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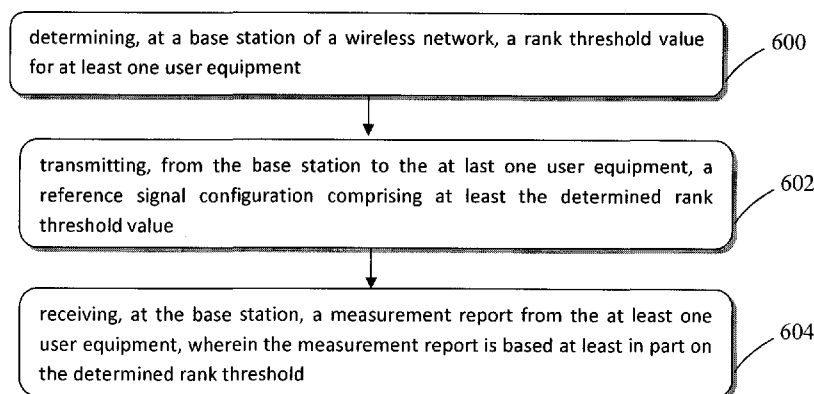


FIG. 6

(57) Abstract: According to an example embodiment, a method is provided including determining, at a base station of a wireless network, a rank threshold for at least one user equipment; transmitting, from the base station to the at least one user equipment, a reference signal configuration comprising at least the determined rank threshold; and receiving, at the base station, a measurement report from the at least one user equipment, wherein the measurement report is based at least in part on the determined rank threshold.



RANK ADAPTIVE CSI-RS DESIGN

TECHNICAL FIELD

[0001] This invention relates generally to wireless networks and, more specifically,
5 relates to Channel Status Information Resource Signal (CSI-RS) design.

BACKGROUND

[0002] This section is intended to provide a background or context to the invention disclosed below. The description herein may include concepts that could be pursued,
10 but are not necessarily ones that have been previously conceived, implemented or described. Therefore, unless otherwise explicitly indicated herein, what is described in this section is not prior art to the description in this application and is not admitted to be prior art by inclusion in this section. Abbreviations that may be found in the specification and/or the drawing figures are defined below, after the main part of the
15 detailed description section.

[0003] Channel Status Information Resource Signal (CSI-RS) plays an important role in CSI measurement and reporting. Typically, LTE systems include two types of CSI-RS, namely, precoded CSI-RS and unprecoded CSI-RS. Precoded CSI-RS may be precoded with a UE specific beam vector. Unprecoded CSI-RS are not UE-specific and
20 are mainly used for serving a group of UEs, or possibly all UEs of one cell. For either precoded CSI-RS or unprecoded CSI-RS, the configuration is semi-static and relative fixed regardless of UE traffic conditions or channel environment status. In the legacy LTE system, CSI-RS pattern is associated with antenna port number. It means for one CSI-RS resource, its pattern is depending on indicated antenna port number. When one
25 UE is indicated by base station with certain antenna port number, its pattern is also determined.

BRIEF SUMMARY

[0004] This section is intended to include examples and is not intended to be limiting.

[0005] In an example of an embodiment, a method is disclosed that includes determining, at a base station of a wireless network, a rank threshold value for at least one user equipment; transmitting, from the base station to the at last one user equipment, a reference signal configuration comprising at least the determined rank threshold value; and receiving, at the base station, a measurement report from the at least one user equipment, wherein the measurement report is based at least in part on the determined rank threshold.

[0006] An additional example of an embodiment includes a computer program, comprising code for performing the method of the previous paragraph, when the computer program is run on a processor. The computer program according to this paragraph, wherein the computer program is a computer program product comprising a computer-readable medium bearing computer program code embodied therein for use with a computer.

[0007] An example of an apparatus includes one or more processors and one or more memories including computer program code. The one or more memories and the computer program code are configured to, with the one or more processors, cause the apparatus to at least: determine, at a base station of a wireless network, a rank threshold value for at least one user equipment; transmit, from the base station to the at last one user equipment, a reference signal configuration comprising at least the determined rank threshold value; and receive, at the base station, a measurement report from the at least one user equipment, wherein the measurement report is based at least in part on the determined rank threshold.

[0008] In another example of an embodiment, an apparatus comprises means for determining, at a base station of a wireless network, a rank threshold value for at least one user equipment; transmitting, from the base station to the at last one user equipment, a reference signal configuration comprising at least the determined rank threshold value; and receiving, at the base station, a measurement report from the at least one user equipment, wherein the measurement report is based at least in part on the determined rank threshold.

[0009] In an example of an embodiment, a method is disclosed that includes receiving, at a user equipment of a wireless network, a reference signal configuration comprising at least an indication of a rank threshold value; determining, at the user equipment, a

specific rank adaptive reference signal pattern corresponding to the rank threshold; performing, at the user equipment, measurements of one or more reference signals received according to the determined rank adaptive reference signal pattern; and transmitting, from the user equipment to a base station of the wireless network, a measurement report comprising information corresponding to the performed measurements.

[0010] An additional example of an embodiment includes a computer program, comprising code for performing the method of the previous paragraph, when the computer program is run on a processor. The computer program according to this paragraph, wherein the computer program is a computer program product comprising a computer-readable medium bearing computer program code embodied therein for use with a computer.

[0011] An example of an apparatus includes one or more processors and one or more memories including computer program code. The one or more memories and the computer program code are configured to, with the one or more processors, cause the apparatus to at least: receive, at a user equipment of a wireless network, a reference signal configuration comprising at least an indication of a rank threshold value; determine, at the user equipment, a specific rank adaptive reference signal pattern corresponding to the rank threshold; perform, at the user equipment, measurements of one or more reference signals received according to the determined rank adaptive reference signal pattern; and transmit, from the user equipment to a base station of the wireless network, a measurement report comprising information corresponding to the performed measurements.

[0012] In another example of an embodiment, an apparatus comprises means for receiving, at a user equipment of a wireless network, a reference signal configuration comprising at least an indication of a rank threshold value; means for determining, at the user equipment, a specific rank adaptive reference signal pattern corresponding to the rank threshold; means for performing, at the user equipment, measurements of one or more reference signals received according to the determined rank adaptive reference signal pattern; and means for transmitting, from the user equipment to a base station of the wireless network, a measurement report comprising information corresponding to the performed measurements.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] In the attached Drawing Figures:

[0014] FIG. 1 is a block diagram of one possible and non-limiting exemplary system in which the exemplary embodiments may be practiced;

[0015] FIG. 2A-2F illustrate example CSI-RS resource patterns for different ranks and different configurations;

[0016] FIG. 3 is an example base station having three beams associated with different groups of user equipment in accordance with example embodiments;

[0017] FIG. 4 signaling diagram according to example embodiments; and

[0018] FIGS. 5 and 6 are logic flow diagrams for rank adaptive CSI-RS design, and illustrate the operation of exemplary methods, a result of execution of computer program instructions embodied on a computer readable memory, functions performed by logic implemented in hardware, and/or interconnected means for performing functions in accordance with exemplary embodiments.

DETAILED DESCRIPTION

[0019] The description below generally refers to LTE terms, however this is not intended to be limiting. The description is equally applicable to other wireless networks, such as 5G NR wireless networks for example. For example, the LTE term 'eNB' is equally applicable to a 5G base station (commonly referred to as a 'gNB') for the purposes of the description below.

[0020] Example embodiments herein describe techniques for rank adaptive CSI-RS design. Additional description of these techniques is presented after a system into which the exemplary embodiments may be used is described.

[0021] Turning to FIG. 1, this figure shows a block diagram of one possible and non-limiting exemplary system in which the exemplary embodiments may be practiced. In FIG. 1, a user equipment (UE) 110 is in wireless communication with a wireless network 100. A UE is a wireless, typically mobile device that can access a wireless network. The UE 110 includes one or more processors 120, one or more memories 125,

and one or more transceivers 130 interconnected through one or more buses 127. Each of the one or more transceivers 130 includes a receiver, Rx, 132 and a transmitter, Tx, 133. The one or more buses 127 may be address, data, or control buses, and may include any interconnection mechanism, such as a series of lines on a motherboard or integrated circuit, fiber optics or other optical communication equipment, and the like. The one or more transceivers 130 are connected to one or more antennas 128. The one or more memories 125 include computer program code 123. The UE 110 includes a measurement module, comprising one of or both parts 140-1 and/or 140-2, which may be implemented in a number of ways. The measurement module may be implemented in hardware as measurement module 140-1, such as being implemented as part of the one or more processors 120. The measurement module 140-1 may be implemented also as an integrated circuit or through other hardware such as a programmable gate array. In another example, the measurement module may be implemented as measurement module 140-2, which is implemented as computer program code 123 and is executed by the one or more processors 120. For instance, the one or more memories 125 and the computer program code 123 may be configured to, with the one or more processors 120, cause the user equipment 110 to perform one or more of the operations as described herein. The UE 110 communicates with eNB 170 via a wireless link 111.

