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S11— Node transmitting a downlink signal and/or a downlink channel in beam-sweeping mode

FIG. 2

(57) Abstract: Methods for downlink transmission based on beamforming are disclosed. A method includes: transmitting, by a node, a downlink signal and/or downlink channel in beam-sweeping mode, where in the beam-sweeping mode the downlink signal or downlink channel is carried by at least two beams and is transmitted in at least two time units in one cycle, wherein the formation of the beams at least uses analog beamforming. There are also provided associated nodes and UEs. Thus, the present disclosure can address the issues of limited coverage of high-frequency carriers and the high hardware cost and high power consumption of digital beamforming.



**METHODS, NODES, AND USER EQUIPMENTS FOR DOWNLINK
TRANSMISSION BASED ON BEAMFORMING**

TECHNICAL FIELD

[0001] Embodiments of the present disclosure generally relate to communications, and more particularly relate to methods, nodes, and user equipments (UEs) for downlink transmission based on beamforming.

BACKGROUND

[0002] Multiple-Input and Multiple-Output (MIMO) is a method for multiplying the capacity of a radio link using multiple transmit and receive antennas to exploit multipath propagation.

[0003] The massive MIMO system is revealed to have great potentials, the main advantages of which include greatly increased energy efficiency, high spatial multiplexing gain, channel hardening effect, etc. FD-MIMO (full-dimension MIMO) is a specific implementation of massive MIMO used by 3GPP. An FD-MIMO system is equipped with a two-dimensional antenna array (e.g., including columns of cross-poles) with multiple transceiver units (TXRUs) per transmission point, where a TXRU has its own independent amplitude and phase control.

[0004] As shown in FIG. 1, in the downlink signal and/or downlink channel beamforming process in FD-MIMO, the mapping from the antenna ports to the antenna elements of the antenna array includes two stages: port virtualization and TXRU virtualization. The port virtualization, also known as digital beamforming, refers to the mapping of antenna ports to TXRUs using a port virtualization matrix X , while the TXRU virtualization, also known as analog beamforming, refers to the mapping of the TXRUs to the antenna elements using a TXRU virtualization matrix Y . The digital beamforming is implemented in the baseband processor and thus can be different for different physical resource blocks (PRBs). On the other hand, the analog beamforming is implemented at the RF end and thus cannot be frequency-selective.

[0005] In LTE/LTE-A, the carrier frequency usually ranges from a few hundred MHz to a few GHz. In New Radio (NR), two types of radio environments will be considered, namely

sub-6GHz band and above-6GHz band. One of the advantages of above-6GHz band is the much wider bandwidth. However, high carrier frequency will also bring some issues, such as the shorter coverage due to large pathloss, particularly in the transmission of downlink signals and/or downlink channels without the use of beamforming.

[0006] In addition, in current LTE/LTE-A, the analog beamforming is usually static and has a wide beam width. As a result, the beamforming operation is mainly implemented in the digital beamforming since it is more flexible and can be frequency selective. In order to compensate for the large pathloss of the high carrier frequency in NR, a large number of RF chains will be needed to harness the gain of large-scale antenna array if only the digital baseband precoding is used, which however results in high hardware cost and high power consumption.

SUMMARY

[0007] In view of the above, embodiments of the present disclosure provide methods, nodes, and user equipments for downlink transmission based on beamforming, aiming at addressing the issues of limited coverage of high-frequency carriers and the high hardware cost and high power consumption of digital beamforming.

[0008] There is provided a method for downlink transmission based on beamforming, the method comprising: transmitting, by a node, a downlink signal and/or downlink channel in beam-sweeping mode, where in the beam-sweeping mode the downlink signal or downlink channel is carried by at least two beams and is transmitted in at least two time units in one cycle, the formation of the beams at least using analog beamforming.

[0009] Each time unit may comprise one or more subframes, time slots, or symbols.

[0010] Transmitting the downlink signal and/or downlink channel in the beam-sweeping mode may comprise: transmitting, by the node, the downlink signal and/or downlink channel in the beam-sweeping mode in accordance with a beam configuration, the beam configuration comprising at least one of a number of the beams, a length of the time unit, a length of the cycle, and a sweeping pattern.

[0011] The sweeping pattern may comprise a consecutive or inconsecutive time allocation for the beams of which directions lie in one or several same predetermined ranges and which

make up a beam group.

[0012] The method may further comprise: receiving an uplink signal and/or uplink channel from a UE in beamforming manner.

[0013] There may be a time dependency between the transmission and reception of the beams of which directions lie in one or several same predetermined ranges, and the beam configuration may further contain the time dependency.

[0014] The transmission and reception of the beams of which directions lie in one or several same predetermined ranges may be performed in a same time slot or subframe.

[0015] The method may further comprise: sending, by the node, the beam configuration to the UE using L1/L2 signaling or higher-layer signaling.

[0016] Transmitting the downlink signal and downlink channel in the beam-sweeping mode may comprise: transmitting, by the node, initial-access signals and broadcast channels in the beam-sweeping mode, the initial-access signals and the broadcast channels being jointly used for beam training.

[0017] The method may further comprise: receiving, by the node, a beam training result fed back from the UE; and selecting, by the node, one or more serving beams for the UE according to the beam training result.

[0018] Transmitting the initial-access signals and the broadcast channels in the beam-sweeping mode may comprise: transmitting, by the node, the initial-access signals and the broadcast channels in the first time unit of each beam group in the time domain, the beam group consisting of beams of which directions lie in one or several same predetermined ranges.

[0019] Transmitting the initial-access signals and the broadcast channels in the beam-sweeping mode may comprise: transmitting, by the node, the initial-access signals and the broadcast channels using the beams in all directions sequentially during a training period.

[0020] The training period may be located at an initial position of a cycle.

[0021] Transmitting the initial-access signals and the broadcast channels in the beam-sweeping mode may comprise: transmitting, by the node, the initial-access signals and the broadcast channels in one time unit using at least two levels of beam sets respectively, each level of beam set comprising one or more beams, at least one beam in the lower-level

beam set being a sub-beam of a beam in the upper-level beam set, and the beams in all of the beam sets using a same set of TXRU virtualization matrices during the beamforming process.

[0022] The initial-access signals and the broadcast channels may comprise synchronization signals, beam reference signal (BRS), and physical broadcast channel (PBCH), wherein the synchronization signal may be carried by a first-level beam set, while the BRS and the PBCH may be carried by a second-level beam set.

[0023] The synchronization signals may comprise primary synchronization signal (PSS) and secondary synchronization signal (SSS).

[0024] The synchronization signals may further comprise extended synchronization signal (ESS), wherein the ESS may be used to indicate a time location of the synchronization signals.

[0025] The initial-access signals and the broadcast channels may further comprise extended BRS (eBRS) and extended PBCH (ePBCH) that are carried by a third-level beam set.

[0026] PSS, SSS, PBCH, or ePBCH may be further used to indicate a time location of the synchronization signals.

[0027] eBRS and ePBCH may have a different periodicity from BRS and PBCH.

[0028] eBRS and ePBCH may be transmitted on demand.

[0029] RE allocations of different beams in a same beam set can be multiplexed in at least one of time domain, frequency domain, and code domain.

[0030] RE allocations of different beams in different beam sets may be multiplexed in time domain and/or frequency domain.

[0031] There may be a dependency for RE allocation between the beams in different levels of beam sets.

[0032] The node may be a base station, distributed unit (DU), transmission point (TP), transmission reception point (TRP), or radio remote head (RRH).

[0033] There is also provided a method for downlink transmission based on beamforming, the method comprising: receiving, at a UE, a downlink signal and/or downlink channel that is transmitted from a node in beam-sweeping mode, where in the beam-sweeping mode the downlink signal or downlink channel is carried by at least two beams and is transmitted in at least two time units in one cycle, the formation of the beams at least using analog

beamforming.

[0034] Each time unit may comprise one or more subframes, time slots, or symbols.

[0035] A beam carrying the downlink signal or downlink channel may originate from one or more nodes.

[0036] The method may further comprise: receiving, at the UE, a beam configuration that the node sends using L1/L2 signaling or higher-layer signaling.

[0037] Receiving the downlink signal and the downlink channel that the node transmits in the beam-sweeping mode may comprise: receiving, at the UE, initial-access signals and broadcast channels that the node transmits in the beam-sweeping mode, the initial-access signals and the broadcast channels being jointly used for beam training.

[0038] The method may further comprise: measuring, by the UE, the initial-access signals and the broadcast channels to obtain a measurement result, and generating a beam training result based on the measurement result; and transmitting, by the UE, the beam training result to the node, so that the node may select one or more serving beams for the UE according to the beam training result.

[0039] Measuring the initial-access signals and the broadcast channels and generating the beam training result may comprise: measuring, by the UE, all of the beams carrying the initial-access signals and the broadcast channels to obtain the measurement result, the measurement result containing a signal strength/quality of each beam; and selecting, by the UE, one or more beams with the best signal quality or the highest signal power from among all of the measured beams as the beam training result.

[0040] Measuring the initial-access signals and the broadcast channels and generating the beam training result may comprise: measuring, by the UE, a beam carrying the initial-access signals and the broadcast channels to obtain the measurement result, the measurement result containing a signal strength/quality of the measured beam; and determining, by the UE, whether the signal strength/quality of the measured beam is greater than a preset threshold, and if yes, adding the beam to the beam training result.

[0041] The initial-access signals and the broadcast channels may be carried in one time unit by at least two levels of beam sets respectively, each level of beam set comprising one or more beams, at least one beam in the lower-level beam set being a sub-beam of a beam in the

upper-level beam set, and the beams in all of the beam sets using a same set of TXRU virtualization matrices during their beamforming process. Measuring the initial-access signals and the broadcast channels and generating the beam training result may comprise: measuring, by the UE, the at least two levels of beam sets according to an order from top level to bottom level, and estimating a beam selection result of each level, wherein when measuring the lower-level beam set, only the sub-beams of the beams in the upper-level beam selection result will be measured, the beam training result being the beam selection result of the lowest level.

