illustrated with reference to Figure 7, which illustrates the angular beam pointing directions of rank-1

precoders in a codebook according to one example. In this example, the network node has a 4x4 antenna array where no mechanical downtilt is used. The Kronecker codebook consists of 8 vertical and 8 horizontal precoders, i.e. $N_H = N_V = 8$. In this example, codebook subset restriction is applied to restrict beams with pointing directions in the zenith interval $[80°, 100°]$ (the interval is illustrated with dotted lines). That is, codebook subset restriction is applied in the angular interval $80° < \theta < 100°$, such that the precoders with indices l-index 3 and 4 are restricted. The restricted beams are illustrated with an 'o' while the unrestricted beams are illustrated with an 'x'. The beam index k in the horizontal codebook and l in the vertical codebook is written next to the beams as (k, l). To signal the codebook subset restriction in this example, therefore, the bitmap '00011000' of l values, consisting of $N_V = 8$ bits, may be sent. With this scheme, a large reduction of the number of bits required to signal the codebook subset restriction is seen.

In another embodiment, the device 14 shall assume that a precoder is restricted if both the vertical and horizontal precoder in the Kronecker structure are restricted. This allows to restrict a rectangular "window" of beam former pointing angles as seen from the network node 10.

This can also be accomplished by signaling the restriction as a "rectangle" of precoders defined by the index pairs (k_0, l_0) and (k_1, l_1). With this scheme, precoders with indices $k_0 < k < k_1$and $l_0 < l < l_1$ are restricted.

Component-based restriction of a precoder group is just one example of embodiments that provide for rank-agnostic CSR signalling. Other embodiments herein also provide for such rank-agnostic signaling. For example, some embodiments herein generate signaling to jointly indicate that a group of precoders which transmit in whole or in part in certain angular pointing direction(s) are restricted, by generating the signaling to (explicitly or implicitly) indicate those angular pointing direction(s). The signaling may for instance specify an angular area or interval that is restricted, in terms of one or more angular parameters. This restriction may concern the angular pointing direction of a precoder as a whole, or the angular pointing direction of any beam precoder forming the precoder.

In one embodiment, the angular area or interval may be represented by angular points (ϕ_0, θ_0) and (ϕ_1, θ_1), spanning a rectangle in the angular domain. Here, ϕ and θ are the azimuth and zenith angles with respect to the eNodeB respectivly. Multiple such rectangular areas may be signaled although the present embodiment focuses on the case of a single rectangular area for simplicity. The device 14 may then calculate the angular pointing directions of the precoders in the codebook and compare them to the restricted angular area to derive the codebook subset restriction. The device 14 may need some additional information regarding what to assume about the transmitter antenna array (which does not need to correspond to the actually used antenna array) to be able to calculate the pointing directions of the precoders.

Consider an exemplary embodiment where the (sub)-codebooks of the Kronecker codebook consist of DFT-precoders, i.e

The horizontal codebook can be expressed as

$\boldsymbol{X}_H^k = \left[1 \; e^{j2\pi\frac{1k+\Delta_h}{M_hQ_h}} \; \cdots \; e^{j2\pi\frac{(M_h-1)k+\Delta_h}{M_hQ_h}}\right]^T, k = 0, \ldots, M_hQ_h - 1$, where Q_h is an integer horizontal oversampling factor and Δ_h can take on value in the interval 0 to 1 so as to "shift" the beam pattern (Δ_h =0.5 could be an interesting value for creating symmetry of beams with respect to the broadside of an array).

The vertical codebook can be expressed as $\boldsymbol{X}_V^l = \left[1 \; e^{j2\pi\frac{1l+\Delta_v}{M_vQ_v}} \; \cdots \; e^{j2\pi\frac{(M_v-1)l+\Delta_v}{M_vQ_v}}\right]^T, l = 0, \ldots, M_vQ_v - 1$, where $Q_v$is an integer vertical oversampling factor and Δ_v is similarly defined as above.

The pointing direction of precoder (k, l) can be calculated by first calculating the pointing angle with respect to the broadside of the antenna array:

$$\tilde{\theta} = acos\left(\frac{k + \Delta - \frac{Q_vM_v}{2}}{d_VQ_vM_v}\right)$$

$$\tilde{\phi} = asin\left(\frac{l + \Delta - \frac{Q_hM_h}{2}}{d_HQ_hM_h\sin(\tilde{\theta})}\right)$$

Where d_V and d_H is the vertical and horizontal antenna element spacing of the array, in wavelengths, respectively. The mechanical downtilt angle β is taken into account in order to calculate the actual beam pointing angles as:

$$\phi = \angle\left(\cos(\tilde{\phi})\sin(\tilde{\theta})\cos(-\beta) - \cos(\tilde{\theta})\sin(-\beta) + j\sin(\tilde{\theta})\sin(\tilde{\theta})\right)$$

$$\theta = acos\left(\cos(\tilde{\phi})\sin(\tilde{\theta})\sin(-\beta) + \cos(-\beta)\cos(\tilde{\theta})\right)$$

The device 14 needs to be signaled the additional information d_H, d_V and β to be able to calculate the beam pointing direction of the precoders in the codebook. It is assumed that the device 14 already knows the parameters Q_v, M_v, Q_h, M_h and Δ as part of the codebook structure.

The set of parameters $\phi_0, \theta_0, \phi_1, \theta_1, d_H, d_V, \beta$ thus parameterizes the codebook subset restriction in this embodiment. When signaling said parameters, several strategies may be used.

In one embodiment, each parameter is uniformly quantized with a number of bits, over a predefined interval. An example is given in the table below.

Parameters	Interval	Quantization bits
$\phi_0, \theta_0, \phi_1, \theta_1$	[0,180] [deg]	6
d_H, d_V	[0,2]	4
β	[-30,30] [deg]	6

In this embodiment, the number of bits required to signal the codebook subset restriction is 38. Note that this is independent of the codebook size.

In another embodiment, each parameter may take a value from a fixed set of possible values. Each possible value of the parameter is encoded with a different number of bits depending on e.g. the perceived likelihood of the parameter taking that value. For example, the horizontal array element spacing d_H may be encoded as follows

Value	0.5	0.8	0.65	1	4	2	0.75
Bits	1	01	011	010	001	0001	0000

In this embodiment, the encoding of d_H was designed to take into account $d_H = 0.5$ is a common value for horizontal antenna element separation, thus encoding this value with a low number of bits. Other, less common, values are encoded with a larger number of bits. Note that the encoding of d_H in this embodiment constitutes a uniquely decodable code.

In another embodiment, some of the parameters are uniformly quantized with a number of bits over a predefined interval, while other parameters are encoded with a different number of bits as in the previous embodiment.

In some other embodiments, different sets of parameters relating to the restricted angular area may constitute the parameters that define the codebook subset restriction. In one such embodiment, only a zenith interval $\theta_0 \leq \theta < \theta_1$ is restricted, and thus, θ_0, θ_1 may be sent. In another such embodiment, the restriction is only an azimuth interval $\phi_0 \leq \phi < \phi_1$. In yet another such embodiment, the angle interval may be open-ended, i.e. $\phi < \phi_1$ constitutes the restriction.

In other embodiments, parameters relating to the antenna array such as d_H, d_V and Ψ are not a part of the codebook subset restriction parameters, instead they may be already known to the UE or the UE assumes a default value of said parameters and the eNodeB chooses restriction angles (ϕ_0, θ_0) and (ϕ_1, θ_1) in such a way that the intended precoders are restricted when the UE calculates the restriction based on the default values of said parameters, where the default values of said parameters may differ from the actual value of said parameters.

In other embodiments, more parameters may be included in the codebook subset restriction parameters. In one such embodiment, the roll angle γ of the antenna array may be included in the codebook subset restriction parameters.

In view of the above modifications and variations, one recognizes that there are many ways that the CSR signaling can jointly restrict precoders in a group. The signaling can be rank-agnostic or not. And the signaling can restrict a certain component that is common to the group or signal angular parameters associated with the group. The signaling can take the form of a bitmap for beam precoder indices, take the form of angular parameters, take the form of sub-

codebook index pairs, take the form of a bitmap for indices of a single sub-codebook, etc. Irrespective of these particular variations, though, CSR signaling overhead is reduced based on correlation of the precoder restrictions or equivalently grouping of precoders. But the group-based joint restriction means that not all of the 2^N codebook subset restriction configurations are possible to convey to the device 14. Instead, only a subset of the possible configurations may be chosen.

Accordingly, at least some embodiments balance the loss in flexibility caused by joint restriction with the signaling overhead gains by such joint restriction by performing joint restriction with respect to only a portion of precoders in the codebook. That is, codebook subset restriction may be configured with full flexibility on a subset A of the precoders in the codebook (meaning that each of the precoders may be turned on or off individually), while only a few configurations may be chosen for the remaining set B of precoders. For example, the codebook subset restriction for the remaining set B of precoders may only be represented with one bit, turning all precoders in the set either on or off. This will reduce the CSR signaling overhead which is beneficial.

As an example in the context of beam precoders, the codebook may consist of two sets of precoders. One of the sets consist of precoders which may be equivalently expressed as a function of layer-specific beam precoders (as defined above) while the other set may consist of arbitrary precoders. In this embodiment, the first set of precoders may be configured with full flexibility while the other precoders in the codebook may be configured with limited flexibility.

This embodiment is just one example of grouping of the precoders in the codebook where precoders belonging to set A is individually represented by one bit while precoders in set B are all jointly restricted with a single bit. This embodiment can be further extended by having multiple sets B as B_1,B_2,... B_N where each of the set B_n, n=1,..,N contain at least two precoders each and is associated with one CSR bit. In Figure 8 an example is shown where Precoder 1 to 14 are each represented by an individual bit (Set A), while all precoders in group B1 are represented by a single CSR bit, e.g. the bit for precoder 15.

The defined groups may also be overlapping, so that a given precoder exists in multiple groups. If this is the case, then priority or combining rules needs to be defined, so that the device 14 understands how to interpret the case when one precoder is restricted by the signaling of one group but not from another group it belong to.

In a further detailed embodiment, therefore, the groups B_n in Figure 8 may be overlapping and rules are specified in standard text on how the device 14 shall interpret CSR signaling. For instance, assume two groups B_1 and B_2 each represented by one bit and that one precoder belongs to both groups. One rule may be that if a precoder is restricted in any of the groups it belongs, then the precoder should be assumed to be restricted. Another alternative is that the precoder must be restricted in both groups for the precoder to be assumed to be restricted.

In some embodiments in this disclosure, codebook subset restriction is discussed using the terminology *precoders* and *codebooks*. It may be assumed that beam specific restriction is used in said embodiments, and that the terminology may be interchanged to *beam precoders* and *set of beam precoders*, depending on the granularity being discussed.

Note that although terminology from 3GPP LTE has been used in this disclosure to exemplify embodiments herein, this should not be seen as limiting the scope of the embodiments to only the aforementioned system. Other wireless systems, including WCDMA, WiMax, UMB and GSM, may also benefit from exploiting the ideas covered within this disclosure.

Also note that terminology such as eNodeB and UE 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 "UE" 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 embodiments herein are equally applicable in the uplink.

Embodiments herein also include methods in a wireless communication device 14 corresponding to the methods described above in a network node 10. These methods receive and decode the signaling that the network node 10 generates according to any of the embodiments above.

According to one embodiment shown in Figure 9, for example, a method is implemented by a wireless communication device 14 (e.g., a UE) for decoding signaling from a network node 10 indicating which precoders in a codebook are restricted from being used. The method includes receiving the signaling (Block 300). The method also includes, for each of one or more groups of precoders in the codebook, decoding the signaling to identify which of different possible configurations is actually signaled for that group. Different possible configurations in this regard restrict different subgroups of precoders in the group from being used. This decoding proceeds on a group-by-group basis, starting with a first group (Block 310). Specifically, the decoding entails identifying one or more reference configurations for the first group, the bit pattern identified for signaling each reference configuration, and the length of that bit pattern (Block 320). These reference configuration(s) may be predefined at the device 14, or may be signaled from the network node 10. Regardless, decoding then entails detecting the actual configuration signaled for the group, by detecting a bit pattern in the received signaling whose length depends on (i) whether the actual configuration matches one of the one or more reference configurations; and/or (ii) which reference configuration the actual configuration matches (Block 330).

Such may entail, for example, determining the length B of the bit pattern defined for signaling a particular reference configuration, and checking whether a B-length string of the next bits in the signaling corresponds to the bit pattern defined for signaling that reference configuration. This determination and checking may be performed for each of the one or more

reference configurations, after which (if no reference configurations are identified as being signaled) a default-length string of the next bits in the signaling is decoded for detecting non-reference configurations.

Regardless of the particular implementation of the decoding process (Blocks 320-330), the decoding is repeated for each of the one or more groups of precoders in the codebook (Blocks 340, 350).

Those skilled in the art will appreciate that the device-side embodiments include decoding of any of the network-side embodiments illustrated with reference to Figure 3, including for instance the "similar rows embodiments" and the "similar columns embodiment."

According to one or more other embodiments shown in Figure 10, a method is implemented by a wireless communication device 14 (e.g., a UE) for decoding signaling from a network node 10 indicating which precoders in a codebook are restricted from being used (e.g., which Kronecker product precoders are restricted). As shown, the method includes receiving the signaling from a network node 10 (e.g., a base station) (Block 400). The method also includes decoding the signaling as jointly restricting precoders in each of one or more groups of precoders (Block 410). In at least some embodiments, such decoding involves decoding the signaling (i) as being rank-agnostic so as to restrict precoders irrespective of their transmission rank; and/or (ii) as jointly restricting a group of precoders by restricting a certain component that those precoders have in common.

Those skilled in the art will appreciate that the device-side embodiments include decoding of any of the network-side embodiments illustrated with reference to Figure 5. So, for example, the device 14 in some embodiments decodes the signaling as jointly restricting a group of precoders that have a certain beam precoder in common, by restricting that beam precoder. And one or more device-side embodiments likewise advantageously exploit a codebook's Kronecker structure to decode the signaling of Figure 10 in terms of indices k, l, and/or m. In some embodiments, for example, the signaling is decoding as jointly restricting, e.g., with a single bit, a group of precoders that either (i) have the same value of index k; (ii) have the same value of index l; or (iii) have the same pair of values for indices (k, l).

With the above modifications and variations in mind, Figure 11 illustrates additional details of the network node 500 (corresponding to network node 10) according to one or more embodiments. The network node 500 is configured, e.g., via functional means or units 540-570, to implement the processing in Figure 2 for signaling to a wireless communication device 14 which precoders in a codebook are restricted from being used. The network node 500 in some embodiments for example includes a reference configuration identifying means or unit 540 for identifying one or more reference configurations for each of one or more groups of precoders. The network node 500 in such case further includes an actual configuration identifying means or unit 550 for identifying an actual configuration for each of the one or more groups. The network node 500 also includes a signal generating means or unit 560 for generating signaling to

indicate the actual configuration for each of the one or more groups, by generating the signaling as a bit pattern whose length depends on (i) whether the actual configuration matches one of the one or more reference configurations; and/or (ii) which reference configuration the actual configuration matches. The network node 500 finally includes a sending means or unit 570 for sending the generated signaling to the wireless communication device.

In at least some embodiments, the network node 500 comprises one or more processing circuits 510 configured to implement this processing, such as by implementing functional means or units 540-570. In one embodiment, for example, the node's processing circuit(s) 510 implement functional means or units 540-570 as respective circuits. The circuits in this regard may comprise circuits dedicated to performing certain functional processing and/or one or more microprocessors in conjunction with memory 520. In embodiments that employ memory 520, which may comprise one or several types of memory such as read-only memory (ROM), random-access memory, cache memory, flash memory devices, optical storage devices, etc., the memory stores program code that, when executed by the one or more for carrying out one or more microprocessors, carries out the techniques described herein.

In one or more embodiments, the network node 500 also comprises one or more communication interfaces 530. The one or more communication interfaces 530 include various components (not shown) for sending and receiving data and control signals. More particularly, the interface(s) 530 include a transmitter that is configured to use known signal processing techniques, typically according to one or more standards, and is configured to condition a signal for transmission (e.g., over the air via one or more antennas). Similarly, the interface(s) 530 include a receiver that is configured to convert signals received (e.g., via the antenna(s)) into digital samples for processing by the one or more processing circuits 510.

Figure 12 illustrates additional details of the network node 600 according to one or more embodiments. The network node 600 is configured, e.g., via functional means or units 640-650, to implement the processing in Figure 5 for signaling to a wireless communication device which precoders in a codebook are restricted from being used. The network node 600 in some embodiments for example includes a generating means or unit 640 for generating codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group, e.g., with a single signaling bit. The network node 600 also includes a sending means or unit 650 for sending the generated signaling to the wireless communication device.

In at least some embodiments, the network node 600 comprises one or more processing circuits 610 configured to implement this processing, such as by implementing functional means or units 640-650. In one embodiment, for example, the node's processing circuit(s) 610 implement functional means or units 640-650 as respective circuits (similarly to that described above, e.g., in conjunction with memory 620). In one or more embodiments, the network node 600 also comprises one or more communication interfaces 630.

Figure 13 illustrates additional details of the wireless communication device 700 (corresponding to wireless communication device 14) according to one or more embodiments The device 700 is configured, e.g., via functional means or units 740-760, to implement the processing in Figure 9 for decoding signaling from a network node indicating which precoders in a codebook are restricted from being used. The device 700 in some embodiments for example includes a receiving means or unit 740 for receiving the signaling from the network node. The device 700 further includes an identifying means or unit 750 configured, for each of one or more groups of precoders, to identify one or more reference configurations for the group, the bit pattern identified for signaling each reference configuration, and the length of that bit pattern. The device 700 finally includes a detecting means or unit 760 configured to detect the actual configuration signaled for the group, by detecting a bit pattern in the received signaling whose length depends on (i) whether the actual configuration matches one of the one or more reference configurations; and/or (ii) which reference configuration the actual configuration matches.

In at least some embodiments, the device 700 comprises one or more processing circuits 710 configured to implement this processing, such as by implementing functional means or units 740-760. In one embodiment, for example, the device's processing circuit(s) 710 implement functional means or units 740-760 as respective circuits. The circuits in this regard may comprise circuits dedicated to performing certain functional processing and/or one or more microprocessors in conjunction with memory 720. In embodiments that employ memory 720, which may comprise one or several types of memory such as read-only memory (ROM), random-access memory, cache memory, flash memory devices, optical storage devices, etc., the memory stores program code that, when executed by the one or more for carrying out one or more microprocessors, carries out the techniques described herein.

In one or more embodiments, the device 700 also comprises one or more communication interfaces 730. The one or more communication interfaces 730 include various components (not shown) for sending and receiving data and control signals. More particularly, the interface(s) 730 include a transmitter that is configured to use known signal processing techniques, typically according to one or more standards, and is configured to condition a signal for transmission (e.g., over the air via one or more antennas). Similarly, the interface(s) 730 include a receiver that is configured to convert signals received (e.g., via the antenna(s)) into digital samples for processing by the one or more processing circuits 710.

Figure 14 illustrates additional details of the device 800 according to one or more other embodiments. The device 800 is configured, e.g., via functional means or units 840-850, to implement the processing in Figure 10 for decoding signaling from a network node indicating which precoders in a codebook are restricted from being used. The device 800 in some embodiments for example includes a receiving means or unit 840 for receiving the signaling from the network node. The device 800 further includes a decoding means or unit 850 for

decoding the signaling as jointly restricting precoders in each of one or more groups of precoders.

In at least some embodiments, the device 800 comprises one or more processing circuits 810 configured to implement this processing, such as by implementing functional means or units 840-850. In one embodiment, for example, the device's processing circuit(s) 810 implement functional means or units 840-850 as respective circuits (similarly to that described above, e.g., in conjunction with memory 820). In one or more embodiments, the device 800 also comprises one or more communication interfaces 830.

Those skilled in the art will also appreciate that embodiments herein further include corresponding computer programs.

A computer program comprises instructions which, when executed on at least one processor of the network node or the wireless communication device, cause node or device to carry out any of the respective processing described above. Embodiments further include a carrier containing such a computer program. This carrier may comprise one of an electronic signal, optical signal, radio signal, or computer readable storage medium.

A computer program in this regard may comprise one or more code modules corresponding to the means or units described above.

General Embodiments

In a first embodiment, a UE is able to receive messages in order to turn individual codewords on/off. The following holds for the set of possible messages:

At least one of these messages, which correspond to a certain configuration out of the 2^N possible configurations, is represented by less than N bits.

The message will contain information to define on/off for each individual codeword in the entire codebook.

Each message is uniquely decodable to the UE and will correspond to one of the 2^N possible configurations.

In a second embodiment, the UE of the first embodiment is configured such that codebook subset restriction is done on beam precoders.

In a third embodiment, the UE of the first embodiment is configured such that codebook subset restriction is configured with full flexibility for a subset of precoders in the codebook, while codebook subset restriction is configured with a limited flexibility for other precoders in the codebook.

In a fourth embodiment, the UE of the third embodiment is configured such that the set of precoders for which codebook subset restriction is configured with full flexibility is the set of precoders that may be equivalently expressed as a function of layer-specific beam precoders.

In a fifth embodiment, the UE of the first embodiment is configured such that $N = N_H \cdot N_V$ from the Kronecker structure.

In a sixth embodiment, the UE of any of the first through the fifth embodiments is configured such that the information used to design the set of messages consists of information about angular intervals which are likely to be restricted.

In a seventh embodiment, the UE of the first embodiment is configured such that only a subset of the 2^N possible configurations may be configured.

In an eighth embodiment, the UE of the first embodiment is configured such that at least one of the messages, which corresponds to a certain configuration out of the 2^N possible configurations, is represented more than N bits.

In a ninth embodiment, the UE of the first embodiment is configured such that the set of messages are designed using information about the likelihood of certain configurations being chosen.

In a tenth embodiment, the UE of the first embodiment is configured such that the information about the likelihood of certain configurations being chosen is only an implicit assumption of the likelihoods.

In an eleventh embodiment, the UE of the first embodiment is configured such that a set of angles specifies the configuration.

CLAIMS

What is claimed is:

1. A method implemented by a network node (10) for signaling to a wireless communication device (14) which precoders in a codebook are restricted from being used, the method characterized by:

generating (210) codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common; and

sending (220) the generated signaling from the network node (10) to the wireless communication device (14).

2. A method implemented by a wireless communication device (14) for decoding signaling from a network node (10) indicating which precoders in a codebook are restricted from being used, the method characterized by:

receiving (400) codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common; and

decoding (410) the received signaling as jointly restricting precoders in each of the one or more groups of precoders.

3. The method of any of claims 1-2, wherein the codebook subset restriction signaling is rank-agnostic signaling that jointly restricts the precoders in a group without regard to the precoders' transmission rank.

4. The method of any of claims 1-3, wherein the certain component comprises a beam precoder.

5. The method of any of claims 1-4, wherein a precoder comprising one or more beam precoders is restricted if at least one of its one or more beam precoders is restricted.

6. The method of any of claims 4-5, wherein a beam precoder is a Kronecker product of different beamforming vectors associated with different dimensions of a multi-dimensional antenna array.

7. The method of claim 6, wherein the different beamforming vectors comprise Discrete Fourier Transform (DFT) vectors.

8. The method of any of claims 4-7, wherein a beam precoder is a beamforming vector used to transmit on a particular layer of a multi-layer transmission, wherein different scaled versions of that beamforming vector are transmitted on different polarizations;

9. The method of any of claims 4-7, wherein a beam precoder is a beamforming vector used to transmit on:

multiple different layers of a multi-layer transmission;

multiple different layers of a multi-layer transmission, wherein the layers are sent on orthogonal polarizations; or

a particular layer and on a particular polarization.

10. The method of any of claims 1-9, wherein the codebook subset restriction signaling comprises a bitmap, with different bits in the bitmap respectively dedicated to indicating whether or not different beam precoders are restricted from being used.

11. The method of any of claims 1-9, wherein a beam precoder is a Kronecker product of first and second beamforming vectors with first and second indices, wherein the first and second beamforming vectors are associated with different dimensions of a multi-dimensional antenna array, and wherein the codebook subset restriction signaling jointly restricts the precoders in a group of precoders that have the same pair of values for the first and second indices.

12. The method of any of claims 1-3, wherein each precoder comprises one or more beam precoders, wherein each beam precoder comprises multiple different components corresponding to different dimensions of a multi-dimensional antenna array, and wherein said certain component comprises a component of a beam precoder.

13. The method of any of claims 1-12, wherein the codebook subset restriction signaling jointly restricts the precoders in a group of precoders that transmit at least in part towards a certain angular pointing direction, by restricting a certain component which has that angular pointing direction.

14. A method implemented by a network node (10) for signaling to a wireless communication device (14) which precoders in a codebook are restricted from being used, the method characterized by:

for each of one or more groups of precoders in the codebook:

identifying (110) one or more reference configurations for the group, wherein each reference configuration is one of different possible configurations

that restrict different subgroups of precoders in the group from being used;

identifying (120), from the different possible configurations for the group, an actual configuration to be signaled for the group; and

generating (130) signaling to indicate the actual configuration for the group, by generating the signaling as a bit pattern whose length depends on (i) whether the actual configuration matches one of the one or more reference configurations and/or (ii) which reference configuration the actual configuration matches; and

sending (160) the generated signaling to the wireless communication device (14).

15. A method implemented by a wireless communication device (14) for decoding signaling from a network node (10) indicating which precoders in a codebook are restricted from being used, the method characterized by:

receiving (300) signaling from the network node (10).

for each of one or more groups of precoders in the codebook:

identifying (320) one or more reference configurations for the group, wherein each reference configuration is one of different possible configurations that restrict different subgroups of precoders in the group from being used;

identifying (320) a bit pattern defined for signaling each reference configuration, and a length of that bit pattern; and

detecting (330) an actual configuration signaled for the group, by detecting in the signaling a bit pattern whose length depends on (i) whether the actual configuration matches one of the one or more reference configurations and/or (ii) which reference configuration the actual configuration matches.

16. The method of any of claims 14-15, wherein the signaling is a short bit pattern when the actual configuration matches any one of the one or more reference configurations and is a long bit pattern when the actual configuration does not match any of the one or more reference configurations, wherein a long bit pattern has more bits than a short bit pattern.

17. The method of claim 16, wherein the one or more reference configurations for at least one of the one or more groups comprise a single reference configuration, and wherein different long bit patterns are respectively defined for signaling different configurations other than the single reference configuration.

18. The method of any of claims 16-17, wherein a long bit pattern defined for signaling the actual configuration for the group comprises:

a non-reference bit pattern defined for signaling that the actual configuration does not match a reference configuration for the group; and

a bitmap comprising different bits respectively dedicated to indicating whether different precoders in the group are restricted from being used.

19. The method of any of claims 14-15, wherein the one or more reference configurations for at least one of the one or more groups comprise multiple reference configurations, and wherein, when the actual configuration matches a particular one of the multiple reference configurations, the signaling is a bit pattern whose length is shorter than that of a bit pattern generated when the actual configuration matches a different one of the multiple reference configurations.

20. The method of any of claims 14-19, wherein the one or more reference configurations for a group each have an actual or assumed higher probability of being signaled than any other possible configuration that is not one of the one or more reference configurations.

21. The method of any of claims 14-19, wherein the method is performed for multiple different groups that respectively include different portions of the precoders in the codebook, wherein the signaling indicates the actual configurations for the groups in a defined order, wherein the one or more reference configurations for each group comprises a single reference configuration, and wherein the single reference configuration for any given group is the actual configuration, if any, signaled immediately before that of the given group.

22. The method of any of claims 14-21, wherein the codebook is a Kronecker codebook defined for a multi-dimensional antenna array and comprises different precoders indexed by different possible values of a single index parameter, wherein the different possible values of the single index parameter are divided into different clusters of consecutively ordered values, and wherein precoders in different ones of the one or more groups are respectively indexed by the different clusters of consecutively ordered values.

23. The method of any of claims 14-21, wherein the codebook is a Kronecker codebook defined for a multi-dimensional antenna array and comprises different precoders indexed by different pairs of possible values for a first-dimension index parameter and a second-dimension index parameter, and wherein precoders in each of the one or more groups are indexed by pairs that have the same value for either the first-dimension index parameter or the second-dimension index parameter.

24. A network node (10, 600) for signaling to a wireless communication device (14, 800) which precoders in a codebook are restricted from being used, the network node (10, 600) configured to:

generate codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common; and

send the generated signaling from the network node (10, 600) to the wireless communication device (14, 800).

25. The network node of claim 24, configured to perform the method of any of claims 3-13

26. A network node (10, 600) for signaling to a wireless communication device (14, 800) which precoders in a codebook are restricted from being used, the network node (10, 600) characterized by:

a generating module (640) for generating codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common; and

a sending module (650) for sending the generated signaling from the network node (10, 600) to the wireless communication device (14, 800).

27. A wireless communication device (14, 800) for decoding signaling from a network node (10, 600) indicating which precoders in a codebook are restricted from being used, the wireless communication device (14, 800) configured to:

receive codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common; and

decode the received signaling as jointly restricting precoders in each of the one or more groups of precoders.

28. The wireless communication device of claim 27, configured to perform the method of any of claims 3-13.

29. A wireless communication device (14, 800) for decoding signaling from a network node (10, 600) indicating which precoders in a codebook are restricted from being used, the wireless communication device (14, 800) characterized by:

a receiving module (840) for receiving codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the

group by restricting a certain component that the precoders in the group have in common; and

a decoding module (850) for decoding the received signaling as jointly restricting precoders in each of the one or more groups of precoders.

30. A network node (10, 500) for signaling to a wireless communication device which precoders in a codebook are restricted from being used, the network node (10, 500) configured to:

for each of one or more groups of precoders in the codebook:

identify one or more reference configurations for the group, wherein each reference configuration is one of different possible configurations that restrict different subgroups of precoders in the group from being used;

identify, from the different possible configurations for the group, an actual configuration to be signaled for the group; and

generate signaling to indicate the actual configuration for the group, by generating the signaling as a bit pattern whose length depends on (i) whether the actual configuration matches one of the one or more reference configurations and/or (ii) which reference configuration the actual configuration matches; and

send the generated signaling to the wireless communication device.