[0022] The eNB (evolved NodeB) 170 is a base station (e.g., for LTE, long term evolution) that provides access by wireless devices such as the UE 110 to the wireless network 100. The eNB 170 includes one or more processors 152, one or more memories 155, one or more network interfaces (N/W I/F(s)) 161, and one or more transceivers 160 interconnected through one or more buses 157. Each of the one or more transceivers 160 includes a receiver, Rx, 162 and a transmitter, Tx, 163. The one or more transceivers 160 are connected to one or more antennas 158. The one or more memories 155 include computer program code 153. The eNB 170 includes a CSI-RS configuration module, comprising one of or both parts 150-1 and/or 150-2, which may be implemented in a number of ways. The CSI-RS configuration module may be implemented in hardware as CSI-RS configuration module 150-1, such as being implemented as part of the one or more processors 152. The CSI-RS configuration module 150-1 may be implemented also as an integrated circuit or through other hardware such as a programmable gate array. In another example, the CSI-RS configuration module may be implemented as CSI-RS configuration module 150-2,

which is implemented as computer program code 153 and is executed by the one or more processors 152. For instance, the one or more memories 155 and the computer program code 153 are configured to, with the one or more processors 152, cause the eNB 170 to perform one or more of the operations as described herein. The one or more network interfaces 161 communicate over a network such as via the links 176 and 131. Two or more eNBs 170 communicate using, e.g., link 176. The link 176 may be wired or wireless or both and may implement, e.g., an X2 interface.

[0023] The one or more buses 157 may be address, data, or control buses, and may include any interconnection mechanism, such as a series of lines on a motherboard or integrated circuit, fiber optics or other optical communication equipment, wireless channels, and the like. For example, the one or more transceivers 160 may be implemented as a remote radio head (RRH) 195, with the other elements of the eNB 170 being physically in a different location from the RRH, and the one or more buses 157 could be implemented in part as fiber optic cable to connect the other elements of the eNB 170 to the RRH 195.

[0024] It is noted that description herein indicates that “cells” perform functions, but it should be clear that the eNB that forms the cell will perform the functions. The cell makes up part of an eNB. That is, there can be multiple cells per eNB. For instance, there could be three cells for a single eNB carrier frequency and associated bandwidth, each cell covering one-third of a 360 degree area so that the single eNB’s coverage area covers an approximate oval or circle. Furthermore, each cell can correspond to a single carrier and an eNB may use multiple carriers. So if there are three 120 degree cells per carrier and two carriers, then the eNB has a total of 6 cells.

[0025] The wireless network 100 may include one or more network control elements (NCE) 190 that may include MME (Mobility Management Entity) and/or SGW (Serving Gateway) functionality, and which provides connectivity with a further network, such as a telephone network and/or a data communications network (e.g., the Internet). The eNB 170 is coupled via a link 131 to the NCE 190. The link 131 may be implemented as, e.g., an S1 interface. The NCE 190 includes one or more processors 175, one or more memories 171, and one or more network interfaces (N/W I/F(s)) 180, interconnected through one or more buses 185. The one or more memories 171 include computer program code 173. The one or more memories 171 and the computer program

code 173 are configured to, with the one or more processors 175, cause the NCE 190 to perform one or more operations.

[0026] The wireless network 100 may implement network virtualization, which is the process of combining hardware and software network resources and network functionality into a single, software-based administrative entity, a virtual network. Network virtualization involves platform virtualization, often combined with resource virtualization. Network virtualization is categorized as either external, combining many networks, or parts of networks, into a virtual unit, or internal, providing network-like functionality to software containers on a single system. Note that the virtualized entities that result from the network virtualization are still implemented, at some level, using hardware such as processors 152 or 175 and memories 155 and 171, and also such virtualized entities create technical effects.

[0027] The computer readable memories 125, 155, and 171 may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor based memory devices, flash memory, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The computer readable memories 125, 155, and 171 may be means for performing storage functions. The processors 120, 152, and 175 may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on a multi-core processor architecture, as non-limiting examples. The processors 120, 152, and 175 may be means for performing functions, such as controlling the UE 110, eNB 170, and other functions as described herein.

[0028] In general, the various embodiments of the user equipment 110 can include, but are not limited to, cellular telephones such as smart phones, tablets, personal digital assistants (PDAs) having wireless communication capabilities, portable computers having wireless communication capabilities, image capture devices such as digital cameras having wireless communication capabilities, gaming devices having wireless communication capabilities, music storage and playback appliances having wireless communication capabilities, Internet appliances permitting wireless Internet access and browsing, tablets with wireless communication capabilities, as well as portable units or terminals that incorporate combinations of such functions.

[0029] Having thus introduced one suitable but non-limiting technical context for the practice of the exemplary embodiments of this invention, the exemplary embodiments will now be described with greater specificity.

5 [0030] CSI-RS pattern and configuration in 5G wireless networks are expected to be more adaptive and flexible in order to match rich traffic types and various application scenarios being introduced in 5G wireless networks. More specifically, 5G will support at least three main applications: eMBB, massive MTC, URLLC (ultra reliability and low latency communication). For eMBB, its main target is to provide good coverage and high throughput, normally requiring high rank transmission for capacity and low rank for coverage; for massive MTC, its data packet is quite small, where low rank transmission is sufficient; for URLLC application, it will require high reliability, normally low rank is needed to ensure transmission reliability. Meanwhile, it will support, e.g., indoor hotspot, dense urban, rural, urban macro, and high speed cases. Different scenarios will have different channel environment and SINR conditions, for example, in a high speed case, Doppler shifting is quite severe, thus high rank transmission is not suitable. 5G will also support various traffic types, such as voice, video, email and internet applications for example.

20 [0031] In 3GPP LTE Release 13, CSI-RS and related CSI-RS feedback may be categorized by two classes, referred to as class A and class B. In class A, a cell specific CSI-RS operation is configured and a single unprecoded CSI-RS resource is configured to allow codebook based CSI-RS feedback. In class B, multiple beamformed CSI-RS resources are configured to a single UE and the UE will select and report a favored beam index and related CSI information based on the selected CSI-RS resource. For Class A, the configuration is often fixed and cell specific, hence, antenna port number and pattern of CSI-RS resource is difficult to change to meet UE specific requirements. For class B, the configuration may be UE specific but operates in a semi-static way and the antenna port and pattern in each CSI-RS resource is also stable and not able to adapt to different traffic and channel environments.

30 [0032] In 5G new radio (NR) systems, beam specific CSI-RS is introduced as one beam acquisition based CSI-RS, however, there is no significant change to the current CSI acquisition based CSI-RS. Traffic types, such as broadcast information for example, often use a rank 1 transmission, while traffic types having larger data packets, such as an FTP service or video service for example, will often use a multiple layer (high rank)

transmission. If a UE is suffering from hostile channel conditions then a low rank transmission is often used.

[0033] A single adaptive CSI-RS design may help address changes to UE traffic and channel environment. Since the number of data streams is limited to channel
5 environment and traffic load, suitable rank configuration is meaningful to save overhead and simplify UE behaviors.

[0034] Example embodiments relate to a rank adaptive CSI-RS pattern design that may be adapted for different rank thresholds. In one example, the CSI-RS pattern design could be one unified CSI-RS pattern for different rank thresholds. One or more example
10 embodiments, which are described in more detail below, generally relate to defining a rank adaptive CSI-RS pattern design that may be adapted for different rank thresholds; transmitting an indication of a rank threshold and the corresponding CSI-RS resource pattern to a user equipment for tracking traffic load and changes in channel environment; and receiving a CSI report including information based on the rank
15 threshold indication and a predefined CSI feedback mechanism related to rank threshold.

[0035] For example, when the number of antenna ports is larger (e.g. ≥ 8), then there is only one beam specific resource group within one CSI-RS resource. Therefore, there is no need to report a favored beam index (corresponding to the one resource group).
20 When the antenna port number is small (e.g. < 8), there may be multiple beam specific resource groups. When this is the case, the beam index may be reported. Furthermore, if a different codebook structure is applied for different rank thresholds, for example, when rank threshold is equal to 1, then there is no need to report PMI. When rank threshold is 2, then one single PMI is enough. When rank threshold is more than 4,
25 multiple PMI reporting may be required, either long term plus short term PMI, or multiple beam based PMI. Thus, according to some example embodiments, the reporting mechanism may be predefined in a standard to enable this understanding between the base station and the UE.

[0036] The rank thresholds may be, e.g., equivalent to maximum layer number in DL
30 transmission, and an eNB may indicate a rank threshold and an associated pattern to the UE based on at least one of: UE SINR, traffic load and other channel environment conditions. In some examples, the indication may be dynamic to track changes in traffic

and channel scenarios. When a rank threshold is configured, the succeeding data transmission may follow this limitation until a new rank threshold configuration. The maximum DL rank in the following data transmission will not exceed this rank threshold, until UE receives one new rank threshold indication. It is noted that the maximum DL data stream number will be less than or equal to the indicated rank threshold even if rank adaptation is enabled for this UE.