[0042] There is also provided a node comprising: a transmitting module configured to transmit a downlink signal and/or downlink channel in beam-sweeping mode, where in the beam-sweeping mode the downlink signal or downlink channel is carried by at least two beams and is transmitted in at least two time units in one cycle, the formation of the beams at least using analog beamforming.

[0043] Each time unit may comprise one or more subframes, time slots, or symbols.

[0044] The transmitting module may further be configured to transmit a beam configuration to a UE using L1/L2 signaling or higher-layer signaling.

[0045] The transmitting module may be configured to transmit initial-access signals and broadcast channels in the beam-sweeping mode, the initial-access signals and the broadcast channels being jointly used for beam training.

[0046] The node may further comprise: a receiving module configured to receive a beam training result fed back from the UE; and a selection module configured to select one or more serving beams for the UE according to the beam training result.

[0047] The transmitting module may be configured to transmit the initial-access signals and the broadcast channels in one time unit using at least two levels of beam sets respectively, each beam set comprising one or more beams, at least one beam in the lower-level beam set being a sub-beam of a beam in the upper-level beam set, and beams in all of the beam sets using a same set of TXRU virtualization matrices during their beamforming process.

[0048] The node may be a base station, DU, TP, TRP, or RRH.

[0049] There is also provided a UE that comprises: a receiving module configured to receive a downlink signal and/or downlink channel which a node transmits in beam-sweeping

mode, where in the beam-sweeping mode the downlink signal or downlink channel is carried by at least two beams and is transmitted in at least two time units in one cycle, the formation of the beams at least using analog beamforming.

[0050] Each time unit may comprise one or more subframes, time slots, or symbols.

[0051] A beam carrying the downlink signal or downlink channel may originate from one or more nodes.

[0052] The UE may further comprise: a measurement module configured to measure initial-access signals and broadcast channels that the node transmits in the beam-sweeping mode to obtain a measurement result, and generate a beam training result based on the measurement result; and a feedback module configured to transmit the beam training result to the node, so that the node may select one or more serving beams for the UE according to the beam training result.

[0053] The initial-access signals and the broadcast channels may be carried in one time unit by at least two levels of beam sets respectively, each beam set comprising one or more beams, at least one beam in the lower-level beam set being a sub-beam of a beam in the upper-level beam set, and beams in all of the beam sets using a same set of TXRU virtualization matrices during their beamforming process. The measurement module may be configured to measure the at least two levels of beam sets according to an order from top level to bottom level, and estimate a beam selection result of each level, wherein when measuring the lower-level beam set, only the sub-beams of the beams in the upper-level beam selection result are measured, the beam training result being the beam selection result at the lowest level.

[0054] There is also provided a node comprising a processor and a transceiver coupled to the processor, the processor being configured to transmit via the transceiver a downlink signal and/or downlink channel in beam-sweeping mode, where in the beam-sweeping mode the downlink signal or downlink channel is carried by at least two beams and is transmitted in at least two time units in one cycle, the formation of the beams at least using analog beamforming.

[0055] Each time unit may comprise one or more subframes, time slots, or symbols.

[0056] The processor may be configured to transmit via the transceiver the downlink signal and/or downlink channel in the beam-sweeping mode in accordance with a beam

configuration, the beam configuration comprising at least one of a number of the beams, a length of the time unit, a length of the cycle, and a sweeping pattern.

[0057] The sweeping pattern may comprise a consecutive or inconsecutive time allocation for the beams of which directions lie in one or several same predetermined ranges and which make up a beam group.

[0058] The processor may further be configured to receive via the transceiver an uplink signal and/or uplink channel from a UE in beamforming manner.

[0059] There may be a time dependency between the transmission and reception of the beams of which directions lie in one or several same predetermined ranges, and the beam configuration may further comprise the time dependency.

[0060] The transmission and reception of the beams of which directions lie in one or several same predetermined ranges may be performed in a same time slot or subframe.

[0061] The processor may further be configured to transmit via the transceiver the beam configuration to the UE using L1/L2 signaling or higher-layer signaling.

[0062] The processor may be configured to transmit via the transceiver initial-access signals and broadcast channels in the beam-sweeping mode, the initial-access signals and the broadcast channels being jointly used for beam training.

[0063] The processor may further be configured to: receive via the transceiver a beam training result fed back from the UE; and select one or more serving beams for the UE according to the beam training result.

[0064] The processor may be configured to transmit via the transceiver the initial-access signals and the broadcast channels in the first time unit of each beam group in the time domain, the beam group consisting of beams of which directions lie in one or several same predetermined ranges.

[0065] The processor may be configured to transmit via the transceiver the initial-access signals and the broadcast channels using the beams in all directions sequentially during a training period.

[0066] The training period may be located at an initial position of a cycle.

[0067] The processor may be configured to transmit via the transceiver the initial-access signals and the broadcast channels in one time unit using at least two levels of beam sets

respectively, each beam set comprising one or more beams, at least one beam in the lower-level beam set being a sub-beam of a beam in the upper-level beam set, and the beams in all of the beam sets using a same set of TXRU virtualization matrices during the beamforming process.

[0068] The initial-access signals and the broadcast channels may comprise synchronization signals, BRS, and PBCH, wherein the synchronization signal may be carried by a first-level beam set, while the BRS and the PBCH may be carried by a second-level beam set.

[0069] The synchronization signals may comprise PSS and SSS.

[0070] The synchronization signals may further comprise ESS, wherein the ESS may be used to indicate a time location of the synchronization signals.

[0071] The initial-access signals and the broadcast channels may further comprise eBRS and ePBCH that are carried by a third-level beam set.

[0072] PSS, SSS, PBCH, or ePBCH may be further used to indicate a time location of the synchronization signals.

[0073] eBRS and ePBCH may have a different periodicity from BRS and PBCH.

[0074] eBRS and ePBCH may be transmitted on demand.

[0075] RE allocations of different beams in a same beam set can be multiplexed in at least one of time domain, frequency domain, and code domain.

[0076] RE allocations of different beams in different beam sets may be multiplexed in time domain and/or frequency domain.

[0077] There may be a dependency for RE allocation between the beams in different levels of beam sets.

[0078] The node may be a base station, DU, TP, TRP, or RRH.

[0079] There is also provided a UE comprising a processor and a communication circuit coupled to the processor, the processor being configured to receive via the communication circuit a downlink signal and/or downlink channel that a node transmits in beam-sweeping mode, where in the beam-sweeping mode the downlink signal or downlink channel is carried by at least two beams and is transmitted in at least two time units in one cycle, the formation of the beams at least using analog beamforming.

[0080] Each time unit may comprise one or more subframes, time slots, or symbols.

[0081] A beam carrying the downlink signal or downlink channel may originate from one or more nodes.

[0082] The processor may further be configured to receive via the communication circuit a beam configuration that the node sends using L1/L2 signaling or higher-layer signaling.

[0083] The processor may be configured to receive via the communication circuit initial-access signals and broadcast channels the node transmits in the beam-sweeping mode, the initial-access signals and the broadcast channels being jointly used for beam training.

[0084] The processor may further be configured to: measure via the communication circuit the initial-access signals and the broadcast channels to obtain a measurement result, and generate a beam training result based on the measurement result; and transmit via the communication circuit the beam training result to the node, so that the node may select one or more serving beams for the UE according to the beam training result.

[0085] The processor may be configured to measure via the communication circuit all of the beams carrying the initial-access signals and the broadcast channels to obtain the measurement result, the measurement result containing a signal strength/quality of each beam; and select one or more beams with the best signal quality or the highest signal power from among all of the beams as the beam training result.

[0086] The processor may be configured to measure via the communication circuit a beam carrying the initial-access signals and the broadcast channels to obtain the measurement result, the measurement result containing a signal strength/quality of the measured beam; and determine whether the signal strength/quality of the measured beam is greater than a preset threshold, and if yes, add the beam to the beam training result.

[0087] The initial-access signals and the broadcast channels may be carried in one time unit by at least two levels of beam sets respectively, each level of beam set comprising one or more beams, at least one beam in the lower-level beam set being a sub-beam of a beam in the upper-level beam set, and beams in all of the beam sets using a same set of TXRU virtualization matrices during their beamforming process. The processor may be configured to measure via the communication circuit the at least two levels of beam sets according to an order from top level to bottom level, and estimating a beam selection result of each level, wherein when measuring the lower-level beam set, only the sub-beams of the beams in the

upper-level beam selection result are measured, the beam training result being the beam selection result at the lowest level.

[0088] According to the Summary above, the downlink signal and/or downlink channel can be transmitted in the beam-sweeping mode, where the downlink signal and/or downlink channel are carried by at least two beams and the formation of the beams at least uses analog beamforming, so the gain of the FD-MIMO-based beamforming can compensate for the large pathloss thus improving the coverage of the high-frequency carriers, also the introduction of analog beamforming can reduce the high hardware cost and high power consumption required for sole digital beamforming.

BRIEF DESCRIPTION OF THE DRAWINGS

[0089] FIG. 1 is a schematic diagram showing the mapping process from the antenna ports to the antenna elements of the antenna array in FD-MIMO.

[0090] FIG. 2 is a flowchart illustrating a first embodiment of a method for downlink transmission based on beamforming according to the disclosure.

[0091] FIG. 3 is a schematic diagram illustrating the beam sweeping in the first embodiment of the downlink transmission method.

