



(51) International Patent Classification:

H04B 7/0417 (2017.01) H04B 7/06 (2006.01)

H04B 7/0452 (2017.01)

(21) International Application Number:

PCT/EP2021/056691

(22) International Filing Date:

16 March 2021 (16.03.2021)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

20205276 18 March 2020 (18.03.2020) FI

(71) Applicant: NOKIA TECHNOLOGIES OY [FI/FI];
Karakaari 7, 02610 Espoo (FI).

(72) Inventors: MUELLER, Axel; 9, rue Adolphe Focillon,
75014 Paris (FR). ROSE, Luca; 52, avenue des Cottages,
91400 Orsay (FR). MASO, Marco; 41, Avenue Bourgain,
92130 Issy les Moulineaux (FR). HAJRI, Salah Eddine; 7
avenue Saint-Exupéry, 92160 Antony (FR).

(74) Agent: NOKIA EPO REPRESENTATIVES; Nokia
Technologies Oy, Karakaari 7, 02610 Espoo (FI).

(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,

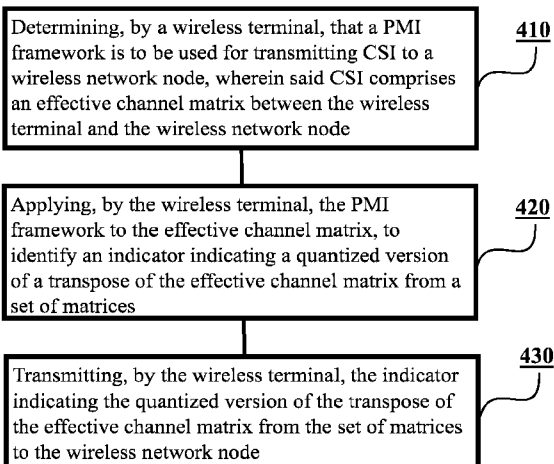
CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO,
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN,
KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD,
ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO,
NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW,
SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ,
UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: TRANSMISSION OF CHANNEL STATE INFORMATION IN WIRELESS COMMUNICATION NETWORKS



(57) Abstract: According to an example aspect of the present invention, there is provided a method comprising, determining, by a wireless terminal, that a precoding matrix indicator framework is to be used for transmitting channel state information to a wireless network node, wherein said channel state information comprises an effective channel matrix between the wireless terminal and a wireless network node, applying, by the wireless terminal, the precoding matrix indicator framework to the effective channel matrix, to identify an indicator indicating a quantized version of a transpose of the effective channel matrix from a set of matrices and means for transmitting, by the wireless terminal, the indicator indicating the quantized version of the transpose of the effective channel matrix from the set of matrices to the wireless network node.

FIGURE 4

TRANSMISSION OF CHANNEL STATE INFORMATION IN WIRELESS COMMUNICATION NETWORKS

FIELD

- 5 **[0001]** Various example embodiments relate in general to wireless communication networks and more specifically, to transmission of Channel State Information, CSI, in such networks.

BACKGROUND

- 10 **[0002]** In various wireless communication networks it would be important to inform a transmitter about Channel State Information, CSI, measured by a receiver, because the transmitter should know as much as possible about radio propagation conditions to be able to optimize its transmissions. For instance, CSI may be exploited in cellular networks, such as, in networks operating according to Long Term Evolution, LTE, and/or 5G radio access
15 technology. 5G radio access technology may also be referred to as New Radio, NR, access technology. Since its inception, LTE has been widely deployed and 3rd Generation Partnership Project, 3GPP, still develops LTE. Similarly, 3GPP also develops standards for 5G/NR. In general, there is a need to provide improvements related to transmission of explicit CSI. Such improvements may be exploited at least in LTE and NR networks, and
20 also in other communication networks in the future as well.

SUMMARY

- [0003]** According to some aspects, there is provided the subject-matter of the independent claims. Some embodiments are defined in the dependent claims.
- 25 **[0004]** The scope of protection sought for various embodiments of the invention is set out by the independent claims. The embodiments and features, if any, described in this specification that do not fall under the scope of the independent claims are to be interpreted as examples useful for understanding various embodiments of the invention.

[0005] According to a first aspect of the present invention, there is provided an apparatus comprising means for determining, by a wireless terminal, that a precoding matrix indicator framework is to be used for transmitting channel state information to a wireless network node, wherein said channel state information comprises an effective channel matrix
5 between the wireless terminal and the wireless network node, means for applying, by the wireless terminal, the precoding matrix indicator framework to the effective channel matrix, to identify an indicator indicating a quantized version of a transpose of the effective channel matrix from a set of matrices and means for transmitting, by the wireless terminal, the indicator indicating the quantized version of the transpose of the effective channel matrix
10 from the set of matrices to the wireless network node. The apparatus of the first aspect may be the wireless terminal, such as a user equipment, or a device controlling functioning thereof, possibly when installed therein.

[0006] Embodiments of the first aspect may comprise at least one feature from the following bulleted list:

- 15 • wherein said means for applying the precoding matrix indicator framework to the effective channel matrix further comprises means for generating the effective channel matrix between the wireless terminal and the wireless network node by multiplying a matrix of channel coefficients between the wireless terminal and the wireless network node by an equalizer matrix, means for determining a transpose of
20 the effective channel matrix, means for compressing the transpose of the effective channel matrix according to the precoding matrix indicator framework, to generate the quantized version of the transpose of the effective channel matrix and means for identifying the indicator indicating the quantized transpose of the effective channel matrix from the set of matrices;
- 25 • means for transmitting, by the wireless terminal, a capability indication to the wireless network node, the capability indication indicating that the wireless terminal supports re-use of the precoding matrix indicator framework for transmitting said channel state information;
- means for transmitting, by the wireless terminal, the capability indication upon
30 determining that the wireless terminal would like to report said channel state information instead of a precoding matrix indicator;
- means for transmitting, by the wireless terminal, another capability indication to the wireless network node, said another capability indication indicating that the wireless

terminal does not support re-use of the precoding matrix indicator framework for transmitting said channel state information;

- means for receiving, by the wireless terminal, a configuration from the wireless network node, the configuration configuring the wireless terminal to use the precoding matrix indicator framework for transmitting said channel state information.

[0007] According to a second aspect of the present invention, there is provided an apparatus comprising means for determining, by a wireless network node, that a precoding matrix indicator framework is used for transmitting channel state information from a wireless terminal, wherein said channel state information comprises an effective channel matrix between the wireless terminal and the wireless network node, means for receiving, by the wireless network node, an indicator indicating a quantized version of a transpose of the effective channel matrix from a set of matrices from the wireless terminal and means for applying, by the wireless network node, the precoding matrix indicator framework to the indicator indicating the quantized version of the transpose of the effective channel matrix from the set of matrices, to derive a quantized version of the effective channel matrix. The apparatus of the second aspect may be the wireless network node, such as a base station, or a device controlling functioning thereof, possibly when installed therein.

[0008] Embodiments of the second aspect may comprise at least one feature from the following bulleted list:

- wherein said means for applying the precoding matrix indicator framework to the effective channel matrix further comprises means for identifying, based on the indicator, the quantized version of the transpose of the effective channel matrix from the set of matrices and means for determining a transpose of the quantized version of the transpose of the effective channel matrix, to derive the quantized version of the effective channel matrix;
- means for receiving, by the wireless network node, a capability indication from the wireless terminal, the capability indication indicating that the wireless terminal supports re-use of the precoding matrix indicator framework for transmitting said channel state information;
- means for receiving, by the wireless network node, another capability indication from the wireless terminal, said another capability indication indicating that the wireless

terminal does not support re-use of the precoding matrix indicator framework for said transmitting said channel state information;

- means for transmitting, by the wireless network node, a configuration to the wireless terminal, the configuration configuring the wireless terminal to use the precoding matrix indicator framework for transmitting said channel state information;
- means for transmitting, by the wireless network node, the configuration upon determining that the precoding matrix indicator framework is to be used for transmitting said channel state information.

[0009] According to a third aspect, there is provided a first method comprising determining, by a wireless terminal, that a precoding matrix indicator framework is to be used for transmitting channel state information to a wireless network node, wherein said channel state information comprises an effective channel matrix between the wireless terminal and the wireless network node, applying, by the wireless terminal, the precoding matrix indicator framework to the effective channel matrix, to identify an indicator indicating a quantized version of a transpose of the effective channel matrix from a set of matrices and transmitting, by the wireless terminal, the indicator indicating the quantized version of the transpose of the effective channel matrix from the set of matrices to the wireless network node.

[0010] According to a fourth aspect, there is provided a second method comprising determining, by a wireless network node, that a precoding matrix indicator framework is used for transmitting channel state information from a wireless terminal, wherein said channel state information comprises an effective channel matrix between the wireless terminal and the wireless network node, receiving, by the wireless network node, an indicator indicating a quantized version of a transpose of the effective channel matrix from a set of matrices from the wireless terminal and applying, by the wireless network node, the precoding matrix indicator framework to the indicator indicating the quantized version of the transpose of the effective channel matrix from the set of matrices, to derive a quantized version of the effective channel matrix.