31. The network node of claim 30, configured to perform the method of any of claims 16-23.

32. A network node (10, 500) for signaling to a wireless communication device (14, 700) which precoders in a codebook are restricted from being used, the network node (10, 500) characterized by:

for each of one or more groups of precoders in the codebook:

a reference configuration identifying module (540) for identifying one or more reference configurations for the group, wherein each reference configuration is one of different possible configurations that restrict different subgroups of precoders in the group from being used;

an actual configuration identifying module (550) for identifying, from the different possible configurations for the group, an actual configuration to be signaled for the group; and

a generating module (560) for generating signaling to indicate the actual configuration for the group, by generating the signaling as a bit pattern whose length depends on (i) whether the actual configuration matches

one of the one or more reference configurations and/or (ii) which reference configuration the actual configuration matches; and

a sending module (570) for sending the generated signaling to the wireless communication device (14, 700).

33. The network node of claim 32, configured to perform the method of any of claims 16-23.

34. A wireless communication device (14, 700) for decoding signaling from a network node (10, 500) indicating which precoders in a codebook are restricted from being used, the wireless communication device (14, 700) configured to:

receive signaling from the network node (10, 500).

for each of one or more groups of precoders in the codebook:

identify one or more reference configurations for the group, wherein each reference configuration is one of different possible configurations that restrict different subgroups of precoders in the group from being used;

identify a bit pattern defined for signaling each reference configuration, and a length of that bit pattern; and

detect an actual configuration signaled for the group, by detecting in the signaling a bit pattern whose length depends on (i) whether the actual configuration matches one of the one or more reference configurations and/or (ii) which reference configuration the actual configuration matches.

35. The wireless communication device of claim 34, configured to perform the method of any of claims 16-23.

36. A wireless communication device (14, 700) for decoding signaling from a network node (10, 500) indicating which precoders in a codebook are restricted from being used, the wireless communication device characterized by:

a receiving module (740) for receiving signaling from the network node (10, 500).

for each of one or more groups of precoders in the codebook:

an identifying module (750) for identifying one or more reference configurations for the group, wherein each reference configuration is one of different possible configurations that restrict different subgroups of precoders in the group from being used; and for identifying a bit pattern defined for signaling each reference configuration, and a length of that bit pattern; and

a detecting module (760) for detecting an actual configuration signaled for the group, by detecting in the signaling a bit pattern whose length depends on

(i) whether the actual configuration matches one of the one or more reference configurations and/or (ii) which reference configuration the actual configuration matches.

37. A computer program comprising instructions which, when executed by at least one processor of a node (10, 14), causes the node (10, 14) to carry out the method of any of embodiments 1-23.

38. A carrier containing the computer program of embodiment 37, wherein the carrier is one of an electronic signal, optical signal, radio signal, or computer readable storage medium.

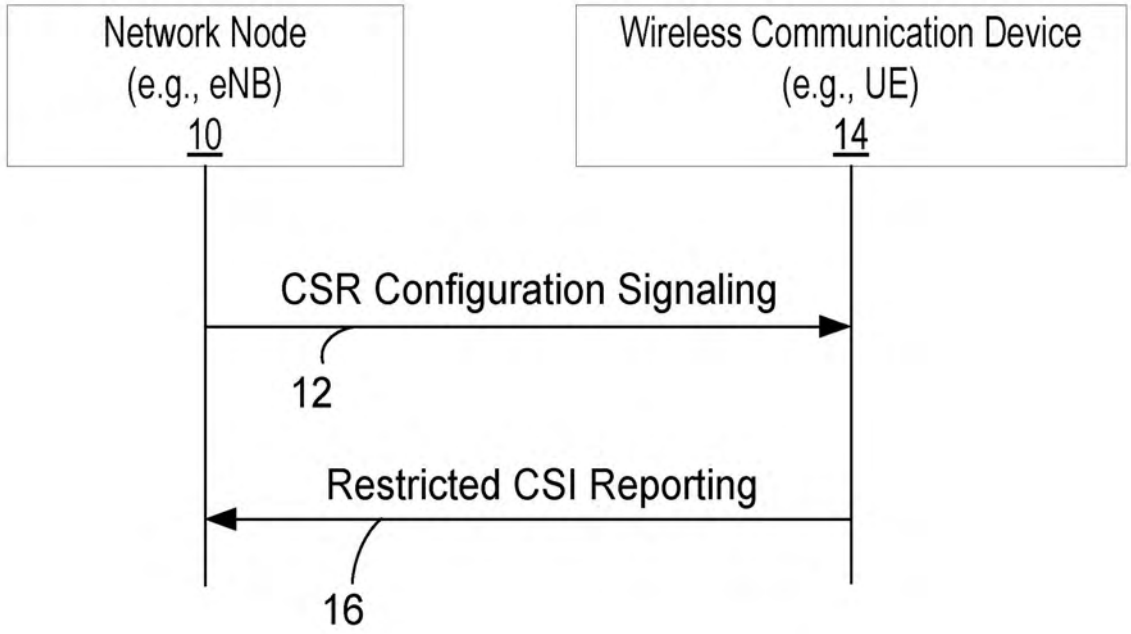
Network Node
(e.g., eNB)
10
Wireless Communication Device
(e.g., UE)
14
CSR Configuration Signaling
12
Restricted CSI Reporting
16

Figure 1

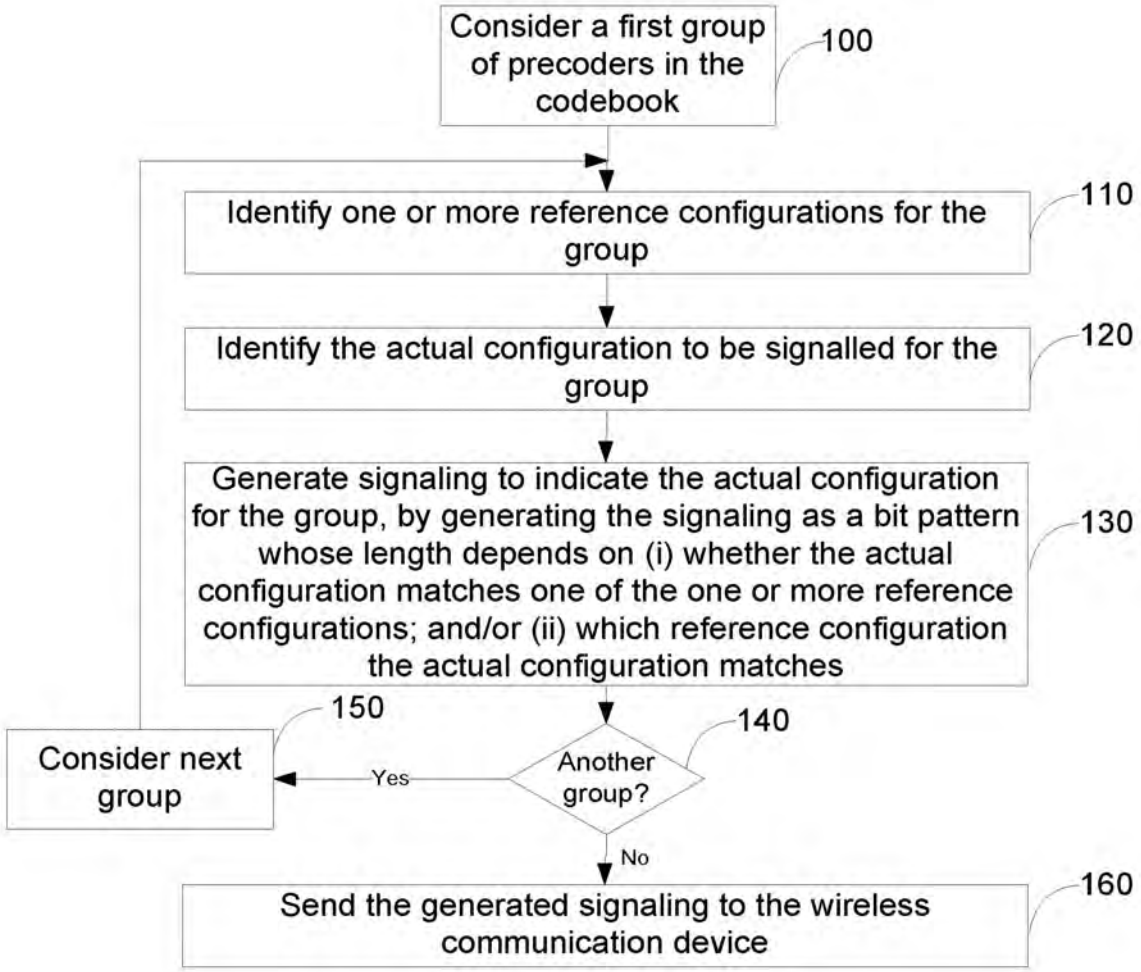
Consider a first group of precoders in the codebook
100
Identify one or more reference configurations for the group
110
Identify the actual configuration to be signalled for the group
120
Generate signaling to indicate the actual configuration for the group, by generating the signaling as a bit pattern whose length depends on (i) whether the actual configuration matches one of the one or more reference configurations; and/or (ii) which reference configuration the actual configuration matches
130
Another group?
140
Yes
Consider next group
150
No
Send the generated signaling to the wireless communication device
160

Figure 2

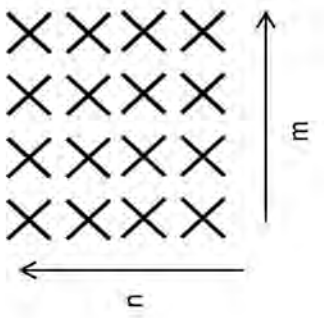

Figure 3

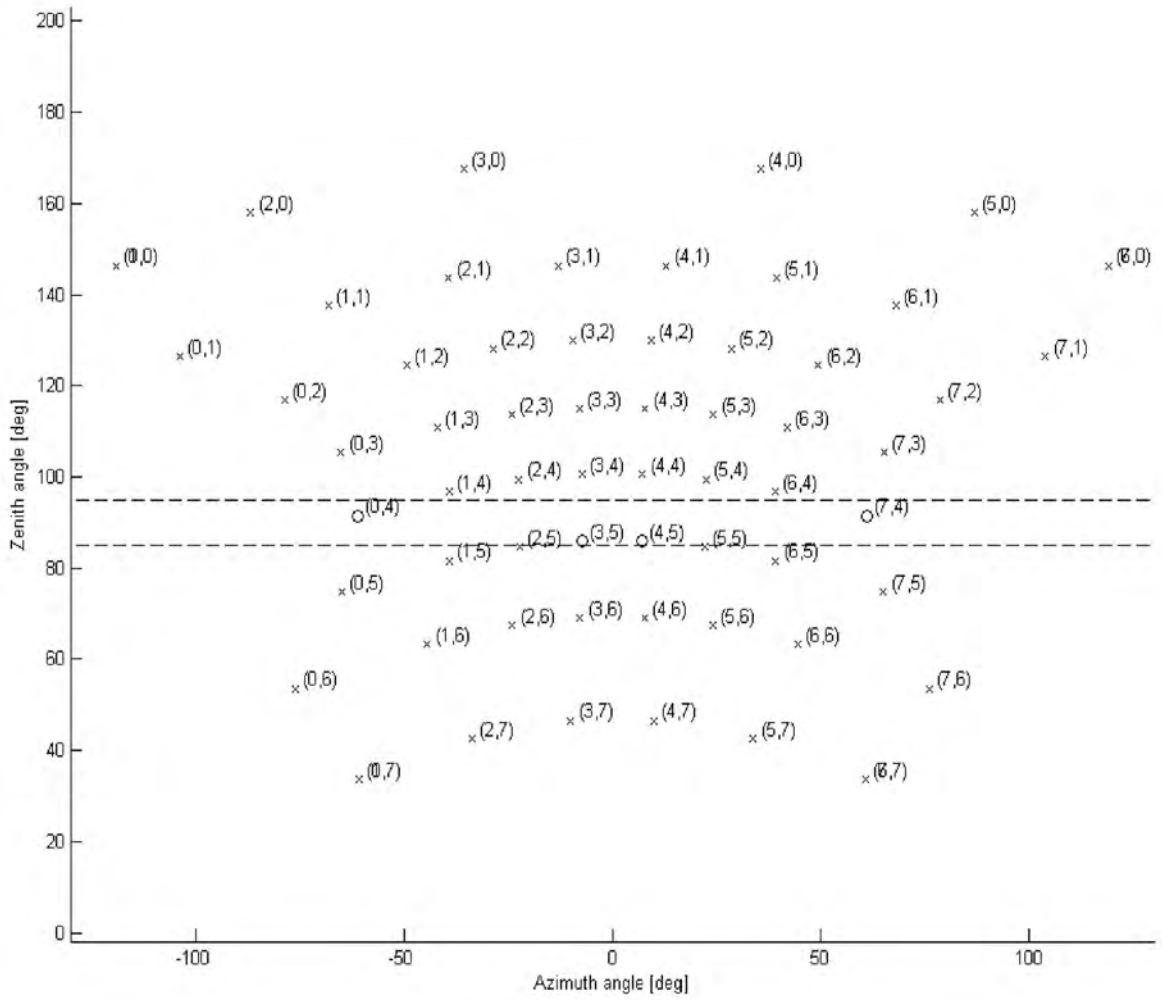
Zenith angle [deg]
Azimuth angle [deg]
200
180
160
140
120
100
80
60
40
20
0
-100
-50
0
50
100
(0,0)
(1,0)
(2,0)
(3,0)
(4,0)
(5,0)
(6,0)
(0,1)
(1,1)
(2,1)
(3,1)
(4,1)
(5,1)
(6,1)
(7,1)
(0,2)
(1,2)
(2,2)
(3,2)
(4,2)
(5,2)
(6,2)
(7,2)
(0,3)
(1,3)
(2,3)
(3,3)
(4,3)
(5,3)
(6,3)
(7,3)
(0,4)
(1,4)
(2,4)
(3,4)
(4,4)
(5,4)
(6,4)
(7,4)
(0,5)
(1,5)
(2,5)
(3,5)
(4,5)
(5,5)
(6,5)
(7,5)
(0,6)
(1,6)
(2,6)
(3,6)
(4,6)
(5,6)
(6,6)
(7,6)
(0,7)
(1,7)
(2,7)
(3,7)
(4,7)
(5,7)
(6,7)
(7,7)

FIGURE 4

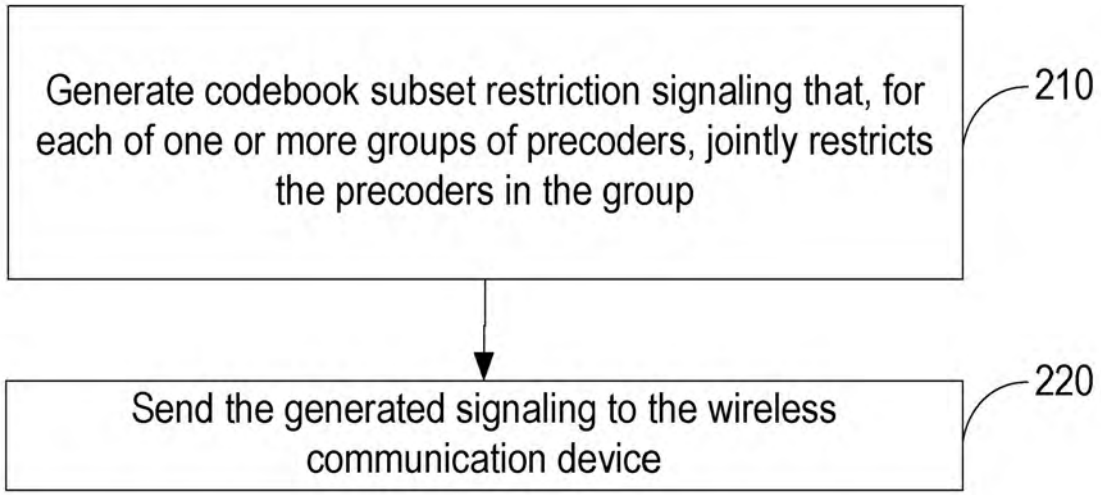
Generate codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group
210
Send the generated signaling to the wireless communication device
220

Figure 5

$$\varphi_n = e^{j\pi n/2}$$

$$v_m = \begin{bmatrix} 1 & e^{j2\pi m/32} & e^{j4\pi m/32} & e^{j6\pi m/32} \end{bmatrix}^T$$

Codebook for 2-layer CSI reporting using antenna ports 15 to 22

i_1	i_2			
	0	**1**	**2**	**3**
0 – 15	$W^{(2)}_{2i_1,2i_1,0}$	$W^{(2)}_{2i_1,2i_1,1}$	$W^{(2)}_{2i_1+1,2i_1+1,0}$	$W^{(2)}_{2i_1+1,2i_1+1,1}$
i_1	i_2			
	4	**5**	**6**	**7**
0 – 15	$W^{(2)}_{2i_1+2,2i_1+2,0}$	$W^{(2)}_{2i_1+2,2i_1+2,1}$	$W^{(2)}_{2i_1+3,2i_1+3,0}$	$W^{(2)}_{2i_1+3,2i_1+3,1}$
i_1	i_2			
	8	**9**	**10**	**11**
0 – 15	$W^{(2)}_{2i_1,2i_1+1,0}$	$W^{(2)}_{2i_1,2i_1+1,1}$	$W^{(2)}_{2i_1+1,2i_1+2,0}$	$W^{(2)}_{2i_1+1,2i_1+2,1}$
i_1	i_2			
	12	**13**	**14**	**15**
0 – 15	$W^{(2)}_{2i_1,2i_1+3,0}$	$W^{(2)}_{2i_1,2i_1+3,1}$	$W^{(2)}_{2i_1+1,2i_1+3,0}$	$W^{(2)}_{2i_1+1,2i_1+3,1}$
where $W^{(2)}_{m,m',n} = \frac{1}{4}\begin{bmatrix} v_m & v_{m'} \\ \varphi_n v_m & -\varphi_n v_{m'} \end{bmatrix}$				

Figure 6

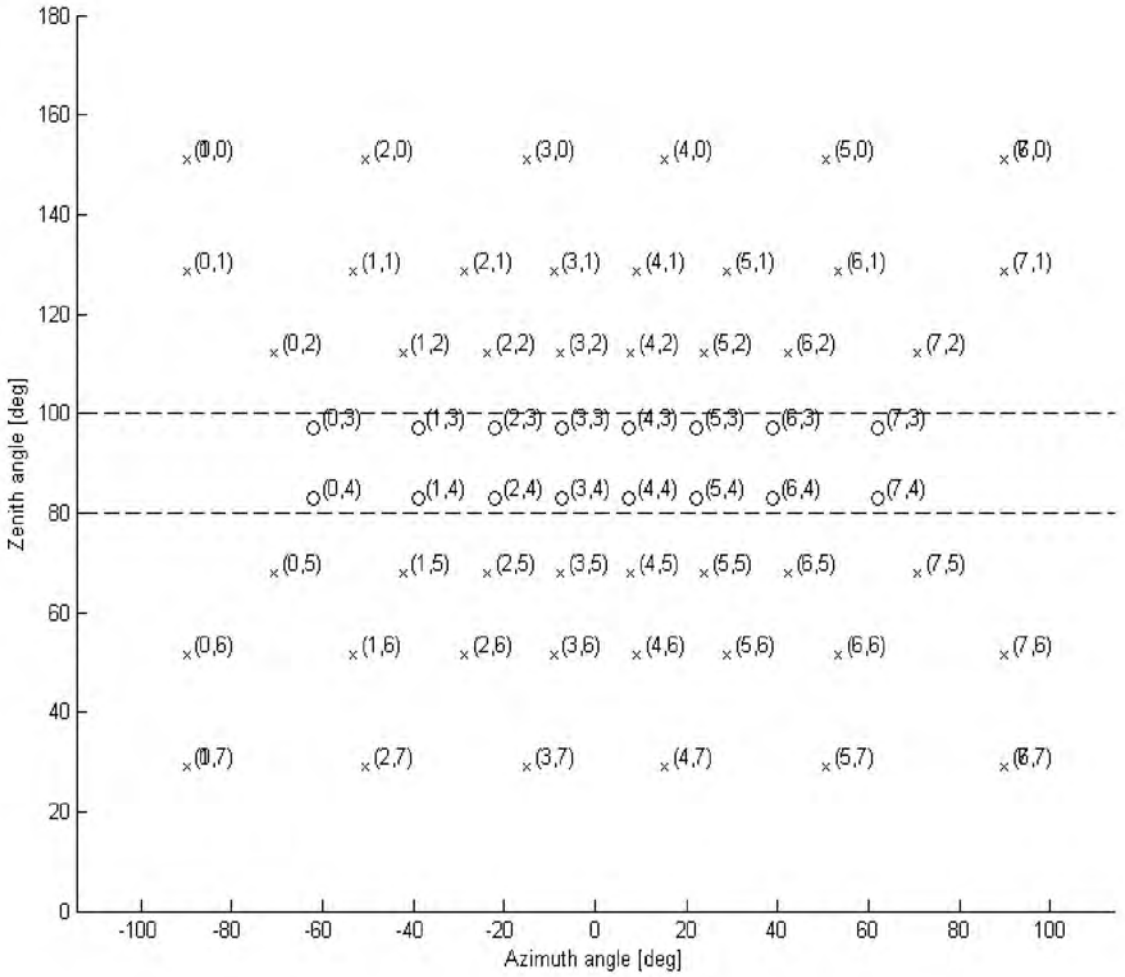
Zenith angle [deg]
Azimuth angle [deg]
180
160
140
120
100
80
60
40
20
0
-100
-80
-60
-40
-20
0
20
40
60
80
100
(0,0)
(2,0)
(3,0)
(4,0)
(5,0)
(6,0)
(0,1)
(1,1)
(2,1)
(3,1)
(4,1)
(5,1)
(6,1)
(7,1)
(0,2)
(1,2)
(2,2)
(3,2)
(4,2)
(5,2)
(6,2)
(7,2)
(0,3)
(1,3)
(2,3)
(3,3)
(4,3)
(5,3)
(6,3)
(7,3)
(0,4)
(1,4)
(2,4)
(3,4)
(4,4)
(5,4)
(6,4)
(7,4)
(0,5)
(1,5)
(2,5)
(3,5)
(4,5)
(5,5)
(6,5)
(7,5)
(0,6)
(1,6)
(2,6)
(3,6)
(4,6)
(5,6)
(6,6)
(7,6)
(0,7)
(2,7)
(3,7)
(4,7)
(5,7)
(6,7)

Figure 7

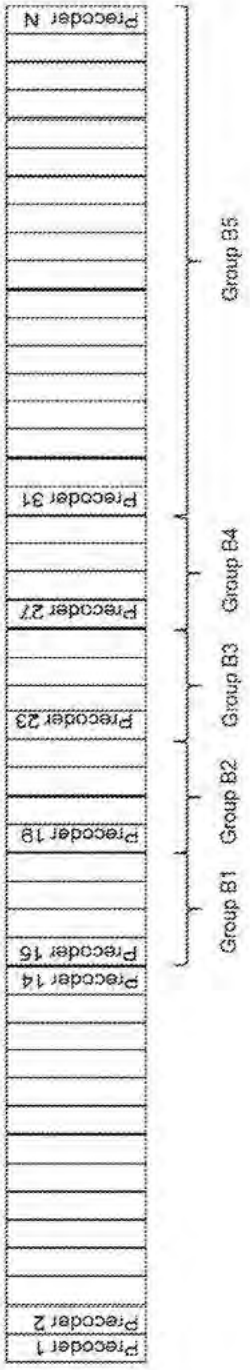
Precoder 1
Precoder 2
Precoder 14
Precoder 15
Precoder 18
Precoder 23
Precoder 27
Precoder 31
Precoder N
Group B1
Group B2
Group B3
Group B4
Group B5

Figure 8

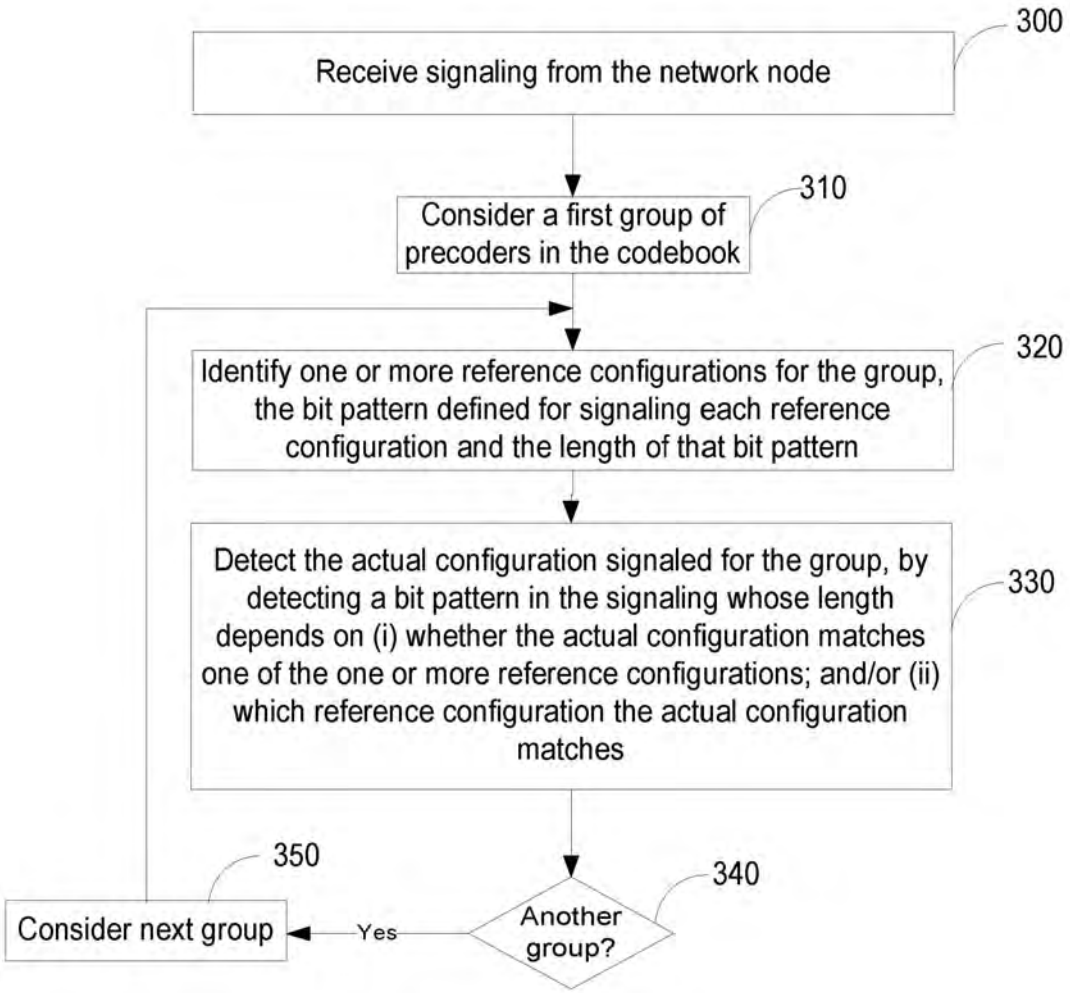
Receive signaling from the network node
300
Consider a first group of precoders in the codebook
310
Identify one or more reference configurations for the group, the bit pattern defined for signaling each reference configuration and the length of that bit pattern
320
Detect the actual configuration signaled for the group, by detecting a bit pattern in the signaling whose length depends on (i) whether the actual configuration matches one of the one or more reference configurations; and/or (ii) which reference configuration the actual configuration matches
330
Another group?
340
Yes
Consider next group
350

Figure 9

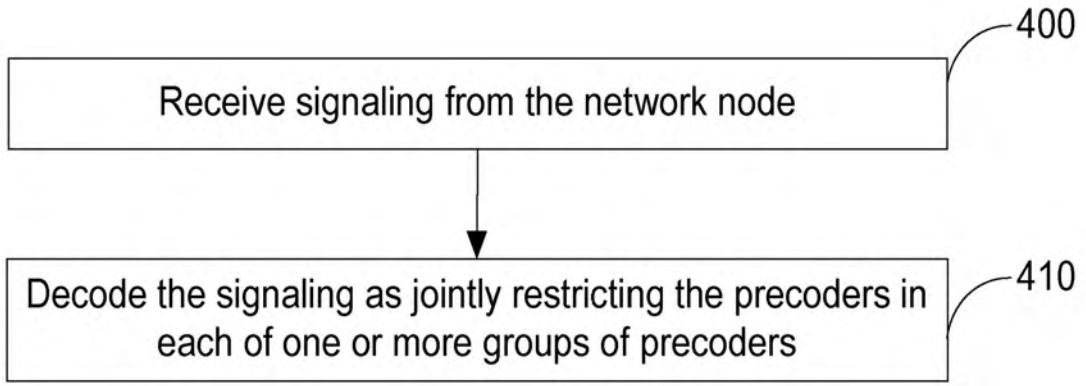
400
Receive signaling from the network node
Decode the signaling as jointly restricting the precoders in each of one or more groups of precoders
410