[0092] FIG. 4 is a flowchart illustrating a second embodiment of the method for downlink transmission based on beamforming according to the disclosure.

[0093] FIG. 5 is a schematic diagram illustrating a sweeping pattern namely inconsecutive time allocation for the beam groups in the second embodiment of the downlink transmission method.

[0094] FIG. 6 is a schematic diagram illustrating a sweeping pattern namely consecutive time allocation for the beam groups in the second embodiment of the downlink transmission method.

[0095] FIG. 7 is a schematic diagram illustrating a sweeping pattern namely consecutive time allocation for the beam groups applied to a TDD system in the second embodiment of the downlink transmission method.

[0096] FIG. 8 is a flowchart illustrating a third embodiment of the method for downlink transmission based on beamforming according to the disclosure.

[0097] FIG. 9 is a schematic diagram illustrating the time dependency between the transmission and reception of beams of which directions lie in one or several same predetermined ranges in the third embodiment of the downlink transmission method.

[0098] FIG. 10 is a schematic diagram illustrating a self-contained subframe in the third embodiment of the downlink transmission method.

[0099] FIG. 11 is a flowchart illustrating a fourth embodiment of the method for downlink transmission based on beamforming according to the disclosure.

[00100] FIG. 12 is a schematic diagram showing a training period in the fourth embodiment of the downlink transmission method.

[00101] FIG. 13 is a schematic diagram illustrating a parent-beam and sub-beams in a fifth embodiment of the downlink transmission method.

[00102] FIG. 14 is a schematic diagram illustrating an RE allocation for initial-access signals and broadcast channels in the fifth embodiment of the downlink transmission method, the time duration of the initial-access block being one time slot.

[00103] FIG. 15 is a schematic diagram illustrating another RE allocation for initial-access signals and broadcast channels in the fifth embodiment of the downlink transmission method, the time duration of the initial-access block being one subframe.

[00104] FIG. 16 is a schematic diagram illustrating another RE allocation for initial-access signals and broadcast channels in the fifth embodiment of the downlink transmission method, the time duration of the initial-access block being three symbols.

[00105] FIG. 17 is a schematic diagram illustrating another RE allocation for initial-access signals and broadcast channels in the fifth embodiment of the downlink transmission method, the time duration of the initial-access block being three symbols.

[00106] FIG. 18 is a schematic diagram illustrating another RE allocation for initial-access signals and broadcast channels in the fifth embodiment of the downlink transmission method, the time duration of the initial-access block being one symbol.

[00107] FIG. 19 is a flowchart illustrating a sixth embodiment of the method for downlink transmission based on beamforming according to the disclosure.

[00108] FIG. 20 is a flowchart illustrating a seventh embodiment of the method for downlink transmission based on beamforming according to the disclosure.

[00109] FIG. 21 is a flowchart illustrating an eighth embodiment of the method for downlink transmission based on beamforming according to the disclosure.

[00110] FIG. 22 is a flowchart illustrating a ninth embodiment of the method for downlink transmission based on beamforming according to the disclosure.

[00111] FIG. 23 is a flowchart illustrating a tenth embodiment of the method for downlink transmission based on beamforming according to the disclosure.

[00112] FIG. 24 is a block diagram illustrating a first embodiment of a node according to the disclosure.

[00113] FIG. 25 is a block diagram illustrating a second embodiment of the node according to the disclosure.

[00114] FIG. 26 is a block diagram illustrating a third embodiment of the node according to the disclosure.

[00115] FIG. 27 is a block diagram illustrating a first embodiment of a UE according to the disclosure.

[00116] FIG. 28 is a block diagram illustrating a second embodiment of the UE according to the disclosure.

[00117] FIG. 29 is a block diagram illustrating a third embodiment of the UE according to the disclosure.

[00118] This disclosure includes references to “one embodiment,” “a particular embodiment,” “some embodiments,” “various embodiments,” or “an embodiment.” The appearances of the phrases “in one embodiment,” “in a particular embodiment,” “in some embodiments,” “in various embodiments,” or “in an embodiment,” do not necessarily refer to the same embodiment. Particular features, structures, or characteristics may be combined in any suitable manner consistent with this disclosure. Various modules, units, circuits, or other components may be described or claimed as “configured to” perform a task or tasks. In such contexts, “configured to” is used to connote structure by indicating that the modules/units/circuits/components include structure (e.g., circuitry) that performs those task or tasks during operation. As such, the modules/units/circuits/components can be said to be configured to perform the task even when the specified module/unit/circuit/component is not currently operational (e.g., is not on). The modules/units/circuits/components used with the

“configured to” language include hardware—for example, circuits, memory storing program instructions executable to implement the operation, etc. Reciting that a module/unit/circuit/component is “configured to” perform one or more tasks is expressly intended not to invoke 35 U.S.C. §112(f), for that module/unit/circuit/component. Additionally, “configured to” can include a generic structure (e.g., generic circuitry) that is manipulated by software and/or firmware (e.g., an FPGA or a general-purpose processor executing software) to operate in a manner that is capable of performing the task(s) at issue. “Configured to” may also include adapting a manufacturing process (e.g., a semiconductor fabrication facility) to fabricate devices (e.g., integrated circuits) that are adapted to implement or perform one or more tasks. As used herein, the term “based on” describes one or more factors that affect a determination. This term does not foreclose additional factors that may affect the determination. That is, a determination may be solely based on those factors or based, at least in part, on those factors. Consider the phrase “determine A based on B.” While in this case, B is a factor affects the determination of A, such a phrase does not foreclose the determination of A from also being based on C. In other instances, A may be determined based solely on B.

DETAILED DESCRIPTION

[00119] Referring to FIG. 2, a flowchart is depicted illustrating a first embodiment of a method for downlink transmission based on beamforming. The method can be implemented on a node and may comprise the following block.

[00120] In S11, the node may transmit a downlink signal and/or downlink channel in beam-sweeping mode.

[00121] The node may be a base station, which is connected to a core network and performs radio communications with multiple UEs thus providing communications coverage for the associated geographical area. The base station may comprise, but are not limited to, macro base stations, micro base stations, or pico base stations. In various embodiments, a base station is also being interchangeably referred to as a wireless base station, an access point, a Node B, an evolved Node B (eNodeB or eNB), and so forth. If the radio access network is a central unit (CU), distributed unit (DU), or other similar architectures, the base station can be

used to represent the CU and the multiple DUs under control of the CU. In CU/DU architecture, a CU connects to and controls multiple DUs, the CU and DUs both carrying an air interface protocol stack.

[00122] The node may also be a DU in the CU/DU architecture, or a transmission point (TPP), transmission reception point (TRP), or radio remote head (RRH) in other similar architectures.

[00123] By beam-sweeping mode, it means that a same downlink signal or downlink channel is carried by at least two beams and transmitted in at least two time units in one cycle. The beamforming may use only analog beamforming, or hybrid beamforming, i.e., a combination of digital beamforming and analog beamforming. For the same downlink signal or downlink channel, one time unit may be carried by only one beam or at least two beams. An example of beam sweeping is shown in FIG. 3, in which the solid-line beams represent the actually transmitted beams while the dashed-line beams are for illustrative purposes only.

[00124] The node may need to send multiple types of downlink signals or downlink channels. For the common signals/channels oriented to all the UEs, the combined coverage of all the beams used to carry the common signals/channels may need to cover the entire coverage area of the node (i.e., full coverage sweeping) in a number (typically one) of cycles. On the other hand, for the dedicated signals/channels serving some particular UEs, the coverage of the beams used to carry these dedicated signals/channels may only need to cover the area where their served subjects are located without the need of considering the coverage area of the node.

[00125] The time unit may comprise one or more subframes, time slots, symbols, or other predefined time lengths. It should be noted that for high carrier frequency, the subcarrier spacing may be increased and the time duration of one symbol may be reduced. In analog beamforming, i.e., by adjusting the TXRU virtualization matrix, the switching between different analog beams requires a non-negligible time for a short symbol duration. Therefore, longer CP length may be needed before the symbol of analog beam switching. Because different beams transmitted within a longer time unit, say one or more time slots, subframes, or multiple symbols, and/or in some adjacent time units, are switched by digital beamforming (i.e., by adjusting the port virtualization matrix) instead of analog beamforming, the impact of

the beam switching time in analog beamforming can be reduced.

[00126] According to the above embodiment, the downlink signal and/or downlink channel can be transmitted in the beam-sweeping mode, where the downlink signal and/or downlink channel are carried by at least two beams and the formation of the beams at least uses analog beamforming, so the gain of the FD-MIMO-based beamforming can compensate for the large pathloss thus improving the coverage of the high-frequency carriers, also the introduction of analog beamforming can reduce the high hardware cost and power consumption required for sole digital beamforming.

[00127] Referring now to FIG. 4, a flowchart is depicted illustrating a second embodiment of the method for downlink transmission based on beamforming according to the disclosure, which is based on the first embodiment of the downlink transmission method and in which a beam configuration is further introduced. The present embodiment is a further extension of the first embodiment method, so the common contents as those of the first embodiment will not be detailed again. The method according to the present embodiment may comprise the following blocks.

[00128] In S111, the node may transmit a downlink signal and/or downlink channel in beam-sweeping mode in accordance with a beam configuration.

[00129] The beam configuration may comprise at least one of a number of the beams, a length of the time unit, a length of the cycle, and a sweeping pattern.