[0011] According to a fifth aspect of the present invention, there is provided an apparatus comprising at least one processing core, at least one memory including computer program code, the at least one memory and the computer program code being configured to, with the at least one processing core, cause the apparatus at least to perform, determine, by

a wireless terminal, that a precoding matrix indicator framework is to be used for transmitting channel state information to a wireless network node, wherein said channel state information comprises an effective channel matrix between the wireless terminal and the wireless network node, apply, by the wireless terminal, the precoding matrix indicator
5 framework to the effective channel matrix, to identify an indicator indicating a quantized version of a transpose of the effective channel matrix from a set of matrices and transmit, by the wireless terminal, the indicator indicating the quantized version of the transpose of the effective channel matrix from the set of matrices to the wireless network node. The apparatus of the fifth aspect may be the wireless terminal, such as a user equipment, or a device
10 controlling functioning thereof, possibly when installed therein.

[0012] According to a sixth aspect of the present invention, there is provided an apparatus comprising at least one processing core, at least one memory including computer program code, the at least one memory and the computer program code being configured to, with the at least one processing core, cause the apparatus at least to perform, determine, by
15 a wireless network node, that a precoding matrix indicator framework is used for transmitting channel state information from a wireless terminal, wherein said channel state information comprises an effective channel matrix between the wireless terminal and the wireless network node, receive, by the wireless network node, an indicator indicating a quantized version of a transpose of the effective channel matrix from a set of matrices from
20 the wireless terminal and apply, by the wireless network node, the precoding matrix indicator framework to the indicator indicating the quantized version of the transpose of the effective channel matrix from the set of matrices, to derive a quantized version of the effective channel matrix. The apparatus of the sixth aspect may be the wireless network node, such as a base station, or a device controlling functioning thereof, possibly when installed therein.

[0013] According to a seventh aspect of the present invention, there is provided non-transitory computer readable medium having stored thereon a set of computer readable instructions that, when executed by at least one processor, cause an apparatus to at least perform the first method. According to an eighth aspect of the present invention, there is provided non-transitory computer readable medium having stored thereon a set of computer
30 readable instructions that, when executed by at least one processor, cause an apparatus to at least perform the second method.

[0014] According to a ninth aspect of the present invention, there is provided a computer program configured to perform the first method. According to a tenth aspect of the present invention, there is provided a computer program configured to perform the second method.

5

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIGURE 1 illustrates an exemplary network scenario in accordance with at least some example embodiments;

10 [0016] FIGURE 2 illustrates a signaling graph in accordance with at least some embodiments;

[0017] FIGURE 3 illustrates an example apparatus capable of supporting at least some embodiments;

[0018] FIGURE 4 illustrates a flow graph of a first method in accordance with at least some embodiments;

15 [0019] FIGURE 5 illustrates a flow graph of a second method in accordance with at least some embodiments.

EMBODIMENTS

[0020] Transmission of Channel State Information, CSI, in a cellular communication
20 network may be improved by the procedures described herein. More specifically, a Precoding Matrix Indicator, PMI, framework may be re-used for transmitting explicit CSI. Said explicit CSI may be in the form of an effective channel matrix. In some example embodiments, the effective channel matrix may be an effective channel coefficient matrix between a wireless terminal, such as a User Equipment, UE, and a wireless network node,
25 such as a Base Station, BS. The wireless terminal may apply the PMI framework to the effective channel matrix, to identify an indicator indicating the effective channel matrix from a set of matrices. The wireless terminal may transmit the indicator to the wireless network node. The wireless network node may then also apply the PMI framework to the received

indicator, to derive the effective channel matrix between the wireless terminal and the wireless network node.

[0021] In some example embodiments, said explicit CSI, such as the effective channel matrix, may be referred to as explicit channel coefficients. The effective channel matrix may be further specified as a function of a physical channel and an equalizer matrix, thereby allowing re-use of the PMI framework. Such function does not need to take into account the precoder, because according to some example embodiments, the wireless network node may decide the precoder based on said the received explicit CSI, i.e., the wireless terminal does not know the precoder that will be used by the wireless network node.

[0022] FIGURE 1 illustrates an exemplary network scenario in accordance with at least some example embodiments. According to the example scenario of FIGURE 1, there may be a cellular communication network which comprises wireless terminal 110, such as a UE, wireless network node 120, such as a BS, and core network element 130.

[0023] Wireless terminal 110 may comprise, for example, a smartphone, a cellular phone, a Machine-to-Machine, M2M, node, Machine-Type Communications, MTC, node an Internet of Things, IoT, node, a car telemetry unit, a laptop computer, a tablet computer or, indeed, any kind of suitable wireless terminal. In the example system of FIGURE 1, wireless terminal 110 may communicate wirelessly with wireless network node 120, such as a BS or with a cell of the BS, via air interface 115. In some example embodiments, the BS may be considered as a serving BS, for wireless terminal 110.

[0024] Wireless terminal 110 may be connected to wireless network node 120 via air interface 115. Air interface 115 between wireless terminal 110 and wireless network node 120 may be configured in accordance with a Radio Access Technology, RAT, which wireless terminal 110 and wireless network node 120 are configured to support. Examples of cellular RATs include Long Term Evolution, LTE, New Radio, NR, which may also be known as fifth generation, 5G, radio access technology and MulteFire. For example, in the context of LTE, wireless network node 120 may be referred to as eNB while in the context of NR, wireless network node 120 may be referred to as gNB. In any case, example embodiments are not restricted to any particular wireless technology. Instead, example embodiments may be exploited in any wireless communication network wherein it is desirable to transmit explicit CSI by re-using the PMI framework.

[0025] Wireless network node 120 may be connected, directly or via at least one intermediate node, with core network 130 via interface 125. Core network 130 may be, in turn, coupled via interface 135 with another network (not shown in FIGURE 1), via which connectivity to further networks may be obtained, for example via a worldwide interconnection network. Wireless network node 120 may be connected with at least one other wireless network node as well via an inter-base station interface (not shown in FIGURE 1), even though in some example embodiments the inter-base station interface may be absent. Wireless network node 120 may be connected, directly or via at least one intermediate node, with core network 130 or with another core network.

[0026] In general, in wireless communication systems it is of imperative importance to know as much as possible about the radio propagation conditions on the transmitter side, to achieve high throughput by maximising the signal energy at an intended receiver while minimising the interference at all receivers. This is especially important for example in 5G/NR systems, wherein Multiple-Input Multiple-Output, MIMO, techniques, such as multi-user MIMO (Spatial Division Multiple Access, SDMA, precoding and/or beamforming) may be used to improve performance. Such techniques require extensive knowledge of radio propagation conditions though. The radio propagation conditions may be presented in the form of channel matrices which comprise phase and amplitude coefficients between all receiver and transmitter branches.

[0027] At least in cellular communication networks a receiver may feedback indirect information about a channel between a transmitter and the receiver by informing the transmitter about a precoder that the transmitter should use. Such indirect feedback information may be referred to as Precoding Matrix Indicator, PMI, feedback. PMI feedback is suboptimal though, because in case of PMI feedback the receiver makes the decision about the PMI feedback based on its own channel measurements, but the channel measurements of the receiver do not take other receivers into account, because only the central transmitter, such as the wireless network node, has information about other receivers.

[0028] Hence multi-user precoding decisions should be made by a central transmitter, e.g., a wireless network node such as a BS, by combining feedback information from all of the receivers and it is not sufficient if the receiver only provides the PMI feedback about the precoder that the transmitter should have used only based on the receiver's knowledge. The PMI feedback cannot be mapped 1-to-1, i.e., bijectively, into valid channel estimates and

thus there is a need to provide improvements for providing feedback about explicit channel estimates to the transmitter.

[0029] Example embodiments of the present invention therefore provide a way to provide explicit CSI feedback to the transmitter, with little implementation impact to specifications, such as RAN1 specifications of 5G/NR, and little impact on the implementation of wireless terminal 110, such as an UE. Such benefits can be achieved by re-using a PMI framework, as agreed for example in 3GPP standard specification TS 38.214, in Section 5.2.2.2. to indicate CSI, such as a transpose of an effective channel matrix. The effective channel matrix may refer to a matrix which has been generated by multiplying channel coefficients between wireless terminal 110 and wireless network node 120, as measured by wireless terminal 110, with an equalizer matrix of wireless terminal 110.

[0030] The compression schemes and implementation of the agreed TypeI and TypeII PMI frameworks are not touched. They are simply applied to the measured channel, even if this is non-optimal. The applicability rules of the measurement follow exactly the configuration of the PMI feedback applicability. Thus, the transmitted indicator, which has been generated according to the PMI framework, may be interpreted as CSI at the receiver.

[0031] That is to say, in some example embodiments, wireless terminal 110 may measure a physical channel matrix, e.g., via reference signals, such as CSI-RS or DM-RS. Wireless terminal may also determine an equalizer matrix. The effective channel matrix may be then determined by wireless terminal 110 by multiplying the physical channel matrix with the equalizer matrix. Multiplying the physical channel matrix with the equalizer matrix may change how received energy is allocated to subspaces, i.e. to the eigenvectors of the effective channel matrix. Specifically, the received energy may in the effective channel matrix preferably be allocated to a first group of eigenvectors, while less energy may be allocated to a second group of eigenvectors. The first group of eigenvectors may be the group of *nbr* strongest eigenvectors, i.e. the eigenvectors with largest eigenvalues in the channel matrix. The *nbr* strongest eigenvectors may be used for transmission of *nbr* signal layers, while the other eigenvectors are not used for signal transmission. In some embodiments the eigenvalues of the *nbr* strongest eigenvectors may be substantially equal. In some embodiments the eigenvalues of the *nbr* strongest eigenvectors may be obtained by applying a method based on a water filling principle. In some example embodiments, an exhaustive search may be then used by wireless terminal 110 to find a compressed, i.e., quantized,

representation of the effective channel matrix that minimizes a distance metric between the effective channel matrix and matrices in a set of matrices, i.e., matrices of a codebook. For instance, a least square metric may be used.