Figure 10

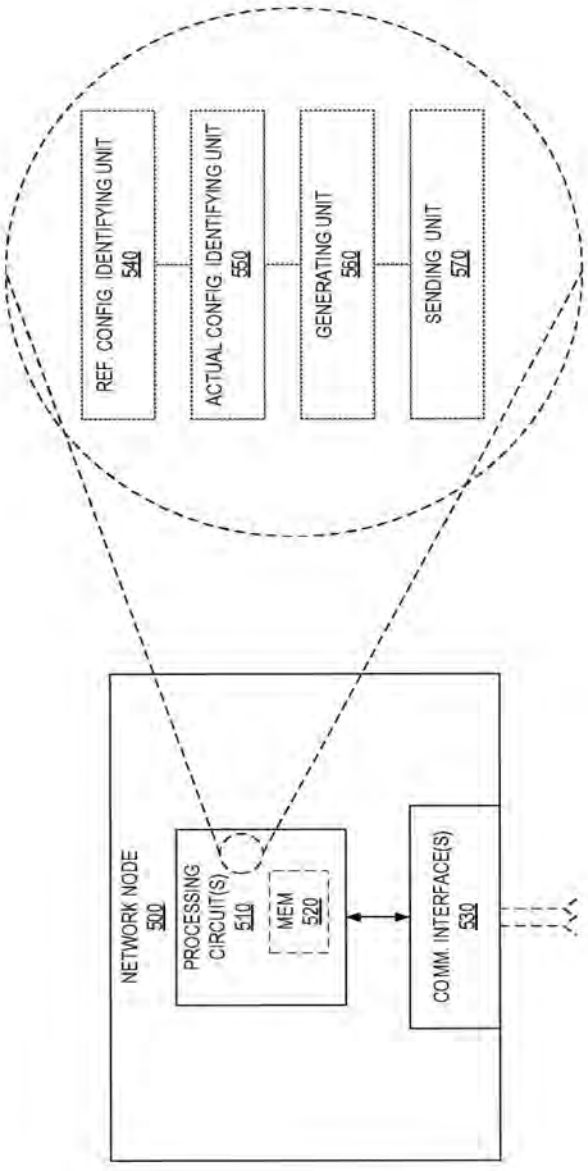
NETWORK NODE
500
PROCESSING CIRCUIT(S)
510
MEM
520
COMM. INTERFACE(S)
530
REF. CONFIG. IDENTIFYING UNIT
540
ACTUAL CONFIG. IDENTIFYING UNIT
550
GENERATING UNIT
560
SENDING UNIT
570

Figure 11

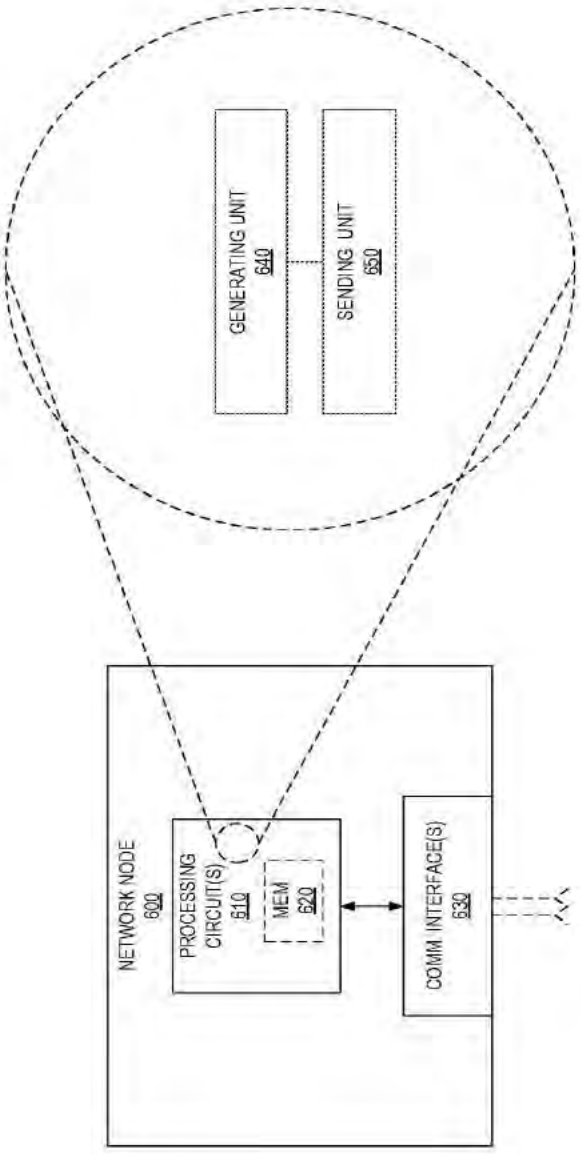
GENERATING UNIT
640
SENDING UNIT
650
NETWORK NODE
600
PROCESSING CIRCUIT(S)
610
MEM
620
COMM INTERFACE(S)
630

Figure 12

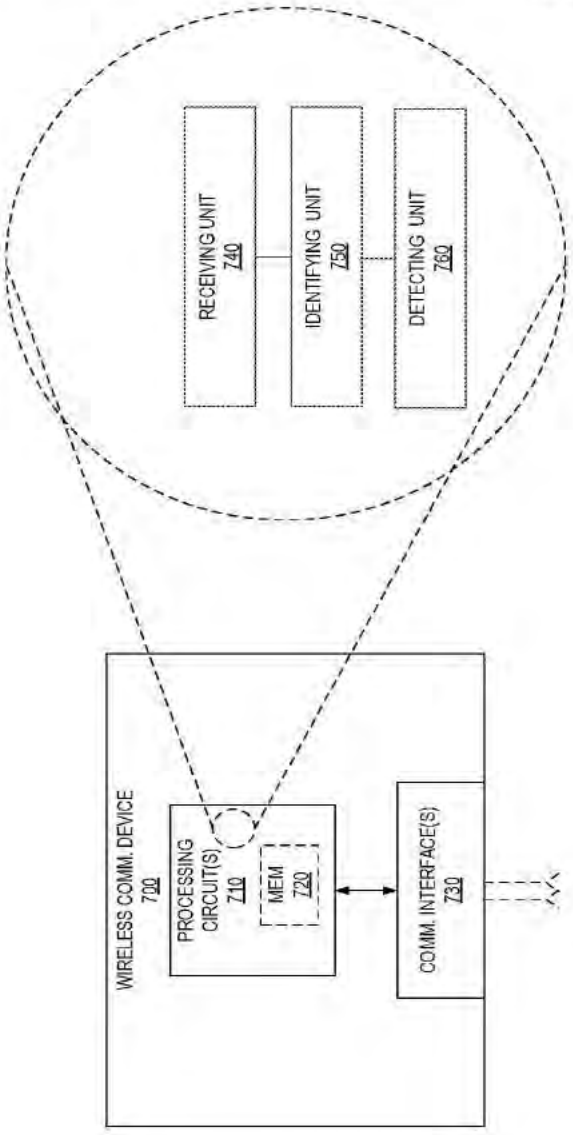
RECEIVING UNIT
740
IDENTIFYING UNIT
750
DETECTING UNIT
760
WIRELESS COMM. DEVICE
700
PROCESSING CIRCUIT(S)
710
MEM
720
COMM. INTERFACE(S)
730

Figure 13

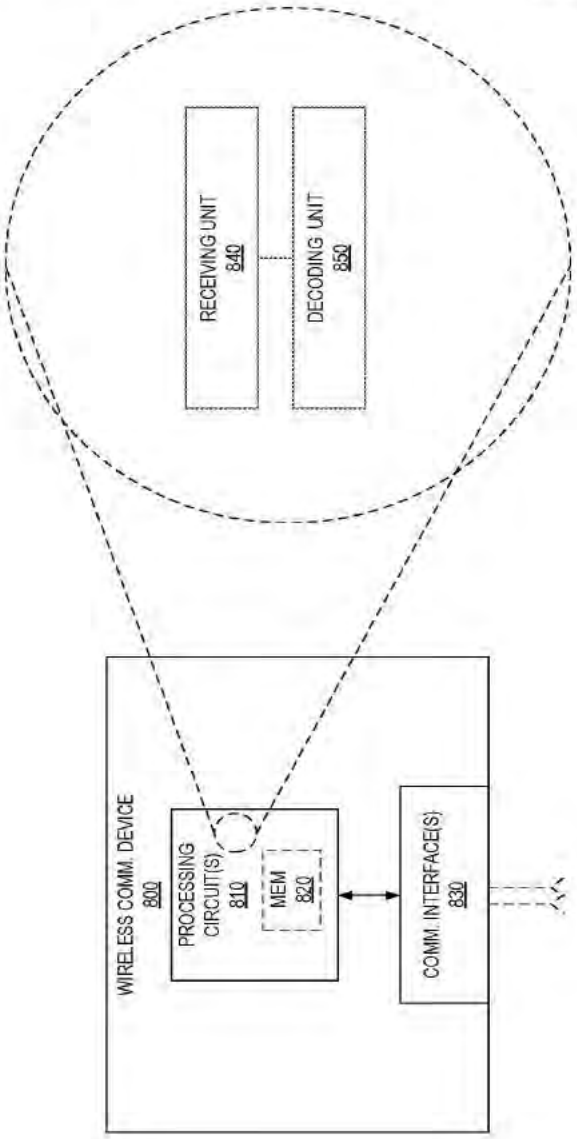
RECEIVING UNIT
840
DECODING UNIT
850
WIRELESS COMM. DEVICE
800
PROCESSING CIRCUIT(S)
810
MEM
820
COMM. INTERFACE(S)
830

Figure 14

Information on Search Strategy - Pilot phase (see OJ 2015, A86)
The type of information contained in this sheet may change during the pilot for improving the usefulness of this new service.

Application Number
PCT/SE2016/050009

TITLE:

APPLICANT: TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)

IPC CLASSIFICATION: H04B7/04, H04B7/06, H03M7/30

EXAMINER: Toumpakaris, D

CONSULTED DATABASES: WPI, TXTE, EPODOC, XP3GPP, NPL

CLASSIFICATION SYMBOLS DEFINING EXTENT OF THE SEARCH:

IPC:

CPC: H04B7/0473, H04B7/0478, H04B7/0639, H04B7/0658, H04B7/0456, H03M7/30

FI/F-TERMS:

KEYWORDS OR OTHER ELEMENTS FEATURING THE INVENTION:
group 1: A system using codebook subset restriction. Instead of individually restricting precoders using a bitmap, precoders in one or more groups are restricted using a common component. E.g. if a beamforming vector is restricted, precoders containing the vector or functions of the vector are restricted. Other common components can be individual elements. Use of the method in multi-dimensional arrays and arrays with polarized elements is also disclosed.
group 2: a method to signal codebook subset restriction. If chosen (actual) configuration is reference use some encoding. If not, send uncoded (a standard bitmap). Bit pattern indicates whether a reference or a non-reference configuration is being signalled.

EPO FORM P04A42

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference P45698WO1	**FOR FURTHER ACTION**	See Form PCT/IPEA/416
International application No. PCT/SE2016/050009	International filing date *(day/month/year)* 11.01.2016	Priority date *(day/month/year)* 14.01.2015

International Patent Classification (IPC) or national classification and IPC
INV. H04B7/04

Applicant
Telefonaktiebolaget LM Ericsson (Publ)

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 7 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *(sent to the applicant and to the International Bureau)* a total of 11 sheets, as follows:
      ☒ sheets of the description, claims and/or drawings which have been amended and/or sheets containing rectifications authorized by this Authority, unless those sheets were superseded or cancelled, and any accompanying letters (see Rules 46.5, 66.8, 70.16, 91.2, and Section 607 of the Administrative Instructions).
      ☐ sheets containing rectifications, where the decision was made by this Authority not to take them into account because they were not authorized by or notified to this Authority at the time when this Authority began to draw up this report, and any accompanying letters (Rules 66.4bis, 70.2(e), 70.16 and 91.2).
      ☐ superseded sheets and any accompanying letters, where this Authority either considers that the superseding sheets contain an amendment that goes beyond the disclosure in the international application as filed, or the superseding sheets were not accompanied by a letter indicating the basis for the amendments in the application as filed, as indicated in item 4 of Box No. I and the Supplemental Box (see Rule 70.16(b)).
   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing, in the form of an Annex C/ST.25 text file, as indicated in the Supplemental Box Relating to Sequence Listing (see paragraph 3*ter* of Annex C of the Administrative Instructions).

4. This report contains indications relating to the following items:
   - ☒ Box No. I Basis of the report
   - ☐ Box No. II Priority
   - ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - ☐ Box No. IV Lack of unity of invention
   - ☒ Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - ☐ Box No. VI Certain documents cited
   - ☒ Box No. VII Certain defects in the international application
   - ☒ Box No. VIII Certain observations on the international application

Date of submission of the demand	Date of completion of this report
14.11.2016	25.01.2017

Name and mailing address of the international preliminary examining authority:	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Fax: +49 89 2399 - 4465	Toumpakaris, D Telephone No. +49 89 2399-8983

Form PCT/IPEA/409 (cover sheet) (January 2015)

Box No. I Basis of the report

1. With regard to the **language**, this report is based on

☒ the international application in the language in which it was filed

☐ a translation of the international application into , which is the language of a translation furnished for the purposes of:
- ☐ international search (under Rules 12.3(a) and 23.1(b))
- ☐ publication of the international application (under Rule 12.4(a))
- ☐ international preliminary examination (under Rules 55.2(a) and/or 55.3(a) and (b))

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

Description, Pages

1-30 as originally filed

Claims, Numbers

1-20 filed with the letter of 28-12-2016

Drawings, Sheets

1/14-14/14 as originally filed

☐ a sequence listing - see Supplemental Box Relating to Sequence Listing.

3. ☐ The amendments have resulted in the cancellation of:
- ☐ the description, pages
- ☐ the claims, Nos.
- ☐ the drawings, sheets/figs
- ☐ the sequence listing *(specify)*:

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since either they are considered to go beyond the disclosure as filed, or they were not accompanied by a letter indicating the basis for the amendments in the application as filed, as indicated in the Supplemental Box (Rules 70.2(c) and (c-*bis*)):
- ☐ the description, pages
- ☐ the claims, Nos.
- ☐ the drawings, sheets/figs
- ☐ the sequence listing *(specify)*:

5. ☐ This report has been established:
- ☐ taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rules 66.1(d-*bis*) and 70.2(e)).
- ☐ without taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91(Rules 66.4*bis* and 70.2(e)).

6. ☒ With regard to top-up searches (Rules 66.1*ter* and 70.2(f)):
   - ☒ A top-up search was carried out by this Authority on 12.01.2017 (all discovered documents are listed in the Supplemental Box Relating to Top-up Search).
     - ☐ Additional relevant documents have been discovered during the top-up search.
   - ☐ No top-up search was carried out by this Authority because it would serve no useful purpose.

7. ☐ Supplementary international search report(s) from Authority(ies) has/have been received and taken into account in establishing this report (Rule 45bis.8(b) and (c)).

* *If item 4 applies, some or all of those sheets may be marked "superseded".*

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-20
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-20
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-20
	No:	Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

Box No. VII Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

see separate sheet

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

D1	US 2013/163687 A1 (JING MEIFANG [CN] ET AL) 27 June 2013 (2013-06-27)
D2	US 2014/016549 A1 (NOVLAN THOMAS DAVID [US] ET AL) 16 January 2014 (2014-01-16)

1.1 The document D1 is regarded as being the prior art closest to the subject-matter of claim 1, and discloses (the references in parentheses applying to this document)

A method implemented by a network node for signaling to a wireless communication device which precoders in a codebook are restricted from being used (paragraph [0022], "*setting, information to identify the respective groups in the codebooks as restricted or unrestricted, into a codebook subset restriction option of higher-layer signalling.*"), the method characterized by:

generating codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common (paragraphs [0017]-[0019], "*grouping per identical precoding matrix to take identical precoding matrixes in the codebooks as a group; grouping per same beam direction to take precoding matrixes in the same beam direction in the codebooks as a group; and grouping per precoding matrix element to take precoding matrixes with identical precoding matrix elements in the codebooks as a group.*" and paragraph [0022] as above); and

sending the generated signaling from the network node to the wireless communication device (paragraph [0024], "*transmitting the higher-layer signalling to a UE to instruct the UE to report a Precoding Matrix Indicator(s), PMI, and/or a Rank Indicator, RI(s), according to the codebook subset restriction option in the higher-layer signalling.*").

1.2 The subject-matter of claim 1 therefore differs from this known method in that claim 1 further discloses that

a) the precoders are Kronecker product precoders; and

b) the signaling is rank-agnostic so as to restrict precoders irrespective of their transmission rank.

Therefore, claim 1 is novel (Article 33(2) PCT).

1.3 This has the technical effect that codewords on specific elevation and azimuth directions can be restricted, and also that the amount of signaling can be reduced by restricting all precoders having a common component irrespective of their rank.

1.4 The problem to be solved by the present invention may therefore be regarded as how to design the precoders and how to treat precoders of each rank.

1.5 The solution to this problem proposed in claim 1 of the present application is considered to involve an inventive step (Article 33(3) PCT), for the following reasons:

Beamforming vectors that can be written as a Kronecker product of different beamforming vectors associated with different dimensions are well-established (see, e.g. paragraph [0042] of document D2). A person skilled in the art would therefore combine the teachings of document D1 with D2 and would arrive to feature a).

However, although Document D1 discloses (paragraph [0038]) that the codebooks at respective ranks can have the same or different grouping rules, the disclosed embodiments disclose grouping within each rank and there is no teaching in document D1 that would indicate restricting precoders in a rank-agnostic way, namely restrict all precoders with a common component irrespective of their rank.

Thus, a person skilled in the art would not arrive to feature b) in combination with the features disclosed in document D1 and feature a). Therefore, the subject-matter of claim 1 is also inventive (Article 33(3) PCT).

In conclusion, claim 1 meets the requirements of the PCT with respect to novelty and inventive step.

1.6 The same reasoning applies mutatis mutandis to the subject-matter of the corresponding claims 2, 13, 15, 16, 18 and 19. Therefore, notwithstanding the clarity objections in Item VIII, claims 2, 13, 15, 16, 18 and 19 also meet the requirements the PCT with respect to novelty and inventive step.

1.7 Claims 3-12, 14, 17 and 20 are dependent on claims 1, 13, 16 and 19 and as such also meet the requirements of the PCT with respect to novelty and inventive step.

Re Item VII

Certain defects in the international application

1 The application does not meet the requirements of Rule 5.1(a)(ii) PCT, because document D1 is not identified in the description and the relevant background art disclosed therein is not discussed.

Re Item VIII

Certain observations on the international application

1 The application does not meet the requirements of Article 6 PCT, because claims 3-10, 11, 13, 15, 16, 18 and 20 are not clear. In particular:

1.1 Claim 3 defines a "beam precoder". Use of the term in the claim without defining it renders the scope of protection of the claim unclear. This objection might have been overcome if "beam precoder" had been defined as e.g. in page 16 lines 13-14 of the description or as in claim 5 or 8.

1.2 The same clarity objection applies to claims 4, 9, 10 and 11.

1.3 Claim 4 defines restricting a precoder comprising one or more beam precoders if at least one of its one or more beam precoders is restricted. On the other hand, claim 1 defines restricting the precoders in one or more groups of precoders. It is therefore unclear if claim 4 defines restricting a group of precoders comprising one or more beam precoders or if it defines restricting one precoder which comprises beam precoders and which may also belong to the group. In the latter case, it appears that this is not consistent with claim 1, as claim 1 defines restricting the precoders in a group.

1.4 Claim 7 defines a beam precoder and is dependent on claim 5, which provides a different definition for a beam precoder. Therefore, claims 5, 6 and 7 are not consistent.

1.5 The same clarity objection holds for claim 8.

1.6 Claim 9 is dependent on claims 1-8 and defines signaling to indicate whether or not different beam precoders are restricted. However, a certain component being a beam precoder is defined in claim 3. This renders the scope of protection of claim 9 unclear.

1.7 The same objection applies to claim 11.

1.8 Claim 10 which defines a beam precoder and restricts codebook subset restriction depends on claim 1. However, the certain component comprising a beam precoder is defined in claim 2. This renders the scope of claim 10 unclear.

1.9 Moreover, claim 10 is not consistent with claims 7 and 8.

1.10 Although claims 13 and 15 have been drafted as separate independent claims, they appear to relate effectively to the same subject-matter and to differ from each other only with regard to the definition of the subject-matter for which protection is sought and/or in respect of the terminology used for the features of that subject-matter. The aforementioned claims therefore lack conciseness and as such do not meet the requirements of Article 6 PCT.

1.11 The same clarity objection also applies to claims 16 and 18.

1.12 Claim 20 defines a carrier containing a computer program. It is not clear how a carrier for a computer program can be a signal, as such a carrier is not disclosed in the application and it would not be obvious to the person skilled in the art how to use a computer program contained in a signal to perform the methods disclosed in the application.

ERICSSON

Date
2016-12-28
Your Date

Reference (Document No)
P45698 WO1
Your Reference

Attending to this matter
Hannes Nordmark +46107165788

Via CMS (epoline Case Management System)

European Patent Office

80298 Munich
GERMANY

Response to Written Opinion pursuant to Article 34 PCT

Application Number:	PCT/SE2016/050009
Application Date:	2016-01-11
Applicant:	Telefonaktiebolaget LM Ericsson (publ)
Our Reference:	P45698 WO1

Enclosure(s):
Claims: Substitute claims number 1-20
Marked up claim amendments for information purpose

Dear Sirs,
In response to the Written Opinion of , Applicant hereby submits the following comments and enclosed amendments pursuant to Article 34 PCT.

Amendments and Support

The claims have been amended to specify that the codebook has a Kronecker structure. Support can be found at least in on page 15 lines 19-20, describing an embodiment where the CSR signaling limits precoders which are Kronecker product precoders.

The claims have been further limited to specify that the signaling, indicating the component to be restricted, is rank-agnostic so as to restrict precoders irrespective of their transmission rank. Support can at least be found on page 15, lines 23-24.

Claims corresponding to, as defined by the examiner, group 2 has been removed.

Certain Observations on the international application

The claims are clear under Art 6 PCT because the preamble of the independent claims defines that the signaling relates to which precoders in a codebook that are restricted from being used. This is already in line with what the examiner is proposing to make the claim clear.

Novelty
The present invention is based on an insight that using a Kronecker codebook enables the use of a rank-agnostic CSR signaling which effectively reduces the number of bits required for restricting the use of precoders in a UE.

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Reg No: 556056-6258

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D1, US 20130163687 A1, discusses different ways of grouping a codebook and sets off by stating the grouping of matrixes in the codebook is done at the respective rank.

> **[0011]** grouping precoding matrixes in codebooks at respective ranks with N antenna ports respectively, where N is a natural number; and

The rest of the summery are examples for grouping at each rank, which is further emphasized in

> **[0013]** Preferably grouping the precoding matrixes in the codebooks at respective ranks respectively includes any one of:

and lastly in

> **[0020]** Particularly the codebooks at different ranks can be grouped in the same or different ways.

D1 is thus concerned with the idea of grouping per transmission rank according to different options.

D1 also silent with respect to the precoders being Kronecker product precoders.

The subject-matter of the independent claims are thus novel.

Inventive step

The subject-matter of claim 1 differs from D1 in that the precoders being Kronecker product precoders and that the signaling is rank-agnostic so as to restrict precoders irrespective of their transmission rank.

The subject-matter of claim 1 differs at least from D2 (US 20140016549 A1) in that the - for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, wherein the signaling is rank-agnostic so as to restrict precoders irrespective of their transmission rank; and

The objective technical problem starting from D2 is to reduce signaling associated with codebook subset restriction.

There is nothing in D2 either explaining or suggesting that a solution for reducing CSR is to restrict a certain component of the codebook so as to restrict the precoders irrespective of their transmission rank.

Accordingly, there is nothing that would lead a person skilled in the art to a solution falling within the scope of claim 1.

D1 teaches grouping precoders per rank and thus also fails to teach the use of a certain component of the codebook so as to restrict the precoders irrespective of their transmission rank.

A person skilled in the art would therefore not arrive at a solution falling within the scope of claim 1, and claim 1 thus involves an inventive step.

The same reasoning is applicable for the other independent claims as well.

Summary

The claims are considered to fulfill the requirements on conciseness, support by the description, novelty, and inventive step. A positive International Preliminary Examination Report is therefore expected.

Should the Examiner have any questions that may be favorably discussed over the telephone or deems further minor amendments to be needed before issuance of a positive IPRP, you are welcome to contact the case responsible patent engineer/patent attorney, Hannes Nordmark on +46107165788.

Hannes Nordmark
European Patent Attorney
Association No: 643

CLAIMS

What is claimed is:

1. A method implemented by a network node (10) for signaling to a wireless communication device (14) which precoders in a codebook are restricted from being used, the method characterized by:

generating (210) codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, and wherein the precoders are Kronecker product precoders and wherein the signaling is rank-agnostic so as to restrict precoders irrespective of their transmission rank; and

sending (220) the generated signaling from the network node (10) to the wireless communication device (14).

2. A method implemented by a wireless communication device (14) for decoding signaling from a network node (10) indicating which precoders in a codebook are restricted from being used, the method characterized by:

receiving (400) codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, and wherein the precoders are Kronecker product precoders and wherein the signaling is rank-agnostic so as to restrict precoders irrespective of their transmission rank; and

decoding (410) the received signaling as jointly restricting precoders in each of the one or more groups of precoders.

3. The method of any of claims 1-2, wherein the certain component comprises a beam precoder.

4. The method of any of claims 1-3, wherein a precoder comprising one or more beam precoders is restricted if at least one of its one or more beam precoders is restricted.

5. The method of any of claims 3-4, wherein a beam precoder is a Kronecker product of different beamforming vectors associated with different dimensions of a multi-dimensional antenna array.

Deleted: 3. The method of any of claims 1-2, wherein the codebook subset restriction signaling is rank-agnostic signaling that jointly restricts the precoders in a group without regard to the precoders' transmission rank.¶
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6. The method of claim 5, wherein the different beamforming vectors comprise Discrete Fourier Transform (DFT) vectors.

7. The method of any of claims 3-6, wherein a beam precoder is a beamforming vector used to transmit on a particular layer of a multi-layer transmission, wherein different scaled versions of that beamforming vector are transmitted on different polarizations;

8. The method of any of claims 3-6, wherein a beam precoder is a beamforming vector used to transmit on:

multiple different layers of a multi-layer transmission;

multiple different layers of a multi-layer transmission, wherein the layers are sent on orthogonal polarizations; or

a particular layer and on a particular polarization.

9. The method of any of claims 1-8, wherein the codebook subset restriction signaling comprises a bitmap, with different bits in the bitmap respectively dedicated to indicating whether or not different beam precoders are restricted from being used.

10. The method of any of claims 1-8, wherein a beam precoder is a Kronecker product of first and second beamforming vectors with first and second indices, wherein the first and second beamforming vectors are associated with different dimensions of a multi-dimensional antenna array, and wherein the codebook subset restriction signaling jointly restricts the precoders in a group of precoders that have the same pair of values for the first and second indices.

11. The method of any of claims 1-2, wherein each precoder comprises one or more beam precoders, wherein each beam precoder comprises multiple different components corresponding to different dimensions of a multi-dimensional antenna array, and wherein said certain component comprises a component of a beam precoder.

12. The method of any of claims 1-11, wherein the codebook subset restriction signaling jointly restricts the precoders in a group of precoders that transmit at least in part towards a certain angular pointing direction, by restricting a certain component which has that angular pointing direction.

13. A network node (10, 600) for signaling to a wireless communication device (14, 800) which precoders in a codebook are restricted from being used, the network node (10, 600) configured to:

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Deleted: 14. A method implemented by a network node (10) for signaling to a wireless communication device (14) which precoders in a codebook are restricted from being used, the method characterized by:¶
for each of one or more groups of precoders in the codebook,¶
identifying (110) one or more reference configurations for the group, wherein each reference configuration is one of different possible configurations that restrict different subgroups of precoders in the group from being used;¶
identifying (120), from the different possible configurations for the group, an actual configuration to be signaled for the group; and¶
generating (130) signaling to indicate the actual configuration for the group, by generating the signaling as a bit pattern whose length depends on (i) whether the actual configuration matches one of the one or more reference configurations and/or (ii) which reference configuration the actual configuration matches; and¶
sending (160) the generated signaling to the wireless communication device (14).¶
¶
15. A method implemented by a wireless communication device (14) for decoding signaling from a network node (10) indicating which precoders in a codebook are restricted from being used, the method characterized by:¶
receiving (300) signaling from the network node (10),¶
for each of one or more groups of precoders in the codebook:¶
identifying (320) one or more reference configurations for the group, wherein each reference configuration is one of different possible configurations that restrict different subgroups of precoders in the group from being used;¶
identifying (320) a bit pattern defined for signaling each reference configuration, and a length of that bit pattern; and¶
detecting (330) an actual configuration signaled for the group, by detecting in the signaling a bit pattern whose length depends on (i) whether the actual configuration matches one of the one or more reference configurations and/or (ii) which reference configuration the actual configuration matches.¶
¶
16. The method of any of claims 14-15, wherein the signaling is a short bit pattern when the actual configuration matches any one of the one or more reference configurations and is a long bit pattern when the actual configuration does not match any of the one or more reference configurations, wherein a long bit pattern has more bits than a short bit pattern.¶
¶
17. The method of claim 16, wherein the one or more reference configurations for at least one of the one or more groups comprise a single reference configuration, and wherein different long bit patterns are respectively defined for signaling different configurations other than the single reference configuration.¶

generate codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, and wherein the precoders are Kronecker product precoders and wherein the signaling is rank-agnostic so as to restrict precoders irrespective of their transmission rank; and

send the generated signaling from the network node (10, 600) to the wireless communication device (14, 800).

14. The network node of claim 13, configured to perform the method of any of claims 3-12.

15. A network node (10, 600) for signaling to a wireless communication device (14, 800) which precoders in a codebook are restricted from being used, the network node (10, 600) characterized by:

a generating module (640) for generating codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, and wherein the precoders are Kronecker product precoders and wherein the signaling is rank-agnostic so as to restrict precoders irrespective of their transmission rank; and

a sending module (650) for sending the generated signaling from the network node (10, 600) to the wireless communication device (14, 800).

16. A wireless communication device (14, 800) for decoding signaling from a network node (10, 600) indicating which precoders in a codebook are restricted from being used, the wireless communication device (14, 800) configured to:

receive codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, and wherein the precoders are Kronecker product precoders and wherein the signaling is rank-agnostic so as to restrict precoders irrespective of their transmission rank; and

decode the received signaling as jointly restricting precoders in each of the one or more groups of precoders.

17. The wireless communication device of claim 16, configured to perform the method of any of claims 3-12.

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18. A wireless communication device (14, 800) for decoding signaling from a network node (10, 600) indicating which precoders in a codebook are restricted from being used, the wireless communication device (14, 800) characterized by:

a receiving module (840) for receiving codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, and wherein the precoders are Kronecker product precoders and wherein the signaling is rank-agnostic so as to restrict precoders irrespective of their transmission rank; and

a decoding module (850) for decoding the received signaling as jointly restricting precoders in each of the one or more groups of precoders.

19. A computer program comprising instructions which, when executed by at least one processor of a node (10, 14), causes the node (10, 14) to carry out the method of any of embodiments 1-12.