Defining a Rank Adaptive CSI-RS Pattern

[0037] According to an example embodiment, a rank threshold value is predefined with specific levels, such as 1, 2, 4, or 8 levels for example. Non-limiting examples of rank adaptive CSI-RS patterns are now described with reference to FIGS. 2A-2D.

[0038] FIGS. 2A-2D illustrate non-limiting example CSI-RS patterns for rank thresholds equal to 1, 2, 4, and 8, respectively, within one physical resource block (PRB) in accordance with example embodiments. In the examples in FIGS. 2A-2D, one OFDM symbol is used to carry the CSI-RS resource, where the OFDM symbol includes a number of resource elements (namely RE1-RE8). It is assumed in the examples shown in FIGS. 2A-2D that two consecutive resource elements in frequency domain formulate one basic resource unit. A basic resource unit may comprise two consecutive resource elements aggregated either in frequency domain or in time domain within one physical resource block. It is also assumed two code sequences are used to differentiate between two antenna ports for each basic resource unit, for example, using orthogonal cover code (OCC) sequences (+1+1, +1-1). Though this basic resource unit in FIGS. 2A-2D is placed in frequency domain, it can be generalized in time domain on the two consecutive OFDM symbols, or located in arbitrary time-frequency resource locations.

[0039] It is noted that a reference signal (RS) group refers to a group of resource elements for transmitting a reference signal, which is used to measure CSI information on one certain beam direction. One CSI-RS pattern may comprise one or multiple RS groups. A number of identifiable CSI-RS ports of one RS group is equal to rank threshold. The size of an RS group depends on rank threshold and resource mapping way of CSI-RS. For example, if the rank threshold is 4, the required CSI-RS port number of one RS group is equal to 4. Thus, for orthogonal resource mapping, 4 resource elements should be comprised within one RS group. For non-orthogonal

resource mapping, the number of resource elements may be less than the number of antenna ports, and the number of resource elements of one RS group is less than 4.

[0040] Referring now to FIG. 2A, this figure shows an example rank 1 CSI-RS pattern 210 in accordance with example embodiments. In particular, this example includes a single CSI-RS resource having eight independent antenna ports, and for each RS group 215 of two resource elements there are two antenna ports orthogonal via an OCC sequence. Each antenna port may be associated with a different beam. Each circle represents a different beam.

[0041] Referring to FIG. 2B, this figure shows an example rank 2 CSI-RS pattern 220 in accordance with example embodiments. Each RS group 225 comprises two REs and is associated with a different beam. In this example, there are four beams where each beam is represented by a circle. Two antenna ports in one RS group 225 map into two antenna elements, or two subarrays, used for 2 transmitter (TX) precoding matrix indicator (PMI) reporting.

[0042] Referring to FIG. 2C, this figure shows an example rank 4 CSI-RS pattern 240 in accordance with example embodiments. The rank 4 CSI-RS pattern 240 includes 2 independent RS groups 245 within one CSI-RS resource, where each RS group 245 comprises four REs. Each RS group 245 is associated with one of the two different beams, and includes two 2-RE basic resource units corresponding to 4 antenna ports. A 4-port RS may be transmitted within one RS group 245 and may be used for 4TX PMI measurement and reporting.

[0043] Referring to FIG. 2D, this figure shows an example rank 8 CSI-RS pattern 280 in accordance with example embodiments: there is one RS group 285 which includes eight REs. The RS group 285 is associated with one beam, including four 2-RE basic resource units, corresponding to 8 antenna ports. An 8-antenna port RS may be transmitted on RS group 285 and may be used for 8TX PMI measurement and reporting.

[0044] In some examples embodiments, one or more CSI-RS patterns are also possible, and these patterns may not necessarily be unified, as shown in FIGS. 2E and 2F for example. FIG. 2E shows an example rank 4 CSI-RS pattern 290 where OCC=4. The rank 4 CSI-RS pattern 290 includes two 4-port RS groups 292, namely, a first group including RE1-RE4 and second group including RE5-RE8. . Each resource group 292

is associated with one specific beam direction. A length 4 OCC code is used to indicate 4 antenna ports. FIG. 2F, shows another example rank 4 CSI-RS pattern 295 spanning two consecutive OFDM symbols. Similar to FIG. 2E the OCC length is still equal to 4 in the rank 4 CSI pattern 295, but the pattern 295 maps to both time and frequency domain. Four RS groups 296 are specified for this CSI-RS pattern 295 which correspond to 4 different beam directions.

[0045] Those skilled in the art will appreciate that the OCC and frequency location examples described above may be extended for different multiplexing scenarios and/or time-frequency positions.

CSI measurement and reporting based on rank threshold and CSI-RS pattern

[0046] In accordance with example embodiments, a UE may receive an indication of a rank threshold and determine a corresponding CSI-RS pattern. The rank threshold may correspond to a maximum DL layer number from this indication. For instance, the indication of the rank threshold from the base station may be a value that is equal to the corresponding maximum DL layer number. Since the indicated rank threshold value is associated with a specific CSI-RS pattern, the UE may determine the corresponding CSI-RS pattern based on the rank threshold value. For different rank thresholds, the pattern may be predefined, such as in a specification for example. Thus, if a UE receives a rank threshold value its pattern may be known. For example, the UE may have the various CSI-RS patterns and corresponding to different rank thresholds stored in a memory of the UE. As long as the intended data stream number is less than this rank threshold, rank adaptation is possible. For different rank threshold, the CSI measurement and reporting way could be same or different, which can be implicitly linked to the rank threshold, or indicated by an eNB.

[0047] When the rank threshold value is equal to 1, the UE will report one or multiple beam indexes having the highest SINR value among the measured antenna ports. CQI will be reported to the eNB based on the selected beam(s). The beam index and CQI are fed back in a periodic or aperiodic way based on the configuration from the eNB. The feedback may be transmitted, for example, via PUCCH or PUSCH.

[0048] When rank threshold value is equal to 2, the UE will report one or multiple beam indexes with maximum SINR and 2 TX PMI, RI CQI associated with this

selected beam(s). For example, beam information and CSI related information may be jointly or separately reported, and such reports may be sent either in a periodic or aperiodic manner

5 [0049] When the rank threshold is equal to 4, the UE will report one or multiple beam indexes with maximum SINR and 4 TX PMI, RI CQI associated with selected beam(s). Beam information and CSI related information will may be jointly or separately reported, and such reports may be sent either in a periodic or aperiodic manner.

10 [0050] When the rank threshold value is equal to 8, the UE will report one or multiple beam indexes with maximum SINR and 8 TX PMI, RI CQI associated with selected beam(s). Beam information and CSI related information will be reported by dynamic way. If the beam number within the CSI-RS pattern is only one, beam index reporting is not needed.

Resource group restriction

15 [0051] According to an example embodiment, if a rank specific pattern includes multiple RS groups (such as shown in FIGS. 2A-2C, 2E and 2F for example) then a UE can be configured to one or more of these RS groups for the indicated pattern. Referring again to the non-limiting example in FIG. 2B, this figure shows four RS groups 225 for the rank 2 pattern, where each group includes two REs. Accordingly, a UE may be configured to monitor all four RS group 225 in the rank 2 pattern, or alternatively, the
20 UE may be configured to monitor fewer than the four RS groups 225 (e.g. only one or two of the RS groups 225) based on resource group restriction. In an example embodiment, the indication of the resource group restriction may be included in the CSI-RS configuration. In some example embodiments the indication of the resource group restriction may be indicated separately from the CSI-RS configuration. Resource
25 group restriction reduces the CSI-RS overhead and also allows multiple UEs to share CSI-RS resources if different UEs need different beam tracking.

[0052] Traffic load and UE capability may impact rank selection. For instance, a low rank is needed to provide a highly reliable service, while a high rank is needed for high load and good channel environments. Example embodiments may determine the rank
30 threshold value for a given UE based on the UE's capability, SINR, channel environment, and/or traffic load for example. The rank threshold value limits the

maximum rank in one period, and so rank adaptation is still possible within this threshold. According to some example embodiments, an eNB may determine SINR and channel environment information based on one or more of: the UE's CSI feedback history, UL sounding reference signal (SRS), and/or speed measurements of the UE.

5 [0053] According to example embodiments, resource restriction and/or user grouping may be used to reduce overhead control. As described above, resource restriction may include configuring a UE with one or multiple RS groups extracted from defined RS groups. Different UEs may be configured to monitor different RS groups through resource restriction. For user grouping, a group of UEs can be covered by one specific
10 beam and those UEs can be configured with either a same RS group within one CSI-RS resource or one same CSI-RS resource. Based on UE grouping, CSI-RS resource overhead can be saved significantly because in real application, predefined beam number is not too much.