[00130] The sweeping pattern may comprise a consecutive or inconsecutive time allocation for the beams of which directions lie in one or several same predetermined ranges and which make up a beam group. The division of the beam groups may be performed based on the TXRU virtualization matrix. Namely, the beams of a same beam group may use a same set of TXRU virtualization matrices in their beamforming process, while beams of different beam groups may use different sets of TXRU virtualization matrices during their beamforming process. Constrained by the TXRU virtualization matrices, directions of the beams in the same beam group may lie in one or several same predetermined ranges. In one cycle, the node may need to send different downlink signals and/or channels using different beam groups, while the sweeping pattern may reflect the distribution of the beam groups in the time domain. As such, after determining its one or more serving beams, the UE can learn when

to detect the one or more serving beams according to the sweeping pattern, rather than performing the detection blindly at each transmission time interval (TTI), thus reducing the power consumption of the UE.

[00131] The sweeping pattern will be described in greater detail below with reference to the accompanying drawings.

[00132] As shown in FIG. 5, each block represents a time unit, and different filling patterns represent different beam groups. In the figure there are a total of four beam groups, including A, B, C, and D, and each beam group is inconsecutive in the time domain. From the part shown in the figure, different beam groups are interweaved in the time domain, where beam group A occupies time units 0, 4 and 8, beam group B occupies time units 1, 5 and 9, beam group C occupies time units 2, 6 and 10, and beam group D occupies time units 3 and 7.

[00133] As shown in FIG. 6, each block represents a time unit, and different filling patterns represent different beam groups. In the figure there are a total of four beam groups, including E, F, G, and H, and each beam group is consecutive in the time domain, where the beam group E occupies time units 0, 1 and 2, beam group F occupies time units 3 and 4, beam group G occupies time units 5, 6, 7 and 8, and beam group H occupies time units 9 and 10.

[00134] In a TDD system, a cycle may contain some time units for receiving the uplink signals and/or uplink channels. As shown in FIG. 7, each block represents a time unit, and unfilled or blank blocks represent the time units for uplink reception, while the blocks filled with patterns represent the time units for downlink transmission, where different filling patterns denote different beam groups. In the figure there are a total of four beam groups, including I, J, K, and L, and each beam group is inconsecutive in the time domain, where the 4th to 7th time units are used for uplink reception. The beam group I occupies time units 0 and 8, beam group J occupies time units 1 and 9, beam group K occupies time units 2 and 10, and beam group L occupies time unit 3. Of course, in the TDD system, each beam group may be consecutive in the time domain.

[00135] In S112, the node may send the beam configuration to the UE using L1/L2 signaling or higher-layer signaling.

[00136] For example, the node may pack the beam configuration in the system information and send the system information to the UE, or send the beam configuration to the UE using

RRC connection reconfiguration message. The beam configuration may be that of the current node, and/or of another node which belongs to the same cell as the current node or belongs to a neighboring cell of the current cell to facilitate the RRM measurement of the UE. If some information in the beam configuration is fixed, then the node can choose not to send the part of fixed information to reduce the signaling overhead.

[00137] Referring now to FIG. 8, a flowchart is depicted illustrating a third embodiment of the method for downlink transmission based on beamforming according to the disclosure, which is based on the first embodiment of the downlink transmission method and further comprises the following blocks.

[00138] In S12, the node may receive an uplink signal and/or uplink channel from a UE in beamforming manner.

[00139] Performing the reception based on beamforming can enable the uplink signal and/or uplink channel transmitted from the UE in a particular direction to have better signal strength/quality. Similarly, the node may perform the uplink reception based on beam sweeping in order to improve the uplink reception over the entire coverage area.

[00140] There may be a time dependency, e.g., a fixed or configurable time delay, between the transmission and reception of the beams of which directions lie in one or several same predetermined ranges. As shown in FIG. 9, each block represents a time unit, in the n th time unit the node may use a beam for downlink transmission, then in the $(n+x)$ th time unit the node may perform uplink reception using a beam of which the direction lies in the one or several same predetermined ranges as the beam used for the downlink transmission, where x represents the time dependency between the transmission and the reception.

[00141] The transmission and reception of the beams of which the directions lie in the one or several same predetermined ranges may be performed in one same time slot or subframe, which can be called a self-contained slot/subframe. As shown in FIG. 10, for example, in a self-contained subframe, the first nine symbols may be used for downlink transmission, the tenth symbol may serve as a guard period (GP), while the last four symbols may be used for uplink reception.

[00142] Thus, in one embodiment, the beam configuration can further contain the above-mentioned time dependency or the self-contained slot/subframe information (index of

the self-contained slot/subframe and which symbols thereof are used for downlink transmission and which symbols are used for uplink transmission), so that the UEs would be able to know when to transmit the uplink signals and/or uplink channels to achieve the highest reception gain.

[00143] Referring now to FIG. 11, a flowchart is depicted illustrating a fourth embodiment of the method for downlink transmission based on beamforming according to the disclosure, which is based on the first embodiment of the downlink transmission method and in which the downlink signal and the downlink channel are respectively initial-access signals and broadcasts channel which are jointly used for beam training. The present embodiment is a further extension of the first embodiment downlink transmission method, so the common contents as those of the first embodiment will not be detailed again. The method according to the present embodiment can comprise the following blocks.

[00144] In S121, the node may transmit initial-access signals and broadcast channels in beam-sweeping mode.

[00145] The initial-access signals and the broadcast channels are used for the initial access of a UE. The initial access is a necessary step in the process by which the UE accessing the network. In the present embodiment, the initial-access signals and the broadcast channels may jointly be used for beam training. By beam training, it refers to the process by which the UE measures and evaluates different beams and select one or more beams from the measured beams.

[00146] The node can send the initial-access signals and the broadcast channels in the first time unit of each beam group in the time domain, e.g., the 0th, 1th, 2th and 3th time units shown in FIG. 5, the 0th, 3th, 5th and 9th time units shown in FIG. 6, or the 0th, 1th, 2th and 3th time units as shown in FIG. 7.

[00147] The node may also transmit the initial-access signals and the broadcast channels using the beams in all directions sequentially during the training period. Typically, the training period may be located at the beginning of the cycle so that the node can send control signaling/data according to the beam training result fed back by the UE. As shown in FIG. 12, for example, each block in the upper half of the figure represents one cycle, each block in the lower half represents one time unit, and different filling patterns denote different beam

groups. The training period may be the first time unit in the labeled cycle. The node may send the initial-access signals and the broadcast channels in time unit 0, and start to use different beams to send control signaling/data since time unit 1.

[00148] In S122, the node may receive a beam training result fed back from the UE.

[00149] The beam training result may contain identifiers of beams the UE has selected, and may further include the signal strength/quality of each beam the UE selects.

[00150] In S123, the node may select one or more serving beams for the UE according to the beam training result.

[00151] The node may directly accept the beam training result without making any modifications, i.e., directly take a beam indicated in the beam training result as the serving beam for the UE. Alternatively, the node can make some adaptive changes to the beam training result and take the modified result as the serving beams for the UE. For example, the traffic load of a beam may be based on to determine whether to add the beam to the beam training result or delete the beam from the beam training result. The selected beams can be used for the subsequent communication between the node and the UE.

[00152] A fifth embodiment of the downlink transmission method is provided, which is based on the fourth embodiment of the downlink transmission method and in which at least two levels of beam sets are used in one time unit to transmit the initial-access signals and the broadcast channels respectively.

[00153] Initial-access signals and broadcasting channels may include (if supported but not limited to) synchronization signals, physical broadcast channel (PBCH), beam reference signal (BRS), extended physical broadcast channel (ePBCH), and extended beam reference signals (eBRS). PBCH is used to deliver master information block (MIB) and uses BRS for decoding. ePBCH is used to deliver system information block (SIB) and uses eBRS for decoding. The synchronization signals may include primary synchronization signal (PSS), secondary synchronization signal (SSS) and extended synchronization signal (ESS). The design of the PSS and SSS in the present embodiment can be similar to that in LTE, and ESS is used to indicate the time location of the synchronization signals, e.g., the subframe index or slot index within one radio frame, or symbol index within one subframe or slot. PSS, SSS, PBCH, or ePBCH can be further used to indicate the time location of the synchronization

signal and ESS can be omitted.

[00154] The initial-access block may include the PSS/SSS/ESS, PBCH, BRS, ePBCH and eBRS. For a UE to complete the initial access procedure, a three-stage detection would be needed: (1) Synchronization signals (PSS/SSS/ESS) detection; (2) PBCH and BRS detection; (3) ePBCH and eBRS detection. Each detection stage may correspond to a level of beam set.

[00155] The synchronization signals, including PSS, SSS and ESS (PSS/SSS/ESS) may be carried by a first-level beam set and used for beam training at the first level. Synchronization signals may share the same antenna ports, and the number of antenna ports can be one, two, or more. One antenna port of PSS/SSS/ESS may map to one first-level beam direction. Different antenna ports and the corresponding beams can be multiplexed in time domain, frequency domain, code domain or the combination of two or all.

[00156] BRS may be carried by a second-level beam set and used for the second-level beam training. The number of antenna ports of BRS can be one, two, or more. One or more antenna ports may map to one second-level beam direction. The BRS of different antenna ports and corresponding beams can be multiplexed in time domain, frequency domain, code domain or the combination of two or all. PBCH may share the same antenna ports as BRS, and thus PBCH may also be carried by the second-level beam set, where BRS is also used for the channel estimation for detecting PBCH.

[00157] eBRS may be carried by a third-level beam set and used for the third-level beam training. The number of antenna ports of eBRS can be one, two, or more. One or more antenna ports may map to one third-level beam direction. The eBRS of different antenna ports and corresponding beams can be multiplexed in time domain, frequency domain, code domain or the combination of two or all. ePBCH may share the same antenna ports as eBRS, and thus ePBCH may also be carried by the third-level beam set, where eBRS is also used for the channel estimation for detecting ePBCH.