20. A carrier containing the computer program of embodiment 19, wherein the carrier is one of an electronic signal, optical signal, radio signal, or computer readable storage medium.

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30. A network node (10, 500) for signaling to a wireless communication device which precoders in a codebook are restricted from being used, the network node (10, 500) configured to:¶
for each of one or more groups of precoders in the codebook:¶
identify one or more reference configurations for the group, wherein each reference configuration is one of different possible configurations that restrict different subgroups of precoders in the group from being used;¶
identify, from the different possible configurations for the group, an actual configuration to be signaled for the group; and¶
generate signaling to indicate the actual configuration for the group, by generating the signaling as a bit pattern whose length depends on (i) whether the actual configuration matches one of the one or more reference configurations and/or (ii) which reference configuration the actual configuration matches; and¶
send the generated signaling to the wireless communication device.¶
¶
31. The network node of claim 30, configured to perform the method of any of claims 16-23.¶
¶
32. A network node (10, 500) for signaling to a wireless communication device (14, 700) which precoders in a codebook are restricted from being used, the network node (10, 500) characterized by:¶
for each of one or more groups of precoders in the codebook:¶
a reference configuration identifying module (540) for identifying one or more reference configurations for the group, wherein each reference configuration is one of different possible configurations that restrict different subgroups of precoders in the group from being used;¶
an actual configuration identifying module (550) for identifying, from the different possible configurations for the group, an actual configuration to be signaled for the group; and¶
a generating module (560) for generating signaling to indicate the actual configuration for the group, by generating the signaling as a bit pattern whose length depends on (i) whether the actual configuration matches one of the one or more reference configurations and/or (ii) which reference configuration the actual configuration matches; and¶
a sending module (570) for sending the generated signaling to the wireless communication device (14, 700).¶
¶
33. The network node of claim 32, configured to perform the method of any of claims 16-23.¶
¶
34. A wireless communication device (14, 700) for decoding signaling from a network node (10, 500) indicating which precoders in a codebook are restricted from being used, the wireless communication device (14, 700) configured to:¶
receive signaling from the network node (10, 500).¶
for each of one or more groups of precoders in the codebook:¶
identify one or more reference configurations for the group, wherein each reference configuration is one of different possible configurations that restrict different subgroups of precoders in the group from being used;¶
identify a bit pattern defined for signaling each reference configuration, and a length of that bit pattern; and¶
detect an actual configuration signaled for the group, by detecting in the signaling a bit pattern whose length depends on (i) whether the actual configuration matches one of the one or more reference configurations and/or (ii) which reference configuration the actual configuration matches.¶
¶
35. The wireless communication device of claim 34, configured to perform the method of any of claims 16-23.¶
¶

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CLAIMS

What is claimed is:

1. A method implemented by a network node (10) for signaling to a wireless communication device (14) which precoders in a codebook are restricted from being used, the method characterized by:

generating (210) codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, and wherein the precoders are Kronecker product precoders and wherein the signaling is rank-agnostic so as to restrict precoders irrespective of their transmission rank; and

sending (220) the generated signaling from the network node (10) to the wireless communication device (14).

2. A method implemented by a wireless communication device (14) for decoding signaling from a network node (10) indicating which precoders in a codebook are restricted from being used, the method characterized by:

receiving (400) codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, and wherein the precoders are Kronecker product precoders and wherein the signaling is rank-agnostic so as to restrict precoders irrespective of their transmission rank; and

decoding (410) the received signaling as jointly restricting precoders in each of the one or more groups of precoders.

3. The method of any of claims 1-2, wherein the certain component comprises a beam precoder.

4. The method of any of claims 1-3, wherein a precoder comprising one or more beam precoders is restricted if at least one of its one or more beam precoders is restricted.

5. The method of any of claims 3-4, wherein a beam precoder is a Kronecker product of different beamforming vectors associated with different dimensions of a multi-dimensional antenna array.

6. The method of claim 5, wherein the different beamforming vectors comprise Discrete Fourier Transform (DFT) vectors.

7. The method of any of claims 3-6, wherein a beam precoder is a beamforming vector used to transmit on a particular layer of a multi-layer transmission, wherein different scaled versions of that beamforming vector are transmitted on different polarizations;

8. The method of any of claims 3-6, wherein a beam precoder is a beamforming vector used to transmit on:

multiple different layers of a multi-layer transmission;

multiple different layers of a multi-layer transmission, wherein the layers are sent on orthogonal polarizations; or

a particular layer and on a particular polarization.

9. The method of any of claims 1-8, wherein the codebook subset restriction signaling comprises a bitmap, with different bits in the bitmap respectively dedicated to indicating whether or not different beam precoders are restricted from being used.

10. The method of any of claims 1-8, wherein a beam precoder is a Kronecker product of first and second beamforming vectors with first and second indices, wherein the first and second beamforming vectors are associated with different dimensions of a multi-dimensional antenna array, and wherein the codebook subset restriction signaling jointly restricts the precoders in a group of precoders that have the same pair of values for the first and second indices.

11. The method of any of claims 1-2, wherein each precoder comprises one or more beam precoders, wherein each beam precoder comprises multiple different components corresponding to different dimensions of a multi-dimensional antenna array, and wherein said certain component comprises a component of a beam precoder.

12. The method of any of claims 1-11, wherein the codebook subset restriction signaling jointly restricts the precoders in a group of precoders that transmit at least in part towards a certain angular pointing direction, by restricting a certain component which has that angular pointing direction.

13. A network node (10, 600) for signaling to a wireless communication device (14, 800) which precoders in a codebook are restricted from being used, the network node (10, 600) configured to:

generate codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, and wherein the precoders are Kronecker product precoders and wherein the signaling is rank-agnostic so as to restrict precoders irrespective of their transmission rank; and

send the generated signaling from the network node (10, 600) to the wireless communication device (14, 800).

14. The network node of claim 13, configured to perform the method of any of claims 3-12.

15. A network node (10, 600) for signaling to a wireless communication device (14, 800) which precoders in a codebook are restricted from being used, the network node (10, 600) characterized by:

a generating module (640) for generating codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, and wherein the precoders are Kronecker product precoders and wherein the signaling is rank-agnostic so as to restrict precoders irrespective of their transmission rank; and

a sending module (650) for sending the generated signaling from the network node (10, 600) to the wireless communication device (14, 800).

16. A wireless communication device (14, 800) for decoding signaling from a network node (10, 600) indicating which precoders in a codebook are restricted from being used, the wireless communication device (14, 800) configured to:

receive codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, and wherein the precoders are Kronecker product precoders and wherein the signaling is rank-agnostic so as to restrict precoders irrespective of their transmission rank; and

decode the received signaling as jointly restricting precoders in each of the one or more groups of precoders.

17. The wireless communication device of claim 16, configured to perform the method of any of claims 3-12.

18. A wireless communication device (14, 800) for decoding signaling from a network node (10, 600) indicating which precoders in a codebook are restricted from being used, the wireless communication device (14, 800) characterized by:

a receiving module (840) for receiving codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, and wherein the precoders are Kronecker product precoders and wherein the signaling is rank-agnostic so as to restrict precoders irrespective of their transmission rank; and

a decoding module (850) for decoding the received signaling as jointly restricting precoders in each of the one or more groups of precoders.

19. A computer program comprising instructions which, when executed by at least one processor of a node (10, 14), causes the node (10, 14) to carry out the method of any of embodiments 1-12.

20. A carrier containing the computer program of embodiment 19, wherein the carrier is one of an electronic signal, optical signal, radio signal, or computer readable storage medium.

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(Not for submission under 37 CFR 1.99)

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First Named Inventor	Faxér
Art Unit	
Examiner Name	
Attorney Docket Number	4015-9595 / P45698-US2

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	2	20140016549	A1	2014-01-16	Novlan et al.	
	3	20130229980	A1	2013-09-05	Wernersson et al.	
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	Filing Date	2016-06-17
	First Named Inventor	Faxér
	Art Unit	
	Examiner Name	
	Attorney Docket Number	4015-9595 / P45698-US2

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That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

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See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Justin J. Leonard, Reg. No. 60986/	Date (YYYY-MM-DD)	2016-08-02
Name/Print	Justin Leonard	Registration Number	60986

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5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

CHAPTER 3

ASYMPTOTIC EQUIPARTITION PROPERTY

In information theory, the analog of the law of large numbers is the asymptotic equipartition property (AEP). It is a direct consequence of the weak law of large numbers. The *law of large numbers* states that for independent, identically distributed (i.i.d.) random variables, $\frac{1}{n}\sum_{i=1}^{n} X_i$ is close to its expected value EX for large values of n. The AEP states that $\frac{1}{n}\log\frac{1}{p(X_1,X_2,\ldots,X_n)}$ is close to the entropy H, where $X_1, X_2, \ldots, X_n$ are i.i.d. random variables and $p(X_1, X_2, \ldots, X_n)$ is the probability of observing the sequence $X_1, X_2, \ldots, X_n$. Thus, the probability $p(X_1, X_2, \ldots, X_n)$ assigned to an observed sequence will be close to 2^{-nH}.

This enables us to divide the set of all sequences into two sets, the *typical set*, where the sample entropy is close to the true entropy, and the nontypical set, which contains the other sequences. Most of our attention will be on the typical sequences. Any property that is proved for the typical sequences will then be true with high probability and will determine the average behavior of a large sample.

First, an example. Let the random variable $X \in \{0, 1\}$ have a probability mass function defined by $p(1) = p$ and $p(0) = q$. If $X_1, X_2, \ldots, X_n$ are i.i.d. according to $p(x)$, the probability of a sequence $x_1, x_2, \ldots, x_n$ is $\prod_{i=1}^{n} p(x_i)$. For example, the probability of the sequence $(1, 0, 1, 1, 0, 1)$ is $p^{\sum x_i} q^{n-\sum x_i} = p^4 q^2$. Clearly, it is not true that all 2^n sequences of length n have the same probability.

However, we might be able to predict the probability of the sequence that we actually observe. We ask for the probability $p(X_1, X_2, \ldots, X_n)$ of the outcomes $X_1, X_2, \ldots, X_n$, where $X_1, X_2, \ldots$ are i.i.d. $\sim p(x)$. This is insidiously self-referential, but well defined nonetheless. Apparently, we are asking for the probability of an event drawn according to the same

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probability distribution. Here it turns out that $p(X_1, X_2, \ldots, X_n)$ is close to 2^{-nH} with high probability.

We summarize this by saying, "Almost all events are almost equally surprising." This is a way of saying that

$$\Pr\left\{(X_1, X_2, \ldots, X_n) : p(X_1, X_2, \ldots, X_n) = 2^{-n(H \pm \epsilon)}\right\} \approx 1 \qquad (3.1)$$

if $X_1, X_2, \ldots, X_n$ are i.i.d. $\sim p(x)$.

In the example just given, where $p(X_1, X_2, \ldots, X_n) = p^{\sum X_i} q^{n - \sum X_i}$, we are simply saying that the number of 1's in the sequence is close to np (with high probability), and all such sequences have (roughly) the same probability $2^{-nH(p)}$. We use the idea of convergence in probability, defined as follows:

Definition (*Convergence of random variables*). Given a sequence of random variables, $X_1, X_2, \ldots$, we say that the sequence $X_1, X_2, \ldots$ converges to a random variable X:

1. *In probability* if for every $\epsilon > 0$, $\Pr\{|X_n - X| > \epsilon\} \to 0$
2. *In mean square* if $E(X_n - X)^2 \to 0$
3. *With probability 1* (also called *almost surely*) if $\Pr\{\lim_{n\to\infty} X_n = X\} = 1$

3.1 ASYMPTOTIC EQUIPARTITION PROPERTY THEOREM

The asymptotic equipartition property is formalized in the following theorem.

Theorem 3.1.1 (*AEP*) *If $X_1, X_2, \ldots$ are i.i.d. $\sim p(x)$, then*

$$-\frac{1}{n} \log p(X_1, X_2, \ldots, X_n) \to H(X) \qquad \text{in probability.} \qquad (3.2)$$

Proof: Functions of independent random variables are also independent random variables. Thus, since the X_i are i.i.d., so are $\log p(X_i)$. Hence, by the weak law of large numbers,

$$-\frac{1}{n} \log p(X_1, X_2, \ldots, X_n) = -\frac{1}{n} \sum_i \log p(X_i) \qquad (3.3)$$

$$\to -E \log p(X) \qquad \text{in probability} \qquad (3.4)$$

$$= H(X), \qquad (3.5)$$

which proves the theorem. □

Definition The *typical set* $A_\epsilon^{(n)}$ with respect to $p(x)$ is the set of sequences $(x_1, x_2, \ldots, x_n) \in \mathcal{X}^n$ with the property

$$2^{-n(H(X)+\epsilon)} \leq p(x_1, x_2, \ldots, x_n) \leq 2^{-n(H(X)-\epsilon)}. \tag{3.6}$$

As a consequence of the AEP, we can show that the set $A_\epsilon^{(n)}$ has the following properties:

Theorem 3.1.2

1. *If* $(x_1, x_2, \ldots, x_n) \in A_\epsilon^{(n)}$, *then* $H(X) - \epsilon \leq -\frac{1}{n} \log p(x_1, x_2, \ldots, x_n) \leq H(X) + \epsilon$.
2. $\Pr\{A_\epsilon^{(n)}\} > 1 - \epsilon$ *for n sufficiently large.*
3. $|A_\epsilon^{(n)}| \leq 2^{n(H(X)+\epsilon)}$, *where* $|A|$ *denotes the number of elements in the set* A.
4. $|A_\epsilon^{(n)}| \geq (1-\epsilon)2^{n(H(X)-\epsilon)}$ *for n sufficiently large.*

Thus, the typical set has probability nearly 1, all elements of the typical set are nearly equiprobable, and the number of elements in the typical set is nearly 2^{nH}.

Proof: The proof of property (1) is immediate from the definition of $A_\epsilon^{(n)}$. The second property follows directly from Theorem 3.1.1, since the probability of the event $(X_1, X_2, \ldots, X_n) \in A_\epsilon^{(n)}$ tends to 1 as $n \to \infty$. Thus, for any $\delta > 0$, there exists an n_0 such that for all $n \geq n_0$, we have

$$\Pr\left\{\left|-\frac{1}{n} \log p(X_1, X_2, \ldots, X_n) - H(X)\right| < \epsilon\right\} > 1 - \delta. \tag{3.7}$$

Setting $\delta = \epsilon$, we obtain the second part of the theorem. The identification of $\delta = \epsilon$ will conveniently simplify notation later.

To prove property (3), we write

$$1 = \sum_{x \in \mathcal{X}^n} p(\mathbf{x}) \tag{3.8}$$

$$\geq \sum_{x \in A_\epsilon^{(n)}} p(\mathbf{x}) \tag{3.9}$$

$$\geq \sum_{x \in A_\epsilon^{(n)}} 2^{-n(H(X)+\epsilon)} \tag{3.10}$$

$$= 2^{-n(H(X)+\epsilon)} |A_\epsilon^{(n)}|, \tag{3.11}$$

where the second inequality follows from (3.6). Hence

$$|A_\epsilon^{(n)}| \leq 2^{n(H(X)+\epsilon)} \tag{3.12}$$

Finally, for sufficiently large n, $\Pr\{A_\epsilon^{(n)}\} > 1 - \epsilon$, so that

$$1 - \epsilon < \Pr\{A_\epsilon^{(n)}\} \tag{3.13}$$

$$\leq \sum_{x \in A_\epsilon^{(n)}} 2^{-n(H(X)-\epsilon)} \tag{3.14}$$

$$= 2^{-n(H(X)-\epsilon)} |A_\epsilon^{(n)}|, \tag{3.15}$$

where the second inequality follows from (3.6). Hence,

$$|A_\epsilon^{(n)}| \geq (1 - \epsilon) 2^{n(H(X)-\epsilon)}, \tag{3.16}$$

which completes the proof of the properties of $A_\epsilon^{(n)}$. □

3.2 CONSEQUENCES OF THE AEP: DATA COMPRESSION

Let $X_1, X_2, \ldots, X_n$ be independent, identically distributed random variables drawn from the probability mass function $p(x)$. We wish to find short descriptions for such sequences of random variables. We divide all sequences in $\mathcal{X}^n$ into two sets: the typical set $A_\epsilon^{(n)}$ and its complement, as shown in Figure 3.1.

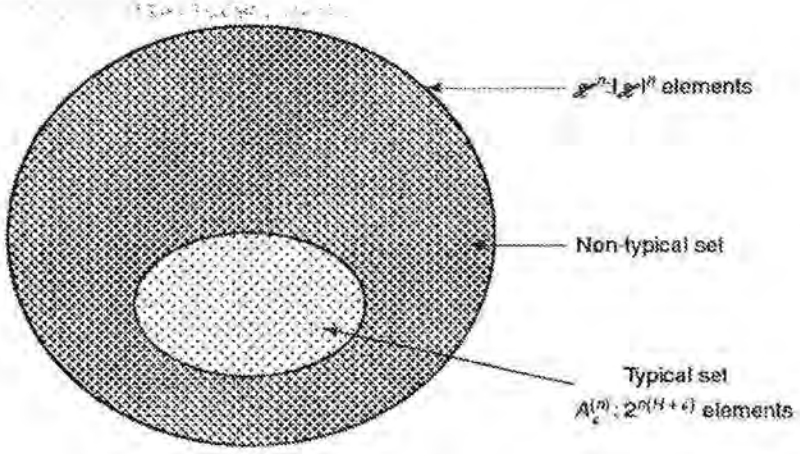

FIGURE 3.1. Typical sets and source coding.

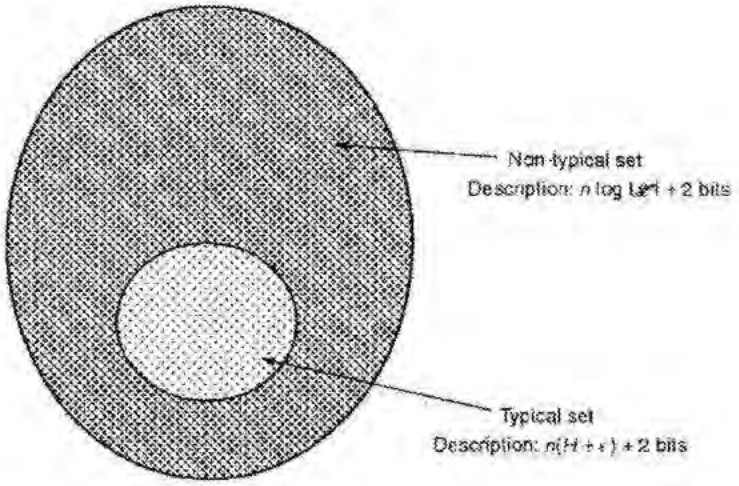

FIGURE 3.2. Source code using the typical set.

We order all elements in each set according to some order (e.g., lexicographic order). Then we can represent each sequence of $A_\epsilon^{(n)}$ by giving the index of the sequence in the set. Since there are $\leq 2^{n(H+\epsilon)}$ sequences in $A_\epsilon^{(n)}$, the indexing requires no more than $n(H+\epsilon)+1$ bits. [The extra bit may be necessary because $n(H+\epsilon)$ may not be an integer.] We prefix all these sequences by a 0, giving a total length of $\leq n(H+\epsilon)+2$ bits to represent each sequence in $A_\epsilon^{(n)}$ (see Figure 3.2). Similarly, we can index each sequence not in $A_\epsilon^{(n)}$ by using not more than $n \log |\mathcal{X}| + 1$ bits. Prefixing these indices by 1, we have a code for all the sequences in $\mathcal{X}^n$.

Note the following features of the above coding scheme:

- The code is one-to-one and easily decodable. The initial bit acts as a flag bit to indicate the length of the codeword that follows.
- We have used a brute-force enumeration of the atypical set $A_\epsilon^{(n)c}$ without taking into account the fact that the number of elements in $A_\epsilon^{(n)c}$ is less than the number of elements in $\mathcal{X}^n$. Surprisingly, this is good enough to yield an efficient description.
- The typical sequences have short descriptions of length $\approx nH$.

We use the notation x^n to denote a sequence $x_1, x_2, \ldots, x_n$. Let $l(x^n)$ be the length of the codeword corresponding to x^n. If n is sufficiently large so that $\Pr\{A_\epsilon^{(n)}\} \geq 1-\epsilon$, the expected length of the codeword is

$$E(l(X^n)) = \sum_{x^n} p(x^n) l(x^n) \tag{3.17}$$

$$= \sum_{x^n \in A_\epsilon^{(n)}} p(x^n) l(x^n) + \sum_{x^n \in A_\epsilon^{(n)c}} p(x^n) l(x^n) \tag{3.18}$$

$$\leq \sum_{x^n \in A_\epsilon^{(n)}} p(x^n)(n(H+\epsilon)+2) + \sum_{x^n \in A_\epsilon^{(n)c}} p(x^n)(n \log |\mathcal{X}| + 2) \tag{3.19}$$

$$= \Pr\left\{A_\epsilon^{(n)}\right\}(n(H+\epsilon)+2) + \Pr\left\{A_\epsilon^{(n)c}\right\}(n \log |\mathcal{X}| + 2) \tag{3.20}$$

$$\leq n(H+\epsilon) + \epsilon n(\log |\mathcal{X}|) + 2 \tag{3.21}$$

$$= n(H+\epsilon'), \tag{3.22}$$

where $\epsilon' = \epsilon + \epsilon \log |\mathcal{X}| + \frac{2}{n}$ can be made arbitrarily small by an appropriate choice of ϵ followed by an appropriate choice of n. Hence we have proved the following theorem.

Theorem 3.2.1 *Let X^n be i.i.d. $\sim p(x)$. Let $\epsilon > 0$. Then there exists a code that maps sequences x^n of length n into binary strings such that the mapping is one-to-one (and therefore invertible) and*

$$E\left[\frac{1}{n} l(X^n)\right] \leq H(X) + \epsilon \tag{3.23}$$

for n sufficiently large.

Thus, we can represent sequences X^n using $nH(X)$ bits on the average.

3.3 HIGH-PROBABILITY SETS AND THE TYPICAL SET

From the definition of $A_\epsilon^{(n)}$, it is clear that $A_\epsilon^{(n)}$ is a fairly small set that contains most of the probability. But from the definition, it is not clear whether it is the smallest such set. We will prove that the typical set has essentially the same number of elements as the smallest set, to first order in the exponent.

Definition For each $n = 1, 2, \ldots$, let $B_\delta^{(n)} \subset \mathcal{X}^n$ be the smallest set with

$$\Pr\{B_\delta^{(n)}\} \geq 1 - \delta. \tag{3.24}$$

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Abstract

With the widening gap between processor and memory speeds, memory system designers may find cache compression beneficial to increase cache capacity and reduce off-chip bandwidth. Most hardware compression algorithms fall into the dictionary-based category, which depend on building a dictionary and using its entries to encode repeated data values. Such algorithms are effective in compressing large data blocks and files. Cache lines, however, are typically short (32-256 bytes), and a per-line dictionary places a significant overhead that limits the compressibility and increases decompression latency of such algorithms. For such short lines, significance-based compression is an appealing alternative.

We propose and evaluate a simple significance-based compression scheme that has a low compression and decompression overhead. This scheme, Frequent Pattern Compression (FPC) compresses individual cache lines on a word-by-word basis by storing common word patterns in a compressed format accompanied with an appropriate prefix. For a 64-byte cache line, compression can be completed in three cycles and decompression in five cycles, assuming 12 FO4 gate delays per cycle. We propose a compressed cache design in which data is stored in a compressed form in the L2 caches, but are uncompressed in the L1 caches. L2 cache lines are compressed to predetermined sizes that never exceed their original size to reduce decompression overhead. This simple scheme provides comparable compression ratios to more complex schemes that have higher cache hit latencies.

1 Introduction

As semiconductor technology continues to improve, the rising disparity between processor and memory speed increasingly dominates performance. Modern processors use two or more levels of cache memories to reduce effective memory latency and bandwidth. Effectively using the limited on-chip cache resources becomes increasingly important as memory latencies continue to increase relative to processor speeds. Cache compression has previously been proposed to improve performance, since compressing data stored in on-chip caches increases their effective capacity, potentially reducing misses.

Most previous proposals in hardware cache or memory compression (Section 2) are hardware implementations of dictionary-based software compression algorithms (e.g., LZ77 [32]). Such hardware dictionary-based schemes depend mainly on maintaining a per-block dictionary and encoding words (or bytes) that match in the dictionary, while keeping words (bytes) that do not match in their original form with an appropriate prefix.

Schemes such as the Block-Referential Compression with Lookahead (BRCL) used in the IBM MXT memory compression depend on having long enough lines / pages to increase the overall compression ratio [14]. BRCL provides a

good compression ratio for 1K-byte or longer blocks. However, cache lines are typically much shorter and BRCL does not perform as well for shorter lines. In addition, decompression latency is high, since the parallel implementation of BRCL decompresses data at a speed of 8 bytes per cycle [26], or 8 cycles for a 64-byte cache line. The X-Match compression scheme [18] tries to compress more data with a small dictionary by allowing partial matches of data words to dictionary entries. Frequent-value cache designs [29, 31] achieve better compression for cache lines by constructing a single dictionary (the Frequent-Value Cache, FVC) for the whole cache, which increases the chance of a single word to be found and compressed. These designs are based on the observation that a few cache values are frequent and thus can be compressed to a fewer number of bits. However, a large FVC requires an increased decompression latency due to the increased FVC access time.

Significance-based compression is based on the observation that most data types (e.g., 32-bit integers) can be stored in a fewer number of bits than the maximum allowed. For example, sign-bit extension is a commonly implemented technique to store small integers (e.g., 8-bit) into 32-bit words, while all the information in the word is stored in the least-significant few bits. In contrast with dictionary-based compression schemes, significance-based compression [9, 11, 12] does not incur a per-line dictionary overhead, which makes it more suitable for the typically-short cache lines. In addition, compression and decompression hardware is faster than dictionary-based encoding and decoding. However, compressibility can be significantly impaired for long cache lines.

In this document, we propose a significance-based compression scheme that provides reasonable compressibility for the typically short cache lines with a relatively fast hardware compression and decompression (Section 3). This scheme, the Frequent Pattern Compression (FPC) compresses a cache line on a word-by-word basis. For each word, FPC detects whether it falls into one of the patterns that can be stored in a smaller number of bits, and stores it in a compressed form with an appropriate prefix. We discuss the implementation of a hardware decompression pipeline that decompresses a 64-byte cache line in five cycles (Section 4). We evaluate this scheme and compare it with other hardware compression schemes in Section 5.

2 Related Work

Several researchers used hardware-based compression to increase effective memory size, reduce memory address and data bandwidth, and increase effective cache size.

IBM's Memory Compression. IBM's MXT technology [26] employs real-time main-memory content compression that can be used to effectively double the main memory capacity without a significant added cost. It was first implemented in the Pinnacle chip [25], a single-chip memory controller. Franaszek, et al. [13], described the design of a compressed random access memory (C-RAM), which formed the basis for the memory organization for the MXT technology, and studied the optimal line size for such an organization. Data in main memory is compressed using a hardware parallelized derivative of the Lempel-Ziv (LZ77) sequential algorithm [32]. This parallel algorithm, Parallel Block-Referential Compression with Directory Sharing, divides the input data block (1 KB in MXT) into sub-blocks (four 256-byte sub-blocks), and cooperatively constructs dictionaries while compressing all sub-blocks in parallel [14]. MXT is shown to have a negligible performance penalty compared to standard memory, and memory contents for many applications and web servers can be compressed by a factor of two to one [1].

Other Hardware Memory Compression Designs. Kjelso, et al. [18], demonstrated that hardware main memory compression is feasible and worthwhile. They used the X-Match hardware compression algorithm that maintains a dictionary and replaces each input data element (whose size is fixed at four bytes) with a shorter code in case of a total or partial match with a dictionary entry. Communication bandwidth is reduced by "compacting" cache-to-memory address streams [12] or data streams [11]. Benini, et al. [8], propose a data compression/decompression scheme to reduce memory traffic in general purpose processor systems. Data is stored uncompressed in the cache, and compressed on the fly when transferred to memory. Memory-to-cache traffic is also decompressed on the fly. They used a differential compression scheme described in [7] that is based on the assumption that it is likely for data words in the same cache line to have some bits in common. Zhang and Gupta [30] introduce a class of common-prefix and narrow-data transformations for general-purpose programs that compress 32-bit addresses and integer words into 15-bit entities. They implemented these transformations by augmenting six data compression extension (DCX) instructions to the MIPS instruction set.

Cache Compression and Related Designs. Lee, et al. [21, 19, 20], propose a compressed memory hierarchy model that selectively compresses L2 cache and memory blocks if they can be reduced to half their original size. Their selective compressed memory system (SCMS) use a hardware implementation of the X-RL compression algorithm [18], a variant of the X-Match algorithm that gives a special treatment for runs of zeros. They propose several techniques to hide decompression overhead, including parallel decompression, selective adaptive compression for blocks that can be compressed to below a certain threshold, and the use of a decompression buffer to be accessed on L1 misses in parallel with L2 access. Ahn, et al. [2], propose several improvements on the X-RL technique that capture common values. Chen, et al. [10], propose a scheme that dynamically partitions the cache into sections of different compressibility, and they use a variant of the LZ compression algorithm. Pomerene, et al. [22], used a shadow directory scheme with more address tags than data blocks to improve upon LRU replacement.

Frequent-Value-Based Compression. Yang and Gupta [28] found out from an analysis of the SPECint95 benchmarks that a small number of distinct values occupy a large fraction of memory access values. This value locality phenomenon enabled them to design energy-efficient caches [27] and data compressed caches [29]. In their compressed cache design, each line in the L1 cache can be either one uncompressed line or two lines compressed to at least half their original sizes based on frequent values [29]. Zhang, et al., designed a value-centric data cache design called the frequent value cache (FVC) [31], which is a small direct-mapped cache dedicated to holding frequent benchmark values. They showed that augmenting a direct mapped cache with a small frequent value cache can greatly reduce the cache miss rate.