[0032] In some example embodiments, wireless terminal 110, such as an UE, may
5 signal its support for re-interpretation, i.e., re-use, of the PMI framework for explicit CSI using a capability indication, e.g., in UE capabilities. For instance, wireless terminal 110 may transmit an indication to wireless network node 110, the indication indicating that wireless terminal 110 supports re-use of the PMI framework for transmitting CSI. In some example embodiments, wireless terminal 110 may signal its support for re-using the PMI
10 framework for transmitting CSI in a flag, for example in a flag in a RRC configuration message, such as CSI-ReportConfig, which may indicate desire to change the interpretation of the PMI. Alternatively, wireless terminal 110 may signal its support for re-using the PMI framework for transmitting CSI using MAC control element, such as UEAssistanceInformation, or using uplink control information. Wireless terminal 110 and
15 wireless network node 120 may then adapt reporting signal flow and decision making according to some example embodiments of the present invention.

[0033] FIGURE 2 illustrates an exemplary signaling graph in accordance with at least some embodiments. On the vertical axes are disposed, from the left to the right, wireless terminal 110 and wireless network node 120 of FIGURE 1. Time advances from the top
20 toward the bottom. In some example embodiments, e.g., in the context of cellular communication networks, wireless terminal 110 may be referred to as an UE and wireless network node may be referred to as a BS.

[0034] In some example embodiments, a process may start, at step 210, wherein wireless terminal 110 may signal its support for re-interpretation, i.e., re-use, of the PMI
25 framework for transmitting CSI to wireless network node 120. That is to say, at step 210, wireless terminal 110 may transmit a capability indication indicating that wireless terminal 110 supports re-use of the PMI framework for transmitting CSI, e.g., an effective channel matrix between wireless terminal 110 and wireless network node 120. For instance, wireless terminal 110 may transmit the capability indication via a UE capability message during a
30 connection setup, or at a later point in time, for example during UE capability update process. In some example embodiments, wireless terminal 110 may thus change, or adapt, its capabilities by transmitting another capability indication as well.

[0035] Wireless terminal may transmit the capability indication indicating that wireless terminal 110 supports re-use of the PMI framework for transmitting CSI for various reasons. For instance, wireless terminal 110 may anticipate or measure unacceptable multi-user interference and hence decide to indicate that it supports re-use of the PMI framework for transmitting CSI, thereby making it possible for wireless network node 120 to perform proper multi-user MIMO/precoding.

[0036] Alternatively, or in addition, wireless terminal 110 may determine that it is running out of computational resources or wants to reduce its computational load to save energy. In such cases, wireless terminal 110 may also want to indicate that it supports re-use of the PMI framework for CSI, i.e., the PMI re-use to be employed, to avoid calculating the precoding matrix to be used at wireless network node 120 and give this task to wireless network node 120. Calculation of the precoding matrix is typically very expensive, as common implementations make use of exhaustive search or Singular Value Decomposition, SVD. Wireless terminal 110 thus must do channel estimation independently of PMI re-use, but if the PMI framework is re-used for transmitting explicit CSI, the precoder calculation step on top of channel estimation can be saved.

[0037] That is to say, in some example embodiments, wireless terminal 110 may, at step 210, transmit the capability indication indicating that it supports re-use of the PMI framework for transmitting CSI, wherein said CSI may comprise an effective channel matrix between wireless terminal 110 and wireless network node 120, upon determining that wireless terminal 110 would like to report said CSI instead of a precoding matrix indicator.

[0038] However, in some example embodiments, the situation of wireless terminal 110 may change and hence it may want to transmit said another capability indicator, e.g., to indicate that wireless terminal 110 does not support re-use of the PMI framework for transmitting said CSI anymore. Typically, said another capability indication may be transmitted after the capability indication transmitted at step 210. In some example embodiments, wireless terminal 110 may not force wireless network node 120 to choose any configuration though. Instead, wireless terminal 110 may give options, such as UE capabilities, and suggestions, such as reports, that wireless network node 120 may decide to ignore or exploit.

[0039] In some example embodiments, wireless terminal 110 may decide to transmit the capability indication indicating that it supports re-use of the PMI framework for

transmitting CSI based on at least one Key Performance Indicator, KPI. For instance, wireless terminal 110 may determine if KPI reduction is observed due to measured interference and if so, decide to transmit the capability indication. Also, wireless terminal 110 may decide to transmit the capability indication based on KPI reduction expected due to interference, KPI reduction expected or observed due to computational load (such as UE current load, UE known schedule, UE known current and future tasks, UE computational resources and/or UE temperature state) and/or KPI reduction expected or observed due to energy usage (such as UE battery state, UE energy plan, UE power usage estimates and/or UE configuration). In some example embodiments, the capability indication may be transmitted in UE capabilities; interpretPMIasChannelCoefficient, ENUMERATED {supported}, OPTIONAL.

[0040] In some example embodiments, wireless terminal 110 may determine, before transmitting the capability indication whether a lockout for the PMI re-use is in place, e.g., based on UE configuration, UE timer, UE feature activation and/or UE interference. If the lockout is not in place, wireless terminal 110 may transmit the capability indication.

[0041] For instance, in some example embodiments, wireless terminal 110 may not want to signal the use of “PMI-reuse”, even though all performance measurements and technical reasons point towards turning it on, e.g., based on licensing considerations or an UE vendor wanting to re-use the same modem in high end and low end market phones. Thus, some example embodiments of the present invention make it possible to deactivate advanced functionality. In addition, or alternatively, wireless terminal 110 may not want to signal the use of “PMI-reuse” if it was used before in this cell/network and actually led to worse performance. So wireless terminal 110 may want to lockout the feature from being active, either for some time or until network change. In some example embodiments, wireless terminal 110 may want to activate another PMI improving feature that is incompatible with “PMI-reuse”. Thus wireless terminal 110 may need to be sure that “PMI-reuse” is deactivated.

[0042] In some example embodiments, wireless network node 120 may configure wireless terminal 110 to use the PMI for transmitting CSI at step 220, e.g., via a flag in the Radio Resource Control, RRC, CSI reporting framework. For instance, wireless network node 120 may, at step 220, transmit a configuration to wireless terminal 110, the configuration configuring wireless terminal 110 to use the PMI for transmitting said CSI. In

some example embodiments, the transmission of the configuration may be conditional on the signaling of wireless terminal 110 at step 210, i.e., wireless network node 120 may transmit the configuration only after receiving the capability indication from wireless terminal 110 at step 210. Wireless terminal 110 may determine based on the received
5 configuration that the PMI framework is to be used for transmitting CSI to wireless network node 120.

[0043] Wireless network node 120 may want to use the PMI framework for transmission of the CSI for various reasons. For instance, wireless network node 120 may want to schedule more than one wireless terminal on a same resource and anticipate multi-
10 user interference, which may be alleviated using multi-user precoding enabled by the re-use of the PMI. Alternatively, or in addition, wireless network node 120 may want to reduce the power consumption and computational load of wireless terminal 110, e.g., because wireless terminal 110 has signalled overheating issues, possibly via the UEAssistanceInformation message. Thus, the expensive precoder calculation task may be moved from wireless
15 terminal 110 to wireless network node 120 by re-using the PMI framework for transmitting said explicit CSI. Expensive precoder calculation tasks may be also moved from wireless terminal 110 to wireless network node 120 for single-user cases, if needed.

[0044] In some example embodiments, wireless network node 120 may decide to transmit the configuration based on at least one KPI. For instance, wireless network node
20 120 may determine if KPI reduction is observed due to measured interference and if so, decide to transmit the configuration. Also, wireless network node 120 may decide to transmit the configuration based on KPI reduction expected due to expected interference with planned system configuration, KPI reduction expected or observed due to computational load (such as BS configuration, BS scheduler and /or UE configurations) and/or KPI reduction expected
25 or observed due to energy usage (such as BS configuration, BS scheduler, UE configurations, UE capabilities and/or assistance information).

[0045] In some example embodiments, wireless network node 120 may determine, before transmitting the configuration whether a lockout for the PMI re-use is in place similarly as wireless terminal 110, e.g., based on BS configuration, BS timer, BS feature
30 activation and/or UE PMI re-use support. If the lockout is not in place, wireless network node 120 may transmit the configuration.

[0046] In some example embodiments, wireless network node 120 may configure wireless terminal 110 with standard RRC CSI reporting codebook reporting quantities, such as the ones defined in 3GPP standard specification TS 38.331 (CSI-ReportConfig), including corresponding CSI-RS resources. That is to say, wireless network node 120 may decide to
5 re-use the standard PMI/reporting framework and configure wireless terminal 110 accordingly. For instance, CSI-ReportConfig may comprise a field interpretPMIasChannelCoefficient, ENUMERATED {true}, OPTIONAL.