[00158] eBRS and ePBCH may have a different periodicity from BRS/PBCH and not appear in every transmission of BRS/PBCH, or may only be transmitted on demand. In other embodiments, the information of ESS may be included in PSS, SSS, PBCH, or ePBCH and so ESS can be omitted. The initial-access signals and broadcasting channels may not include

ePBCH and eBRS, and the SIB can be carried by other downlink channels, e.g., physical downlink shared channel (PDSCH), or by other carriers if the UE is also connected to other carriers. If the eBRS and ePBCH are not transmitted, then finer beams and more antenna ports can be used for the first- and second-level beams.

[00159] Each level of beam sets may include one or more beams. At least one beam in a lower-level beam set may be a sub-beam of a beam in an immediate upper-level beam set, where the beam in the upper-level is referred to as a parent-beam of the sub-beam in the lower-level. The directions of all sub-beams of one parent-beam should be constrained by the direction of this parent-beam, as illustrated in FIG. 13. The beams in all the beam sets may use the same set of TXRU virtualization matrices in their beamforming process, while different beams may use different port virtualization matrices.

[00160] There may be a dependency for the RE resource allocation, e.g., a specified time delay and/or interval between subcarriers, between the beams in different levels of beam sets, e.g., depending on the system ID, such as cell ID, carrier frequency, bandwidth, etc., so that after the UE finds one or several best parent-beams, the UE may only need to detect the RE resources corresponding to these best parent-beams in order to save processing time and power consumption. One or more parent-beams can share the same REs and the same group of antenna ports for transmitting their own sub-beams. The RE allocations of different levels of beams can be multiplexed in the time and/or frequency domains.

[00161] After the connection between the UE and the node is established, the UE may continue monitoring the synchronization signals, BRS and eBRS of its serving cell for beam maintenance. Furthermore, the UE may also monitor the BRS and eBRS of other nodes (e.g., neighboring nodes within the same cell, or nodes within the neighboring cells) for RRM measurement.

[00162] The RE allocation for the initial-access block (i.e., the initial access signals and the broadcast channels) will be described in greater detail in connection with examples.

[00163] As shown in FIG. 14, the time duration of the initial-access block is 1 slot, and the time duration of the initial-access block is typically smaller than or equal to one time unit. Each block in the left sub-figure of FIG. 14 denotes a group of REs with 12 subcarriers and one time symbol. Each block in the right sub-figure denotes one RE.

[00164] Synchronization signals, including PSS, SSS and ESS, occupy the centre REs with the length of 6 PRBs, and locate at symbols #0, #1, #2 of this slot respectively. One antenna port is assigned for them, which is mapped to one beam, so the first-level beam set includes one beam.

[00165] PBCH and BRS are located at the same subcarriers as PSS/SSS/ESS and at symbols #3, #4, #5, #6 of this slot. Eight antenna ports are assigned for PBCH and BRS, each two antenna ports will be mapped to one beam, so the second-level beam set includes 4 beams. As shown in the right top sub-figure, eight REs may be occupied by BRS in every 12 subcarriers, and the eight antenna ports can be multiplexed in time domain, frequency domain, code domain or the combination of two or all. The remaining REs are used for PBCH transmission.

[00166] ePBCH and eBRS occupy the PRBs above or below the PBCH and BRS. In this example, four groups of RE resources are allocated for ePBCH and eBRS and denoted by four different filling patterns. Each group of ePBCH and eBRS RE resources corresponds to one second-level beam. In the right bottom sub-figure, 16 REs (filled with long horizontal lines) are occupied by eBRS within each PRB. The number of antenna ports assigned for ePBCH and eBRS can be four, eight, etc., and mapped to 4 beams. Considering the 4 groups of RE resources each corresponding to one second-level beam, hence the third-level beam set includes 4×4 , i.e., a total of 16 beams. Different antenna ports can be multiplexed in time domain, frequency domain, code domain or the combination of two or all. The remaining REs are used for ePBCH transmission.

[00167] As shown in FIG. 15, the time duration of the initial-access block is 1 subframe, and the time duration of the initial-access block is typically smaller than or equal to one time unit. Each block in the figure denotes a group of REs with 12 subcarriers and one time symbol.

[00168] Two groups of PSS/SSS/ESS occupy the centre REs with the length of 6 PRBs, and locate at symbols #0, #1, #2, #7, #8, #9 of this subframe respectively. One antenna port is assigned for each group of PSS/SSS/ESS, and mapped to one beam, so the first-level beam set includes two beams.

[00169] PBCH and BRS are located at the same subcarriers as PSS/SSS/ESS and at symbols #3, #4, #5, #6, #10, #11, #12, #13 of this subframe. The PBCH and BRS in the first slot use

the sub-beams of the first group of PSS/SSS/ESS, and those in the second slot use the sub-beams of the second group of PSS/SSS/ESS. Eight antenna ports are assigned for each group of PBCH and BRS, each antenna will be mapped to one beam, so the second-level beam set include 2×8 , i.e., a total of 16 beams.

[00170] ePBCH and eBRS occupy the PRBs above or below the PBCH and BRS. In the present embodiment, four groups of RE resources are allocated for ePBCH and eBRS related to the same group of PBCH and BRS. Each group of ePBCH and eBRS RE resources corresponds to two second-level beams. The number of antenna ports assigned for ePBCH and eBRS can be four, eight, etc., and mapped to 4 beams. Considering the 8 groups of RE resources each corresponding to two second-level beams, the third-level beam set includes $2 \times 8 \times 4$, i.e., a total of 64 beams. Different antenna ports can be multiplexed in time domain, frequency domain, code domain or the combination of two or all.

[00171] As shown in FIG. 16, the time duration of the initial-access block is 3 symbols, and the time duration of the initial-access block is typically smaller than or equal to one time unit. Each vertically elongated block in FIG. 16 denotes a group of REs with 12 subcarriers and one time symbol. Each horizontally elongated block in FIG. 16 denotes one RE.

[00172] Synchronization signals, including PSS, SSS and ESS, occupy the centre REs with the length of 6 PRBs. The PBCH/BRS and ePBCH/eBRS are located on the same time symbols as the synchronization signals and multiplexed in frequency domain, which are not necessarily right next to the synchronization signals, and may be distributedly allocated across the whole system bandwidth where the allocated REs may be related to the system ID such as cell ID, carrier frequency, bandwidth, etc. The periodicity of PBCH/BRS and ePBCH/eBRS transmission may be different or ePBCH/eBRS may only be transmitted on demand, and thus as shown in the right sub-figure of FIG. 16, ePBCH/eBRS is not transmitted.

[00173] As shown in FIG. 17, the time duration of the initial-access block is 3 symbols, and the time duration of the initial-access block is typically smaller than or equal to one time unit. Each block in the left sub-figure of FIG. 17 denotes a group of REs with 12 subcarriers and one time symbol. Each block in the right sub-figure denotes one RE.

[00174] Synchronization signals are divided into three groups, each including PSS, SSS, and ESS. Each group of synchronization signals occupy the center REs with the length of 18

PRBs and occupy 1 symbol in the time domain. PBCH/BRS resources are shared by the three groups of synchronization signals. The three groups of synchronization signals may use different beams or use the same beam.

[00175] As shown in FIG. 18, the time duration of the initial-access block is 1 symbol, and the time duration of the initial-access block is typically smaller than or equal to one time unit. Each block in the left sub-figure of FIG. 18 denotes a group of REs with 12 subcarriers and one time symbol. Each block in the right sub-figure denotes one RE.

[00176] The symbol for initial-access block can be allocated at a predetermined location within the first time unit (e.g., time slot or subframe) of one beam group, or the symbols for initial-access block of different beam groups can be successively located in time domain (e.g., the training slots/subframes in FIG. 12). For the latter case, longer CP length can be used for these time symbols to combat with the switching time of the analog beams, e.g., less than 14 symbols for the initial-access block subframe.

[00177] It should be noted that the density and number of REs for each type of signals/channels and the number of beams in the above examples are for illustration only, and may be predefined and fixed, or dynamically and adaptively configurable for real-life implementation.

[00178] Referring to FIG. 19, a flowchart is depicted illustrating a sixth embodiment of the method for downlink transmission based on beamforming according to the disclosure. The present method can be implemented on a UE. The UE can be stationary or mobile, including, but not limited to, cellular phones, personal digital assistants (PDA), wireless modems, tablet computers, notebook computers, cordless phones, and so forth. The method according to the present embodiment can comprise the following blocks.

[00179] In S21, the UE may receive a downlink signal and/or downlink channel which is transmitted from a node in beam-sweeping mode.

[00180] By beam-sweeping mode, it means that a same downlink signal or downlink channel is carried by at least two beams and transmitted in at least two time units in one cycle. The beamforming may use only analog beamforming, or hybrid beamforming, i.e., a combination of digital beamforming and analog beamforming. For the same downlink signal or downlink channel, one time unit may be carried by only one beam or by at least two beams.

[00181] The time unit may comprise one or more subframes, time slots, symbols, or other predefined time lengths. It should be noted that different beams transmitted in a longer time unit, say one or more time slots, subframes, or multiple symbols, and/or in some adjacent time units, are switched by digital beamforming (i.e., by adjusting the port virtualization matrix) instead of analog beamforming, so the impact of the beam switching time in analog beamforming due to the increase of the subcarrier spacing can be reduced.

[00182] In one embodiment, a beam carrying the downlink signal or downlink channel may originate from one or more nodes. For example, the formation of a beam may make use of the electromagnetic waves emitted by the antennas of multiple DUs.

[00183] Referring now to FIG. 20, a flowchart is depicted illustrating a seventh embodiment of the method for downlink transmission based on beamforming according to the disclosure, which is based on the sixth embodiment of the downlink transmission method and further comprises the following blocks.

[00184] In S22, the UE may receive a beam configuration that the node sends using L1/L2 signaling or higher-layer signaling.