Significance-Based Compression. Farrens and Park [12] make use of the fact that many address references transferred between processor and memory have redundant information in their high-order (most significant) portions. They cached these high order bits in a group of dynamically allocated base registers and only transferred small register indexes rather than the high-order address bits between the processor and memory. Citron and Rudolph [11] store common high-order bits in address and data words in a table and transfer only an index plus the low order bits between the processor and memory. Canal, et al. [9], proposed a scheme that compresses data, addresses and instruc-

tions into their significant bytes while maintaining a two or three extension bits to maintain significant byte positions. They use this method to reduce dynamic power consumption in a processor pipeline. Kant and Iyer [16] studied the compressibility properties of address and data transfers in commercial workloads, and report that the high-order bits can be predicted with high accuracy in address transfers but with less accuracy for data transfers.

3 Frequent Pattern Compression (FPC)

We propose a compression scheme that builds on significance-based compression schemes [9, 11, 12]. It is also based on the observation that some data patterns are frequent and also compressible to a fewer number of bits. For example, many small-value integers can be stored in 4, 8 or 16 bits, but are normally stored in a full 32-bit word (or 64-bits for 64-bit architectures). These values are frequent enough to merit special treatment, and storing them in a more compact form can increase the cache capacity. In addition, special treatment is also given to runs of zeros since they are very frequent, which is similar to the special treatment in X-RL [18]. The insight behind FPC is that we want to get most of the benefits of dictionary-based schemes, while keeping the per-line overhead at a minimum.

The Frequent Pattern Compression (FPC) compresses / decompresses on a cache line basis. Each cache line is divided into 32-bit words (e.g., 16 words for a 64-byte line). Each 32-bit word is encoded as a 3-bit prefix plus data. Table 1 shows the different patterns corresponding to each prefix.

Each word in the cache line is encoded into a compressed format if it matches any of the patterns in the first six rows of Table 1. These patterns are: a zero run (one or more all-zero words), 4-bit sign-extended (including one-word zero runs), one byte sign-extended, one halfword sign-extended, one halfword padded with a zero halfword, two byte-sign-extended halfwords, and a word consisting of repeated bytes (e.g. "0x20202020", or similar patterns that can be used for data initialization). These patterns are selected based on their high frequency in many of our integer and commercial benchmarks. A word that doesn't match any of these categories is stored in its original 32-bit format. All prefix values as well as the zero-run length data bits are stored at the beginning of the line to speed up decompression.

3.1 Segmented Frequent Pattern Compression (S-FPC)

To exploit compression, the L2 cache must be able to pack more compressed cache lines than uncompressed lines into the same space. One approach is to decouple the cache access, adding a level of indirection between the address

Table 1. Frequent Pattern Encoding

Prefix	Pattern Encoded	Data Size
000	Zero Run	3 bits (for runs up to 8 zeros)
001	4-bit sign-extended	4 bits
010	One byte sign-extended	8 bits
011	halfword sign-extended	16 bits
100	halfword padded with a zero halfword	The nonzero halfword (16 bits)
101	Two halfwords, each a byte sign-extended	The two bytes (16 bits)
110	word consisting of repeated bytes	8 bits
111	Uncompressed word	Original Word (32 bits)

tag and the data storage. Seznec's decoupled sector cache does this on a per-set basis to improve the utilization of sector (or sub-block) caches [23]. Hallnor and Reinhardt's Indirect-Index Cache (IIC) does this across the whole cache, allowing fully-associative placement and a software managed replacement policy [15]. Lee, et al.'s selective compressed caches use this technique to allow two compressed cache blocks to occupy the space required for one uncompressed block [21, 19, 20]. Decoupled access is simpler if we serially access the cache tags before the data. Fortunately, this is increasingly necessary to limit power dissipation [17].

In theory, a cache line can be compressed into any number of bits. This can be achieved in a completely decoupled design across the whole cache (e.g., IIC). However, such design adds more complexity to cache management. In our compressed cache design, the decoupled variable segment cache [5], each cache line is stored as a group of one or more 8-byte *segments*. For example, a 64-byte line can be stored in 1-8 segments. A compressed line is padded with zeros till its size becomes a multiple of the segment size, and these extra zeros (that do not correspond to any tags) are ignored during decompression. While this approach doesn't permit high compression ratios for some cache lines (e.g., all zero lines), it allows for a more practical and faster implementation of cache accesses.

4 Compression and Decompression

We propose a compressed cache design in which data is stored uncompressed in the level-1 caches and compressed in the level-2 caches [5]. This helps reduce many of the costly L2 cache misses that hinder performance, while not affecting the common case of an L1 hit. However, such a design adds the overhead of compressing or decompressing cache lines when moved between the two levels. FPC allows a relatively fast implementations of both of these functions.

Compression. Cache line compression occurs when data is written back from the L1 to the L2 cache. A cache line is compressed easily using a simple circuit that checks each word (in parallel) for pattern matches. If a word matches any of the seven compressible patterns, a simple encoder circuit is used to encode the word into its most compact form. If no match was found, the whole word is stored with the prefix '111'. This can be performed in one cycle, assuming 12 FO4 delays. For zero runs, we need to detect such runs of consecutive zeros, and increment the data value of the first occurrence to represent their count. Since zero runs are limited in our design to eight zeros, this can be implemented in a single cycle using a simple multiplexer/adder circuit.

Cache line compression can be implemented in a memory pipeline, by allocating three pipeline stages on the L1-to-L2 write path (one for pattern matching, one for zero run encoding, and one for gathering the compressed line). A small victim cache that contains a few entries in both compressed and uncompressed form can be used to hide the compression latency on L1 writebacks.

Decompression. Cache line decompression occurs when data is read from the L2 to the L1 caches. This is a frequent event for most benchmarks whose working sets do not fit in the L1 cache. Decompression latency is critical since it is directly added to the L2 hit latency. Decompression is a slower process than compression, since prefixes for all words in the line have to be accessed in series, because each prefix is used to determine the length of its corresponding encoded word and therefore the starting location of all the subsequent compressed words. Figure 1 presents a sche-

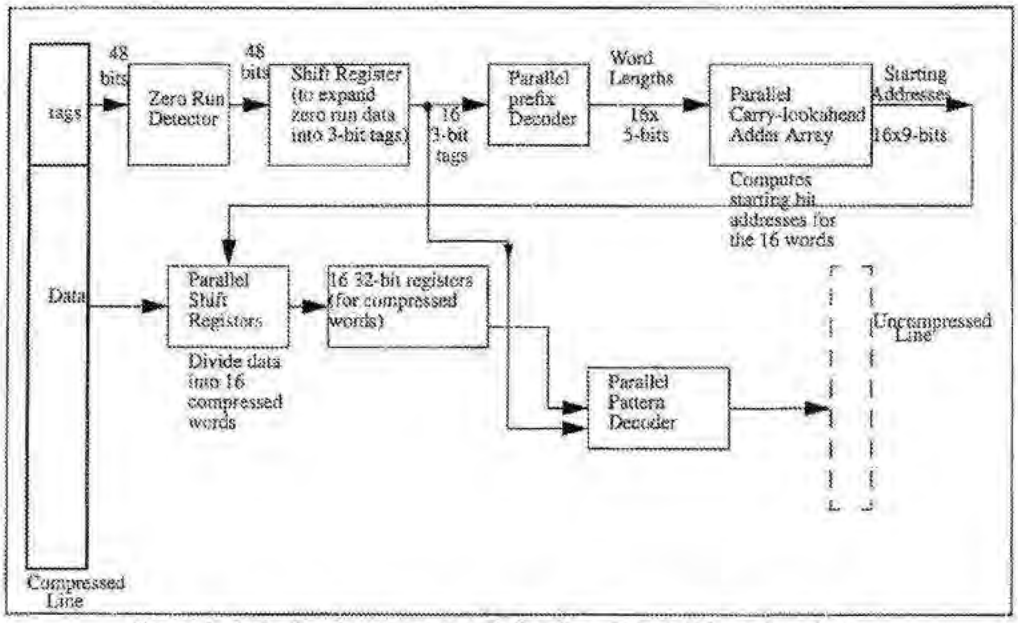

Figure 1. Cache line decompression pipeline for a 64-byte (16-word) cache line.

This is a five-stage pipeline used to decompress a compressed cache line, where each stage contains 12 FO4 gate delays or less. The first pipeline stage (containing the zero run detector, shift register and parallel prefix decoder) decodes the prefix array to determine the length in bits of each word. The second and third stages (Parallel Prefix adder array) compute the starting bit address for each data word by adding the length fields of the preceding words in a hierarchical fashion. The fourth stage (parallel shift registers) contains 16 registers each of which is shifted by the starting address of its word. The fifth and last stage contains the pattern decoder, which decodes the content of each 32-bit register into an uncompressed word according to its corresponding prefix.

matic diagram for a five-stage hardware pipeline that can be used to decompress 64-byte cache lines. Each pipeline stage is 12 FO4 delays or less, assuming the parallel resources required are available for the parallel adder, shift register and pattern decoder. Assuming one processor cycle requires 12 FO4 gate delays, this means that the decompression latency is limited to 5 processor cycles.

5 Evaluation

We evaluate our FPC scheme in terms of its achieved compressibility compared to other compression schemes. We show compression results for our frequent patterns, and demonstrate that zero runs are the most frequent. We also analyze the performance of segmented compression, and the effect of restricting compressed lines to segment boundaries on compression ratios.

5.1 Workloads

To evaluate our design against alternative schemes, we used several multi-threaded commercial workloads from the Wisconsin Commercial Workload Suite [3]. We also used six of the SPEC [24] benchmarks, three from the integer suite (SPECint2000) and three from the floating point suite (SPECfp2000). All of these workloads run under the

Table 2. Workload Descriptions

Online Transaction Processing (OLTP): DB2 with a TPC-C-like workload. The TPC-C benchmark models the database activity of a wholesale supplier, with many concurrent users performing transactions. Our OLTP workload is based on the TPC-C v3.0 benchmark using IBM's DB2 v7.2 EEE database management system. We use a 5 GB database with 25,000 warehouses stored on eight raw disks and an additional dedicated database log disk. We reduced the number of districts per warehouse, items per warehouse, and customers per district to allow more concurrency provided by a larger number of warehouses. There are 16 simulated users, and the database is warmed up for 100,000 transactions.
Java Server Workload: SPECjbb. SPECjbb2000 is a server-side java benchmark that models a 3-tier system, focusing on the middleware server business logic. We use Sun's HotSpot 1.4.0 Server JVM. Our experiments use two threads and two warehouses, a data size of ~44 MB, and a warmup interval of 200,000 transactions.
Static Web Serving: Apache. We use Apache 2.0.43 for SPARC/Solaris 9, configured to use pthread locks and minimal logging as the web server. We use SURGE [6] to generate web requests. We use a repository of 20,000 files (totalling ~500 MB), and disable Apache logging for high performance. We simulate 400 clients each with 25 ms think time between requests, and warm up for 50,000 requests.
Static Web Serving: Zeus. Zeus is another static web serving workload driven by SURGE. Zeus uses an event-driving server model. Each processor of the system is bound by a Zeus process, which is waiting for web serving event (e.g., open socket, read file, send file, close socket, etc.). The rest of the configuration is the same as Apache (20,000 files of ~500 MB total size, 400 clients, 25 ms think time, 50,000 requests for warmup).
SPEC. We use three integer benchmarks (bzip, gcc, and mcf) and three floating point benchmarks (applu, equake, and swim) from the SPECcpu2000 set to cover a wide range of compressibility properties and working set sizes. We use the first reference input for each benchmark. We warm up caches of each benchmark run for 1 billion instructions.

Solaris 9 operating system. These workloads are briefly described in Table 2. For each data point in our results, we present the average and the 95% confidence interval of multiple simulations to account for space variability [4].

5.2 Compression Ratio

To evaluate the success of our compression scheme, we estimated the compressibility properties of our set of benchmarks. A snapshot is taken of the L2 cache contents for each of these benchmarks after a warm-up interval. Assuming variable length cache lines that can occupy any number of bits, we compare the compression ratio from our Frequent Pattern Compression scheme (FPC) with two other memory compression schemes:

- The X-RL algorithm [18] used in some compressed cache implementations [21, 19, 20].
- The Block-Referential Compression with Lookahead (BRCL) scheme [14], which is an upper bound for the parallel compression scheme used for memory compression in the IBM MXT technology [26]. We apply it here to cache lines.

We also compare against the "Deflate" algorithm used in the gzip unix utility, which combines an LZ-variant implementation with Huffman encoding of codewords in the dictionary. For this algorithm, we run the gzip utility on the whole cache snapshot file (as opposed to 64-byte lines individually compressed by the other three schemes). The "Deflate" algorithm is used to provide a practical bound on compressibility of dictionary-based schemes for arbitrarily long cache lines.

Figure 2 shows results that compare the four compression schemes. While FPC is faster to implement in hardware, it provides comparable compression ratios to the dictionary-based XRL and BRCL, and even approaches gzip for some benchmarks. FPC is slightly better than XRL and BRCL for the four commercial benchmarks.

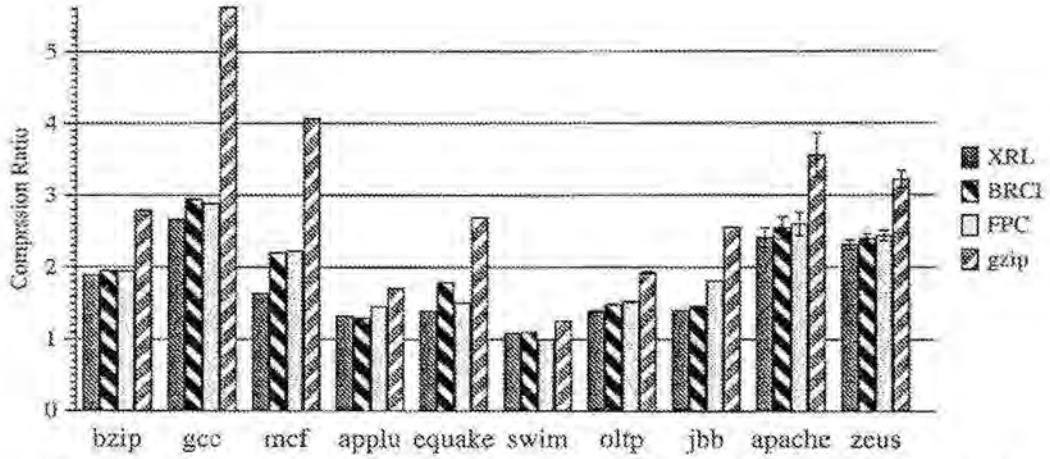

Figure 2. Compression ratios (original size / compressed size) for XRL, BRCL, FPC and gzip

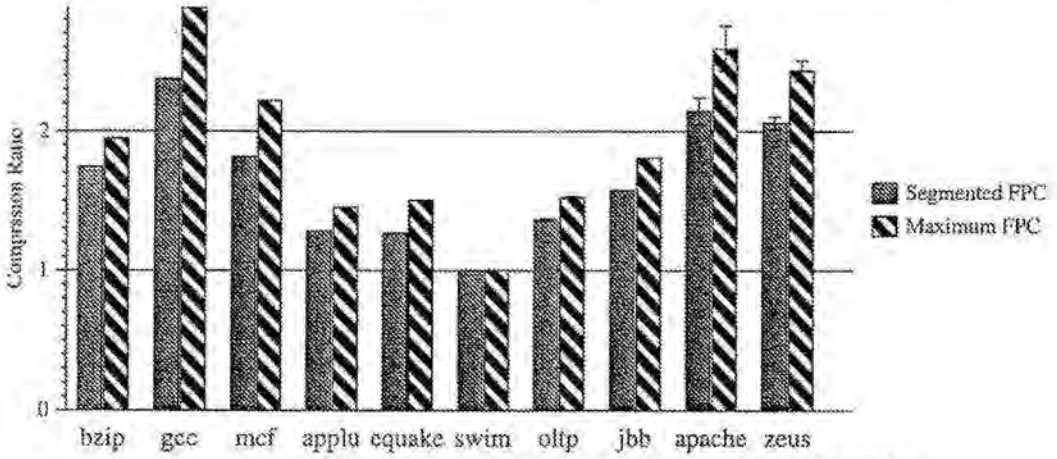

Figure 3. Compression ratios for segmented and variable-length FPC

In most practical cache designs, cache lines cannot occupy any arbitrary number of bits. Restricting the compressed line sizes to a certain subset of all possible lengths (as we do in our segmented design) partially reduces compressibility. To assess the loss in compressibility, we compare the compression ratio from our Segmented Frequent Pattern Compression scheme (Segmented-FPC) against the compression ratio from the Frequent Pattern Compression scheme assuming variable-length lines are possible (Maximum-FPC).

Figure 3 shows the compression ratios from the two schemes for our ten benchmarks. The simple scheme (Segmented-FPC) has compression ratios of 1.7-2.4 for the three SPECint2000 benchmarks, 1.0-1.3 for the three SPECfp2000 benchmarks, 1.4-2.1 for the four commercial benchmarks. OLTP had the lowest compression ratio among our set of commercial benchmarks, since its data is randomly generated. A real OLTP application would have much less randomness, and thus have a higher compression ratio.

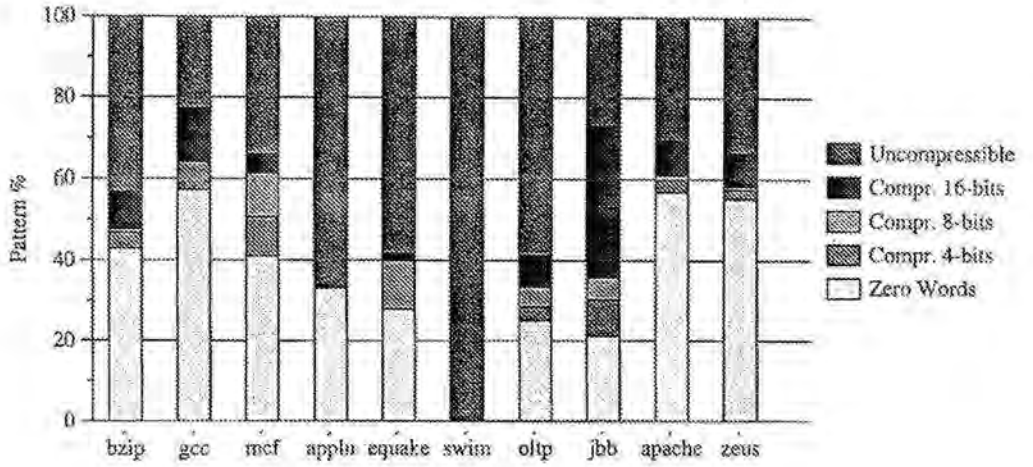

Figure 4. Frequent Pattern Histogram

Compression ratios are higher for all integer benchmarks (1.4-2.4) than floating point benchmarks. For example, only 0.4% of all cache lines in *swim* are compressible. This is because of the nature of floating point benchmarks where floating point numbers might not fit any of the frequent patterns. However, some benefit is still possible for benchmarks with lots of zero words. Segmented-FPC achieved most of the compression benefit from variable-length lines of Maximum-FPC.

5.3 Which Patterns Are Frequent?

Frequent Pattern Compression (FPC) is built on the observation that some word patterns are more frequent than others. We experimented with cache snapshots for our different benchmarks to come up with a reasonable set of frequent patterns (described in Table 1). Figure 4 shows the relative frequency of incompressible words, zero words and words compressible to 4, 8 and 16 bits. The 4-, 8-, and 16-bit patterns are present with various frequencies across our integer and commercial benchmarks. Unfortunately, most of the words in floating point benchmarks are incompressible with FPC, since our patterns are mainly integer patterns.

As Figure 4 demonstrates, zero words are the most frequent compressible pattern across all benchmarks, which is why some compression techniques (e.g., X-RL) specifically optimize for runs of zeros. Figure 5 shows the average number of zeros in a zero run for our set of benchmarks. Except for equake and jbb, the average zero run length for all benchmarks is greater than two. In developing the FPC scheme, we had two options to compress zeros. The first was to have a prefix for each zero word with no data. The second was to encode zero runs with a single prefix and save the length of the run in the data part corresponding to that prefix. However, since most zero runs have more than two (and in most cases three) words, the additional compressibility justifies having special treatment for zero runs.

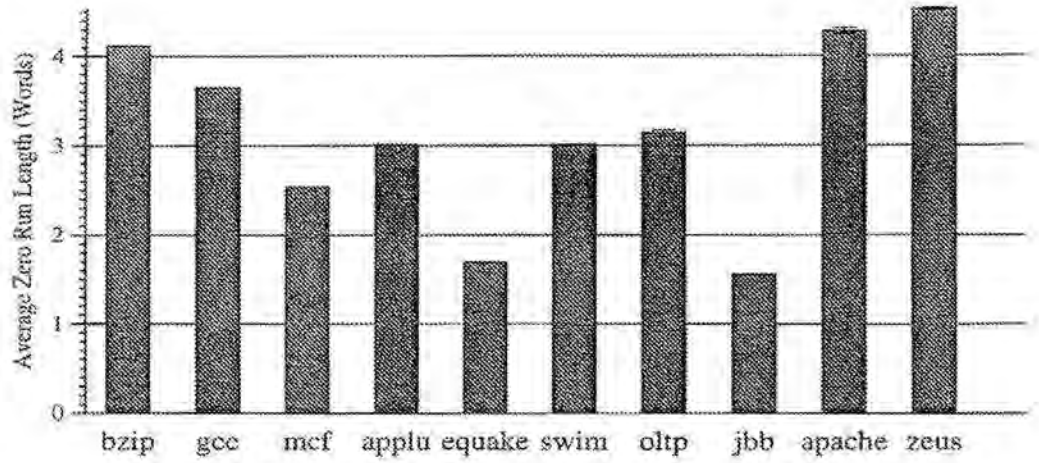

Figure 5. Average number of words in a zero run for our ten benchmarks

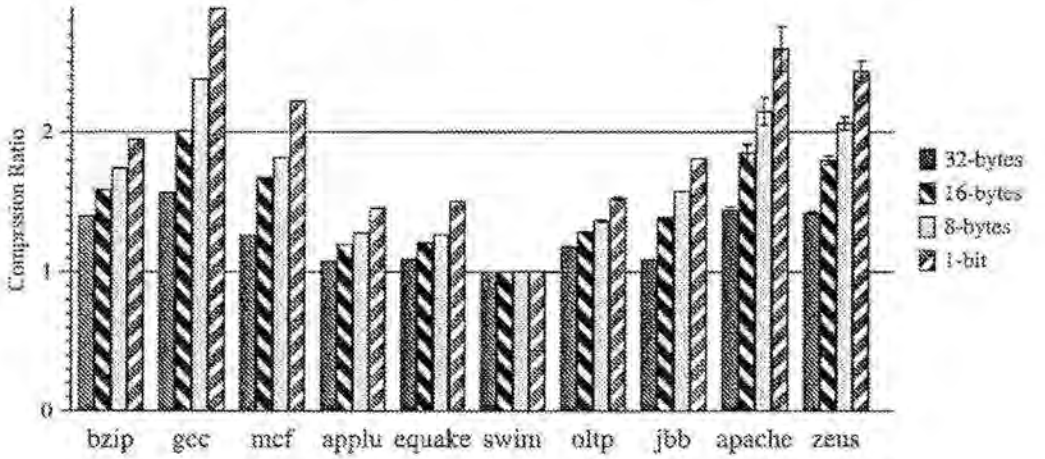

Figure 6. FPC Compression ratios for segment sizes (1 bit to 32 bytes)

5.4 Analysis of Segmented Frequent Pattern Compression

In designing a practical compressed cache implementation, selecting a specific base segment size is critical. A compressed line can only be stored in a size that is an integer multiple of the base segment size. Smaller segments allow for higher compression ratios. On the other hand, larger segments decrease the cache design complexity. Cache design should balance the tradeoff between these two conflicting issues. We selected a base segment size of 8-bytes (i.e., up to 8 segments for 64-byte lines) in our Segmented FPC design.

Figure 6 shows the sensitivity of our compression schemes to the base segment size. The four bars for each benchmark represent compression ratios if we have two possible sizes, i.e., an uncompressed line occupying two segments (32-byte segments), four (16-byte segments), eight (8-byte segments, which is the same as Segmented-FPC in

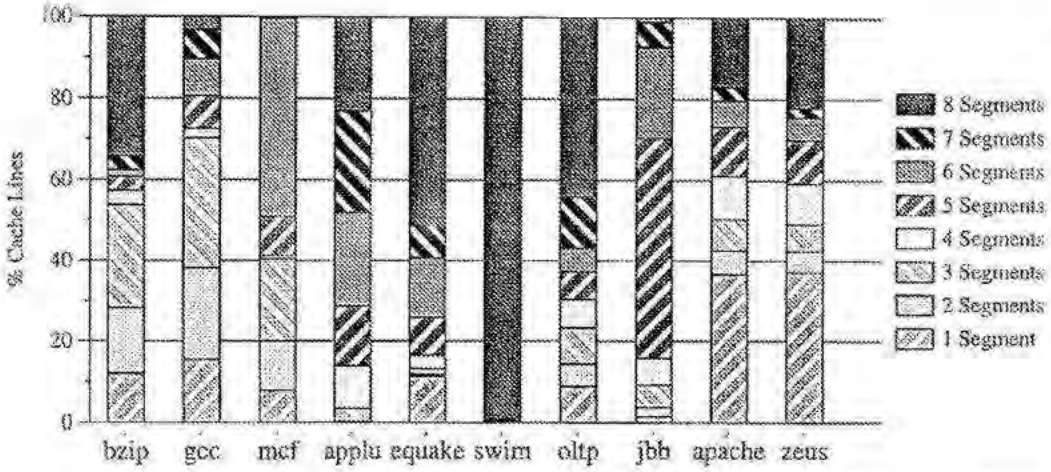

Figure 7. Segment Length Histogram: Percentage of cache lines compressed into 1-8 Segments

Figure 3), and all possible sizes (1-bit segments, the same as Maximum-FPC). Our 8-byte-segment design increases the compression ratio by up to 52% vs. 32-byte segments, and up to 19% vs. 16-byte segments. Figure 7 shows the percentage of lines that can be compressed into 1-8 segments. We show a more detailed distribution in Figure 8, demonstrating the cumulative distribution of compressed cache line sizes (1-512 bits) for our ten benchmarks, as well as the 25th, 50th and 75th percentiles.

6 Conclusion

Cache designers might consider using cache compression to increase cache capacity and reduce off-chip bandwidth. In this document, we propose and evaluate a simple significance-based compression scheme suitable for cache lines, since it has a low compression and decompression overhead. This scheme, Frequent Pattern Compression (FPC) compresses individual cache lines on a word-by-word basis by storing common word patterns in a compressed format accompanied with an appropriate prefix. This simple scheme provides comparable compression ratios to more complex schemes that have higher cache hit latencies.

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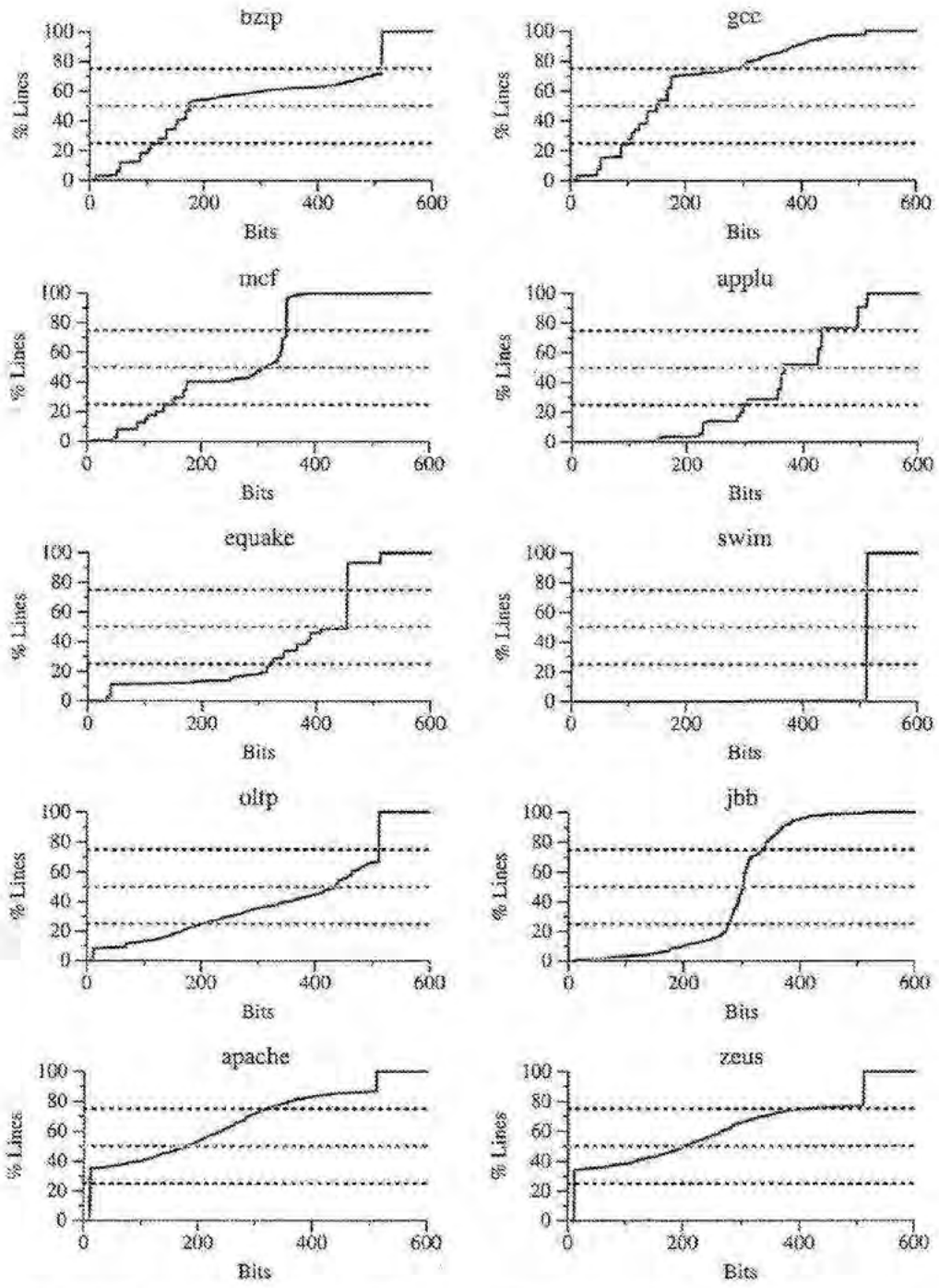

Figure 8. Cumulative Distribution of Compressed Line Lengths (1 to 512 bits). These graphs highlight the 25th, 50th and 75th percentile values.