[0047] At step 230, wireless network node 120 may transmit at least one reference signal, such as CSI-RS aligned with RRC configuration. Reporting of CSI may be triggered
10 by wireless network node 120 using various methods, such as DCI, MAC CE or RRC reconfiguration. Wireless terminal 110 may then apply a previously configured PMI codebook reporting framework to an effective channel matrix measured by wireless terminal 110 using the received reference signals, such as the CSI-RS, transmitted by wireless network node 120. For instance, wireless terminal may determine a compression scheme of
15 the previously configured PMI framework and apply the same compression scheme to the CSI, i.e., compress the effective channel matrix using the compression scheme of the PMI framework.

[0048] Wireless terminal 110 may measure the channel between wireless terminal 110 and wireless network node 120, and adapt the channel measurements to the PMI framework.
20 For that, wireless terminal 110 may first determine an effective channel matrix. The effective channel matrix may be the matrix of channel coefficients between the CSI-RS ports of the wireless network node 120 and the output ports of an equalizer at wireless terminal 110. In some example embodiments, the effective channel matrix may be determined according to standard methods, such as minimum mean square error estimation on measured CSI-RS
25 resources, wherein it specified that the UE decides the precoder on a channel that includes the equalizer.

[0049] Wireless terminal 110 may determine the effective channel matrix by first measuring a physical channel matrix using the received reference signals, such as CSI-RS. The physical channel matrix may be referred to as a matrix of channel coefficients between
30 the wireless terminal and the wireless network node. Then, wireless terminal 110 may determine a fitting equalizer/MIMO receiver for the measured physical channel matrix, i.e., an equalizer matrix. Wireless terminal 110 may know the equalizer that will be used to detect

downlink transmissions. For instance, in some example embodiments, the equalizer matrix may be known due to usage of demodulation reference signals during transmission/detection of downlink data, or estimation of the channel based on reference signals or with other signals with a waveform known by wireless terminal 110.

5 **[0050]** After that, wireless terminal 110 may multiply the measured physical channel matrix with the determined equalizer matrix, to generate the effective channel matrix. Wireless terminal 110 may then transpose the effective channel matrix, i.e., determine a transpose of the effective channel matrix.

10 **[0051]** Wireless terminal 110 may then apply the PMI framework to the transposed effective channel matrix, to identify an indicator indicating the transpose of the effective channel matrix from a set of matrices. Said indicator may be referred to as a pointer or an index as well, such as a pointer to a certain matrix in the set of matrices. The transpose of the effective channel matrix may be approximated with a previously configured PMI codebook for example, i.e., the transpose of the effective channel matrix may be compressed
15 according to the PMI framework, to identify an indicator indicating a compressed version of the transpose of the effective channel matrix from a set of matrices. The compressed effective channel matrix may be thus described by a sequence of bits, wherein the sequence of bits is compatible with the configured PMI framework.

20 **[0052]** The set of matrices may be predefined in a standard specification for example. So both, wireless terminal 110 and wireless network node 120, may know a mapping between one indicator and one matrix in the set of matrices. That is to say, if wireless terminal 110 selects a certain indicator, to indicate a certain matrix from the set of matrices, wireless network node 120 may also know what is the matrix indicated by the selected indicator. The indicator may be referred to as a codebook index as well. In some example
25 embodiments, the set of matrices may be defined similarly as the matrices in 3GPP standard specification TS 38.214, in Table 5.2.2.2.1-1 and the following tables therein.

30 **[0053]** That is to say, wireless terminal 110 may select an indicator that corresponds to a matrix from the table. A matrix which is closest to the determined effective channel matrix may be selected first and the indicator corresponding to the selected matrix may be selected after that.

[0054] At step 240, wireless terminal 110 may transmit the indicator indicating a compressed version of a transpose of the effective channel matrix from a set of matrices to wireless network node 120. Upon receiving the indicator, wireless network node 120 may interpret the received indicator as an indicator concerning the transpose of the effective channel matrix measured by wireless terminal 110. That is to say, wireless network node 120 may determine, due to the transmitted configuration, that the PMI framework is used for transmitting the CSI and extract the indicator from other reports of wireless terminal 110.

[0055] In some example embodiments, wireless network node may treat the indicator as follows. Wireless network node 120 may apply the PMI framework to the indicator to derive the effective channel matrix. For instance, wireless terminal 110 may identify, based on the indicator, the compressed version of the transpose of the effective channel matrix from the set of matrices and undo the transposition function to arrive at the effective channel matrix measured by wireless terminal 110, i.e., wireless network node 120 may determine a transpose of the effective channel matrix between wireless terminal 110 and wireless network node 120. The compressed effective channel matrix may be then stored, e.g., to be used in system operation, for example for precoding, scheduling, performance metric calculation, etc.

[0056] That is to say, wireless network node 120 may match the received indicator indicating the compressed version of the transpose of the effective channel matrix to one matrix in the set of matrices using normal reporting framework (PMI_UE_x → PMI_matrix_compressed_UE_x). That is to say, as a single indicator points to a single matrix in the set of matrices, wireless network node 120 may determine the effective channel matrix that corresponds to the received indicator. Thus, wireless network node 120 may select the correct compressed version of the transpose of the effective channel matrix from the set of matrices based on the received indicator.

[0057] In some example embodiments, wireless network node 120 may aggregate all information about effective channel matrices measured by more than one wireless terminals 110, thereby enabling proper multi-user MIMO precoding. That is to say, a real full channel matrix that should be used to calculate the BS side multi-user precoder, may be the concatenation of all the channel matrices from each UE, which have just been fed back using example embodiments of the present invention.

[0058] It should be noted that multi-user zero forcing precoding may serve one wireless terminal 110 while placing zeros/nulling interference for other wireless terminals. Such operation would not be possible with non-explicit CSI feedback, such as PMI feedback. In some example embodiments, wireless network node 120 may choose to aggregate all
5 information about effective channel matrices measured by more than one wireless terminals 110 based on its own architectural make up, as some architecture may only do baseband precoding for a maximum number of wireless terminals 110 at the same time. For instance, wireless network node 120 may choose different effective CSI aggregation levels based on its own current computational load, which might limit multi-user MIMO precoding
10 dimensionality. That is to say, wireless network node 120 may want to selectively aggregate just a few wireless terminals 110, for example wireless terminals 110 that interfere with each other the most, and calculate the multi-user precoder based on those.

[0059] At step 250, wireless network node 120 may transmit a downlink transmission to wireless terminal 110. Wireless network node 120 may base its precoding for the downlink
15 transmission by exploiting the derived compressed effective channel matrix, i.e., wireless network node 120 may base its precoding on the effective channel obtained by re-interpreting the received modified PMI as measurements of the effective channel. In some example embodiments, wireless network node 120 may not be forced to aggregate the effective channel matrices of more than one wireless terminal 110. Even in such a single-
20 user approach, wireless network node 120 may though make better decisions concerning precoding than wireless terminal 110, if wireless network node 120 takes for example buffer status and other internal parameters into account.

[0060] At some point after step 250, wireless terminal 110 may decide to change its capability for re-using the PMI framework for transmitting CSI. Wireless terminal 110 may
25 thus transmit, at step 260, another capability indication to wireless network node 120, said another capability indication indicating that wireless terminal 110 does not support re-use of the CSI for transmitting CSI. Wireless terminal 110 may decide to transmit said another capability indication based on measurements or any other reasoning, e.g., using the lockout feature to activate a different feature/optimization that is incompatible with PMI re-use or
30 because the observed performance is worse than expected. Said another capability indication may be transmitted using a UE capability messaging framework for example.

[0061] Alternatively, or in addition, wireless network node 120 may change the configuration of wireless terminal 110 concerning the use of the PMI framework for transmitting CSI, e.g., by using a RRC re-configuration framework.

[0062] Example embodiments of the present invention therefore provide a way to transmit explicit CSI at minimum additional signaling cost and complexity. Moreover, the complexity and computational load of wireless terminal 110 may be reduced. In addition, handling of multi-user interference in the system may be enabled, thereby increasing throughput. Also, in some example embodiments, the impact on standardization may be small, e.g., an addition on top of 5G NR Rel-15 (T38.331, 38.212, and 38.214).

[0063] FIGURE 3 illustrates an example apparatus capable of supporting at least some embodiments. Illustrated is device 300, which may comprise, for example, wireless terminal 110 or wireless network node 120. Comprised in device 300 is processor 310, which may comprise, for example, a single- or multi-core processor wherein a single-core processor comprises one processing core and a multi-core processor comprises more than one processing core. Processor 310 may comprise, in general, a control device. Processor 310 may comprise more than one processor. Processor 310 may be a control device. A processing core may comprise, for example, a Cortex-A8 processing core manufactured by ARM Holdings or a Steamroller processing core produced by Advanced Micro Devices Corporation. Processor 310 may comprise at least one Qualcomm Snapdragon and/or Intel Atom processor. Processor 310 may comprise at least one Application-Specific Integrated Circuit, ASIC. Processor 310 may comprise at least one Field-Programmable Gate Array, FPGA. Processor 310 may be means for performing method steps in device 300. Processor 310 may be configured, at least in part by computer instructions, to perform actions.