[00185] The beam configuration may comprise at least one of a number of the beams, a length of the time unit, a length of the cycle, and a sweeping pattern. If the node receives an uplink signal and/or uplink channel transmitted from the UE based on beamforming, then the beam configuration may further contain the time dependency or the self-contained slot/subframe information. For details, see the relevant description of the second and third embodiments of the downlink transmission method.

[00186] Referring now to FIG. 21, a flowchart is depicted illustrating an eighth embodiment of the method for downlink transmission based on beamforming according to the disclosure, which is based on the sixth embodiment of the downlink transmission method and in which the downlink signal and the downlink channel are respectively initial-access signals and broadcast channels which are jointly used for beam training. The present embodiment is a further extension of the sixth embodiment of the downlink transmission method, so the common contents as those of the sixth embodiment method will not be detailed again. The method according to the present embodiment can comprise the following blocks.

[00187] In S210, the UE may receive initial-access signals and broadcast channels that the

node transmits in beam-sweeping mode.

[00188] The initial-access signals and the broadcast channels may be used for the initial access of the UE and for beam training. By beam training, it refers to the process by which the UE measures and evaluates different beams and select one or more beams from the measured beams.

[00189] The UE can receive the initial-access signals and the broadcast channels that the node transmits in the first time unit of each beam group in the time domain, or receive in the training period (typically at the initial position of a cycle) the initial-access signals and the broadcast channels that the node transmits using the beams in all directions.

[00190] In S220, the UE may measure the initial-access signals and the broadcast channels and generate a beam training result based on the measure result.

[00191] The UE can measure all of the beams carrying the initial-access signals and the broadcast channels to obtain a measurement result and so select one or more optimal beams as the beam training result, which will be described in greater detail in the following ninth embodiment. Alternatively, the UE can measure different beams, and add the beam, of which the signal strength/quality is greater than a preset threshold, to the beam training result, which will be described in greater detail in the following tenth embodiment.

[00192] In one embodiment, the initial-access signals and the broadcast channels may be carried in one time unit by at least two levels of beam sets respectively, each beam set comprising one or more beams, at least one beam in a lower-level beam set being a sub-beam of a beam in an immediate upper-level beam set, and the beams in all the beam sets using a same set of TXRU virtualization matrices during their beamforming process.

[00193] In this case, the UE may measure the at least two levels of beam sets according to an order from top level to bottom level, and estimate a beam selection result of each level, wherein when measuring the lower-level beam set, only the sub-beams of the beams in the upper-level beam selection result are measured, the beam training result being the beam selection result of the lowest level.

[00194] When the number of sub-beams is large, the hierarchical measurement and evaluation can effectively reduce the number of measurements to reduce power consumption. For example, there are three levels of beam sets. The first-level beam set includes 2 beams,

each being the parent-beam of eight beams in the second-level beam set, so the second-level beam set includes 2×8 , i.e., 16 beams. Similarly, each beam in the second-level beam set is the parent-beam of 8 beams in the third-level beam, thus the third-level beam set includes 16×8 , i.e., 128 beams. Assuming that only one optimal beam is selected for each evaluation, then selecting one beam from the 128 beams included in the third-level beam set would require three times of measurements, in which the number of beams measured is 2, 8 and 8, respectively, i.e., a total of 18 beams. In contrast, if directly measuring and evaluating the third-level beam set, then a total number of 128 beams would need to be measured.

[00195] Of course, if the signal strength/quality of all the beams in the first-level beam set is smaller than the preset threshold, then the UE may not measure the lower-level beam sets to further reduce the power consumption.

[00196] In S230, the UE may send the beam training result to the node.

[00197] The beam training result may contain identifiers of the beams the UE has selected, and may further include the signal strength/quality of each beam in the beam training result. As such, the node can select one or more serving beams for the UE according to the beam training result.

[00198] The present embodiment describes the procedure by which the UE performs beam training utilizing the initial-access signals and the broadcast channels, where the procedure can be performed either during the UE initial access or after the UE has completed the access, so that the UE would be able to select one or more superior serving beams. In addition, the UE can also measure the initial access signals or broadcast channels from other nodes (e.g., neighboring nodes within the same cell, or nodes within the neighboring cells) for RRM measurement.

[00199] Referring now to FIG. 22, a flowchart is depicted illustrating a ninth embodiment of the method for downlink transmission based on beamforming according to the disclosure, which is based on the eighth embodiment of the downlink transmission method and in which the block S220 further comprises the following steps.

[00200] In S221, the UE may measure all the beams carrying the initial-access signals and the broadcast channels to obtain a measurement result.

[00201] The measurement result may contain the signal strength/quality of each measured

beam, where the signal strength is typically expressed as RSRP, and the signal quality is usually represented by RSRQ.

[00202] In S222, the UE may select one or more beams with the best signal quality or the highest signal power from all of the measured beams as the beam training result.

[00203] If the initial-access signals and the broadcast channels are transmitted in the first time unit of each beam group in the time domain and each beam group is continuously distributed over the time domain, then the UE may require a longer period of time, e.g., approximately one cycle, to complete the measurement and evaluation of the initial-access signals and the broadcast channels. If the initial-access signals and the broadcast channels are transmitted in the first time unit of each beam group in the time domain and different beam groups are interweaved over the time domain, or if the initial-access signals and the broadcast channels are only transmitted in the training period, then the time required for the UE to perform the measurement and evaluation will be greatly reduced.

[00204] Referring now to FIG. 23, a flowchart is depicted illustrating a tenth embodiment of the method for downlink transmission based on beamforming according to the disclosure, which is based on the eighth embodiment of the downlink transmission method and in which the block S220 further comprises the following steps.

[00205] In S223, the UE may measure a beam carrying the initial-access signals and the broadcast channels to obtain a measurement result.

[00206] The measurement result may contain the signal strength/quality of the measured beam, where the signal strength is typically expressed as RSRP, and the signal quality is usually represented by RSRQ.

[00207] In S224, the UE may determine whether the signal strength/quality of the measured beam is greater than a preset threshold, and if yes, add the beam to the beam training result.

[00208] When adding a new beam, if the number of beams in the beam training result reaches the upper limit, then the UE can choose to remove the beam with the worst signal strength/quality or the beam added the earliest.

[00209] If the initial-access signals and the broadcast channels are transmitted in the first time unit of each beam group in the time domain and each beam group is continuously distributed over the time domain, and within one cycle the UE can choose to send the beam

training result to the node after each time of measurement and evaluation, then the UE can send a new beam training result or a variation between the new beam training result and the old one only when the beam training result changes. If the initial-access signals and the broadcast channels are transmitted in the first time unit of each beam group in the time domain and different beam groups are interweaved over the time domain, or if the initial-access signals and the broadcast channels are only transmitted in the training period, then within one cycle the UE can choose to send once a beam training result to the node after each time of measurement and evaluation, or after a number of times of measurements and evaluations, or after completing all the measurements and evaluations.

[00210] Referring now to FIG. 24, a block diagram is depicted illustrating a first embodiment of a node according to the disclosure. The node may comprise a transmitting module 11.

[00211] The transmitting module 11 may be configured to transmit a downlink signal and/or downlink channel in beam-sweeping mode, where in the beam-sweeping mode the downlink signal or downlink channel is carried by at least two beams and is transmitted in at least two time units in one cycle, wherein the formation of the beams at least uses analog beamforming.

[00212] The node may be a base station, distributed unit (DU), transmission point (TP), transmission reception point (TRP), or radio remote head (RRH).

[00213] Each time unit may comprise one or more subframes, time slots, or symbols.

[00214] The transmitting module 11 may further be configured to transmit a beam configuration to a UE using L1/L2 signaling or higher-layer signaling.

[00215] Referring now to FIG. 25, a block diagram is depicted illustrating a second embodiment of the node according to the disclosure, which is based on the first embodiment node and in which the transmitting module 11 is configured to transmit initial-access signals and broadcast channels in the beam-sweeping mode, where the initial-access signals and the broadcast channels may be jointly used for beam training, and the node may further comprise a receiving module 12 configured to receive the beam training result fed back from the UE and a selection module 13 configured to select one or more serving beams for the UE according to the beam training result.

[00216] The transmitting module 11 may be configured to transmit the initial-access signals

and the broadcast channels in one time unit using at least two levels of beam sets respectively, where each beam set may comprise one or more beams, at least one beam in a lower-level beam set may be a sub-beam of a beam in an immediate upper-level beam set, and beams in all of the beam sets may use a same set of TXRU virtualization matrices during their beamforming process.

[00217] Referring now to FIG. 26, a block diagram is depicted illustrating a third embodiment of the node according to the disclosure. The node may comprise a processor 110 and a transceiver 120 coupled to the processor 110 via a bus.

[00218] The transceiver 120 may be configured to transmit and receive data, and serve as an interface through which the node communicates with other communications equipment.

[00219] The processor 110 may control the operations of the node, and may also be referred to as a central processing unit (CPU). Processor 110 may be an integrated circuit chip with signal processing capabilities, or a general-purpose processor, digital signal processor (DSP), application specific integrated circuit (ASIC), field programmable gate array (FPGA), or other programmable logic devices, discrete gates, transistor logic devices, discrete hardware components. The general-purpose processor may be a microprocessor or any conventional processor.

[00220] The node may further comprise a memory (not shown) used to store the commands and data necessary for the operations of the processor 110. The memory can also store the data received at the transceiver 120.

[00221] The processor 110 may be configured to transmit via the transceiver 120 a downlink signal and/or downlink channel in beam-sweeping mode, where in the beam-sweeping mode the downlink signal or downlink channel is carried by at least two beams and is transmitted in at least two time units in one cycle, the formation of the beams at least uses analog beamforming.

[00222] Each time unit may comprise one or more subframes, time slots, or symbols.