[0054] Referring to FIG. 3, this figure shows a base station 302 and eight UEs (i.e. UE1
15 to UE8) in accordance with example embodiments. In this example, the group 306 includes UE1-UE3 and is associated with beam 304-1; the group 308 includes UE3-UE5 and is associated with beam 304-2, and group 310 includes UE6 and UE7 and is associated with beam 304-3. In this way, each of the UE groups 306, 308, 310 may be configured with a same RS group, such as the RS groups shown in FIGS. 2A to
20 2F for example.

[0055] Referring now to FIG. 4, this figure shows an example signaling diagram according to an example embodiment. At 400 the eNB (e.g. eNB 170) determines a rank threshold for a user equipment (e.g. UE 110) and transmits a CSI-RS configuration including the rank threshold value at step 402. The CSI-RS configuration may include,
25 e.g., a CSI-RS resource indication, pattern, CSI measurement and other related information. At 404, the UE determines which resources should be monitored for reference signals sent by the eNB 170. For, example, the UE 110 may determine a CSI-RS pattern based on the received CSI-RS configuration. At 406 the eNB 170 transmits one or more CSI-RSs according to the indicated rank threshold and CSI-RS
30 pattern. Meanwhile, at 408 the UE 110 monitors for the CSI-RS. At 410, the UE generates and transmits a CSI measurement report to the eNB.

[0056] FIG. 5 is a logic flow diagram for the rank adaptive CSI-RS design. This figure further illustrates the operation of an exemplary method or methods, a result of execution of computer program instructions embodied on a computer readable memory, functions performed by logic implemented in hardware, and/or interconnected means for performing functions in accordance with exemplary embodiments. For instance, the measurement module 140-1 and/or 140-2 may include multiples ones of the blocks in FIG. 5, where each included block is an interconnected means for performing the function in the block. The blocks in FIG. 5 are assumed to be performed by the UE 110, e.g., under control of the measurement module 140-1 and/or 140-2 at least in part.

[0057] Referring to FIG. 5, an example method may include receiving, at a user equipment of a wireless network, a reference signal configuration comprising at least an indication of a rank threshold value as indicated by block 500; determining, at the user equipment, a specific rank adaptive reference signal pattern corresponding to the rank threshold as indicated by block 502; performing, at the user equipment, measurements of one or more reference signals received according to the determined rank adaptive reference signal pattern as indicated by block 504; and transmitting, from the user equipment to a base station of the wireless network, a measurement report comprising information corresponding to the performed measurements as indicated by block 506.

[0058] Determining the specific rank adaptive reference signal pattern corresponding to the rank threshold value may include selecting the rank adaptive reference signal pattern from a plurality of rank adaptive reference signal patterns such that each of the reference signal patterns is associated with a different rank threshold value. Each of the plurality of rank adaptive reference signal patterns may include a same number of resource elements and a same basic resource unit, wherein the basic resource unit comprises at least two consecutive resource elements aggregated either in frequency domain or in time domain within one physical resource block. Each of the rank adaptive reference signal patterns may include a set of one or more reference signal groups, wherein each reference signal group in the set corresponds to resources for monitoring a reference signal corresponding to a specific beam. The reference signal configuration may include a restriction indication to configure the at least user equipment to perform reference signal measurements on a subset of the reference signal groups. The measurement report may include at least: a beam index corresponding to a reference

signal associated with one of the reference signal groups; and a precoding matrix indicator, a rank indicator, and channel quality information associated with the reference signal. The measurement report may: lack a precoding matrix indicator (PMI), comprise one PMI; or comprise multiple PMIs depending on the rank threshold value. The rank threshold value may correspond to a maximum downlink transmission data stream number in a downlink transmission.

[0059] An example of an embodiment includes a computer program, comprising code for executing a method according to any one of paragraphs [0057] or [0058], when the computer program is run on a processor. The computer program according to this paragraph, wherein the computer program is a computer program product may comprise a computer-readable medium bearing computer program code embodied therein for use with a computer.

[0060] According to an example embodiment, an apparatus is provided comprising: at least one processor; and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to at least: receive, at a user equipment of a wireless network, a reference signal configuration comprising at least an indication of a rank threshold value; determine, at the user equipment, a specific rank adaptive reference signal pattern corresponding to the rank threshold; perform, at the user equipment, measurements of one or more reference signals received according to the determined rank adaptive reference signal pattern; and transmit, from the user equipment to a base station of the wireless network, a measurement report comprising information corresponding to the performed measurements.

[0061] The determination of the specific rank adaptive reference signal pattern corresponding to the rank threshold value may include selecting the rank adaptive reference signal pattern from a plurality of rank adaptive reference signal patterns such that each of the reference signal patterns is associated with a different rank threshold value. Each of the plurality of rank adaptive reference signal patterns may include a same number of resource elements and a same basic resource unit, wherein the basic resource unit comprises at least two consecutive resource elements aggregated either in frequency domain or in time domain within one physical resource block.

[0062] According to an example embodiment, an apparatus is provided, comprising: means for receiving, at a user equipment of a wireless network, a reference signal configuration comprising at least an indication of a rank threshold value; means for determining, at the user equipment, a specific rank adaptive reference signal pattern corresponding to the rank threshold; means for performing, at the user equipment, measurements of one or more reference signals received according to the determined rank adaptive reference signal pattern; and means for transmitting, from the user equipment to a base station of the wireless network, a measurement report comprising information corresponding to the performed measurements.

10 [0063] FIG. 6 is a logic flow diagram for the rank adaptive CSI-RS design. This figure further illustrates the operation of an exemplary method or methods, a result of execution of computer program instructions embodied on a computer readable memory, functions performed by logic implemented in hardware, and/or interconnected means for performing functions in accordance with exemplary embodiments. For instance, the
15 CSI-RS configuration module 150-1 and/or 150-2 may include multiples ones of the blocks in FIG. 6, where each included block is an interconnected means for performing the function in the block. The blocks in FIG. 6 are assumed to be performed by a base station such as eNB 170, e.g., under control of the CSI-RS configuration module 150-1 and/or 150-2 at least in part.

20 [0064] Referring to FIG. 6, an example embodiment may include a method including determining, at a base station of a wireless network, a rank threshold value for at least one user equipment as indicated by block 600; transmitting, from the base station to the at last one user equipment, a reference signal configuration comprising at least the determined rank threshold value as indicated by block 602; and receiving, at the base
25 station, a measurement report from the at least one user equipment, wherein the measurement report is based at least in part on the determined rank threshold as indicated by block 604.

[0065] The rank threshold value may correspond to a maximum downlink transmission data stream number in a downlink transmission. The reference signal configuration
30 may be indicative of a specific rank adaptive reference signal pattern of a plurality of rank adaptive reference signal patterns based on the rank threshold value. Each of the plurality of rank adaptive reference signal patterns may include a same number of resource elements and a same basic resource unit, wherein the basic resource unit

comprises at least two consecutive resource elements aggregated either in frequency domain or in time domain within one physical resource block. Each of the rank adaptive reference signal patterns may include a set of one or more reference signal groups, wherein each reference signal group in the set corresponds to resources for transmitting a reference signal using a specific beam. The reference signal configuration may include a restriction indication to configure the at least user equipment to perform reference signal measurements on a subset of the reference signal groups. The base station may configure at least two user equipments to share a reference signal resource based at least on the rank threshold value and the restriction indication. The received measurement report may include at least a beam index corresponding to one resource group of one CSI-RS resource configured by the base station with the highest signal to interference and noise ratio (SINR) measured by the at least one user equipment. Determining the rank threshold value may be based on information corresponding to the at least one user equipment comprising: measurement information; channel environment information; and/or traffic load information. The information related to the at least one user equipment may include at least one of: historical measurement information; speed measurement information; and an uplink reference signal received by the base station. The method may further include: transmitting one or more reference signals to the at least one user equipment according to the reference signal configuration.

[0066] An example of an embodiment includes a computer program, comprising code for executing a method according to any one of paragraphs [0064] or [0065], when the computer program is run on a processor. The computer program according to this paragraph, wherein the computer program is a computer program product may comprise a computer-readable medium bearing computer program code embodied therein for use with a computer.

[0067] According to another example embodiment, an apparatus is provided including at least one processor; and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to at least: determine, at a base station of a wireless network, a rank threshold value for at least one user equipment; transmit, from the base station to the at least one user equipment, a reference signal configuration comprising at least the determined rank threshold value; and receive, at the base station, a

measurement report from the at least one user equipment, wherein the measurement report is based at least in part on the determined rank threshold.