[0064] A processor may comprise circuitry, or be constituted as circuitry or circuitries, the circuitry or circuitries being configured to perform phases of methods in accordance with embodiments described herein. As used in this application, the term “circuitry” may refer to one or more or all of the following: (a) hardware-only circuit implementations, such as implementations in only analog and/or digital circuitry, and (b) combinations of hardware circuits and software, such as, as applicable: (i) a combination of analog and/or digital hardware circuit(s) with software/firmware and (ii) any portions of hardware processor(s) with software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as UE 110 or BS 120, to perform various functions) and

(c) hardware circuit(s) and or processor(s), such as a microprocessor(s) or a portion of a microprocessor(s), that requires software (e.g., firmware) for operation, but the software may not be present when it is not needed for operation.

[0065] This definition of circuitry applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term circuitry also covers an implementation of merely a hardware circuit or processor (or multiple processors) or portion of a hardware circuit or processor and its (or their) accompanying software and/or firmware. The term circuitry also covers, for example and if applicable to the particular claim element, a baseband integrated circuit or processor integrated circuit for a mobile device or a similar integrated circuit in server, a cellular network device, or other computing or network device.

[0066] Device 300 may comprise memory 320. Memory 320 may comprise random-access memory and/or permanent memory. Memory 320 may comprise at least one RAM chip. Memory 320 may comprise solid-state, magnetic, optical and/or holographic memory, for example. Memory 320 may be at least in part accessible to processor 310. Memory 320 may be at least in part comprised in processor 310. Memory 320 may be means for storing information. Memory 320 may comprise computer instructions that processor 310 is configured to execute. When computer instructions configured to cause processor 310 to perform certain actions are stored in memory 320, and device 300 overall is configured to run under the direction of processor 310 using computer instructions from memory 320, processor 310 and/or its at least one processing core may be considered to be configured to perform said certain actions. Memory 320 may be at least in part comprised in processor 310. Memory 320 may be at least in part external to device 300 but accessible to device 300.

[0067] Device 300 may comprise a transmitter 330. Device 300 may comprise a receiver 340. Transmitter 330 and receiver 340 may be configured to transmit and receive, respectively, information in accordance with at least one cellular or non-cellular standard. Transmitter 330 may comprise more than one transmitter. Receiver 340 may comprise more than one receiver. Transmitter 330 and/or receiver 340 may be configured to operate in accordance with Global System for Mobile Communication, GSM, Wideband Code Division Multiple Access, WCDMA, 5G/NR, Long Term Evolution, LTE, IS-95, Wireless Local Area Network, WLAN, Ethernet and/or Worldwide Interoperability for Microwave Access, WiMAX, standards, for example.

[0068] Device 300 may comprise a Near-Field Communication, NFC, transceiver 350. NFC transceiver 350 may support at least one NFC technology, such as NFC, Bluetooth, Wibree or similar technologies.

[0069] Device 300 may comprise User Interface, UI, 360. UI 360 may comprise at least one of a display, a keyboard, a touchscreen, a vibrator arranged to signal to a user by causing device 300 to vibrate, a speaker and a microphone. A user may be able to operate device 300 via UI 360, for example to accept incoming telephone calls, to originate telephone calls or video calls, to browse the Internet, to manage digital files stored in memory 320 or on a cloud accessible via transmitter 330 and receiver 340, or via NFC transceiver 350, and/or to play games.

[0070] Device 300 may comprise or be arranged to accept a user identity module 370. User identity module 370 may comprise, for example, a Subscriber Identity Module, SIM, card installable in device 300. A user identity module 370 may comprise information identifying a subscription of a user of device 300. A user identity module 370 may comprise cryptographic information usable to verify the identity of a user of device 300 and/or to facilitate encryption of communicated information and billing of the user of device 300 for communication effected via device 300.

[0071] Processor 310 may be furnished with a transmitter arranged to output information from processor 310, via electrical leads internal to device 300, to other devices comprised in device 300. Such a transmitter may comprise a serial bus transmitter arranged to, for example, output information via at least one electrical lead to memory 320 for storage therein. Alternatively to a serial bus, the transmitter may comprise a parallel bus transmitter. Likewise processor 310 may comprise a receiver arranged to receive information in processor 310, via electrical leads internal to device 300, from other devices comprised in device 300. Such a receiver may comprise a serial bus receiver arranged to, for example, receive information via at least one electrical lead from receiver 340 for processing in processor 310. Alternatively to a serial bus, the receiver may comprise a parallel bus receiver.

[0072] Device 300 may comprise further devices not illustrated in FIGURE 3. For example, where device 300 comprises a smartphone, it may comprise at least one digital camera. Some devices 300 may comprise a back-facing camera and a front-facing camera, wherein the back-facing camera may be intended for digital photography and the front-

facing camera for video telephony. Device 300 may comprise a fingerprint sensor arranged to authenticate, at least in part, a user of device 300. In some embodiments, device 300 lacks at least one device described above. For example, some devices 300 may lack a NFC transceiver 350 and/or user identity module 370.

5 **[0073]** Processor 310, memory 320, transmitter 330, receiver 340, NFC transceiver 350, UI 360 and/or user identity module 370 may be interconnected by electrical leads internal to device 300 in a multitude of different ways. For example, each of the aforementioned devices may be separately connected to a master bus internal to device 300, to allow for the devices to exchange information. However, as the skilled person will
10 appreciate, this is only one example and depending on the embodiment various ways of interconnecting at least two of the aforementioned devices may be selected without departing from the scope of the present invention.

[0074] FIGURE 4 is a flow graph of a first method in accordance with at least some embodiments. The phases of the illustrated first method may be performed by wireless
15 terminal 110, or by a control device configured to control the functioning thereof, possibly when installed therein.

[0075] The first method may comprise, at step 410, determining, by a wireless terminal, that a precoding matrix indicator framework is to be used for transmitting channel state information to a wireless network node, wherein said channel state information
20 comprises an effective channel matrix between the wireless terminal and the wireless network node. The first method may also comprise, at step 430, applying, by the wireless terminal, the precoding matrix indicator framework to the effective channel matrix, to identify an indicator indicating a quantized version of a transpose of the effective channel matrix from a set of matrices. Finally, the first method may comprise, at step 430,
25 transmitting, by the wireless terminal, the indicator indicating the quantized version of the transpose of the effective channel matrix from the set of matrices to the wireless network node.

[0076] FIGURE 5 is a flow graph of a second method in accordance with at least some embodiments. The phases of the illustrated second method may be performed by or wireless
30 network node 120, or by a control device configured to control the functioning thereof, possibly when installed therein.

[0077] The second method may comprise, at step 510, determining, by a wireless network node, that a precoding matrix indicator framework is used for transmitting channel state information from a wireless terminal, wherein said channel state information comprises an effective channel matrix between the wireless terminal and the wireless network node.

5 The second method may also comprise, at step 520, receiving, by the wireless network node, an indicator indicating a quantized version of a transpose of the effective channel matrix from a set of matrices from the wireless terminal. Finally, the second method may comprise, at step 430, applying, by the wireless network node, the precoding matrix indicator framework to the indicator indicating the quantized version of the transpose of the effective
10 channel matrix from the set of matrices, to derive a quantized version of the effective channel matrix.

[0078] It is to be understood that the embodiments disclosed are not limited to the particular structures, process steps, or materials disclosed herein, but are extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts.

15 It should also be understood that terminology employed herein is used for the purpose of describing particular embodiments only and is not intended to be limiting.

[0079] Reference throughout this specification to one embodiment or an embodiment means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, appearances of the phrases “in
20 one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment. Where reference is made to a numerical value using a term such as, for example, about or substantially, the exact numerical value is also disclosed.

[0080] As used herein, a plurality of items, structural elements, compositional
25 elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary. In addition, various
30 embodiments and examples may be referred to herein along with alternatives for the various components thereof. It is understood that such embodiments, examples, and alternatives are

not to be construed as de facto equivalents of one another, but are to be considered as separate and autonomous representations.

[0081] In an exemplary embodiment, an apparatus, such as, for example, wireless terminal 110 or wireless network node 120, may comprise means for carrying out the
5 embodiments described above and any combination thereof.

[0082] In an exemplary embodiment, a computer program may be configured to cause a method in accordance with the embodiments described above and any combination thereof. In an exemplary embodiment, a computer program product, embodied on a non-transitory computer readable medium, may be configured to control a processor to perform a process
10 comprising the embodiments described above and any combination thereof.

[0083] In an exemplary embodiment, an apparatus, such as, for example, wireless terminal 110 or wireless network node 120, may comprise at least one processor, and at least one memory including computer program code, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus
15 at least to perform the embodiments described above and any combination thereof.

[0084] Furthermore, the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. In the preceding description, numerous specific details are provided, such as examples of lengths, widths, shapes, etc., to provide a thorough understanding of embodiments of the invention. One skilled in the
20 relevant art will recognize, however, that the invention can be practiced without one or more of the specific details, or with other methods, components, materials, etc. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the invention.

[0085] While the forgoing examples are illustrative of the principles of the
25 embodiments in one or more particular applications, it will be apparent to those of ordinary skill in the art that numerous modifications in form, usage and details of implementation can be made without the exercise of inventive faculty, and without departing from the principles and concepts of the invention. Accordingly, it is not intended that the invention be limited, except as by the claims set forth below.