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Electronic Acknowledgement Receipt

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First Named Inventor/Applicant Name:	Sebastian FaxÃ©r
Customer Number:	24112
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Filer Authorized By:	Justin J. Leonard
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In re Application of **Faxér**	)	
	)	
Serial No.: **15/105648**	)	
	)	Examiner: TBD
Filed: **June 17, 2016**	)	
	)	Group Art Unit: TBD
For: **Codebook Subset Restriction Signaling**	)	
	)	Confirmation No.: 5548
Attorney's Docket No: **4015-9595/P45698-US2**	)	
	)	
	)	

MS AMENDMENT
Commissioner for Patents
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Alexandria, VA 22313-1450

INFORMATION DISCLOSURE STATEMENT

In accordance with 37 C.F.R. 1.56, counsel wishes to make of record the attached items of information for the Examiner's consideration in connection with this application. Also attached is Form PTO/SB/08A for the Examiner's convenience in making such consideration of record. Inclusion herein of any particular item of information is not to be construed as an admission that same is prior art. Each item of information contained in the information disclosure statement:

☐ was first cited in any communication from a patent office in a counterpart foreign or international application or from the Office, and this communication was not received by an individual designated in §1.56(c) more than thirty days prior to the filing of the information disclosure statement; or

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☒ No statement re Patent Term Adjustment (PTA).

The Commissioner is hereby authorized to charge any fees that may be required or credit any overpayment to Deposit Account 18-1167.

Respectfully submitted,
COATS & BENNETT, P.L.L.C.

Justin Leonard

Dated: August 2, 2016

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PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 15/105,648

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	300
SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A			N/A	520
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	760
TOTAL CLAIMS (37 CFR 1.16(i))	32 minus 20 =	* 12			OR	x 100 =	1200
INDEPENDENT CLAIMS (37 CFR 1.16(h))	4 minus 3 =	* 1				x 460 =	460
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						0.00
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00
* If the difference in column 1 is less than zero, enter "0" in column 2			TOTAL			TOTAL	3240

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)	OR	RATE($)	ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
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COATS & BENNETT, PLLC
1400 Crescent Green, Suite 300
Cary, NC 27518

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371 ACCEPTANCE LETTER

OC000000097075404

Date Mailed: 01/31/2018

NOTICE OF ACCEPTANCE OF APPLICATION UNDER 35 U.S.C 371 AND 37 CFR 1.495

The applicant is hereby advised that the United States Patent and Trademark Office, in its capacity as a Designated / Elected Office (37 CFR 1.495), has ACCEPTED the above identified international application for national patentability examination in the United States Patent and Trademark Office.

The United States Application Number assigned to the application is shown above. A Filing Receipt will be issued for the present application in due course. **THE DATE APPEARING ON THE FILING RECEIPT AS THE "FILING DATE or 371(c) DATE" IS THE DATE ON WHICH THE LAST OF THE 35 U.S.C. 371 (c)(1) and (c)(2) REQUIREMENTS HAS BEEN RECEIVED IN THE OFFICE. THIS DATE IS SHOWN BELOW.** The filing date of the above identified application is the international filing date of the international application (Article 11(3) and 35 U.S.C. 363)

06/17/2016
DATE OF RECEIPT OF 35 U.S.C.
371(c)(1) and (c)(2) REQUIREMENTS

The following items have been received:

- Copy of the International Application filed on 06/17/2016
- Copy of the International Search Report filed on 06/17/2016
- Copy of IPE Report filed on 06/17/2016
- Preliminary Amendments filed on 06/17/2016
- Information Disclosure Statements filed on 06/17/2016
- Inventor's Oath or Declaration filed on 06/17/2016
- Request for Immediate Examination filed on 06/17/2016
- U.S. Basic National Fees filed on 06/17/2016
- Assignment filed on 06/17/2016
- Authorize Access to Search Results filed on 06/17/2016
- Priority Documents filed on 06/17/2016
- Power of Attorney filed on 06/17/2016
- Authorization to Permit Access filed on 06/17/2016
- Application Data Sheet (37 CFR 1.76) filed on 06/17/2016

FORM PCT/DO/EO/903 (371 Acceptance Notice)

Applicant is reminded that any communications to the United States Patent and Trademark Office must be mailed to the address given in the heading and include the U.S. application no. shown above (37 CFR 1.5)

CHERRIE M HAYWOOD

Telephone: (703) 756-1144

MULTIPLE DEPENDENT CLAIM FEE CALCULATION SHEET

Substitute for Form PTO-1360
(For use with Form PTO/SB/06)

Application Number	Filing Date
15105648	

Applicant(s) Sebastian Faxer

* May be used for additional claims or amendments

CLAIMS	AS FILED		AFTER FIRST AMENDMENT		AFTER SECOND AMENDMENT	
	Indep	Depend	Indep	Depend	Indep	Depend
1	1		---	---		
2	1		---	---		
3		2	---	---		
4		(1)	---	---		
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48				1		
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50				1		
Total Indep	8		4		0	
Total Depend	14	↵	28	↵	0	↵
Total Claims	22		32		0	

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	Indep	Depend	Indep	Depend	Indep	Depend
51				1		
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UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
15/105,648	06/17/2016		2860	4015-9595 / P45698-US2	32	4

CONFIRMATION NO. 5548

24112
COATS & BENNETT, PLLC
1400 Crescent Green, Suite 300
Cary, NC 27518

FILING RECEIPT

Date Mailed: 01/31/2018

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Sebastian Faxér, Järfälla, SWEDEN;
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Simon Järmyr, Skarpnäck, SWEDEN;
George Jöngren, Sundbyberg, SWEDEN;
Niklas Wernersson, Solna, SWEDEN;

Applicant(s)

Telefonaktiebolaget LM Ericsson (publ), Stockholm, SWEDEN;

Power of Attorney: The patent practitioners associated with Customer Number 24112

Domestic Priority data as claimed by applicant

This application is a 371 of PCT/SE2016/050009 01/11/2016
which claims benefit of 62/103,101 01/14/2015

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 01/30/2018

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 15/105,648**

Projected Publication Date: 05/10/2018

Non-Publication Request: No

Early Publication Request: No
Title

Codebook Subset Restriction Signaling

Preliminary Class

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

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Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (03-15)
Approved for use through 07/31/2016. OMB 0651-0031
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	15105648
Filing Date	2016-06-17
First Named Inventor	Faxér
Art Unit	
Examiner Name	
Attorney Docket Number	4015-9595 / P45698-US2

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
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Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20120020434	A1	2012-01-26	Callard et al.	Corresponds to RU2011140068A cited herein

If you wish to add additional U.S. Published Application citation information please click the Add button. Add

FOREIGN PATENT DOCUMENTS Remove

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	2011140068	RU	A	2013-04-27	Rockstar Bidco LP		

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NON-PATENT LITERATURE DOCUMENTS Remove

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15105648
	Filing Date	2016-06-17
	First Named Inventor	Faxér
	Art Unit	
	Examiner Name	
	Attorney Docket Number	4015-9595 / P45698-US2

	1		

If you wish to add additional non-patent literature document citation information please click the Add button Add

EXAMINER SIGNATURE

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15105648
	Filing Date	2016-06-17
	First Named Inventor	Faxér
	Art Unit	
	Examiner Name	
	Attorney Docket Number	4015-9595 / P45698-US2

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/ Justin J. Leonard /	Date (YYYY-MM-DD)	2018-03-21
Name/Print	Justin Leonard	Registration Number	60986

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these record s.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Espacenet

Bibliographic data: RU2011140068 (A) — 2013-04-27

TRANSMISSION USING COMMON AND DEDICATED PILOTS

Inventor(s): КОЛЛАРД Аарон, ; ЮЙ Дун-Шень , ; БЭЛАЙ Мохаммадхади, ; МА Цзянлэй

Applicant(s): РОКСТАР БИДКО ЛП

Classification: - international:***H04B1/76***
- cooperative: **H04L5/005**; **H04L5/0051**; H04B7/0417; H04B7/0478; H04B7/0639; H04B7/068

Application number: RU20110140068 20100316

Priority number (s): US20090160452P 20090316 ; US20090244185P 20090921 ; WO2010CA00376 20100316

Also published as: BRPI1012727 (A2) CA2755574 (A1) CA2755574 (C) CN102484501 (A) CN102484501 (B) more

Abstract not available for RU2011140068 (A)
Abstract of corresponding document: WO2010105345 (A1)

A method, system, base station and wireless terminal are provided for transmission of a set of mixed pilots that includes both common and dedicated pilots. The method includes selecting a number D of dedicated pilots having regard to performance of the communication link, D = 0, selecting a first pre-coder for pre-coding D dedicated pilots based on some criteria, performing a first pre-coding of the D dedicated pilots with the first pre-coder to produce a set of pre-coded dedicated pilots, performing a second pre-coding of the set of pre-coded dedicated pilots and a set of common pilots to produce a set of mixed pilots, and transmitting data from the transmitter on the communication link with the set of mixed pilots.

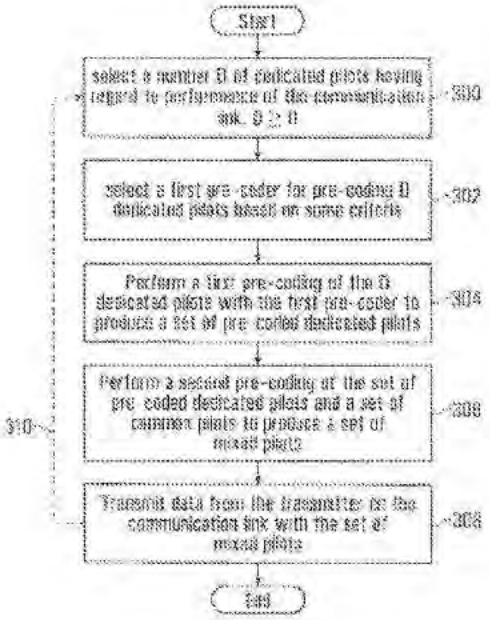

FIG. 11

РОССИЙСКАЯ ФЕДЕРАЦИЯ

(19) **RU** (11) **2011140068** (13) **A**

(51) МПК
H04B 1/76 (2006.01)

ФЕДЕРАЛЬНАЯ СЛУЖБА
ПО ИНТЕЛЛЕКТУАЛЬНОЙ СОБСТВЕННОСТИ

(12) ЗАЯВКА НА ИЗОБРЕТЕНИЕ

(21)(22) Заявка: 2011140068/07, 16.03.2010

Приоритет(ы):
(30) Конвенционный приоритет:
16.03.2009 US 61/160,452;
21.09.2009 US 61/244,185

(43) Дата публикации заявки: 27.04.2013 Бюл. № 12

(85) Дата начала рассмотрения заявки PCT на национальной фазе: 17.10.2011

(86) Заявка PCT:
CA 2010/000376 (16.03.2010)

(87) Публикация заявки PCT:
WO 2010/105345 (23.09.2010)

Адрес для переписки:
119019, Москва, Гоголевский б-р, 11, этаж 3,
"Гоулингз Интернэшнл Инк.", В.А. Клюкину

(71) Заявитель(и):
РОКСТАР БИДКО ЛП (US)

(72) Автор(ы):
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ЮЙ Дун-Шень (CA),
БЭЛАЙ Мохаммадхади (CA),
МА Цзяньэй (CA)

RU 2011140068 A

(54) СПОСОБ ПЕРЕДАЧИ СИГНАЛОВ, СИСТЕМА БЕСПРОВОДНОЙ СВЯЗИ, БАЗОВАЯ СТАНЦИЯ И БЕСПРОВОДНОЙ ТЕРМИНАЛ

(57) Формула изобретения

1. Способ передачи сигналов от передатчика по каналу связи, указанный способ, содержащий следующие стадии:

выбор числа D выделенных пилот-сигналов, принимая во внимание производительность канала связи, D≥0;

выбор первого прекодера для предварительного кодирования D выделенных пилот-сигналов на основе некоторых критериев;

выполнение первого предварительного кодирования D выделенных пилот-сигналов первым прекодером для создания набора предварительно кодированных выделенных пилот-сигналов;

выполнение второго предварительного кодирования набора предварительно кодированных выделенных пилот-сигналов и набора общих пилот-сигналов для создания набора смешанных пилот-сигналов; и

передачу данных с набором смешанных пилот-сигналов от передатчика по каналу связи.

2. Способ по п.1, в котором передатчик включает множество передающих антенн, и передача данных от передатчика включает передачу данных с набором смешанных пилот-сигналов от передатчика по каналу связи через множество передающих антенн.

3. Способ по п.2, в котором выполнение второго предварительного кодирования

RU 2011140068 A

для создания набора смешанных пилот-сигналов содержит предварительное кодирование, основанное на сингулярном разложении (SVD) или его аппроксимации.

4. Способ по п.2, в котором выполнение второго предварительного кодирования для создания набора смешанных пилот-сигналов содержит выполнение предварительного кодирования, основанного на диверсификации передачи.

5. Способ по п.4, в котором выполнение предварительного кодирования, основанного на диверсификации передачи содержит выполнение предварительного кодирования, основанного на любом из пространственно-частотном блочном коде (SFBC) и диверсификации циклической задержки (CDD).

6. Способ по любому из пп.1-5, в котором выбор числа D выделенных пилот-сигналов с учетом производительности канала связи включает выбор числа D выделенных пилот-сигналов, относящихся к пропускной способности канала связи с учетом затрат на передачу сигналов, связанных с общими и выделенными пилот-сигналами.

7. Способ по любому из пп.1-5, в котором выбор первого прекодера для предварительного кодирования D выделенных пилот-сигналов на основе некоторых критериев содержит выбор первого прекодера, который максимизирует принятую мощность D выделенных пилот-сигналов согласно ограничению, по которому первый прекодер остается ортогональным второму прекодеру, используемому для предварительного кодирования набора общих пилот-сигналов.

8. Способ по п.7, дополнительно содержащий прием сигналов обратной связи, относящейся к первому предварительному кодированию D выделенных пилот-сигналов.

9. Способ по п.8, в котором выбор первого прекодера для предварительного кодирования D выделенных пилот-сигналов на основе некоторых критериев является итеративным процессом на основе обратной связи.

10. Способ по п.7, в котором выбор первого прекодера дополнительно содержит выбор первого прекодера для снижения помех, вызванных передачей данных с набором смешанных пилот-сигналов.

11. Способ по п.2, в котором выполнение второго предварительного кодирования для создания набора смешанных пилот-сигналов содержит:

предварительное кодирование набора предварительно кодированных выделенных пилот-сигналов с матрицей тождественного преобразования после первого предварительного кодирования с тем, чтобы набор смешанных пилот-сигналов содержал бы выделенные пилот-сигналы, выровненные с переданными данными; и

предварительное кодирование набора общих пилот-сигналов с кодовой книгой с тем, чтобы набор смешанных пилот-сигналов включал бы предварительно кодированные общие пилот-сигналы.

12. Способ по п.11, в котором передача данных по каналу связи с набором смешанных пилот-сигналов через множество передающих антенн содержит:

передачу выделенных пилот-сигналов в смешанном наборе пилот-сигналов через первую группу передающих антенн из множества передающих антенн; и

передачу предварительно кодированных общих пилот-сигналов в смешанном наборе пилот-сигналов через вторую группу передающих антенн из множества передающих антенн.

13. Способ по п.12, в котором передатчик содержит множество передатчиков, и первая группа передающих антенн расположена в первом множестве передатчиков, и вторая группа передающих антенн расположена во втором множестве передатчиков.

14. Способ по п.13, в котором передача данных с набором смешанных пилот-сигналов включает передачу данных, по меньшей мере, от первого передатчика и второго передатчика из множества передатчиков.

15. Система беспроводной связи, содержащая:

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множество беспроводных терминалов; и

базовую станцию, имеющую множество передающих антенн и предназначенную для передачи данных множеству беспроводных терминалов по соответствующим каналам связи, в которой для каждого канала связи базовая станция используется для выполнения следующих задач:

выбор числа D выделенных пилот-сигналов, принимая во внимание производительность канала связи, $D \geq 0$;

выбор первого прекодера для предварительного кодирования D выделенных пилот-сигналов на основе некоторых критериев;

выполнение первого предварительного кодирования D выделенных пилот-сигналов первым прекодером для создания набора предварительно кодированных выделенных пилот-сигналов;

выполнение второго предварительного кодирования набора предварительно кодированных выделенных пилот-сигналов и набора общих пилот-сигналов для создания набора смешанных пилот-сигналов; и

передачу данных от базовой станции соответствующему беспроводному терминалу по каналу связи с набором смешанных пилот-сигналов через множество передающих антенн.

16. Система по п.15, в которой базовая станция используется для выполнения предварительного кодирования и для создания набора смешанных пилот-сигналов путем выполнения предварительного кодирования на основе сингулярного разложения (SVD) или его аппроксимации.

17. Система по п.15, в которой базовая станция используется для выполнения предварительного кодирования и для создания набора смешанных пилот-сигналов, выполняя предварительное кодирование, основанное на диверсификации передачи.

18. Система по п.17, в которой базовая станция используется для выполнения предварительного кодирования, основанного на диверсификации передачи, выполнении любого пространственно-частотного блочного кода (SFBC) и на основе диверсификации циклической задержки (CDD) предварительного кодирования.

19. Система по любому из пп.15-18, в которой базовая станция используется для выбора числа D выделенных пилот-сигналов, относящихся к пропускной способности канала связи, с учетом затрат на передачу сигналов, связанных с общими и выделенными пилот-сигналами.

20. Система по любому из пп.15-18, в которой базовая станция используется для выбора первого прекодера, чтобы максимизировать принятую мощность D выделенных пилот-сигналов в соответствующем беспроводном терминале согласно ограничению, по которому первый прекодер остается ортогональным второму прекодеру, используемому для предварительного кодирования набора общих пилот-сигналов.

21. Система по п.20, в которой один или несколько из множества беспроводных терминалов конфигурируются, чтобы обеспечить обратную связь с базовой станцией, относящейся к первому предварительному кодированию D выделенных пилот-сигналов.

22. Система по п.21, в которой базовая станция используется для выбора первого прекодера для предварительного кодирования D выделенных пилот-сигналов, используя итеративный процесс на основе обратной связи.

23. Система по п.20, в которой базовая станция используется для выбора первого прекодера, снижающего помехи, создаваемые базовой станцией.

24. Система по п.15, в которой базовая станция дополнительно используется для выполнения следующих задач:

предварительного кодирования набора предварительно кодированных выделенных пилот-сигналов с матрицей тождественного преобразования после первого

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предварительного кодирования с тем, чтобы набор смешанных пилот-сигналов содержал бы выделенные пилот-сигналы, выровненные с переданными данными; и

предварительного кодирования набора общих пилот-сигналов с кодовой книгой с тем, чтобы набор смешанных пилот-сигналов включал бы предварительно кодированные общие пилот-сигналы.

25. Система по п.24, в которой базовая станция дополнительно используется для выполнения следующих задач:

передачи выделенных пилот-сигналов смешанного набора пилот-сигналов через первую группу передающих антенн из множества передающих антенн; и

передачи предварительно кодированных общих пилот-сигналов смешанного набора пилот-сигналов через вторую группу передающих антенн из множества передающих антенн.

26. Система по п.25, в которой базовая станция содержит множество базовых станций, и первая группа передающих антенн расположена в первом множестве базовых станций, а вторая группа передающих антенн расположена во втором множестве базовых станций.

27. Система по п.26, в которой, по меньшей мере, первая базовая станция и вторая базовая станция из множества базовых станций используются для передачи данных вместе с набором смешанных пилот-сигналов.

28. Базовая станция, предназначенная для передачи данных по каналу связи, при этом базовая станция содержит:

множество передающих антенн;

прекодер, используемый для:

выбора числа D выделенных пилот-сигналов, принимая во внимание производительность канала связи, $D \geq 0$;

выбора первого прекодера для предварительного кодирования D выделенных пилот-сигналов на основе некоторых критериев;

выполнения первого предварительного кодирования D выделенных пилот-сигналов первым прекодером для создания набора предварительно кодированных выделенных пилот-сигналов;

выполнения второго предварительного кодирования набора предварительно кодированных выделенных пилот-сигналов и набора общих пилот-сигналов для создания набора смешанных пилот-сигналов; и

радиопередатчик, предназначенный для передачи данных по каналу связи с набором смешанных пилот-сигналов через множество передающих антенн.

29. Базовая станция по п.28, в которой прекодер служит для выполнения предварительного кодирования и для создания набора смешанных пилот-сигналов путем предварительного кодирования, основанного на сингулярном разложении (SVD) или его аппроксимации.

30. Базовая станция по п.28, в которой прекодер служит для выполнения предварительного кодирования и для создания набора смешанных пилот-сигналов, выполняя предварительное кодирование, основанное на диверсификации передачи.

31. Базовая станция по п.30, в которой прекодер служит для выполнения предварительного кодирования, основанного на диверсификации передачи, выполнении любого из пространственно-частотных блочных кодов (SFBC) и диверсификации циклической задержки (CDD) предварительного кодирования.

32. Базовая станция по любому из пп.28-31, в которой прекодер служит для выбора числа D выделенных пилот-сигналов, относящихся к пропускной способности канала связи, с учетом затрат на передачу сигналов, связанных с общими и выделенными пилот-сигналами.

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33. Базовая станция по любому из пп.28-31, в которой прекодер служит для выбора первого прекодера, чтобы максимизировать принятую мощность D выделенных пилот-сигналов в соответствующем беспроводном терминале согласно ограничению, по которому первый прекодер остается ортогональным второму прекодеру, используемому для предварительного кодирования набора общих пилот-сигналов.

34. Базовая станция по п.33, в которой базовая станция дополнительно содержит беспроводной приемник, предназначенный для приема сигналов обратной связи, относящихся к первому предварительному кодированию D выделенных пилот-сигналов.

35. Базовая станция по п.34, в которой прекодер служит для выбора первого прекодера для предварительного кодирования D выделенных пилот-сигналов, используя итеративный процесс на основе обратной связи.

36. Базовая станция по п.33, в которой прекодер служит для выбора первого прекодера, снижающего помехи, созданные базовой станцией.

37. Базовая станция по п.28, в которой прекодер дополнительно используется для выполнения следующих задач:

предварительного кодирования набора предварительно кодированных выделенных пилот-сигналов с матрицей тождественного преобразования после первого предварительного кодирования с тем, чтобы набор смешанных пилот-сигналов содержал бы выделенные пилот-сигналы, выровненные с переданными данными; и

предварительное кодирование набора общих пилот-сигналов с кодовой книгой с тем, чтобы набор смешанных пилот-сигналов включал бы предварительно кодированные общие пилот-сигналы.

38. Базовая станция по п.37, в которой беспроводной передатчик дополнительно используется для выполнения следующих задач:

передачи выделенных пилот-сигналов из набора смешанных пилот-сигналов через первую группу передающих антенн из множества передающих антенн; и

передачи предварительно кодированных общих пилот-сигналов из набора смешанных пилот-сигналов через вторую группу передающих антенн из множества передающих антенн.

39. Базовая станция по п.38, в которой базовая станция содержит множество точек передачи, и первая группа передающих антенн расположена в первой точке из множества точек передачи, и вторая группа передающих антенн расположена во второй точке из множества точек передачи.

40. Базовая станция по п.38, в которой беспроводной передатчик используется для передачи данных вместе с набором смешанных пилот-сигналов, по меньшей мере, с одним другим беспроводным передатчиком.

41. Беспроводной терминал содержит беспроводной приемопередатчик, используемый для приема переданных сигналов, содержащих данные и набор смешанных пилот-сигналов, формированных согласно способу по любому из пп.1-5.

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Electronic Acknowledgement Receipt

EFS ID:	32114811
Application Number:	15105648
International Application Number:	
Confirmation Number:	5548
Title of Invention:	Codebook Subset Restriction Signaling
First Named Inventor/Applicant Name:	Sebastian Faxér
Customer Number:	24112
Filer:	Justin J. Leonard/Kristi Dunshee
Filer Authorized By:	Justin J. Leonard
Attorney Docket Number:	4015-9595 / P45698-US2
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Filing Date:	17-JUN-2016
Time Stamp:	11:57:05
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Form (SB08)	9595IDS.pdf	1035197 [illegible]	no	4

Warnings:

Information:					
2	Foreign Reference	9595Foreign.pdf	4499349 c6bb13f2c611cd966adb11be87e0f32b6378a65	no	7
Warnings:					
Information:					
		Total Files Size (in bytes):	5534546		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/105,648	06/17/2016	Sebastian Faxér	4015-9595 / P45698-US2	5548

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EXAMINER
NGUYEN, BRIAN D

ART UNIT	PAPER NUMBER
2472	

MAIL DATE	DELIVERY MODE
04/13/2018	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No. 15/105,648	Applicant(s) FAXER ET AL.	
	Examiner BRIAN D. NGUYEN	Art Unit 2472	AIA (First Inventor to File) Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☐ Responsive to communication(s) filed on *6/17/16*.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5)☒ Claim(s) *39-70* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☐ Claim(s) _____ is/are allowed.

7)☒ Claim(s) *39,41-44,47,49-52,55,57-60,63 and 65-68* is/are rejected.

8)☒ Claim(s) *40,45,46,48,53,54,56,61,62,64,69 and 70* is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☒ The drawing(s) filed on *6/17/16* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☒ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date *3/21/18, 8/2/16, 6/17/16*.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.

4) ☐ Other: _____.

DETAILED ACTION

1. The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

Claim Objections

2. Claim 45 is objected to because of the following informalities:

Claim 45, line 3, it is suggested to replace "polarization;" with "polarization.".

Claim Rejections - 35 USC § 102

3. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (a)(1) the claimed invention was patented, described in a printed publication, or in public use, on sale or otherwise available to the public before the effective filing date of the claimed invention.

4. Claims 39, 41-42, 47, 49-50, 55, 57-58, 63, and 65-66 are rejected under 35 U.S.C. 102(a)(1) as being anticipated by Jing et al (2013/0163687).

Regarding claims 39 and 55, Jing discloses an apparatus and a method implemented by a network node for signaling to a wireless communication device which precoders in a codebook are restricted from being used, the method characterized by: generating codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common (see a codebook subset restriction and grouping in paragraphs 0009 and 0017-001);

and sending the generated signaling from the network node to the wireless communication device (see paragraph 0024).

Regarding claims 41 and 57, Jing discloses wherein a precoder comprising one or more beam precoders is restricted if at least one of its one or more beam precoders is restricted (see beam in paragraph 0018).

Regarding claims 42 and 58, Jing wherein the certain component comprises a beam precoder (see beam in paragraph 0018).

Regarding claims 47, 49, 50, 63, 65, and 66, claims 47, 49, 50, 63, 65, and 66 have substantially the same limitations as method claims 39, 41, 42, 55, 57, and 58 except that method claims 47, 49, 50, 63, 65, and 66 are reverse process of method claims 39, 41, 42, 55, 57, and 58. Therefore, they are subject to the same rejection.

Claim Rejections - 35 USC § 103

5. The following is a quotation of 35 U.S.C. 103 which forms the basis for all obviousness rejections set forth in this Office action:

> A patent for a claimed invention may not be obtained, notwithstanding that the claimed invention is not identically disclosed as set forth in section 102, if the differences between the claimed invention and the prior art are such that the claimed invention as a whole would have been obvious before the effective filing date of the claimed invention to a person having ordinary skill in the art to which the claimed invention pertains. Patentability shall not be negated by the manner in which the invention was made.

6. Claims 43-44, 51-52, 59-60, and 67-68 are rejected under 35 U.S.C. 103 as being unpatentable over Jing in view of Novlan et al (2014/0016549).

Regarding claims 43, 51, 59, and 67, Jing does not specifically disclose wherein a beam precoder is a Kronecker product. However, Novlan discloses Kronecker (see paragraphs 0042, 0069). The claim would have been obvious because a person of ordinary skill has good reason to

pursue the known options within his or her technical grasp. If this leads to the anticipated success, it is likely the product not of innovation but of ordinary skill and common sense.

Regarding claims 44, 52, 60, and 68, Novlan discloses wherein the different beamforming vectors comprise Discrete Fourier Transform (DFT) vectors (see DFT in paragraph 0032).