[0068] The rank threshold value may correspond to a maximum downlink transmission data stream number in a downlink transmission. The reference signal configuration may be indicative of a specific rank adaptive reference signal pattern of a plurality of rank adaptive reference signal patterns based on the rank threshold value. Each of the plurality of rank adaptive reference signal patterns comprises a same number of resource elements and a same basic resource unit, wherein the basic resource unit comprises at least two consecutive resource elements aggregated either in frequency domain or in time domain within one physical resource block. Each of the rank adaptive reference signal patterns may include a set of one or more reference signal groups, wherein each reference signal group in the set corresponds to resources for transmitting a reference signal using a specific beam. The reference signal configuration may include a restriction indication to configure the at least user equipment to perform reference signal measurements on a subset of the reference signal groups. The received measurement report may include at least a beam index corresponding to one resource group of one CSI-RS resource configured by the base station with the highest signal to interference and noise ratio (SINR) measured by the at least one user equipment. The determination of the rank threshold value may be based on information corresponding to the at least one user equipment comprising: measurement information; channel environment information; and/or traffic load information. The information related to the at least one user equipment may include at least one of: historical measurement information; speed measurement information; and an uplink reference signal received by the base station. The at least one memory and the computer program code may be configured to: transmit one or more reference signals to the at least one user equipment according to the reference signal configuration.

[0069] According to another example embodiment, an apparatus is provided comprising means for determining, at a base station of a wireless network, a rank threshold value for at least one user equipment; means for transmitting, from the base station to the at least one user equipment, a reference signal configuration comprising at least the determined rank threshold value; and means for receiving, at the base station, a measurement report from the at least one user equipment, wherein the measurement report is based at least in part on the determined rank threshold.

[0070] According to another example embodiment, a communication system may include an apparatus in accordance with any one of paragraphs [0060] to [0062] and an apparatus in accordance with any one of paragraphs [0067] to [0069].

5 [0071] Without in any way limiting the scope, interpretation, or application of the claims appearing below, a technical effect of one or more of the example embodiments disclosed herein is simplifying CSI-RS pattern design and configuration by providing one rank adaptive CSI-RS pattern, and/or furthermore one unified CSI-RS pattern for different rank thresholds. Another technical effect of one or more of the example
10 embodiments disclosed herein is that an eNB can set suitable beam number to adjust CSI feedback accuracy. Another technical effect of one or more of the example embodiments disclosed herein is to guarantee CSI measurement accuracy and reduce CSI-RS overhead by configuring a flexible pattern and antenna port according to traffic load and scenario. Another technical effect of one or more of the example embodiments disclosed herein is simplification of UE behavior since, in most cases, 8TX PMI is not
15 needed for UEs only supporting rank 1 or rank 2 operation.

[0072] Embodiments herein may be implemented in software (executed by one or more processors), hardware (e.g., an application specific integrated circuit), or a combination of software and hardware. In an example embodiment, the software (e.g., application logic, an instruction set) is maintained on any one of various conventional
20 computer-readable media. In the context of this document, a “computer-readable medium” may be any media or means that can contain, store, communicate, propagate or transport the instructions for use by or in connection with an instruction execution system, apparatus, or device, such as a computer, with one example of a computer described and depicted, e.g., in FIG. 1. A computer-readable medium may comprise a
25 computer-readable storage medium (e.g., memories 125, 155, 171 or other device) that may be any media or means that can contain, store, and/or transport the instructions for use by or in connection with an instruction execution system, apparatus, or device, such as a computer. A computer-readable storage medium does not comprise propagating signals.

30 [0073] If desired, the different functions discussed herein may be performed in a different order and/or concurrently with each other. Furthermore, if desired, one or more of the above-described functions may be optional or may be combined.

[0074] Although various aspects of the invention are set out in the independent claims, other aspects of the invention comprise other combinations of features from the described embodiments and/or the dependent claims with the features of the independent claims, and not solely the combinations explicitly set out in the claims.

5 [0075] It is also noted herein that while the above describes example embodiments of the invention, these descriptions should not be viewed in a limiting sense. Rather, there are several variations and modifications which may be made without departing from the scope of the present invention as defined in the appended claims.

10 [0076] The following abbreviations that may be found in the specification and/or the drawing figures are defined as follows:

	5G	fifth generation mobile communication system
	BS	base station
	OCC	orthogonal cover code
	CDM	code division multiplex
15	CSI	channel status information
	DL	Downlink
	eNB (or eNodeB)	evolved Node B (e.g., an LTE base station)
	gNB	5G new radio node (5G base station)
	I/F	interface
20	LTE	long term evolution
	MME	mobility management entity
	NCE	network control element
	N/W	network
	RE	resource elements
25	RRH	remote radio head
	Rx	receiver
	SGW	serving gateway
	Tx	transmitter
	UE	user equipment
30	PMI	Precoding matrix indicator

WHAT IS CLAIMED IS:

- 5 1. A method, comprising:
 determining, at a base station of a wireless network, a rank threshold
 value for at least one user equipment;
 transmitting, from the base station to the at last one user equipment, a
 reference signal configuration comprising at least the
10 determined rank threshold value; and
 receiving, at the base station, a measurement report from the at least one
 user equipment, wherein the measurement report is based at least
 in part on the determined rank threshold.
- 15 2. The method of claim 1, wherein the rank threshold value corresponds to a
 maximum downlink transmission data stream number in a downlink
 transmission.
3. The method of claim 1, wherein the reference signal configuration is indicative
20 of a specific rank adaptive reference signal pattern of a plurality of rank
 adaptive reference signal patterns based on the rank threshold value.
4. The method of claim 3, wherein each of the plurality of rank adaptive reference
 signal patterns comprises a same number of resource elements and a same basic
25 resource unit, wherein the basic resource unit comprises at least two
 consecutive resource elements aggregated either in frequency domain or in time
 domain within one physical resource block.
5. The method of claim 3, wherein each of the rank adaptive reference signal
30 patterns comprise a set of one or more reference signal groups, wherein each

reference signal group in the set corresponds to resources for transmitting a reference signal using a specific beam.

- 5 6. The method of any one of claims 1 to 5, wherein the reference signal configuration further comprises a restriction indication to configure the at least user equipment to perform reference signal measurements on a subset of the reference signal groups.
- 10 7. The method of claim 6, wherein the base station configures at least two user equipments to share a reference signal resource based at least on the rank threshold value and the restriction indication.
- 15 8. The method according to any one of the preceding claims, wherein the received measurement report comprises at least a beam index corresponding to one resource group of one CSI-RS resource configured by the base station with the highest signal to interference and noise ratio (SINR) measured by the at least one user equipment.
- 20 9. The method according to any one of the preceding claims, wherein determining the rank threshold value is based on information corresponding to the at least one user equipment comprising:
measurement information;
channel environment information; and/or
traffic load information.

10. The method of claim 9, wherein the information related to the at least one user equipment comprises at least one of:
- historical measurement information;
 - speed measurement information; and
 - 5 an uplink reference signal received by the base station.
11. The method of any one of the preceding claims, further comprising:
- transmitting one or more reference signals to the at least one user equipment according to the reference signal configuration.
- 10
12. An apparatus, comprising:
- at least one processor; and
 - at least one memory including computer program code,
 - the at least one memory and the computer program code configured to, with the
 - 15 at least one processor, cause the apparatus to at least:
- determine, at a base station of a wireless network, a rank threshold value for at least one user equipment;
 - transmit, from the base station to the at least one user equipment, a reference signal configuration comprising at least the
 - 20 determined rank threshold value; and
 - receive, at the base station, a measurement report from the at least one user equipment, wherein the measurement report is based at least in part on the determined rank threshold.
- 25
13. The apparatus of claim 12, wherein the rank threshold value corresponds to a maximum downlink transmission data stream number in a downlink transmission.

14. The apparatus of claim 12, wherein the reference signal configuration is indicative of a specific rank adaptive reference signal pattern of a plurality of rank adaptive reference signal patterns based on the rank threshold value.
- 5 15. The apparatus of claim 14, wherein each of the plurality of rank adaptive reference signal patterns comprises a same number of resource elements and a same basic resource unit, wherein the basic resource unit comprises at least two consecutive resource elements aggregated either in frequency domain or in time domain within one physical resource block.
- 10 16. The apparatus of claim 14, wherein each of the rank adaptive reference signal patterns comprise a set of one or more reference signal groups, wherein each reference signal group in the set corresponds to resources for transmitting a reference signal using a specific beam.
- 15 17. The apparatus of any one of claims 12 to 16, wherein the reference signal configuration further comprises a restriction indication to configure the at least user equipment to perform reference signal measurements on a subset of the reference signal groups.
- 20 18. The apparatus according to any one of claims 12 to 17, wherein the received measurement report comprises at least a beam index corresponding to one resource group of one CSI-RS resource configured by the base station with the highest signal to interference and noise ratio (SINR) measured by the at least
- 25 one user equipment.

19. The apparatus according to any one of claims 12 to 18, wherein determination of the rank threshold value is based on information corresponding to the at least one user equipment comprising:
- 5 measurement information;
channel environment information; and/or
traffic load information.
20. An apparatus, comprising:
- 10 means for determining, at a base station of a wireless network, a rank threshold value for at least one user equipment;
- means for transmitting, from the base station to the at least one user equipment, a reference signal configuration comprising at least the determined rank threshold value; and
- 15 means for receiving, at the base station, a measurement report from the at least one user equipment, wherein the measurement report is based at least in part on the determined rank threshold.
21. A method, comprising:
- 20 receiving, at a user equipment of a wireless network, a reference signal configuration comprising at least an indication of a rank threshold value;
- determining, at the user equipment, a specific rank adaptive reference signal pattern corresponding to the rank threshold;
- 25 performing, at the user equipment, measurements of one or more reference signals received according to the determined rank adaptive reference signal pattern; and
- transmitting, from the user equipment to a base station of the wireless network, a measurement report comprising information corresponding to the performed measurements.