[0086] The verbs “to comprise” and “to include” are used in this document as open
30 limitations that neither exclude nor require the existence of also un-recited features. The

features recited in depending claims are mutually freely combinable unless otherwise explicitly stated. Furthermore, it is to be understood that the use of "a" or "an", that is, a singular form, throughout this document does not exclude a plurality.

5

INDUSTRIAL APPLICABILITY

[0087] At least some embodiments find industrial application in cellular communication networks, wherein it is desirable to transmit CSI by re-using the PMI framework, such as in networks operating according to 3GPP standards.

ACRONYMS LIST

	3GPP	3rd Generation Partnership Project
	ASIC	Application-Specific Integrated Circuit
	BS	Base Station
5	CSI	Channel State Information
	FPGA	Field-Programmable Gate Array
	GSM	Global System for Mobile communication
	IoT	Internet of Things
	KPI	Key Performance Indicator
10	LTE	Long-Term Evolution
	M2M	Machine-to-Machine
	MIMO	Multiple-Input Multiple-Output
	MTC	Machine-Type Communications
	NFC	Near-Field Communication
15	NR	New Radio
	PMI	Precoding Matrix Indicator
	RAT	Radio Access Technology
	RRC	Radio Resource Control
	SIM	Subscriber Identity Module
20	SDMA	Spatial Division Multiple Access
	SVD	Singular Value Decomposition
	UE	User Equipment
	UI	User Interface

WCDMA Wideband Code Division Multiple Access

WiMAX Worldwide Interoperability for Microwave Access

WLAN Wireless Local Area Network

5

REFERENCE SIGNS LIST

110	User Equipment
115, 125, 135	Interfaces
120	Base Station
130	Core network
210 – 260	Steps in the signaling graph of FIGURE 2
300 – 370	Structure of the apparatus of FIGURE 3
410 – 430	Phases of the first method in FIGURE 4
510 – 530	Phases of the second method in FIGURE 5

CLAIMS:

1. Apparatus comprising:

at least one processor and at least one memory including a computer program code, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to:

- determine, by a wireless terminal, that a precoding matrix indicator framework is to be used for transmitting channel state information to a wireless network node, wherein said channel state information comprises an effective channel matrix between the wireless terminal and the wireless network node;
- apply, by the wireless terminal, the precoding matrix indicator framework to the effective channel matrix, to identify an indicator indicating a quantized version of a transpose of the effective channel matrix from a set of matrices; and
- transmit, by the wireless terminal, the indicator indicating the quantized version of the transpose of the effective channel matrix from the set of matrices to the wireless network node.

2. An apparatus according to claim 1, wherein the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to:

- generate the effective channel matrix between the wireless terminal and the wireless network node by multiplying a matrix of channel coefficients between the wireless terminal and the wireless network node by an equalizer matrix;
- determine a transpose of the effective channel matrix;
- compress the transpose of the effective channel matrix according to the precoding matrix indicator framework, to generate the quantized version of the transpose of the effective channel matrix; and
- identify the indicator indicating the quantized transpose of the effective channel matrix from the set of matrices.

3. An apparatus according to claim 1 or claim 2, wherein the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to:

- transmit, by the wireless terminal, a capability indication to the wireless network node, the capability indication indicating that the wireless terminal supports re-use of the precoding matrix indicator framework for transmitting said channel state information.
4. An apparatus according to claim 3, wherein the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to:
- transmit, by the wireless terminal, the capability indication upon determining that the wireless terminal would like to report said channel state information instead of a precoding matrix indicator.
5. An apparatus according to claim 3 or claim 4, wherein the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to:
- transmit, by the wireless terminal, another capability indication to the wireless network node, said another capability indication indicating that the wireless terminal does not support re-use of the precoding matrix indicator framework for transmitting said channel state information.
6. An apparatus according to any of the preceding claims, wherein the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to:
- receive, by the wireless terminal, a configuration from the wireless network node, the configuration configuring the wireless terminal to use the precoding matrix indicator framework for transmitting said channel state information.
7. Apparatus comprising:
- at least one processor and at least one memory including a computer program code, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to:
- determine, by a wireless network node, that a precoding matrix indicator framework is used for transmitting channel state information from a wireless terminal, wherein

said channel state information comprises an effective channel matrix between the wireless terminal and the wireless network node;

- receive, by the wireless network node, an indicator indicating a quantized version of a transpose of the effective channel matrix from a set of matrices from the wireless terminal; and
- apply, by the wireless network node, the precoding matrix indicator framework to the indicator indicating the quantized version of the transpose of the effective channel matrix from the set of matrices, to derive a quantized version of the effective channel matrix.

8. An apparatus according to claim 7, wherein the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to:

- identify, based on the indicator, the quantized version of the transpose of the effective channel matrix from the set of matrices; and
- determine a transpose of the quantized version of the transpose of the effective channel matrix, to derive the quantized version of the effective channel matrix.

9. An apparatus according to claim 7 or claim 8, wherein the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to:

- receive, by the wireless network node, a capability indication from the wireless terminal, the capability indication indicating that the wireless terminal supports re-use of the precoding matrix indicator framework for transmitting said channel state information.

10. An apparatus according to claim 9, wherein the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to:

- receive, by the wireless network node, another capability indication from the wireless terminal, said another capability indication indicating that the wireless terminal does not support re-use of the precoding matrix indicator framework for said transmitting said channel state information.

11. An apparatus according to any of claims 7 to 10, wherein the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to:

- transmit, by the wireless network node, a configuration to the wireless terminal, the configuration configuring the wireless terminal to use the precoding matrix indicator framework for transmitting said channel state information.

12. An apparatus according to claim 11, wherein the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to:

- transmit, by the wireless network node, the configuration upon determining that the precoding matrix indicator framework is to be used for transmitting said channel state information.

13. A method, comprising:

- determining, by a wireless terminal, that a precoding matrix indicator framework is to be used for transmitting channel state information to a wireless network node, wherein said channel state information comprises an effective channel matrix between the wireless terminal and a wireless network node;
- applying, by the wireless terminal, the precoding matrix indicator framework to the effective channel matrix, to identify an indicator indicating a quantized version of a transpose of the effective channel matrix from a set of matrices; and
- transmitting, by the wireless terminal, the indicator indicating the quantized version of the transpose of the effective channel matrix from the set of matrices to the wireless network node.

14. A method according to claim 13, further comprising:

- generating the effective channel matrix between the wireless terminal and the wireless network node by multiplying a matrix of channel coefficients between the wireless terminal and the wireless network node by an equalizer matrix;
- determining a transpose of the effective channel matrix;

- compress the transpose of the effective channel matrix according to the precoding matrix indicator framework, to generate the quantized version of the transpose of the effective channel matrix; and
- identifying the indicator indicating the quantized transpose of the effective channel matrix from the set of matrices.

15. A method according to claim 13 or claim 14, further comprising:

- transmitting, by the wireless terminal, a capability indication to the wireless network node, the capability indication indicating that the wireless terminal supports re-use of the precoding matrix indicator framework for transmitting said channel state information.

16. A method according to claim 15, further comprising:

- transmitting, by the wireless terminal, the capability indication upon determining that the wireless terminal would like to report said channel state information instead of a precoding matrix indicator.

17. A method according to claim 15 or claim 16, further comprising:

- transmitting, by the wireless terminal, another capability indication to the wireless network node, said another capability indication indicating that the wireless terminal does not support re-use of the precoding matrix indicator framework for transmitting said channel state information.

18. A method according to any of claims 13 to 17, further comprising:

- receiving, by the wireless terminal, a configuration from the wireless network node, the configuration configuring the wireless terminal to use the precoding matrix indicator framework for transmitting said channel state information.

19. A method, comprising:

- determining, by a wireless network node, that a precoding matrix indicator framework is used for transmitting channel state information from a wireless terminal, wherein said channel state information comprises an effective channel matrix between the wireless terminal and the wireless network node;

- receiving, by the wireless network node, an indicator indicating a quantized version of a transpose of the effective channel matrix from a set of matrices from the wireless terminal; and
- applying, by the wireless network node, the precoding matrix indicator framework to the indicator indicating the quantized version of the transpose of the effective channel matrix from the set of matrices, to derive a quantized version of the effective channel matrix.

20. A method according to claim 19, further comprising:

- identifying, based on the indicator, the quantized version of the transpose of the effective channel matrix from the set of matrices; and
- determining a transpose of the quantized version of the transpose of the effective channel matrix, to derive the quantized version of the effective channel matrix.

21. A method according to claim 19 or claim 20, further comprising:

- receiving, by the wireless network node, a capability indication from the wireless terminal, the capability indication indicating that the wireless terminal supports re-use of the precoding matrix indicator framework for transmitting said channel state information.

22. A method according to claim 21, further comprising:

- receiving, by the wireless network node, another capability indication from the wireless terminal, said another capability indication indicating that the wireless terminal does not support re-use of the precoding matrix indicator framework for said transmitting said channel state information.

23. A method according to any of claims 19 to 22, further comprising:

- transmitting, by the wireless network node, a configuration to the wireless terminal, the configuration configuring the wireless terminal to use the precoding matrix indicator framework for transmitting said channel state information.

24. A method according to claim 23, further comprising:

- transmitting, by the wireless network node, the configuration upon determining that the precoding matrix indicator framework is to be used for transmitting said channel state information.