[00223] The processor 110 may be configured to transmit via the transceiver the downlink signal and/or downlink channel in the beam-sweeping mode in accordance with a beam configuration, the beam configuration comprising at least one of a number of beams, a length of the time unit, a length of the cycle, and a sweeping pattern.

[00224] The sweeping pattern may comprise a consecutive or inconsecutive time allocation for the beams of which directions lie in one or several same predetermined ranges and which make up a beam group.

[00225] The processor 110 may further be configured to receive via the transceiver an uplink signal and/or uplink channel from a UE in beamforming manner.

[00226] There may be a time dependency between the transmission and reception of the beams of which directions lie in one or several same predetermined ranges, and the beam configuration may further comprise the time dependency.

[00227] The transmission and reception of the beams of which the directions lie in the one or several same predetermined ranges may be performed in a same time slot or subframe.

[00228] The processor 110 may further be configured to transmit via the transceiver the beam configuration to the UE using L1/L2 signaling or higher-layer signaling.

[00229] The processor 110 may be configured to transmit via the transceiver initial-access signals and broadcast channels in the beam-sweeping mode, the initial-access signals and the broadcast channels being jointly used for beam training.

[00230] The processor 110 may further be configured to: receive via the transceiver a beam training result fed back from the UE; and select one or more serving beams for the UE according to the beam training result.

[00231] The processor 110 may be configured to transmit via the transceiver the initial-access signals and the broadcast channels in the first time unit of each beam group in the time domain, the beam group consisting of beams of which directions lie in one or several same predetermined ranges.

[00232] The processor 110 may be configured to transmit the initial-access signals and the broadcast channels using the beams in all directions sequentially during a training period.

[00233] The training period may be located at an initial position of a cycle.

[00234] The processor 110 may be configured to transmit via the transceiver 120 the initial-access signals and the broadcast channels in one time unit using at least two levels of beam sets respectively, each level of beam set comprising one or more beams, at least one beam in the lower-level beam set being a sub-beam of a beam in the upper-level beam set, and beams in all the beam sets using a same set of TXRU virtualization matrices during their

beamforming process.

[00235] The initial-access signals and the broadcast channels may comprise synchronization signal, beam reference signal (BRS), and physical broadcast channel (PBCH), wherein the synchronization signal may be carried by a first-level beam set, while the BRS and the PBCH may be carried by a second-level beam set.

[00236] The synchronization signal may comprise primary synchronization signal (PSS) and secondary synchronization signal (SSS).

[00237] The synchronization signals may further comprise extended synchronization signal (ESS), wherein the ESS may be used to indicate a time location of the synchronization signals.

[00238] The initial-access signals and the broadcast channels may further comprise extended BRS and extended PBCH (ePBCH) that are carried by a third-level beam set.

[00239] PSS, SSS, PBCH, or ePBCH may be further used to indicate a time location of the synchronization signals.

[00240] eBRS and ePBCH may have a different periodicity from BRS and PBCH.

[00241] eBRS and ePBCH may be transmitted on demand.

[00242] RE allocations of different beams in a same beam set can be multiplexed in at least one of time domain, frequency domain, and code domain.

[00243] RE allocations of different beams in different beam sets may be multiplexed in time domain and/or frequency domain.

[00244] There may be a dependency for RE allocation between the beams in different levels of beam sets, e.g., depending on the system ID.

[00245] The node may be a base station, distributed unit (DU), transmission point (TP), transmission reception point (TRP), or radio remote head (RRH).

[00246] For details of functions of various components or modules of the node according to the present embodiment, see the relevant description of corresponding embodiment of the downlink transmission embodiment provided above.

[00247] Referring now to FIG. 27, a block diagram is depicted illustrating a first embodiment of a UE according to the disclosure. The UE may comprise a receiving module 21 configured to receive a downlink signal and/or downlink channel that a node transmits in

beam-sweeping mode, where in the beam-sweeping mode the downlink signal or downlink channel is carried by at least two beams and is transmitted in at least two time units in one cycle, the formation of the beams at least using analog beamforming.

[00248] Each time unit may comprise one or more subframes, time slots, or symbols.

[00249] A beam carrying the downlink signal or downlink channel may originate from one or more nodes.

[00250] Referring now to FIG. 28, a block diagram is depicted illustrating a second embodiment of the UE according to the disclosure, which is based on the first embodiment UE and further comprises: a measurement module 22 configured to measure initial-access signals and broadcast channels that the node transmits in the beam-sweeping mode to obtain a measurement result and generate a beam training result based on the measurement result; and a feedback module 23 configured to send the beam training result back to the node, so that the node may select one or more serving beams for the UE according to the beam training result.

[00251] The initial-access signals and the broadcast channels may be carried in one time unit by at least two levels of beam sets respectively, each level of beam set comprising one or more beams, at least one beam in the lower-level beam set being a sub-beam of a beam in the upper-level beam set, and beams in all the beam sets using a same set of TXRU virtualization matrices during their beamforming process. The measurement module may be configured to measure the at least two levels of beam sets according to an order from top level to bottom level, and estimate a beam selection result of each level, wherein when measuring the lower-level beam set, only the sub-beams of the beams in the upper-level beam selection result are measured, the beam training result being the beam selection result of the lowest level.

[00252] Referring now to FIG. 29, a block diagram is depicted illustrating a third embodiment of the UE according to the disclosure. The UE may comprise a processor 210 and a communication circuit 220 coupled to the processor 210 via a bus.

[00253] The communication circuit 220 may be configured to transmit and receive data, and serve as an interface through which the UE communicates with other communications equipment.

[00254] The processor 210 may be configured to control the operations of the UE, and may

also be referred to as a CPU. The processor 210 may be an integrated circuit chip with signal processing capabilities, or a general-purpose processor, DSP, ASIC, FPGA, or other programmable logic devices, discrete gates, transistor logic devices, discrete hardware components. The general-purpose processor may be a microprocessor or any conventional processor.

[00255] The UE may further include a memory (not shown) used to store the commands and data necessary for the operations of the processor 210. The memory may also store the data received at the communication circuit 220.

[00256] The processor 210 may be configured to receive via the transceiver 220 a downlink signal and/or downlink channel that a node transmits in beam-sweeping mode, where in the beam-sweeping mode the downlink signal or downlink channel is carried by at least two beams and is transmitted in at least two time units in one cycle, the formation of the beams at least using analog beamforming.

[00257] Each time unit may comprise one or more subframes, time slots, or symbols.

[00258] A beam carrying the downlink signal or downlink channel may originate from one or more nodes.

[00259] The processor 210 may further be configured to receive via the communication circuit a beam configuration the node sends using L1/L2 signaling or higher-layer signaling.

[00260] The processor 210 may be configured to receive via the communication circuit initial-access signals and broadcast channels the node transmits in the beam-sweeping mode, the initial-access signals and the broadcast channels being jointly used for beam training.

[00261] The processor 210 may further be configured to: measure via the communication circuit the initial-access signals and the broadcast channels to obtain a measurement result, and generate a beam training result based on the measurement result; and transmit via the communication circuit the beam training result to the node, so that the node may select one or more serving beams for the UE according to the beam training result.

[00262] The processor 210 may be configured to measure via the communication circuit all of the beams carrying the initial-access signals and the broadcast channels to obtain the measurement result, the measurement result containing a signal strength/quality of each measured beam; and select one or more beams with the best signal quality or the highest

signal power from among all of the beams as the beam training result.

[00263] The processor 210 may be configured to measure via the communication circuit a beam carrying the initial-access signals and the broadcast channels to obtain the measurement result, the measurement result containing a signal strength/quality of the measured beam; and determine whether the signal strength/quality of the measured beam is greater than a preset threshold, and if yes, add the beam to the beam training result.

[00264] The initial-access signals and the broadcast channels may be carried in one time unit by at least two levels of beam sets respectively, each level of beam set comprising one or more beams, at least one beam in the lower-level beam set being a sub-beam of a beam in the upper-level beam set, and beams in all of the beam sets using a same set of TXRU virtualization matrices during their beamforming process. The processor 210 may be configured to measure via the communication circuit the at least two levels of beam sets according to an order from top level to bottom level, and estimate a beam selection result of each level, wherein when measuring the lower-level beam set, only the sub-beams of the beams in the upper-level beam selection result are measured, the beam training result being the beam selection result at the lowest level.

[00265] For details of functions of various components or modules of the node according to the present embodiment, see the relevant description of the corresponding embodiment of the downlink transmission method.

[00266] It can be appreciated that the nodes, UEs, and methods disclosed herein can also be implemented in other forms. Rather, the base stations and UEs as described are merely illustrative. For example, the division of modules or units is performed solely based on logic functions, thus in actual implementations there may be other division methods, e.g., multiple units or components may be combined or integrated onto another system, or some features may be ignored or simply not executed. In addition, mutual couplings, direct couplings, or communications connections as displayed or discussed may be achieved through some interfaces, devices, or units, and may be achieved electrically, mechanically, or in other forms.

[00267] Separated units as described may or may not be physically separated. Components displayed as units may or may not be physical units, and may reside at one location or may be distributed to multiple networked units. Part or all of the units may be selectively adopted

according to actual requirements to achieve objectives of the disclosure.

[00268] Additionally, various functional units described herein may be integrated into one processing unit or may be present as a number of physically separated units, and two or more units may be integrated into one. The integrated units may be implemented by hardware or as software functional units.

[00269] If the integrated units are implemented as software functional units and sold or used as standalone products, they may be stored in a computer readable storage medium. On the basis of such an understanding, the essential technical solution or all or part of the technical solution of the disclosure may be embodied as software products. Computer software products can be stored in a storage medium and can include multiple instructions enabling a computing device (e.g., a personal computer, a server, a network device, etc.) or a processor to execute all or part of the methods as described in the disclosure. The storage medium may include all kinds of media that can store program codes, such as a USB flash disk, mobile hard drive, read-only memory (ROM), random access memory (RAM), magnetic disk, or optical disk.