22. The method of claim 20, wherein determining the specific rank adaptive reference signal pattern corresponding to the rank threshold value comprises selecting the rank adaptive reference signal pattern from a plurality of rank adaptive reference signal patterns such that each of the reference signal patterns
5 is associated with a different rank threshold value.
23. The method of claim 22, wherein each of the plurality of rank adaptive reference signal patterns comprises a same number of resource elements and a same basic resource unit, wherein the basic resource unit comprises at least two
10 consecutive resource elements aggregated either in frequency domain or in time domain within one physical resource block.
24. The method of claim 22, wherein each of the rank adaptive reference signal patterns comprise a set of one or more reference signal groups, wherein each
15 reference signal group in the set corresponds to resources for monitoring a reference signal corresponding to a specific beam.
25. The method of any one of claims 20 to 24, wherein the reference signal configuration further comprises a restriction indication to configure the at least
20 user equipment to perform reference signal measurements on a subset of the reference signal groups.
26. The method of any one of claims 24 or 25, wherein the measurement report comprises at least:
25 a beam index corresponding to a reference signal associated with one of the reference signal groups; and
a precoding matrix indicator, a rank indicator, and channel quality information associated with the reference signal.

27. The method of claim 20, wherein the measurement report lacks a precoding matrix indicator (PMI), comprises one PMI; or comprises multiple PMIs depending on the rank threshold value.
- 5 28. The method of any one of claims 20 to 27, wherein the rank threshold value corresponds to a maximum downlink transmission data stream number in a downlink transmission.
29. An apparatus, comprising:
- 10 at least one processor; and
- at least one memory including computer program code,
- the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to at least:
- 15 receive, at a user equipment of a wireless network, a reference signal configuration comprising at least an indication of a rank threshold value;
- determine, at the user equipment, a specific rank adaptive reference signal pattern corresponding to the rank threshold;
- perform, at the user equipment, measurements of one or more reference signals received according to the determined rank adaptive reference signal pattern; and
- 20 transmit, from the user equipment to a base station of the wireless network, a measurement report comprising information corresponding to the performed measurements.

30. The apparatus of claim 29, wherein determination of the specific rank adaptive reference signal pattern corresponding to the rank threshold value comprises selecting the rank adaptive reference signal pattern from a plurality of rank adaptive reference signal patterns such that each of the reference signal patterns is associated with a different rank threshold value.
31. The apparatus of claim 30, wherein each of the plurality of rank adaptive reference signal patterns comprises a same number of resource elements and a same basic resource unit, wherein the basic resource unit comprises at least two consecutive resource elements aggregated either in frequency domain or in time domain within one physical resource block.
32. An apparatus, comprising:
- means for receiving, at a user equipment of a wireless network, a reference signal configuration comprising at least an indication of a rank threshold value;
 - means for determining, at the user equipment, a specific rank adaptive reference signal pattern corresponding to the rank threshold;
 - means for performing, at the user equipment, measurements of one or more reference signals received according to the determined rank adaptive reference signal pattern; and
 - means for transmitting, from the user equipment to a base station of the wireless network, a measurement report comprising information corresponding to the performed measurements.
33. A communication system comprising an apparatus in accordance with any one of the claims 12 to 20 and an apparatus in accordance with any one of the claims 29 to 32.

34. A computer program comprising program code for executing the method according to any of claims 1 to 11 or 21 to 28.
35. The computer program according to claim 34, wherein the computer program is a computer program product comprising a computer-readable medium bearing computer program code embodied therein for use with a computer.
- 5

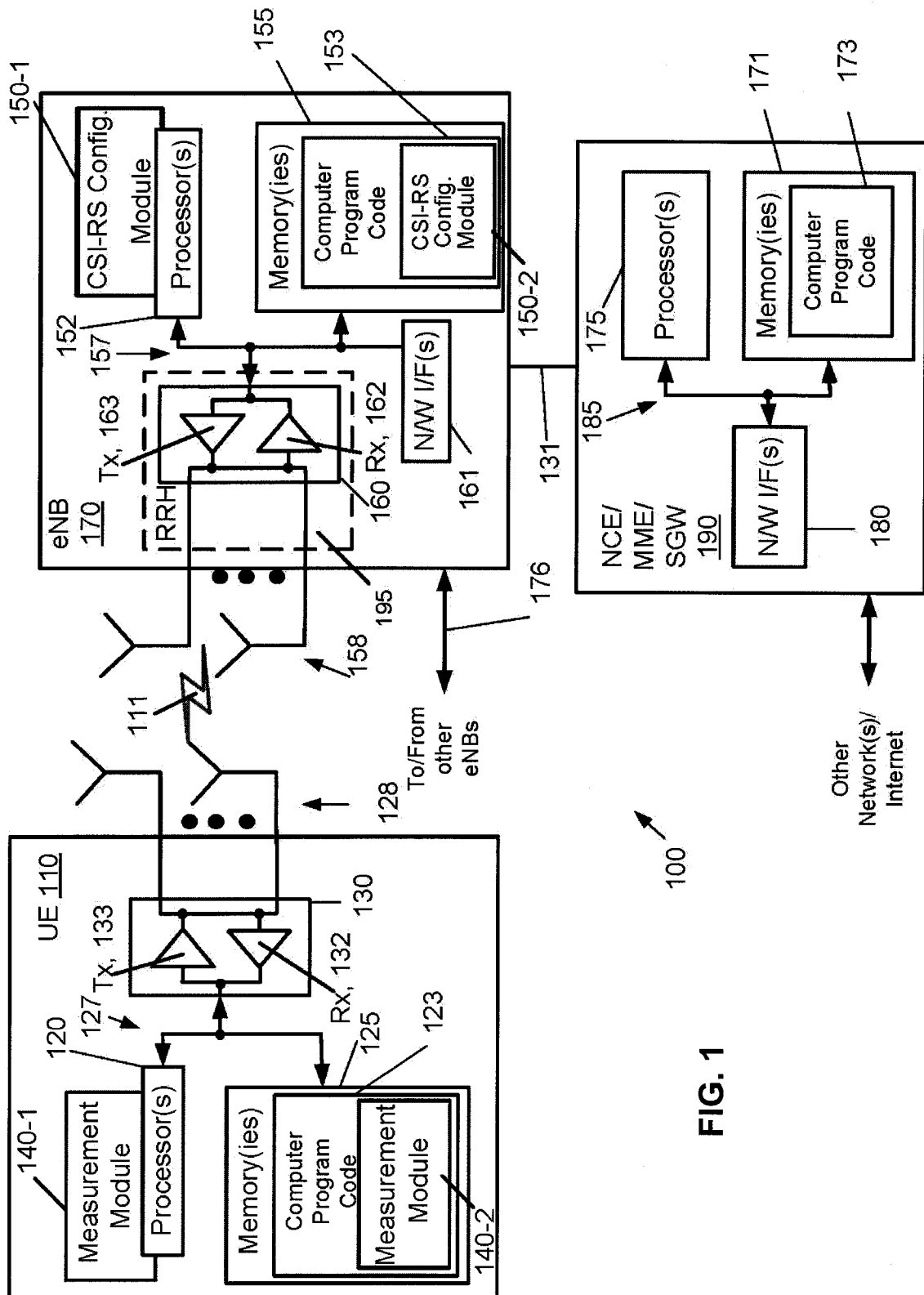
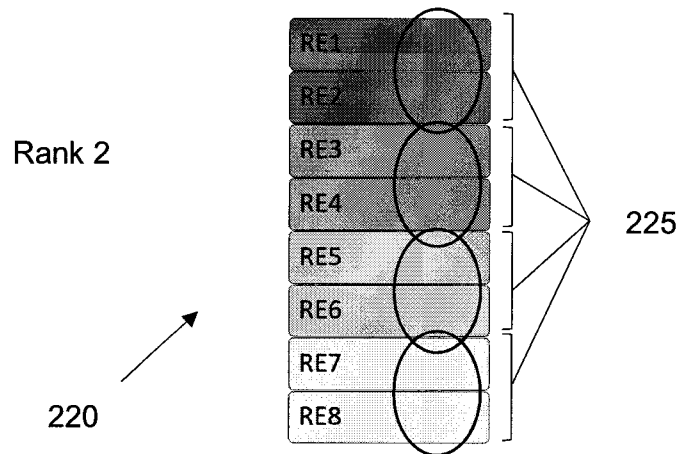
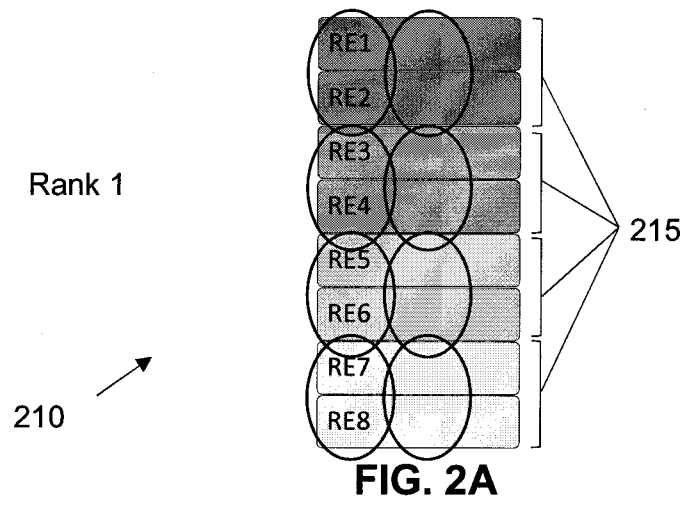