25. A computer program configured to perform a method according to any one of claims 13 to 24.

1/5

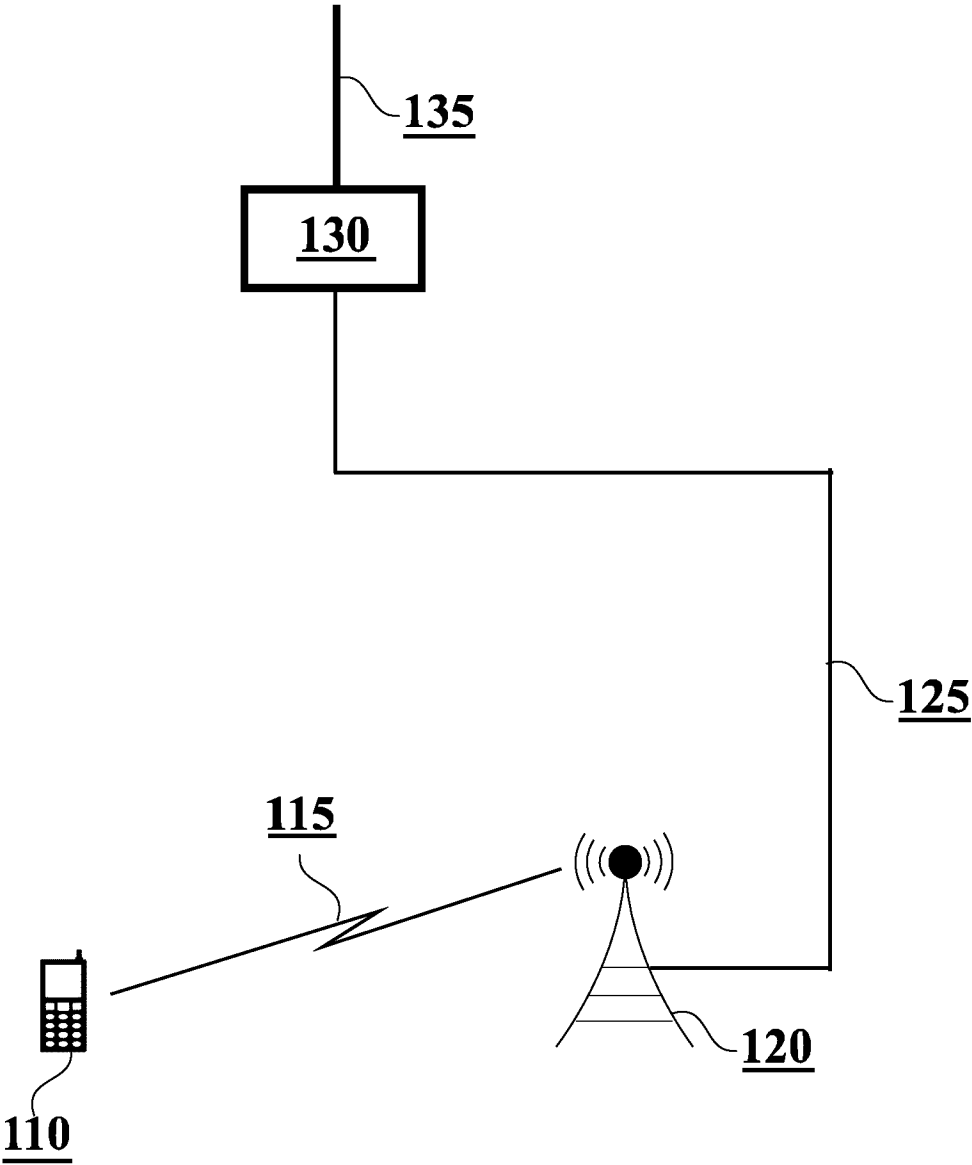


FIGURE 1

2/5

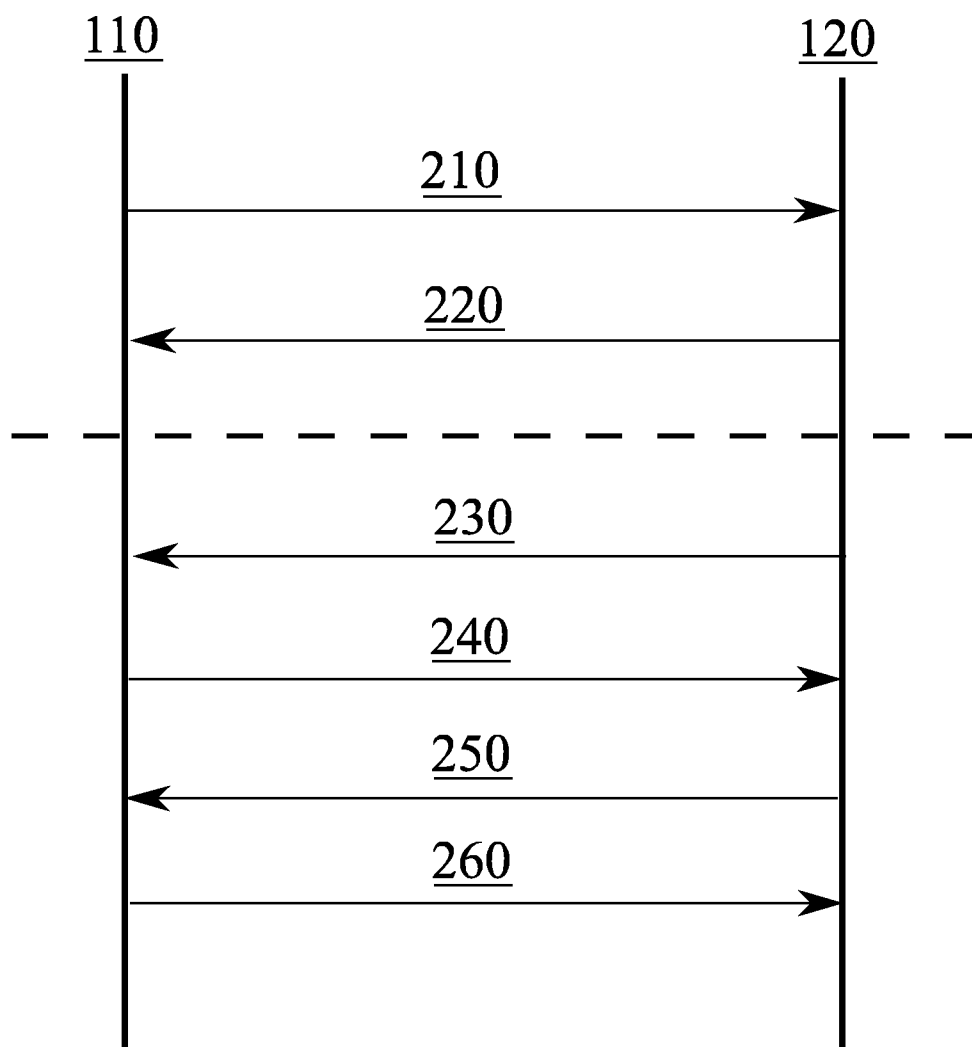


FIGURE 2

3/5

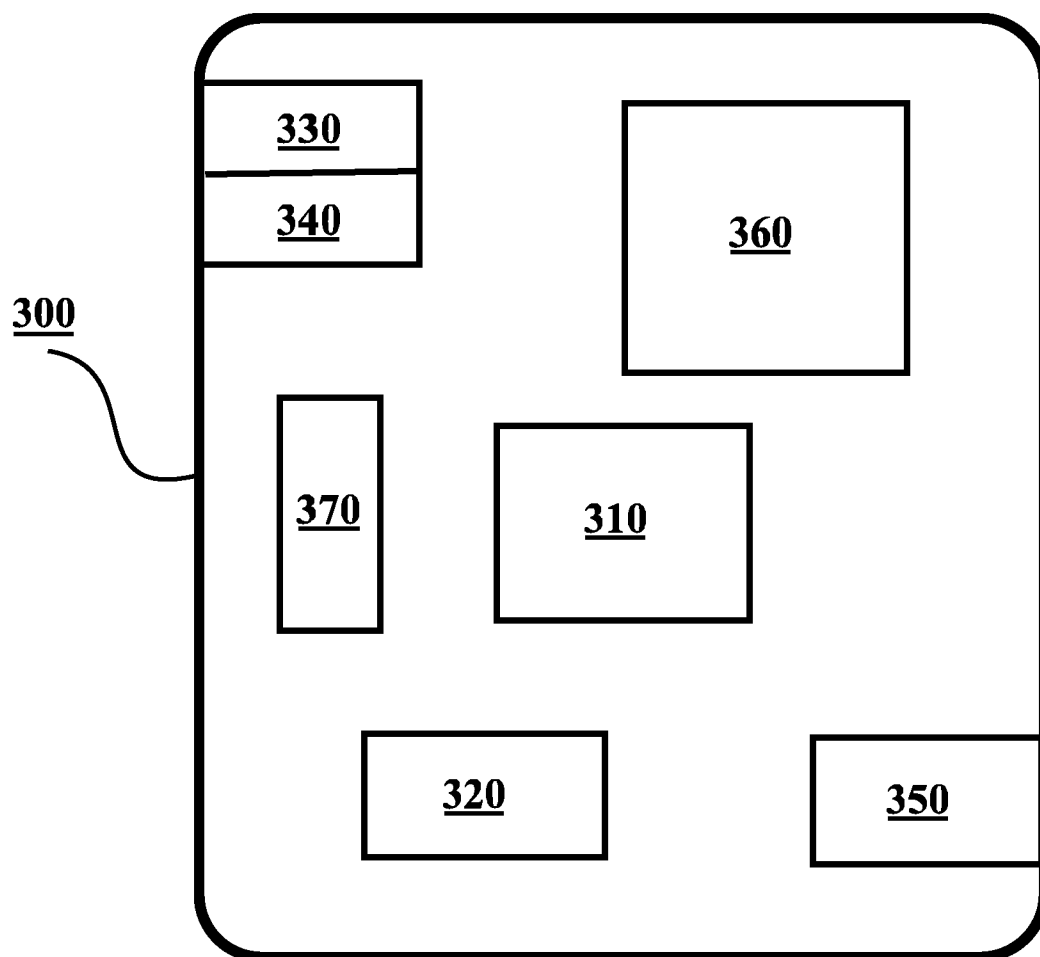


FIGURE 3

4/5

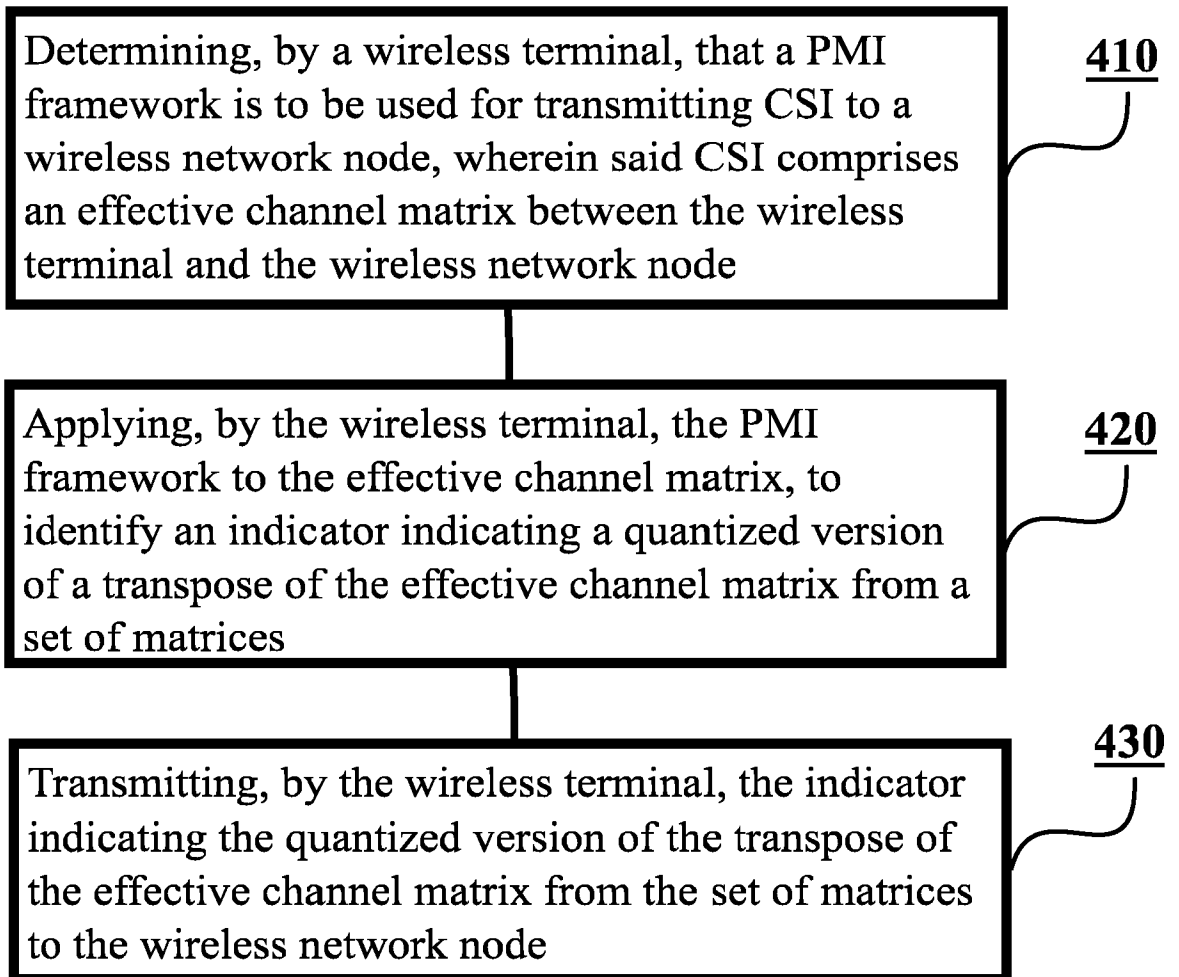


FIGURE 4

5/5

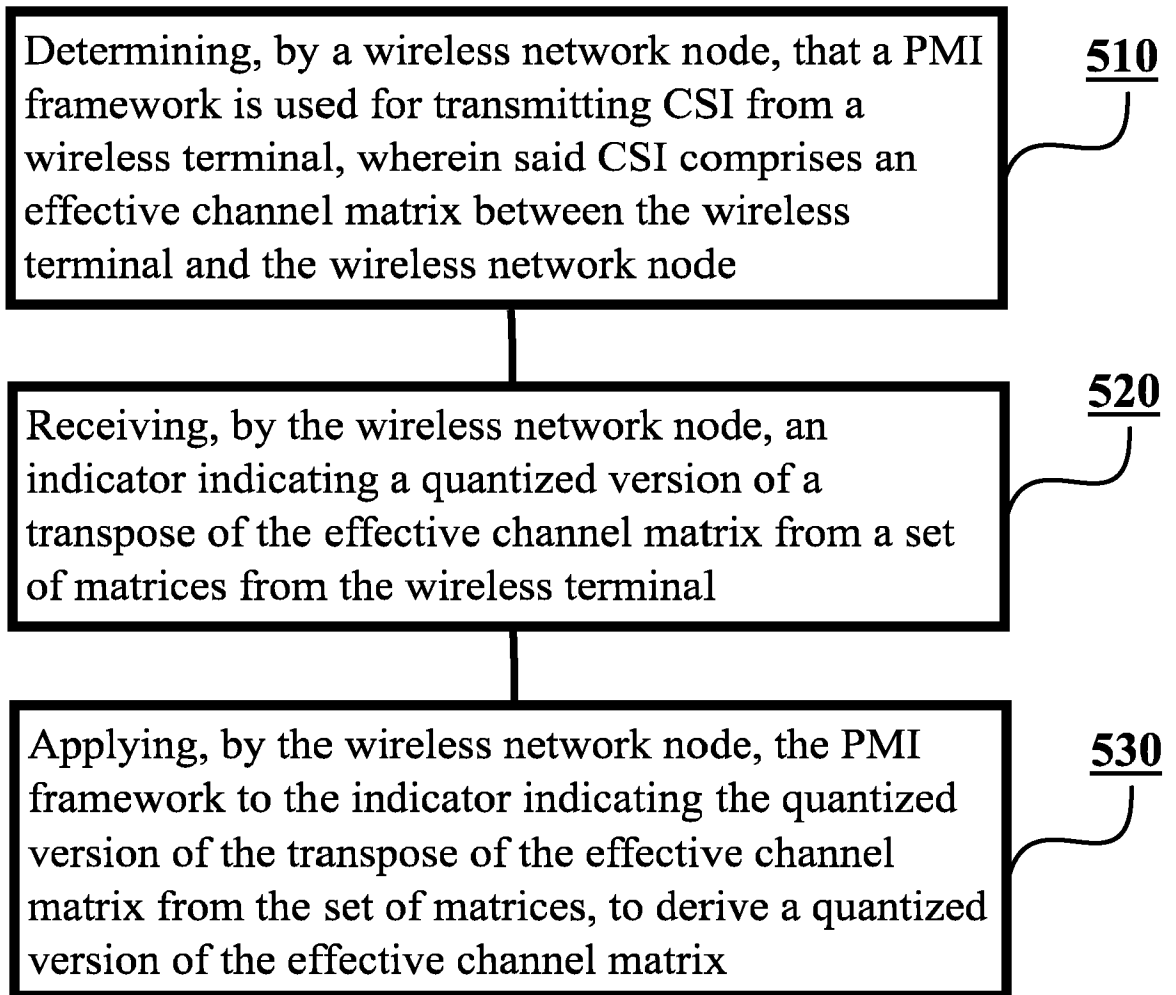


FIGURE 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2021/056691

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04B7/0417 H04B7/0452 H04B7/06
ADD.

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KATSUTOSHI KUSUME ET AL: "Hybrid Single/Multi-User MIMO Transmission Based on Implicit Channel Feedback", ICC 2011 - 2011 IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS - 5-9 JUNE 2011 - KYOTO, JAPAN, IEEE, PISCATAWAY, NJ, USA, 5 June 2011 (2011-06-05), pages 1-6, XP031908869, DOI: 10.1109/ICC.2011.5963117 ISBN: 978-1-61284-232-5	1-3, 5-15, 17-25
A	the whole document -----	4,16



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

31 May 2021

Date of mailing of the international search report

10/06/2021

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Neeb, Christoph