Allowable Subject Matter

7. Claims 40, 45-46, 48, 53-54, 56, 61-62, 64, and 69-70 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Conclusion

8. Any inquiry concerning this communication or earlier communications from the examiner should be directed to BRIAN D. NGUYEN whose telephone number is (571)272-3084. The examiner can normally be reached on 8-4:30 Monday-Friday.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at http://www.uspto.gov/interviewpractice.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Hassan Kizou can be reached on (571) 272-3088. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/BRIAN D NGUYEN/
Primary Examiner, Art Unit 2472

Notice of References Cited	Application/Control No. 15/105,648	Applicant(s)/Patent Under Reexamination FAXÉR ET AL.	
	Examiner BRIAN D. NGUYEN	Art Unit 2472	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-2013/0163687 A1	06-2013	Jing; Meifang	H04B7/0658	375/267
*	B	US-2014/0016549 A1	01-2014	Novlan; Thomas David	H04B7/0417	370/328
*	C	US-2016/0233939 A9	08-2016	Hammarwall; David	H04B7/0634	1/1
*	D	US-2014/0269577 A1	09-2014	Hammarwall; David	H04B7/0634	370/329
*	E	US-2014/0254508 A1	09-2014	Krishnamurthy; Sandeep H.	H04B7/0417	370/329
*	F	US-2014/0205031 A1	07-2014	NAMMI; Sairamesh	H04B7/0413	375/267
*	G	US-2014/0198868 A1	07-2014	Yang; Weidong	H04B7/0478	375/267
*	H	US-2014/0198751 A1	07-2014	Prasad; Narayan	H04B7/0452	370/329
	I	US-				
	J	US-				
	K	US-				
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	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	2	(("20130163687") or ("20140016549")).PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2018/03/28 21:05
S2	2	S1 and (codebook precod$4 restrict$4 group$4)	US-PGPUB; USPAT	OR	ON	2018/03/28 21:07
S3	2	S1 and rank$3	US-PGPUB; USPAT	OR	ON	2018/03/28 21:21
S4	2	S1 and rank$3 and restrict$4	US-PGPUB; USPAT	OR	ON	2018/03/28 21:23
S5	0	"15105648"	US-PGPUB; USPAT	OR	ON	2018/03/28 21:27
S6	2	(("20130163687") or ("20140016549")).PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2018/04/11 21:20
S7	122	beam$4 adj2 precoder	US-PGPUB; USPAT	OR	ON	2018/04/11 21:20
S8	0	S6 and beam$4 adj2 precoder	US-PGPUB; USPAT	OR	ON	2018/04/11 21:20
S9	1	S6 and precoder	US-PGPUB; USPAT	OR	ON	2018/04/11 21:21
S10	1	S6 and pre$3coder	US-PGPUB; USPAT	OR	ON	2018/04/11 21:21
S11	1	S6 and beam$4	US-PGPUB; USPAT	OR	ON	2018/04/11 21:25
S12	2	S6 and precod$4 and codebook	US-PGPUB; USPAT	OR	ON	2018/04/11 21:26
S13	2	S6 and precod$4 and codebook and restrict$4	US-PGPUB; USPAT	OR	ON	2018/04/11 21:26
S14	2	(("20130163687") or ("20140016549")).PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2018/04/11 21:49
S15	2	S14 and precod$4 and codebook and restrict$4	US-PGPUB; USPAT	OR	ON	2018/04/11 21:49
S16	2	(("20130163687") or ("20140016549")).PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2018/04/12 11:15
S17	2	S16 and (scal$4 vector transform$4)	US-PGPUB; USPAT	OR	ON	2018/04/12 11:17
S18	1	S16 and kronecker	US-PGPUB; USPAT	OR	ON	2018/04/12 11:18
S19	2	S16 and (vector$4 kronecker)	US-PGPUB; USPAT	OR	ON	2018/04/12 11:19
S20	11016327	@ad<"20150114"	US-PGPUB; USPAT	OR	ON	2018/04/12 12:15
S21	120	precoder with codebook with restriction	US-PGPUB; USPAT	OR	ON	2018/04/12 12:15
S22	86	S21 and S20	US-PGPUB; USPAT	OR	ON	2018/04/12 12:15

S23	748	H04B7/0469.CPC.	US-PGPUB; USPAT	OR	ON	2018/04/12 12:26
S24	1073	H04B7/0478.CPC.	US-PGPUB; USPAT	OR	ON	2018/04/12 12:26
S25	3061	H04B7/0639.CPC.	US-PGPUB; USPAT	OR	ON	2018/04/12 12:26
S26	66	H03M7/3068.CPC.	US-PGPUB; USPAT	OR	ON	2018/04/12 12:27
S27	454	H03M7/3082.CPC.	US-PGPUB; USPAT	OR	ON	2018/04/12 12:27
S28	10	(("FAXER") near3 ("Sebastian")).INV.	US-PGPUB; USPAT; USOCR	OR	ON	2018/04/12 12:27
S29	227	(("FRENNE") near3 ("Mattias")).INV.	US-PGPUB; USPAT; USOCR	OR	ON	2018/04/12 12:27
S30	4	(("JARMYR") near3 ("Simon")).INV.	US-PGPUB; USPAT; USOCR	OR	ON	2018/04/12 12:28
S31	384	(("JONGREN") near3 ("George")).INV.	US-PGPUB; USPAT; USOCR	OR	ON	2018/04/12 12:28
S32	27	(("WERNERSSON") near3 ("Niklas")).INV.	US-PGPUB; USPAT; USOCR	OR	ON	2018/04/12 12:28
S33	615	S28 S29 S30 S31 S32	US-PGPUB; USPAT	OR	ON	2018/04/12 12:29
S34	82	S33 and codebook.clm.	US-PGPUB; USPAT	OR	ON	2018/04/12 12:29
S35	9	S33 and (restriction and codebook).clm.	US-PGPUB; USPAT	OR	ON	2018/04/12 12:30

EAST Search History (Interference)

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4/12/2018 12:31:31 PM
C:\Users\bnguyen2\Documents\EAST\Workspaces\15105648.wsp

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (03-15)
Approved for use through 07/31/2016. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	15105648
Filing Date	2016-06-17
First Named Inventor	Faxér
Art Unit	
Examiner Name	
Attorney Docket Number	4015-9595 / P45698-US2

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Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20120020434	A1	2012-01-26	Callard et al.	Corresponds to RU2011140068A cited herein

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	1	2011140068	RU	A	2013-04-27	Rockstar Bidco LP		

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Signature	/ Justin J. Leonard /	Date (YYYY-MM-DD)	2018-03-21
Name/Print	Justin Leonard	Registration Number	60986

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Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (03-15)
Approved for use through 07/31/2016. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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	1	20130163687	A1	2013-06-27	Jing et al.	
	2	20140016549	A1	2014-01-16	Novlan et al.	
	3	20130229980	A1	2013-09-05	Wernersson et al.	
	4	20100223237	A1	2010-09-02	Mishra et al.	

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	1	ALAMELDEEN, A., et al., "Frequent Pattern Compression: A Significance-Based Compression Scheme for L2 Caches", Technical Report #1500, 2004-05-01, pp. 1-15, University of Wisconsin	
	2	THOMAS, M. et al., "Elements of Information Theory", Chapter 3, Asymptotic Equipartition Property', 2006-01-01, pp. 57-62, Second edition, John Wiley & Sons, Inc.	

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Examiner Signature	/BRIAN D NGUYEN/	Date Considered	03/28/2018

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☒ A certification statement is not submitted herewith.

SIGNATURE

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Signature	/Justin J. Leonard, Reg. No. 60986/	Date (YYYY-MM-DD)	2016-08-02
Name/Print	Justin Leonard	Registration Number	60986

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ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /B.D.N/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (03-15)
Approved for use through 07/31/2016. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	
	Filing Date	
	First Named Inventor	Faxér
	Art Unit	
	Examiner Name	
	Attorney Docket Number	4015-9595 / P45698-US2

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Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
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Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20110243098	A1	2011-11-06	Koivisto et al.	
	2	20130163687	A1	2013-06-27	Jing et al.	

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Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
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	Application Number	
	Filing Date	
	First Named Inventor	Faxér
	Art Unit	
	Examiner Name	
	Attorney Docket Number	4015-9595 / P45698-US2

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1	ERICSSON, "Remaining Details of Codebook Subset Restriction", 3GPP TSG-RAN WG1#83, Anaheim, USA, 2015-11-15, pp. 1-6, R1-157203, 3GPP	
	2	AT&T, "WF on class A and class B CSI reporting for Rel.13 EB FD-MIMO", 3GPP TSG RAN WG1 Meeting #82bis, Malmö, Sweden, 2015-10-05, pp. 1-10, R1-156165, 3GPP	

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Examiner Signature	/BRIAN D NGUYEN/	Date Considered	03/28/2018

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[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

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	Application Number	
	Filing Date	
	First Named Inventor	Faxér
	Art Unit	
	Examiner Name	
	Attorney Docket Number	4015-9595 / P45698-US2

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/ Justin J. Leonard /	Date (YYYY-MM-DD)	2016-06-17
Name/Print	Justin J. Leonard	Registration Number	60986

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these record s.

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ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /B.D.N/

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15105648	FAXÉR ET AL.
	Examiner	Art Unit
	BRIAN D NGUYEN	2472

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	04/12/2018								
	1	-								
	2	-								
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	34	-								
	35	-								
	36	-								

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CLAIM		DATE								
Final	Original	04/12/2018								
	37	-								
	38	-								
	39	✓								
	40	=								
	41	✓								
	42	✓								
	43	✓								
	44	✓								
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	63	✓								
	64	=								
	65	✓								
	66	✓								
	67	✓								
	68	✓								
	69	=								
	70	=								

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15105648	FAXÉR ET AL.
	Examiner	Art Unit
	BRIAN D NGUYEN	2472

CPC- SEARCHED		
Symbol	Date	Examiner
H04B7/0469	4/12/18	BN
H04B7/0478	4/12/18	BN
H04B7/0639	4/12/18	BN
H03M7/3068	4/12/18	BN
H03M7/3082	4/12/18	BN

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner

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SEARCH NOTES		
Search Notes	Date	Examiner
text and symbols limited by date search	4/12/18	bn

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

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CONFIRMATION NO. 5548

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
15/105,648	06/17/2016 RULE	370	2472	4015-9595 / P45698-US2

APPLICANTS

Telefonaktiebolaget LM Ericsson (publ), Stockholm, SWEDEN;

INVENTORS

Sebastian Faxér, Järfälla, SWEDEN;
Mattias Frenne, Uppsala, SWEDEN;
Simon Järmyr, Skarpnäck, SWEDEN;
George Jöngren, Sundbyberg, SWEDEN;
Niklas Wernersson, Solna, SWEDEN;

**** CONTINUING DATA ***************************

This application is a 371 of PCT/SE2016/050009 01/11/2016
which claims benefit of 62/103,101 01/14/2015

**** FOREIGN APPLICATIONS ***************************

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01/30/2018

Foreign Priority claimed	35 USC 119(a-d) conditions met	Verified and Acknowledged	Met after Allowance	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
☐ Yes ☑ No	☐ Yes ☑ No	/BRIAN D NGUYEN/ Examiner's Signature	☐ Initials	SWEDEN	14	32	4

ADDRESS

COATS & BENNETT, PLLC
1400 Crescent Green, Suite 300
Cary, NC 27518
UNITED STATES

TITLE

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FILING FEE RECEIVED	FEES: Authority has been given in Paper	
2860	No._____ to charge/credit DEPOSIT ACCOUNT No._____ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (02-18)
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	15105648
Filing Date	2016-06-17
First Named Inventor	Sebastian Faxér
Art Unit	2472
Examiner Name	Brian D. Nguyen
Attorney Docket Number	4015-9595 / P45698-US2

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Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
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	1	20110170638	A1	2011-07-14	Yuan et al.	
	2	20110243098	A1	2011-10-06	Koivisto et al.	
	3	20110249713	A1	2011-10-13	Hammarwall et al.	

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	1							

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	Examiner Name	Brian D. Nguyen
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Examiner Signature		Date Considered	

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See attached certification statement.

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A certification statement is not submitted herewith.

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Signature	/David E. Bennett/	Date (YYYY-MM-DD)	2018-05-08
Name/Print	David E. Bennett	Registration Number	32194

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of **Faxér**	)	
Serial No.: **15/105648**	)	Examiner: Brian D. Nguyen
Filed: **June 17, 2016**	)	Group Art Unit: 2472
For: **Codebook Subset Restriction Signaling**	)	Confirmation No.: 5548
Attorney's Docket No: **4015-9595/P45698-US2**	)	

MS AMENDMENT
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

INFORMATION DISCLOSURE STATEMENT

In accordance with 37 C.F.R. 1.56, counsel wishes to make of record the attached items of information for the Examiner's consideration in connection with this application. Also attached is Form PTO/SB/08A for the Examiner's convenience in making such consideration of record. Inclusion herein of any particular item of information is not to be construed as an admission that same is prior art. Each item of information contained in the information disclosure statement:

☐ was first cited in any communication from a patent office in a counterpart foreign or international application or from the Office, and this communication was not received by an individual designated in §1.56(c) more than thirty days prior to the filing of the information disclosure statement; or

☐ is a communication that was issued by a patent office in a counterpart foreign or international application or by the Office, and this communication was not received by any individual designated in § 1.56(c) more than thirty days prior to the filing of the information disclosure statement

☒ No statement re Patent Term Adjustment (PTA).

The Commissioner is hereby authorized to charge any fees that may be required or credit any overpayment to Deposit Account 18-1167.

Respectfully submitted,
COATS & BENNETT, P.L.L.C.

/ David E. Bennett/
David E. Bennett
Registration No.: 32,194
Telephone: (919) 854-1844

Dated: May 8, 2018

Electronic Acknowledgement Receipt

EFS ID:	32560767
Application Number:	15105648
International Application Number:	
Confirmation Number:	5548
Title of Invention:	Codebook Subset Restriction Signaling
First Named Inventor/Applicant Name:	Sebastian Faxér
Customer Number:	24112
Filer:	David E. Bennett/Robert Sivigny
Filer Authorized By:	David E. Bennett
Attorney Docket Number:	4015-9595 / P45698-US2
Receipt Date:	08-MAY-2018
Filing Date:	17-JUN-2016
Time Stamp:	11:57:25
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Form (SB08)	4015-9595_IDS.pdf	1034460 93cf2052a3f330eb5a77ffa0e1ae9dad7f76d0ad	no	4

Warnings:

Information:					
2	Transmittal Letter	4015-9595_IDS_Cover.pdf	96150 1dce34165d9554680c9886b4c1776bd751a...0680f	no	1
Warnings:					
Information:					
			Total Files Size (in bytes):	1130610	

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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
15/105,648	06/17/2016	Sebastian Faxer	4015-9595 / P45698-US2

CONFIRMATION NO. 5548

24112
COATS & BENNETT, PLLC
1400 Crescent Green, Suite 300
Cary, NC 27518

PUBLICATION NOTICE

Title: Codebook Subset Restriction Signaling

Publication No.US-2018-0131420-A1
Publication Date:05/10/2018

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Public Records Division. The Public Records Division can be reached by telephone at (571) 272-3150 or (800) 972-6382, by facsimile at (571) 273-3250, by mail addressed to the United States Patent and Trademark Office, Public Records Division, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently https://portal.uspto.gov/pair/PublicPair. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of **Faxér, *et al.***

Serial No.: **15/105648**

Filed: **June 17, 2016**

For: **Codebook Subset Restriction Signaling**

Docket No: **4015-9595 / P45698-US2**

Examiner: Brian D. Nguyen

Group Art Unit: 2472

Confirmation No.: 5548

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

RESPONSE TO OFFICE ACTION

This paper is being filed in response to the Office Action mailed April 13, 2018, having a reply due date of July 13, 2018. Reconsideration is respectfully requested in light of the remarks below. The Office is hereby authorized to charge any fees required for entry of this paper to Deposit Account 18-1167.

CLAIMS LISTING

1-38. (Cancelled)

39. (Currently Amended) A method implemented by a network node for signaling to a wireless communication device which precoders in a codebook are restricted from being used, the method characterized by:

generating codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, wherein the codebook subset restriction signaling is rank-agnostic signaling that jointly restricts the precoders in a group without regard to the precoders' transmission rank; and

sending the generated signaling from the network node to the wireless communication device.

40. (Cancelled)

41. (Previously Presented) The method of claim 39, wherein a precoder comprising one or more beam precoders is restricted if at least one of its one or more beam precoders is restricted.

42. (Previously Presented) The method of claim 39, wherein the certain component comprises a beam precoder.

43. (Previously Presented) The method of claim 42, wherein a beam precoder is a Kronecker product of different beamforming vectors associated with different dimensions of a multi-dimensional antenna array.

44. (Previously Presented) The method of claim 43, wherein the different beamforming vectors comprise Discrete Fourier Transform (DFT) vectors.

45. (Previously Presented) The method of claim 42, wherein a beam precoder is a beamforming vector used to transmit on a particular layer of a multi-layer transmission, wherein different scaled versions of that beamforming vector are transmitted on different polarizations;

46. (Previously Presented) The method of claim 39, wherein a beam precoder is a Kronecker product of first and second beamforming vectors with first and second indices, wherein the first and second beamforming vectors are associated with different dimensions of a multi-dimensional antenna array, and wherein the codebook subset restriction signaling jointly restricts the precoders in a group of precoders that have the same pair of values for the first and second indices.

47. (Currently Amended) A method implemented by a wireless communication device for decoding signaling from a network node indicating which precoders in a codebook are restricted from being used, the method characterized by:

receiving codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, wherein the codebook subset restriction signaling is rank-agnostic signaling that jointly

restricts the precoders in a group without regard to the precoders' transmission rank; and

decoding the received signaling as jointly restricting precoders in each of the one or more groups of precoders.

48. (Cancelled)

49. (Previously Presented) The method of claim 47, wherein a precoder comprising one or more beam precoders is restricted if at least one of its one or more beam precoders is restricted.

50. (Previously Presented) The method of claim 47, wherein the certain component comprises a beam precoder.

51. (Previously Presented) The method of claim 50, wherein a beam precoder is a Kronecker product of different beamforming vectors associated with different dimensions of a multi-dimensional antenna array.

52. (Previously Presented) The method of claim 51, wherein the different beamforming vectors comprise Discrete Fourier Transform (DFT) vectors.

53. (Previously Presented) The method of claim 50, wherein a beam precoder is a beamforming vector used to transmit on a particular layer of a multi-layer transmission, wherein different scaled versions of that beamforming vector are transmitted on different polarizations;

54. (Previously Presented) The method of claim 47, wherein a beam precoder is a Kronecker product of first and second beamforming vectors with first and second indices, wherein the first and second beamforming vectors are associated with different dimensions of a multi-dimensional antenna array, and wherein the codebook subset restriction signaling jointly restricts the precoders in a group of precoders that have the same pair of values for the first and second indices.

55. (Currently Amended) A network node for signaling to a wireless communication device which precoders in a codebook are restricted from being used, the network node comprising:

a processor and a memory, the memory containing instructions executable by the processor whereby the network node is configured to:

generate codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, wherein the codebook subset restriction signaling is rank-agnostic signaling that jointly restricts the precoders in a group without regard to the precoders' transmission rank; and

send the generated signaling from the network node to the wireless communication device.

56. (Cancelled)

57. (Previously Presented) The network node of claim 55, wherein a precoder comprising one or more beam precoders is restricted if at least one of its one or more beam precoders is restricted.

58. (Previously Presented) The network node of claim 55, wherein the certain component comprises a beam precoder.

59. (Previously Presented) The network node of claim 58, wherein a beam precoder is a Kronecker product of different beamforming vectors associated with different dimensions of a multi-dimensional antenna array.

60. (Previously Presented) The network node of claim 59, wherein the different beamforming vectors comprise Discrete Fourier Transform (DFT) vectors.

61. (Previously Presented) The network node of claim 58, wherein a beam precoder is a beamforming vector used to transmit on a particular layer of a multi-layer transmission, wherein different scaled versions of that beamforming vector are transmitted on different polarizations;

62. (Previously Presented) The network node of claim 55, wherein a beam precoder is a Kronecker product of first and second beamforming vectors with first and second indices, wherein the first and second beamforming vectors are associated with different dimensions of a multi-dimensional antenna array, and wherein the codebook subset restriction signaling jointly restricts the precoders in a group of precoders that have the same pair of values for the first and second indices.

63. (Currently Amended) A wireless communication device for decoding signaling from a network node indicating which precoders in a codebook are restricted from being used, the wireless communication device comprising:

a processor and a memory, the memory containing instructions executable by the processor whereby the wireless communication device is configured to:

receive codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, wherein the codebook subset restriction signaling is rank-agnostic signaling that jointly restricts the precoders in a group without regard to the precoders' transmission rank; and

decode the received signaling as jointly restricting precoders in each of the one or more groups of precoders.

64. (Cancelled)

65. (Previously Presented) The wireless communication device of claim 63, wherein a precoder comprising one or more beam precoders is restricted if at least one of its one or more beam precoders is restricted.

66. (Previously Presented) The wireless communication device of claim 63, wherein the certain component comprises a beam precoder.

67. (Previously Presented) The wireless communication device of claim 66, wherein a beam precoder is a Kronecker product of different beamforming vectors associated with different dimensions of a multi-dimensional antenna array.

68. (Previously Presented) The wireless communication device of claim 67, wherein the different beamforming vectors comprise Discrete Fourier Transform (DFT) vectors.

69. (Previously Presented) The wireless communication device of claim 66, wherein a beam precoder is a beamforming vector used to transmit on a particular layer of a multi-layer transmission, wherein different scaled versions of that beamforming vector are transmitted on different polarizations;

70. (Previously Presented) The wireless communication device of claim 63, wherein a beam precoder is a Kronecker product of first and second beamforming vectors with first and second indices, wherein the first and second beamforming vectors are associated with different dimensions of a multi-dimensional antenna array, and wherein the codebook subset restriction signaling jointly restricts the precoders in a group of precoders that have the same pair of values for the first and second indices.

REMARKS

Applicant appreciates the Examiner indicating that claims 40, 45-46, 48, 53-54, 56, 61-62, 64, and 69-70 are *allowable* if rewritten into independent form including all the limitations of their base claim and any intervening claims. Applicant amends independent claims 39, 47, 55, and 63 to incorporate the *allowable* subject matter of dependent claims 40, 48, 56, and 64, respectively. Claims 40, 48, 56, and 64 have therefore been canceled.

Independent claims 39, 47, 55 and 63 stand rejected under 35 U.S.C. §102 as being anticipated by U.S. Patent Application Publication No. 2013/0163687 to Jing *et al.* ("**Jing**"). While Applicant disagrees with the rejections, Applicant has, in the interest of expedited prosecution, amended the independent claims to include the allowable subject matter. Such amendments render moot any further discussion of Jing. Applicant submits that the independent claims, and their respective dependent claims, define over the cited art for at least the reasons indicated in the Action.

For the forgoing reasons, it is respectfully urged that the present application is in condition for allowance and notice to such effect is respectfully requested.

Respectfully submitted,
COATS & BENNETT, P.L.L.C.

Dated: July 11, 2018

/Brandee N. Woolard/
Brandee N. Woolard
Registration No.: 68,795
Telephone: (919) 854-1844

Electronic Acknowledgement Receipt

EFS ID:	33151887
Application Number:	15105648
International Application Number:	
Confirmation Number:	5548
Title of Invention:	Codebook Subset Restriction Signaling
First Named Inventor/Applicant Name:	Sebastian Faxér
Customer Number:	24112
Filer:	Brandee N. Woolard/Leslie Ruckdeschel
Filer Authorized By:	Brandee N. Woolard
Attorney Docket Number:	4015-9595 / P45698-US2
Receipt Date:	11-JUL-2018
Filing Date:	17-JUN-2016
Time Stamp:	16:46:50
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		Response_OA.pdf	110001 6003f108a098066cc1eef1d5a9f425a4bfd2e6b	yes	9

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Amendment/Req. Reconsideration-After Non-Final Reject	1	1
	Claims	2	8
	Applicant Arguments/Remarks Made in an Amendment	9	9
Warnings:			
Information:			
	Total Files Size (in bytes):	110001	

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New Applications Under 35 U.S.C. 111
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National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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NOTICE OF ALLOWANCE AND FEE(S) DUE

24112 7590 09/11/2018

COATS & BENNETT, PLLC
1400 Crescent Green, Suite 300
Cary, NC 27518

EXAMINER	
NGUYEN, BRIAN D	
ART UNIT	PAPER NUMBER
2472	

DATE MAILED: 09/11/2018

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/105,648	06/17/2016	Sebastian Faxér	4015-9595 / P45698-US2	5548

TITLE OF INVENTION: Codebook Subset Restriction Signaling

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1000	$0.00	$0.00	$1000	12/11/2018

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

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If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

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or Fax (571)-273-2885

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CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

24112 7590 09/11/2018
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(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/105,648	06/17/2016	Sebastian Faxér	4015-9595 / P45698-US2	5548

TITLE OF INVENTION: Codebook Subset Restriction Signaling

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1000	$0.00	$0.00	$1000	12/11/2018

EXAMINER	ART UNIT	CLASS-SUBCLASS
NGUYEN, BRIAN D	2472	370-328000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____
2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. The following fee(s) are submitted:

❑ Issue Fee

❑ Publication Fee (No small entity discount permitted)

❑ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**

❑ A check is enclosed.

❑ Payment by credit card. Form PTO-2038 is attached.

❑ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

❑ Applicant certifying micro entity status. See 37 CFR 1.29

❑ Applicant asserting small entity status. See 37 CFR 1.27

❑ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

PTOL-85 Part B (10-13) Approved for use through 10/31/2013. OMB 0651-0033 U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/105,648	06/17/2016	Sebastian Faxér	4015-9595 / P45698-US2	5548

24112 7590 09/11/2018

COATS & BENNETT, PLLC
1400 Crescent Green, Suite 300
Cary, NC 27518

EXAMINER	
NGUYEN, BRIAN D	

ART UNIT	PAPER NUMBER
2472	

DATE MAILED: 09/11/2018

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

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The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 15/105,648	Applicant(s) Faxér et al.	
	Examiner BRIAN D NGUYEN	Art Unit 2472	AIA Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☑ This communication is responsive to the amendment filed 7/11/18.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☑ The allowed claim(s) is/are See Continuation Sheet . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file areply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☑ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____.
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date. _____.
5. ☐ Examiner's Amendment/Comment
6. ☐ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/BRIAN D NGUYEN/
Primary Examiner, Art Unit 2472

Continuation of 3. The allowed claim(s) is/are: 39,41-47,49-55,57-63 and 65-70

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/105,648	Faxér et al.
	Examiner	Art Unit
	BRIAN D NGUYEN	2472

CPC - Searched*		
Symbol	Date	Examiner
H04B7/0469	4/12/18	BN
H04B7/0478	4/12/18	BN
H04B7/0639	4/12/18	BN
H03M7/3068	4/12/18	BN
H03M7/3082	4/12/18	BN

CPC Combination Sets - Searched*		
Symbol	Date	Examiner

US Classification - Searched*			
Class	Subclass	Date	Examiner

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	Date	Examiner
text and symbols limited by date search	4/12/18	bn
updated	09/04/2018	bn

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner
see the attached printout		09/04/2018	bn

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/105,648	Faxér et al.
	Examiner	Art Unit
	BRIAN D NGUYEN	2472

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

CLAIMS

☑ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	04/12/2018	09/04/2018							
	1	-	-							
	2	-	-							
	3	-	-							
	4	-	-							
	5	-	-							
	6	-	-							
	7	-	-							
	8	-	-							
	9	-	-							
	10	-	-							
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	35	-	-							
	36	-	-							
	37	-	-							
	38	-	-							
1	39	✓	=							
	40	=	-							
2	41	✓	=							
3	42	✓	=							

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/105,648	Faxér et al.
	Examiner	**Art Unit**
	BRIAN D NGUYEN	2472

CLAIM		DATE								
Final	Original	04/12/2018	09/04/2018							
4	43	✓	=							
5	44	✓	=							
6	45	=	=							
7	46	=	=							
8	47	✓	=							
	48	=	-							
9	49	✓	=							
10	50	✓	=							
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14	54	=	=							
15	55	✓	=							
	56	=	-							
16	57	✓	=							
17	58	✓	=							
18	59	✓	=							
19	60	✓	=							
20	61	=	=							
21	62	=	=							
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	64	=	-							
23	65	✓	=							
24	66	✓	=							
25	67	✓	=							
26	68	✓	=							
27	69	=	=							
28	70	=	=							

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/105,648	Faxér et al.
	Examiner	Art Unit
	BRIAN D NGUYEN	2472

CPC							
Symbol						Type	Version
H04B	/	7	/	0469		F	2013-01-01
H04B	/	7	/	0456		I	2013-01-01
H04B	/	7	/	0478		I	2013-01-01
H04B	/	7	/	0658		I	2013-01-01
H03M	/	7	/	3068		I	2013-01-01
H04B	/	7	/	0639		A	2013-01-01
H03M	/	7	/	3082		A	2013-01-01

CPC Combination Sets								
Symbol					Type	Set	Ranking	Version
	/		/					

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	28	
/BRIAN D NGUYEN/ Primary Examiner, Art Unit 2472	04 September 2018	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	5

U.S. Patent and Trademark Office — Part of Paper No.: 20180904

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/105,648	Faxér et al.
	Examiner	Art Unit
	BRIAN D NGUYEN	2472

INTERNATIONAL CLASSIFICATION				
CLAIMED				
H04B	/	7	/	04
H03M	/	7	/	30

NON-CLAIMED				
	/		/	

US ORIGINAL CLASSIFICATION	
CLASS	SUBCLASS

CROSS REFERENCES(S)						
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)					

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	28	
/BRIAN D NGUYEN/ Primary Examiner, Art Unit 2472	04 September 2018	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	5

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/105,648	Faxér et al.
	Examiner	Art Unit
	BRIAN D NGUYEN	2472

☑ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIMS

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
	1		10		19		28		37	7	46	15	55		64
	2		11		20		29		38	8	47		56	23	65
	3		12		21		30	1	39		48	16	57	24	66
	4		13		22		31		40	9	49	17	58	25	67
	5		14		23		32	2	41	10	50	18	59	26	68
	6		15		24		33	3	42	11	51	19	60	27	69
	7		16		25		34	4	43	12	52	20	61	28	70
	8		17		26		35	5	44	13	53	21	62		
	9		18		27		36	6	45	14	54	22	63		

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	28	
/BRIAN D NGUYEN/ Primary Examiner, Art Unit 2472	04 September 2018	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	5

U.S. Patent and Trademark Office — Part of Paper No.: 20180904

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	2	(("20130163687") or ("20140016549")).PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2018/03/28 21:05
S2	2	S1 and (codebook precod$4 restrict$4 group$4)	US-PGPUB; USPAT	OR	ON	2018/03/28 21:07
S3	2	S1 and rank$3	US-PGPUB; USPAT	OR	ON	2018/03/28 21:21
S4	2	S1 and rank$3 and restrict$4	US-PGPUB; USPAT	OR	ON	2018/03/28 21:23
S5	0	"15105648"	US-PGPUB; USPAT	OR	ON	2018/03/28 21:27
S6	2	(("20130163687") or ("20140016549")).PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2018/04/11 21:20
S7	122	beam$4 adj2 precoder	US-PGPUB; USPAT	OR	ON	2018/04/11 21:20
S8	0	S6 and beam$4 adj2 precoder	US-PGPUB; USPAT	OR	ON	2018/04/11 21:20
S9	1	S6 and precoder	US-PGPUB; USPAT	OR	ON	2018/04/11 21:21
S10	1	S6 and pre$3coder	US-PGPUB; USPAT	OR	ON	2018/04/11 21:21
S11	1	S6 and beam$4	US-PGPUB; USPAT	OR	ON	2018/04/11 21:25
S12	2	S6 and precod$4 and codebook	US-PGPUB; USPAT	OR	ON	2018/04/11 21:26
S13	2	S6 and precod$4 and codebook and restrict$4	US-PGPUB; USPAT	OR	ON	2018/04/11 21:26
S14	2	(("20130163687") or ("20140016549")).PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2018/04/11 21:49
S15	2	S14 and precod$4 and codebook and restrict$4	US-PGPUB; USPAT	OR	ON	2018/04/11 21:49
S16	2	(("20130163687") or ("20140016549")).PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2018/04/12 11:15
S17	2	S16 and (scal$4 vector transform$4)	US-PGPUB; USPAT	OR	ON	2018/04/12 11:17
S18	1	S16 and kronecker	US-PGPUB; USPAT	OR	ON	2018/04/12 11:18
S19	2	S16 and (vector$4 kronecker)	US-PGPUB; USPAT	OR	ON	2018/04/12 11:19
S20	11016327	@ad<"20150114"	US-PGPUB; USPAT	OR	ON	2018/04/12 12:15
S21	120	precoder with codebook with restriction	US-PGPUB; USPAT	OR	ON	2018/04/12 12:15
S22	86	S21 and S20	US-PGPUB; USPAT	OR	ON	2018/04/12 12:15

S23	748	H04B7/0469.CPC.	US-PGPUB; USPAT	OR	ON	2018/04/12 12:26
S24	1073	H04B7/0478.CPC.	US-PGPUB; USPAT	OR	ON	2018/04/12 12:26
S25	3061	H04B7/0639.CPC.	US-PGPUB; USPAT	OR	ON	2018/04/12 12:26
S26	66	H03M7/3068.CPC.	US-PGPUB; USPAT	OR	ON	2018/04/12 12:27
S27	454	H03M7/3082.CPC.	US-PGPUB; USPAT	OR	ON	2018/04/12 12:27
S28	10	(("FAXER") near3 ("Sebastian")).INV.	US-PGPUB; USPAT; USOCR	OR	ON	2018/04/12 12:27
S29	227	(("FRENNE") near3 ("Mattias")).INV.	US-PGPUB; USPAT; USOCR	OR	ON	2018/04/12 12:27
S30	4	(("JARMYR") near3 ("Simon")).INV.	US-PGPUB; USPAT; USOCR	OR	ON	2018/04/12 12:28
S31	384	(("JONGREN") near3 ("George")).INV.	US-PGPUB; USPAT; USOCR	OR	ON	2018/04/12 12:28
S32	27	(("WERNERSSON") near3 ("Niklas")).INV.	US-PGPUB; USPAT; USOCR	OR	ON	2018/04/12 12:28
S33	615	S28 S29 S30 S31 S32	US-PGPUB; USPAT	OR	ON	2018/04/12 12:29
S34	82	S33 and codebook.clm.	US-PGPUB; USPAT	OR	ON	2018/04/12 12:29
S35	9	S33 and (restriction and codebook).clm.	US-PGPUB; USPAT	OR	ON	2018/04/12 12:30
S36	1	"15105648"	US-PGPUB; USPAT	OR	ON	2018/09/04 11:30

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S37	872	H04B7/0469.CPC.	US-PGPUB; USPAT	OR	ON	2018/09/04 11:38
S38	1239	H04B7/0478.CPC.	US-PGPUB; USPAT	OR	ON	2018/09/04 11:39
S39	3327	H04B7/0639.CPC.	US-PGPUB; USPAT	OR	ON	2018/09/04 11:39
S40	471	H03M7/3082.CPC.	US-PGPUB; USPAT	OR	ON	2018/09/04 11:39
S41	83	H03M7/3068.CPC.	US-PGPUB; USPAT	OR	ON	2018/09/04 11:39

9/4/2018 11:40:20 AM
C:\Users\bnguyen2\Documents\EAST\Workspaces\15105648.wsp

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (02-18)
Approved for use through 11/30/2020. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	15105648
Filing Date	2016-06-17
First Named Inventor	Sebastian Faxér
Art Unit	2472
Examiner Name	Brian D. Nguyen
Attorney Docket Number	4015-9595 / P45698-US2

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1					

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U.S.PATENT APPLICATION PUBLICATIONS Remove

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20110170638	A1	2011-07-14	Yuan et al.	
	2	20110243098	A1	2011-10-06	Koivisto et al.	
	3	20110249713	A1	2011-10-13	Hammarwall et al.	