FIG. 1



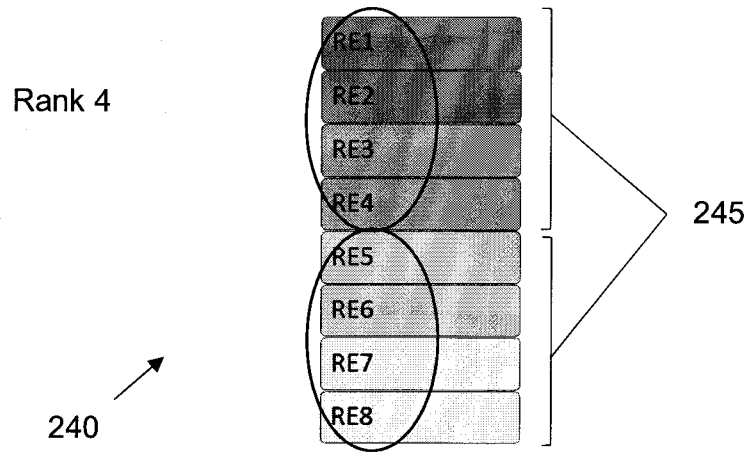


FIG. 2C

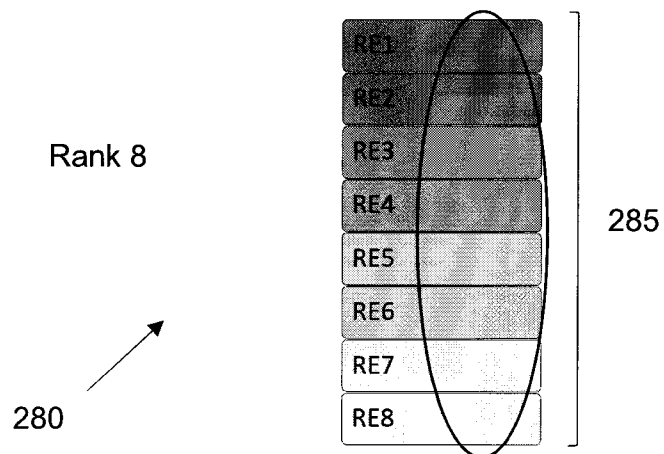
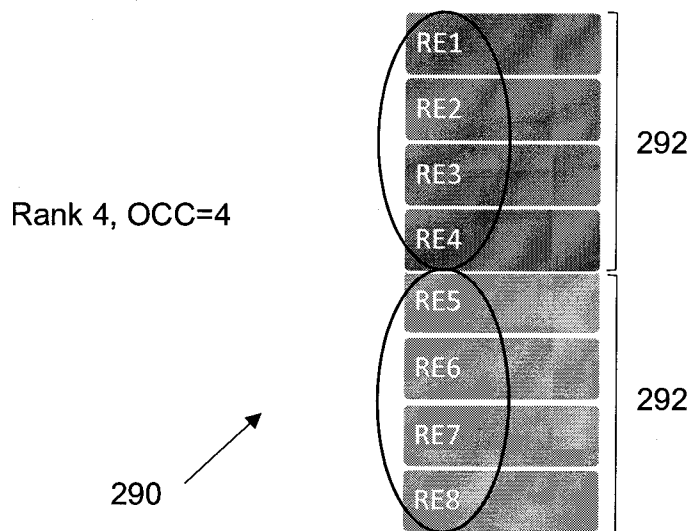
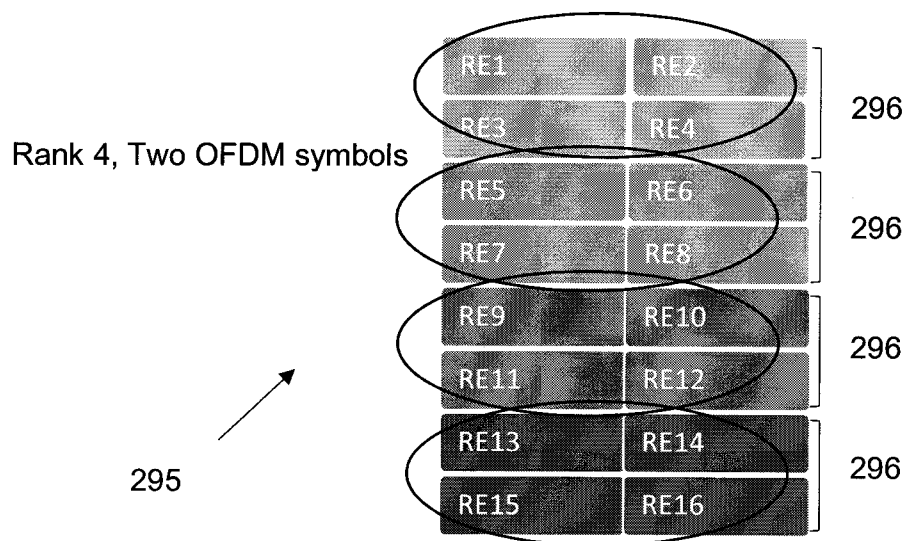
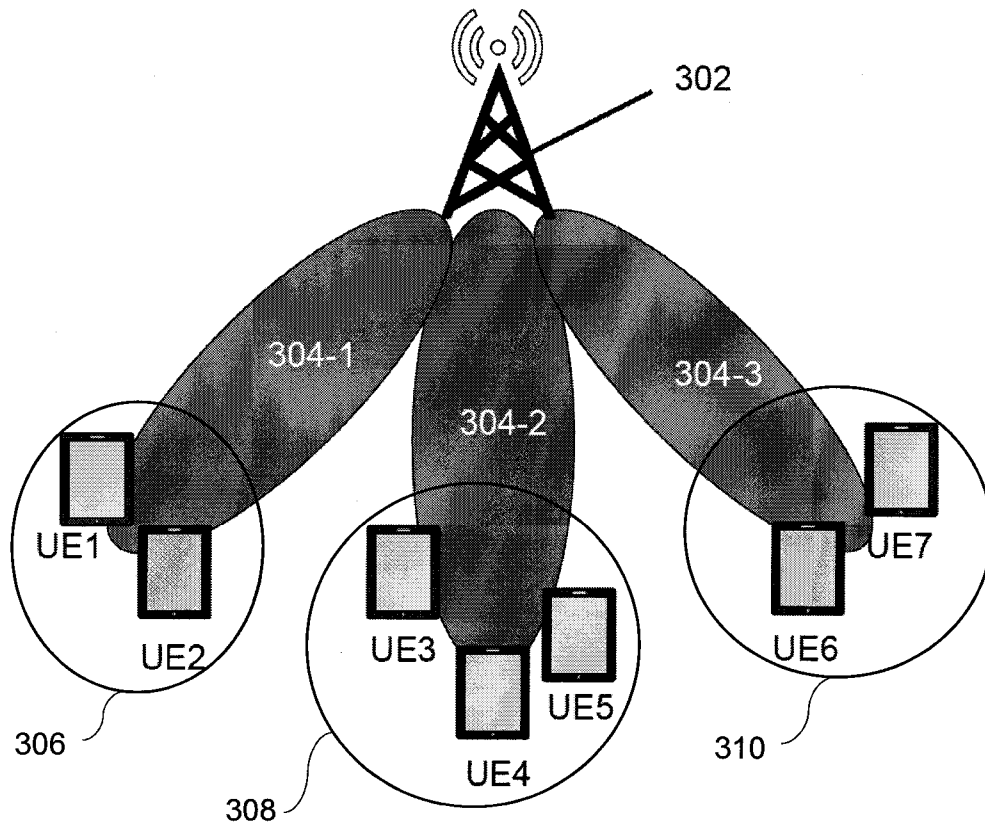
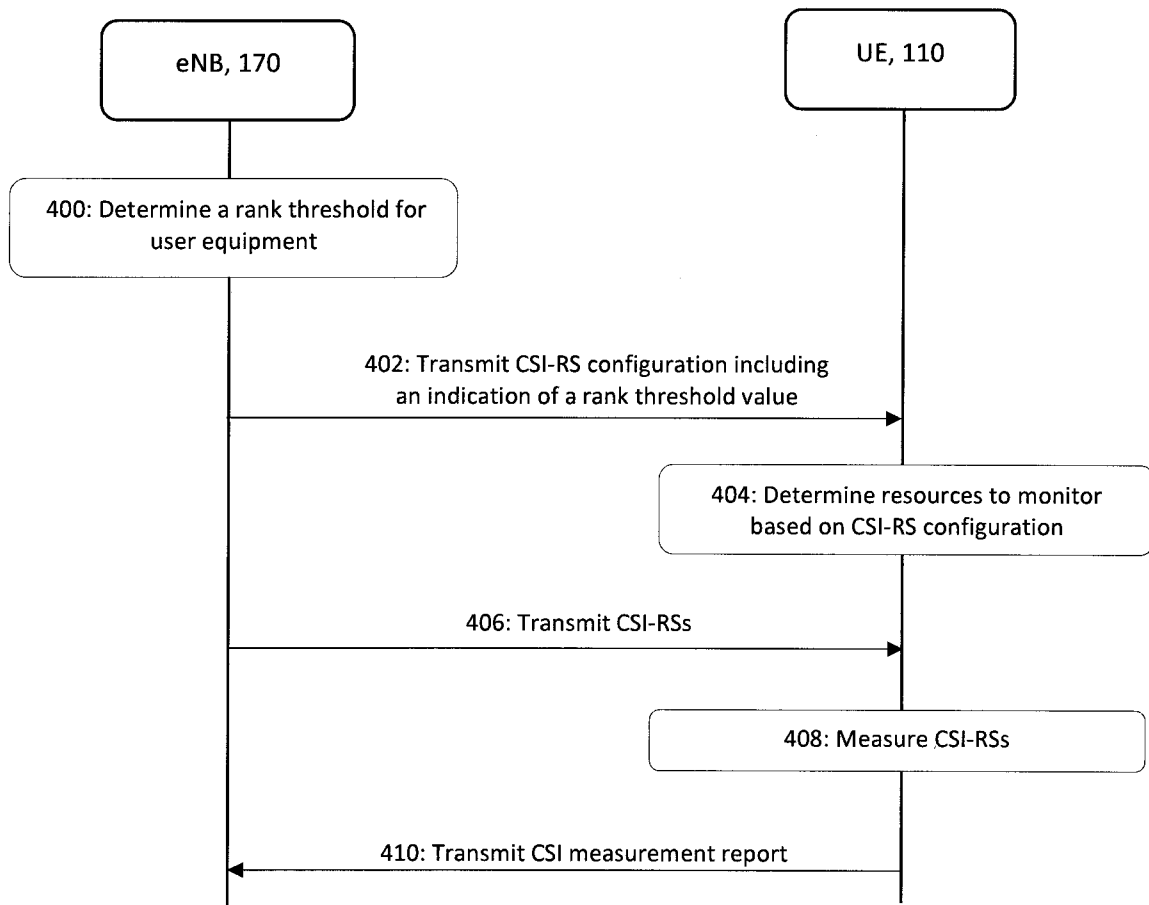
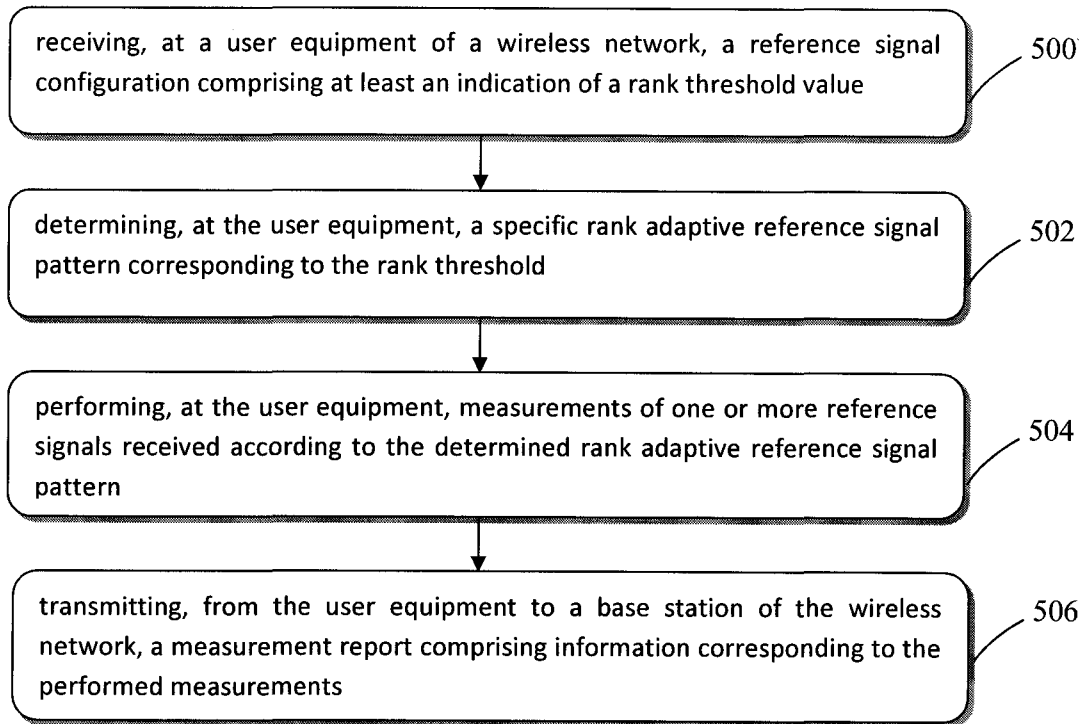
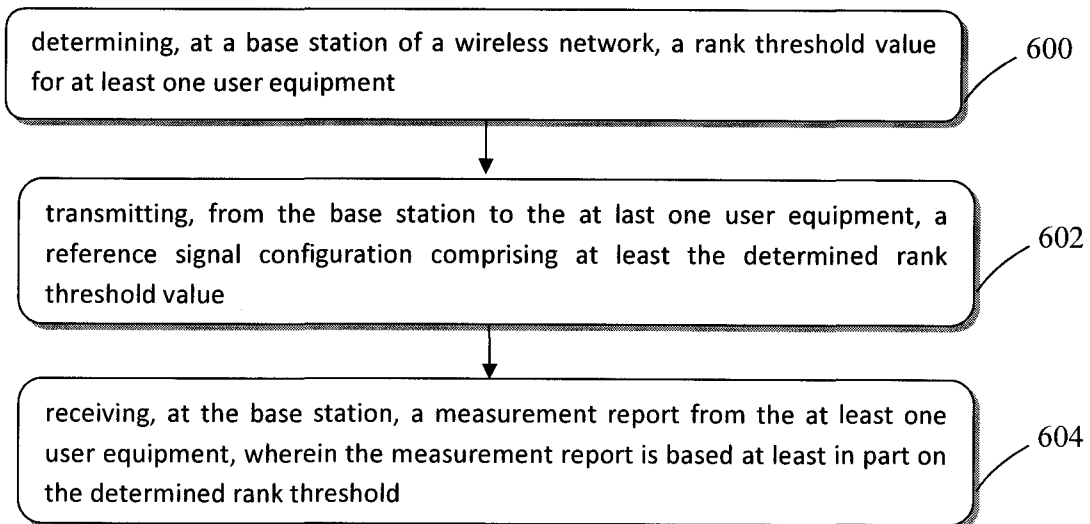


FIG. 2D

**FIG. 2E****FIG. 2F**

**FIG. 3**

**FIG. 4**

**FIG. 5****FIG. 6**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2017/073086

A. CLASSIFICATION OF SUBJECT MATTER

H04L 5/02(2006.01)i

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)

H04L; H04Q; H04W

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)

CNPAT, WPI, EPODOC, CNKI: rank, threshold, reference signal, CSI, base station, AP, eNB, feedback, transmit+, PMI, uplink, downlink

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010246527 A1 (QUALCOMM INCORPORATED) 30 September 2010 (2010-09-30) description paragraphs [0037]-[0063], [0153]-[0211]	1-35
A	WO 2014040771 A1 (TELEFONAKTIEBOLAGET LM ERICSSONPUBL) 20 March 2014 (2014-03-20) the whole document	1-35
A	WO 2016115843 A1 (ZHONGXING MICROELECTRONICS TECHNOLOGY CO., LTD.) 28 July 2016 (2016-07-28) the whole document	1-35

☐ 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

10 October 2017

Date of mailing of the international search report

27 October 2017

Name and mailing address of the ISA/CN

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2017/073086

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
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				KR	20110139759	A	29 December 2011
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				EP	2415196	A1	08 February 2012
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				US	2015229381	A1	13 August 2015
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