If you wish to add additional U.S. Published Application citation information please click the Add button. Add

FOREIGN PATENT DOCUMENTS Remove

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1							

EFS Web 2.1.18

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /B.D.N/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	15105648
Filing Date	2016-06-17
First Named Inventor	Sebastian Faxér
Art Unit	2472
Examiner Name	Brian D. Nguyen
Attorney Docket Number	4015-9595 / P45698-US2

If you wish to add additional Foreign Patent Document citation information please click the Add button **Add**

NON-PATENT LITERATURE DOCUMENTS **Remove**

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1		

If you wish to add additional non-patent literature document citation information please click the Add button **Add**

EXAMINER SIGNATURE

Examiner Signature	/BRIAN D NGUYEN/	Date Considered	09/04/2018

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /B.D.N/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	15105648
Filing Date	2016-06-17
First Named Inventor	Sebastian Faxér
Art Unit	2472
Examiner Name	Brian D. Nguyen
Attorney Docket Number	4015-9595 / P45698-US2

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☒ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/David E. Bennett/	Date (YYYY-MM-DD)	2018-05-08
Name/Print	David E. Bennett	Registration Number	32194

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /B.D.N/

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these record s.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

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5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /B.D.N/

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United States Patent and Trademark Office
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P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/105,648	06/17/2016	Sebastian Faxér	4015-9595 / P45698-US2	5548

24112 7590 10/01/2018
COATS & BENNETT, PLLC
1400 Crescent Green, Suite 300
Cary, NC 27518

EXAMINER	
NGUYEN, BRIAN D	

ART UNIT	PAPER NUMBER
2472	

MAIL DATE	DELIVERY MODE
10/01/2018	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Supplemental Notice of Allowability	**Application No.** 15/105,648	**Applicant(s)** Faxér et al.	
	Examiner BRIAN D NGUYEN	**Art Unit** 2472	**AIA Status** Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☑ This communication is responsive to the amendment filed 7/11/18.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☑ The allowed claim(s) is/are See Continuation Sheet . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file areply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____.
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date. _____.
5. ☑ Examiner's Amendment/Comment
6. ☐ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/BRIAN D NGUYEN/
Primary Examiner, Art Unit 2472

Continuation of 3. The allowed claim(s) is/are: 39,41-47,49-55,57-63 and 65-70

EXAMINER'S AMENDMENT

Notice of Pre-AIA or AIA Status

1. The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

2. The application has been amended as follows:

At the end of claims 45, 53, 61, and 69, replace ";" with ".".

Conclusion

3. Any inquiry concerning this communication or earlier communications from the examiner should be directed to BRIAN D NGUYEN whose telephone number is (571)272-3084. The examiner can normally be reached on Monday-Friday 8:00 - 4:30.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at http://www.uspto.gov/interviewpractice.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Hassan Kizou can be reached on 571-272-3088. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR

system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/BRIAN D NGUYEN/
Primary Examiner, Art Unit 2472

Electronic Acknowledgement Receipt

EFS ID:	34307121
Application Number:	15105648
International Application Number:	
Confirmation Number:	5548
Title of Invention:	Codebook Subset Restriction Signaling
First Named Inventor/Applicant Name:	Sebastian Faxér
Customer Number:	24112
Filer:	Brandee N. Woolard/Kristi Dunshee
Filer Authorized By:	Brandee N. Woolard
Attorney Docket Number:	4015-9595 / P45698-US2
Receipt Date:	14-NOV-2018
Filing Date:	17-JUN-2016
Time Stamp:	13:33:14
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Amendment after Notice of Allowance (Rule 312)	9595Amendment.pdf	86875 [illegible]	no	9

Warnings:

Information:	
Total Files Size (in bytes):	86875

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of **Sebastian Faxér**

Serial No.: **15/105648**

Filed: **June 17, 2016**

For: **Codebook Subset Restriction Signaling**

Docket No: **4015-9595**

Examiner: Brian D. Nguyen

Group Art Unit: 2472

Confirmation No.: 5548

Mail Stop Issue Fee
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

AMENDMENT AFTER ALLOWANCE UNDER 37 C.F.R. §1.312

This paper is being filed in response to Notice of Allowance mailed September 11, 2018 and the Supplemental Notice of Allowability mailed October 1, 2018. Applicant respectfully requests entry of the following amendments under 37 CFR §1.312 after the Notice of Allowance and before payment of the issue fee. The Office is hereby authorized to charge any fees required for entry of this paper to Deposit Account 18-1167.

CLAIMS LISTING

1-38. (Cancelled)

39. (Previously Presented) A method implemented by a network node for signaling to a wireless communication device which precoders in a codebook are restricted from being used, the method characterized by:

generating codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, wherein the codebook subset restriction signaling is rank-agnostic signaling that jointly restricts the precoders in a group without regard to the precoders' transmission rank; and

sending the generated signaling from the network node to the wireless communication device.

40. (Cancelled)

41. (Previously Presented) The method of claim 39, wherein a precoder comprising one or more beam precoders is restricted if at least one of its one or more beam precoders is restricted.

42. (Previously Presented) The method of claim 39, wherein the certain component comprises a beam precoder.

43. (Currently Amended) The method of claim 42, wherein [[a]] the beam precoder is a Kronecker product of different beamforming vectors associated with different dimensions of a multi-dimensional antenna array.

44. (Previously Presented) The method of claim 43, wherein the different beamforming vectors comprise Discrete Fourier Transform (DFT) vectors.

45. (Currently Amended) The method of claim 42, wherein [[a]] the beam precoder is a beamforming vector used to transmit on a particular layer of a multi-layer transmission[[,]]; and wherein different scaled versions of that beamforming vector are transmitted on different polarizations[[;]].

46. (Currently Amended) The method of claim [[39]] 42, wherein [[a]] the beam precoder is a Kronecker product of first and second beamforming vectors with first and second indices, wherein the first and second beamforming vectors are associated with different dimensions of a multi-dimensional antenna array, and wherein the codebook subset restriction signaling jointly restricts the precoders in a group of precoders that have the same pair of values for the first and second indices.

47. (Previously Presented) A method implemented by a wireless communication device for decoding signaling from a network node indicating which precoders in a codebook are restricted from being used, the method characterized by:

receiving codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, wherein the

codebook subset restriction signaling is rank-agnostic signaling that jointly restricts the precoders in a group without regard to the precoders' transmission rank; and

decoding the received signaling as jointly restricting precoders in each of the one or more groups of precoders.

48. (Cancelled)

49. (Previously Presented) The method of claim 47, wherein a precoder comprising one or more beam precoders is restricted if at least one of its one or more beam precoders is restricted.

50. (Previously Presented) The method of claim 47, wherein the certain component comprises a beam precoder.

51. (Currently Amended) The method of claim 50, wherein [[a]] the beam precoder is a Kronecker product of different beamforming vectors associated with different dimensions of a multi-dimensional antenna array.

52. (Previously Presented) The method of claim 51, wherein the different beamforming vectors comprise Discrete Fourier Transform (DFT) vectors.

53. (Currently Amended) The method of claim 50, wherein [[a]] the beam precoder is a beamforming vector used to transmit on a particular layer of a multi-layer transmission[[,]]; and

wherein different scaled versions of that beamforming vector are transmitted on different polarizations[[;]].

54. (Previously Presented) The method of claim [[47]] 50, wherein [[a]] the beam precoder is a Kronecker product of first and second beamforming vectors with first and second indices, wherein the first and second beamforming vectors are associated with different dimensions of a multi-dimensional antenna array, and wherein the codebook subset restriction signaling jointly restricts the precoders in a group of precoders that have the same pair of values for the first and second indices.

55. (Previously Presented) A network node for signaling to a wireless communication device which precoders in a codebook are restricted from being used, the network node comprising:

a processor and a memory, the memory containing instructions executable by the processor whereby the network node is configured to:

generate codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, wherein the codebook subset restriction signaling is rank-agnostic signaling that jointly restricts the precoders in a group without regard to the precoders' transmission rank; and

send the generated signaling from the network node to the wireless communication device.

56. (Cancelled)

57. (Previously Presented) The network node of claim 55, wherein a precoder comprising one or more beam precoders is restricted if at least one of its one or more beam precoders is restricted.

58. (Previously Presented) The network node of claim 55, wherein the certain component comprises a beam precoder.

59. (Currently Amended) The network node of claim 58, wherein [[a]] the beam precoder is a Kronecker product of different beamforming vectors associated with different dimensions of a multi-dimensional antenna array.

60. (Previously Presented) The network node of claim 59, wherein the different beamforming vectors comprise Discrete Fourier Transform (DFT) vectors.

61. (Currently Amended) The network node of claim 58, wherein [[a]] the beam precoder is a beamforming vector used to transmit on a particular layer of a multi-layer transmission[[,]]; and wherein different scaled versions of that beamforming vector are transmitted on different polarizations[[;]].

62. (Currently Amended) The network node of claim [[55]] 58, wherein [[a]] the beam precoder is a Kronecker product of first and second beamforming vectors with first and second indices, wherein the first and second beamforming vectors are associated with different dimensions of a multi-dimensional antenna array, and wherein the codebook subset restriction

signaling jointly restricts the precoders in a group of precoders that have the same pair of values for the first and second indices.

63. (Previously Presented) A wireless communication device for decoding signaling from a network node indicating which precoders in a codebook are restricted from being used, the wireless communication device comprising:

a processor and a memory, the memory containing instructions executable by the processor whereby the wireless communication device is configured to:

receive codebook subset restriction signaling that, for each of one or more groups of precoders, jointly restricts the precoders in the group by restricting a certain component that the precoders in the group have in common, wherein the codebook subset restriction signaling is rank-agnostic signaling that jointly restricts the precoders in a group without regard to the precoders' transmission rank; and

decode the received signaling as jointly restricting precoders in each of the one or more groups of precoders.

64. (Cancelled)

65. (Previously Presented) The wireless communication device of claim 63, wherein a precoder comprising one or more beam precoders is restricted if at least one of its one or more beam precoders is restricted.

66. (Previously Presented) The wireless communication device of claim 63, wherein the certain component comprises a beam precoder.

67. (Currently Amended) The wireless communication device of claim 66, wherein [[a]] the beam precoder is a Kronecker product of different beamforming vectors associated with different dimensions of a multi-dimensional antenna array.

68. (Previously Presented) The wireless communication device of claim 67, wherein the different beamforming vectors comprise Discrete Fourier Transform (DFT) vectors.

69. (Currently Amended) The wireless communication device of claim 66, wherein [[a]]the beam precoder is a beamforming vector used to transmit on a particular layer of a multi-layer transmission[[,]]; and wherein different scaled versions of that beamforming vector are transmitted on different polarizations[[;]].

70. (Currently Amended) The wireless communication device of claim [[63]]66, wherein [[a]]the beam precoder is a Kronecker product of first and second beamforming vectors with first and second indices, wherein the first and second beamforming vectors are associated with different dimensions of a multi-dimensional antenna array, and wherein the codebook subset restriction signaling jointly restricts the precoders in a group of precoders that have the same pair of values for the first and second indices.

REMARKS

Claims 43, 45, 46, 51, 53, 54, 59, 61, 62, 67, 69, and 70 are amended to correct for typographical errors before payment of the issue fee. Entry of the amendments is respectfully requested under 37 CFR §1.312 and in compliance with MPEP § 714.16. An amendment to the claims may be entered by the examiner, without withdrawing the application from issue, where the amendments merely correct formal matters within a claim without changing the scope thereof. MPEP § 714.16 Applicant submits that such amendments are needed to correct minor typographical errors without changing the scope of the claims.

If the Examiner has any questions, it is respectfully requested that the Examiner contact Applicant's representative at the below number.

Respectfully submitted,
COATS & BENNETT, P.L.L.C.

/Brandee N. Woolard/
Brandee N. Woolard
Registration No.: 68,795
Telephone: (919) 854-1844

Dated: November 14, 2018

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/105,648	06/17/2016	Sebastian Faxér	4015-9595 / P45698-US2	5548

24112 7590 11/28/2018
COATS & BENNETT, PLLC
1400 Crescent Green, Suite 300
Cary, NC 27518

EXAMINER	
NGUYEN, BRIAN D	

ART UNIT	PAPER NUMBER
2472	

MAIL DATE	DELIVERY MODE
11/28/2018	PAPER

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The time period for reply, if any, is set in the attached communication.

Response to Rule 312 Communication	Application No.	Applicant(s)	
	15/105,648	Faxér et al.	
	Examiner	Art Unit	AIA Status
	BRIAN D NGUYEN	2472	Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

1. ☑ The amendment filed on 14 November 2018 under 37 CFR 1.312 has been considered, and has been:
   a) ☐ entered.
   b) ☑ entered as directed to matters of form not affecting the scope of the invention.
   c) ☐ disapproved because the amendment was filed after the payment of the issue fee.
      Any amendment filed after the date the issue fee is paid must be accompanied by a petition under 37 CFR 1.313(c)(1) and the required fee to withdraw the application from issue.
   d) ☐ disapproved. See explanation below.
   e) ☐ entered in part. See explanation below.

/BRIAN D NGUYEN/
Primary Examiner, Art Unit 2472

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

2412 7590 09/17/2018
COATS & BENNETT, PLLC
1400 Crescent Green, Suite 300
Cary, NC 27518

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/105,648	06/17/2016	Sebastian Faxér	4015-9595 / P45698-US2	5548

TITLE OF INVENTION: Codebook Subset Restriction Signaling

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1000	$0.00	$0.00	$1000	12/11/2018

EXAMINER	ART UNIT	CLASS-SUBCLASS
NGUYEN, BRIAN D	2472	370-328000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Coats & Bennett, PLLC
2
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: Telefonaktiebolaget LM Ericsson (publ)

(B) RESIDENCE: (CITY and STATE OR COUNTRY): Stockholm, Sweden

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

☒ Issue Fee

☐ Publication Fee (No small entity discount permitted)

☐ Advance Order - # of Copies

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**

☐ A check is enclosed.

☐ Payment by credit card. Form PTO-2038 is attached.

☒ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number 18-1167 (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

☐ Applicant certifying micro entity status. See 37 CFR 1.29

☐ Applicant asserting small entity status. See 37 CFR 1.27

☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature: Brandee N. Woolard Date: December 5, 2018

Typed or printed name: Brandee N. Woolard Registration No.: 68,795

PTOL-85 Part B (10-13) Approved for use through 10/31/2013. OMB 0651-0033 U.S. Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE

Electronic Patent Application Fee Transmittal

Application Number:	15105648
Filing Date:	17-Jun-2016
Title of Invention:	Codebook Subset Restriction Signaling
First Named Inventor/Applicant Name:	Sebastian Faxér
Filer:	Brandee N. Woolard/Kristi Dunshee
Attorney Docket Number:	4015-9595 / P45698-US2

Filed as Large Entity

Filing Fees for U.S. National Stage under 35 USC 371

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
UTILITY APPL ISSUE FEE	1501	1	1000	1000

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	**1000**

Electronic Acknowledgement Receipt

EFS ID:	34490173
Application Number:	15105648
International Application Number:	
Confirmation Number:	5548
Title of Invention:	Codebook Subset Restriction Signaling
First Named Inventor/Applicant Name:	Sebastian Faxér
Customer Number:	24112
Filer:	Brandee N. Woolard/Kristi Dunshee
Filer Authorized By:	Brandee N. Woolard
Attorney Docket Number:	4015-9595 / P45698-US2
Receipt Date:	05-DEC-2018
Filing Date:	17-JUN-2016
Time Stamp:	12:23:49
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	yes
Payment Type	EFT
Payment was successfully received in RAM	$1000
RAM confirmation Number	120618INTEFSW12240700
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	9595Transmittal.pdf	829860 57d1160426d7db921c2194f77015358[illegible]	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	30432 9dd7763e3d5029f7a719e040c[illegible]	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	860292		

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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
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New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/105,648	01/29/2019	10193600	4015-9595 / P45698-US2	5548

24112 7590 01/09/2019

COATS & BENNETT, PLLC
1400 Crescent Green, Suite 300
Cary, NC 27518

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 224 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Telefonaktiebolaget LM Ericsson (publ), Stockholm, SWEDEN;
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George Jöngren, Sundbyberg, SWEDEN;
Niklas Wernersson, Solna, SWEDEN;

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

IN RE APPLICATION OF: U.S. Patent No. 10,193,600

USPTO CONFIRMATION CODE: 5548

APPLICATION NO.: 15/105,648

PCT FILED: January 11, 2016

U.S. FILED: June 17, 2016

EXAMINER: Brian D Nguyen

GROUP ART UNIT: 2472

FOR: CODEBOOK SUBSET RESTRICTION SIGNALING

37 CFR 1.322 & 37 CFR 1.323 REQUEST FOR CERTIFICATE OF CORRECTION FOR USPTO AND/OR APPLICANT MISTAKE

HONORABLE COMMISSIONER OF PATENTS & TRADEMARKS

SIR:

The following is a request for a certificate of correction in Serial Number 15/105,648, now Patent Number 10,193,600.

A certificate of correction under 35 USC 254 is respectfully requested in the above-identified patent.

All errors were the fault of the USPTO, no fee required. In the event that a further fee is required, please charge the amount to our Deposit Account No. 50-1379.

The exact locations where the errors appear in the patent and patent application are as follows:

In Column 4, Line 44, delete "comprise;" and insert - - comprise: - -, therefor.
(ORIGINALLY FILED SPECIFICATION DATED JUNE 17, 2016, PAGE 5 (PAGE 132 OF FW), LINE 8)

In Column 10, Line 17, delete "two PMIS" and insert - - two PMIs - -, therefor.
(ORIGINALLY FILED SPECIFICATION DATED JUNE 17, 2016, PAGE 11 (PAGE 138 OF FW), LINE 26)

In Column 13, Line 30, delete "rank:" and insert - - rank; - -, therefor.
(ORIGINALLY FILED SPECIFICATION DATED JUNE 17, 2016, PAGE 15 (PAGE 142 OF FW), LINE 24)

In Column 15, Lines 51-52, delete "index is" and insert - - index i_2 is - -, therefor.
(ORIGINALLY FILED SPECIFICATION DATED JUNE 17, 2016, PAGE 18 (PAGE 145 OF FW), LINE 7)

In Column 19, Line 53,
delete "$\theta = a\cos(\tilde{\phi})\sin(\tilde{\theta})\sin(-\beta)+\cos(-\beta)\cos(\tilde{\theta}))$," and
insert - - $\theta = a\cos(\cos(\tilde{\phi})\sin(\tilde{\theta})\sin(-\beta) + \cos(-\beta)\cos(\tilde{\theta}))$ - -, therefor.
(ORIGINALLY FILED SPECIFICATION DATED JUNE 17, 2016, PAGE 22 (PAGE 149 OF FW), LINE 17)

In Column 26, Line 14, delete "s configured" and insert - - is configured - -, therefor.
(ORIGINALLY FILED SPECIFICATION DATED JUNE 17, 2016, PAGE 30 (PAGE 157 OF FW), LINE 4)

In Column 26, Line 51, in Claim 4, delete "a beam" and insert - - the beam - -, therefor.
(AMENDMENTS TO THE CLAIMS DATED NOVEMBER 14, 2018, PAGE 3 OF 9, CLAIM 43, LINE 1)

In Column 27, Line 37, in Claim 14, delete "claim 8, wherein a beam" and insert - - claim 10, wherein the beam - -, therefor.
(AMENDMENTS TO THE CLAIMS DATED NOVEMBER 14, 2018, PAGE 5 OF 9, CLAIM 54, LINE 1)

The requested corrections are attached on Form PTO 1050.

Respectfully Submitted

2018

DATE

/Ronald J. Ward,Reg#54870/

Ronald J. Ward
Registration No. 54,870
Attorney of Record

PTO/SB/44 (09-07)
Approved for use through 01/31/2020. OMB 0651-0033
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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 10,193,600 B2

APPLICATION NO. : 15/105,648

ISSUE DATE : January 29, 2019

INVENTOR(S) : Faxer, et al.

It is certified that an error appears or errors appear in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In Column 4, Line 44, delete "comprise;" and insert - - comprise: - -, therefor.

In Column 10, Line 17, delete "two PMIS" and insert - - two PMIs - -, therefor.

In Column 13, Line 30, delete "rank:" and insert - - rank; - -, therefor.

In Column 15, Lines 51-52, delete "index is" and insert - - index i2 is - -, therefor.

In Column 19, Line 53,

delete " $\theta = a\cos(\tilde{\phi})\sin(\tilde{\theta})\sin(-\beta)+\cos(-\beta)\cos(\tilde{\theta}))$ " and

insert - - $\theta = a\cos(\cos(\tilde{\phi})\sin(\tilde{\theta})\sin(-\beta) + \cos(-\beta)\cos(\tilde{\theta}))$ - -, therefor.

MAILING ADDRESS OF SENDER (Please do not use customer number below):

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Plano, TX 75024
972-583-8656

PTO/SB/44 (09-07)
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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 10,193,600 B2

APPLICATION NO. : 15/105,648

ISSUE DATE : January 29, 2019

INVENTOR(S) : Faxer, et al.

It is certified that an error appears or errors appear in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In Column 26, Line 14, delete "s configured" and insert - - is configured - -, therefor.

In Column 26, Line 51, in Claim 4, delete "a beam" and insert - - the beam - -, therefor.

In Column 27, Line 37, in Claim 14, delete "claim 8, wherein a beam" and insert - - claim 10, wherein the beam - -, therefor.

MAILING ADDRESS OF SENDER (Please do not use customer number below):

6300 Legacy, MS EVR 1-C-11
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The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Electronic Patent Application Fee Transmittal

Application Number:	15105648
Filing Date:	17-Jun-2016
Title of Invention:	Codebook Subset Restriction Signaling
First Named Inventor/Applicant Name:	Sebastian Faxér
Filer:	Brian Michael Kearns/Amber Rodgers
Attorney Docket Number:	4015-9595 / P45698-US2

Filed as Large Entity

Filing Fees for U.S. National Stage under 35 USC 371

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
CERTIFICATE OF CORRECTION	1811	1	150	150

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	150

Electronic Acknowledgement Receipt

EFS ID:	36057580
Application Number:	15105648
International Application Number:	
Confirmation Number:	5548
Title of Invention:	Codebook Subset Restriction Signaling
First Named Inventor/Applicant Name:	Sebastian Faxér
Customer Number:	24112
Filer:	Brian Michael Kearns/Amber Rodgers
Filer Authorized By:	Brian Michael Kearns
Attorney Docket Number:	4015-9595 / P45698-US2
Receipt Date:	20-MAY-2019
Filing Date:	17-JUN-2016
Time Stamp:	14:16:06
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	$150
RAM confirmation Number	052119INTEFSW00000509501379
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Request for Certificate of Correction	P45698-US2_2019-05-20_CoC_Request_Letter.pdf	143871 [illegible]	no	3
Warnings:					
Information:					
2	Request for Certificate of Correction	P45698-US2_2019-05-20_CoC_PTO-1050.pdf	159211 [illegible]	no	3
Warnings:					
Information:					
3	Fee Worksheet (SB06)	fee-info.pdf	30437 [illegible]	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	333519		

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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 10,193,600 B2
APPLICATION NO. : 15/105648
DATED : January 29, 2019
INVENTOR(S) : Faxer et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Specification

Column 4, Line 44, delete "comprise;" and insert -- comprise: --, therefor.

Column 10, Line 17, delete "two PMIS" and insert -- two PMIs --, therefor.

Column 13, Line 30, delete "rank:" and insert -- rank; --, therefor.

Column 15, Lines 51-52, delete "index is" and insert -- index i_2 is --, therefor.

Column 19, Line 53, delete "$\theta=a\cos(\tilde{\phi})\sin(\tilde{\theta})\sin(-\beta)+\cos(-\beta)\cos(\tilde{\theta}))$" and insert -- $\theta = acos(cos(\tilde{\phi})\, sin(\tilde{\theta})\, sin(-\beta) + cos(-\beta)\, cos(\tilde{\theta}))$ --, therefor.

Column 26, Line 14, delete "s configured" and insert -- is configured --, therefor.

In the Claims

Column 26, Line 51, Claim 4, delete "a beam" and insert -- the beam --, therefor.

Column 27, Line 37, Claim 14, delete "claim 8, wherein a beam" and insert -- claim 10, wherein the beam --, therefor.

Signed and Sealed this
Twenty-fifth Day of June, 2019

Andrei Iancu
Director of the United States Patent and Trademark Office

Doc Code: RFN.REQ
Document Description Refund

PTO-2326 (04-2019)
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REQUEST FOR REFUND

Reference # *(Patent #, Application #, Trademark Serial #, Registration #, etc.)*	**Title of Invention or Mark Information**	
10,193,600	CODEBOOK SUBSET RESTRICTION SIGNALING	
Attorney Docket # *(if applicable)*	**Payment Date** *(mm/dd/yyyy)*	**Refund Request Amount**
P45698-US2	05/20/2019	$ 150.00

Refund Option *(Select one)*

- (●) If approved, issue the refund to the account associated with the original payment.
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- [ ] Other _____

Rationale *(Supporting documentation may be submitted with this form)*

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patent.development@ericsson.com	469-266-0018	
Requester's Name		**Registration Number** *(if applicable)*
Brian M. Kearns		62,287
Signature		**Date** *(mm/dd/yyyy)*
/Brian M. Kearns/		05/14/2020

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Electronic Acknowledgement Receipt

EFS ID:	39442829
Application Number:	15105648
International Application Number:	
Confirmation Number:	5548
Title of Invention:	Codebook Subset Restriction Signaling
First Named Inventor/Applicant Name:	Sebastian Faxér
Customer Number:	24112
Filer:	Brian Michael Kearns/Amber Rodgers
Filer Authorized By:	Brian Michael Kearns
Attorney Docket Number:	4015-9595 / P45698-US2
Receipt Date:	14-MAY-2020
Filing Date:	17-JUN-2016
Time Stamp:	14:52:03
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Refund Request	P45698-US2_2020-05-14_Refund_Request_Form.pdf	682572	no	1

Warnings:

Information:	
Total Files Size (in bytes):	682572

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New International Application Filed with the USPTO as a Receiving Office

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