[00270] The above description merely illustrates some exemplary embodiments of the disclosure, which however are not intended to limit the scope of the disclosure to these specific embodiments. Any equivalent structural or flow modifications or transformations made to the disclosure, or any direct or indirect applications of the disclosure on any other related fields, shall all fall in the scope of the disclosure.

CLAIMS

1. A method for downlink transmission based on beamforming, comprising:
transmitting, by a node, a downlink signal and/or downlink channel in beam-sweeping mode, where in the beam-sweeping mode the downlink signal or downlink channel is carried by at least two beams and is transmitted in at least two time units in one cycle, wherein formation of the beams at least uses analog beamforming.
2. The method according to claim 1, wherein each time unit comprises one or more subframes, time slots, or symbols.
3. The method according to claim 1, wherein transmitting the downlink signal and/or downlink channel in the beam-sweeping mode comprises:
transmitting, by the node, the downlink signal and/or downlink channel in the beam-sweeping mode in accordance with a beam configuration, the beam configuration comprising at least one of a number of the beams, a length of the time unit, a length of the cycle, and a sweeping pattern.
4. The method according to claim 3, wherein the sweeping pattern comprises a consecutive or inconsecutive time allocation for the beams of which directions lie in one or several same predetermined ranges and which make up a beam group.
5. The method according to claim 3, further comprising:
receiving, by the node, an uplink signal and/or uplink channel from a UE in beamforming manner.
6. The method according to claim 5, wherein there is a time dependency between the transmission and reception of the beams of which directions lie in one or several same predetermined ranges, the beam configuration further comprising the time dependency.
7. The method according to claim 5, wherein the transmission and reception of the beams of which directions lie in one or several same predetermined ranges are performed in a same time slot or subframe.
8. The method according to any one of claims 3-7, further comprising:
transmitting, by the node, the beam configuration to the UE using L1/L2 signaling or higher-layer signaling.

9. The method according to any one of claims 1-7, wherein transmitting the downlink signal and downlink channel in the beam-sweeping mode comprises:

transmitting, by the node, initial access signals and broadcast channels in the beam-sweeping mode, the initial access signals and the broadcast channels being jointly used for beam training.

10. The method according to claim 9, further comprising:

receiving, by the node, a beam training result fed back from the UE; and

selecting, by the node, one or more serving beams for the UE according to the beam training result.

11. The method according to claim 9, wherein transmitting the initial access signals and the broadcast channels in the beam-sweeping mode comprises:

transmitting, by the node, the initial access signals and the broadcast channels in the first time unit of each beam group in time domain, the beam group consisting of beams of which the directions lie in the one or several same predetermined ranges.

12. The method according to claim 9, wherein transmitting the initial access signals and the broadcast channels in the beam-sweeping mode comprises:

transmitting, by the node, the initial access signals and the broadcast channels using the beams in all directions sequentially during a training period.

13. The method according to claim 9, wherein the training period is located at an initial position of a cycle.

14. The method according to claim 9, wherein transmitting the initial access signals and the broadcast channels in the beam-sweeping mode comprises:

transmitting, by the node, the initial access signals and the broadcast channels in one time unit using at least two levels of beam sets respectively, each level of beam set comprising one or more beams, at least one beam in a lower-level beam set being a sub-beam of a beam in an immediate upper-level beam set, and the beams in all of the beam sets using a same set of transceiver-unit (TXRU) virtualization matrices during their beamforming process.

15. The method according to claim 14, wherein the initial access signals and the broadcast channels comprise synchronization signals, beam reference signal (BRS), and

physical broadcast channel (PBCH), the synchronization signals being carried by a first-level beam set, and the BRS and the PBCH being carried by a second-level beam set.

16. The method according to claim 15, wherein the synchronization signals comprise primary synchronization signal (PSS) and secondary synchronization signal (SSS).

17. The method according to claim 16, wherein the synchronization signals further comprise extended synchronization signal (ESS), the ESS being used to indicate a time location of the synchronization signals.

18. The method according to claim 16, wherein the initial access signals and the broadcast channels further comprise extended BRS (eBRS) and extended PBCH (ePBCH) that are carried by a third-level beam set.

19. The method according to claim 18, wherein PSS, SSS, PBCH, or ePBCH is further used to indicate a time location of the synchronization signals.

20. The method according to claim 18, wherein eBRS and ePBCH have a different periodicity from BRS and PBCH.

21. The method according to claim 18, wherein eBRS and ePBCH are transmitted on demand.

22. The method according to claim 14, wherein RE allocations of different beams in the same beam set are multiplexed in at least one of time domain, frequency domain, and code domain.

23. The method according to claim 14, wherein RE allocations of different beams in different beam sets are multiplexed in time domain and/or frequency domain.

24. The method according to claim 14, wherein there is a dependency for RE allocation between the beams in different levels of beam sets.

25. The method according to any one of claims 1-7, wherein the node is a base station, distributed unit (DU), transmission point (TP), transmission reception point (TRP), or radio remote head (RRH).

26. A method for downlink transmission based on beamforming, comprising:
receiving, at a UE, a downlink signal and/or downlink channel that are transmitted from a node in beam-sweeping mode, where in the beam-sweeping mode the downlink signal or

downlink channel is carried by at least two beams and is transmitted in at least two time units in one cycle, wherein formation of the beams at least uses analog beamforming.

27. The method according to claim 26, wherein each time unit comprises one or more subframes, time slots, or symbols.

28. The method according to claim 26, wherein a beam carrying the downlink signal or downlink channel originates from one or more nodes.

29. The method according to claim 26, further comprising:

receiving, at the UE, a beam configuration that the node sends using L1/L2 signaling or higher-layer signaling.

30. The method according to any one of claims 26-29, wherein receiving the downlink signal and downlink channel comprises:

receiving, at the UE, initial access signals and broadcast channels that are transmitted from the node in the beam-sweeping mode, the initial access signals and the broadcast channels being jointly used for beam training.

31. The method according to claim 30, further comprising:

measuring, by the UE, the initial access signals and the broadcast channels to obtain a measurement result, and generating a beam training result based on the measurement result; and

sending, by the UE, the beam training result back to the node, so that the node selects one or more serving beams for the UE according to the beam training result.

32. The method according to claim 31, wherein measuring the initial access signals and the broadcast channels and generating the beam-training result comprises:

measuring, by the UE, all of the beams carrying the initial access signals and the broadcast channels to obtain the measurement result, the measurement result containing signal strength/quality of each measured beam; and

selecting, by the UE, one or more beams with the best signal quality or the highest signal power from all of the measured beams as the beam-training result.

33. The method according to claim 31, wherein measuring the initial access signals and the broadcast channels and generating the beam-training result comprises:

measuring, by the UE, a beam carrying the initial access signals and the broadcast channels to obtain the measurement result, the measurement result containing signal strength/quality of the measured beam; and

determining, by the UE, whether the signal strength/quality of the measured beam is greater than a preset threshold, and if yes, adding the beam to the beam-training result.

34. The method according to claim 31, wherein, the initial access signals and the broadcast channels are carried in one time unit by at least two levels of beam sets respectively, each level of beam set comprising one or more beams, at least one beam in a lower-level beam set being a sub-beam of a beam in an immediate upper-level beam set, and the beams in all of the beam sets using a same set of TXRU virtualization matrices during their beamforming process; and measuring the initial access signals and the broadcast channels and generating the beam-training result comprises:

measuring, by the UE, the at least two levels of beam sets according to an order from top level to bottom level to obtain the measurement result, and estimating a beam-selection result of each level based on the measurement result, wherein when measuring the lower-level beam set, only sub-beams of the beams in the immediate upper-level beam-selection result are measured, the beam-training result being the beam-selection result at the lowest level.

35. A node, comprising:

a transmitting module configured to transmit downlink signal and/or downlink channel in beam-sweeping mode, where in the beam-sweeping mode the downlink signal or downlink channel is carried by at least two beams and is transmitted in at least two time units in one cycle, wherein formation of the beams at least uses analog beamforming.

36. The node according to claim 35, wherein each time unit comprises one or more subframes, time slots, or symbols.

37. The node according to claim 35, wherein the transmitting module is further configured to transmit a beam configuration to a UE using L1/L2 signaling or higher-layer signaling.

38. The node according to claim 35, wherein the transmitting module is configured to transmit initial access signals and broadcast channels in the beam-sweeping mode, the initial access signals and the broadcast channels being jointly used for beam training.

39. The node according to claim 38, further comprising:

a receiving module configured to receive a beam-training result fed back from the UE;

and

a selection module configured to select one or more serving beams for the UE according to the beam-training result.

40. The node according to claim 38, wherein the transmitting module is configured to transmit the initial access signals and the broadcast channels in one time unit using at least two levels of beam sets respectively, each level of beam set comprising one or more beams, at least one beam in a lower-level beam set being a sub-beam of a beam in an immediate upper-level beam set, and the beams in all of the beam sets using a same set of TXRU virtualization matrices during their beamforming process.

41. The node according to any one of claims 35-40, wherein the node is a base station, DU, TP, TRP, or RRH.

42. A User Equipment (UE), comprising:

a receiving module configured to receive a downlink signal and/or downlink channel that are transmitted from a node in beam-sweeping mode, where in the beam-sweeping mode the downlink signal or downlink channel is carried by at least two beams and is transmitted in at least two time units in one cycle, wherein formation of the beams at least uses analog beamforming.

43. The UE according to claim 42, wherein each time unit comprises one or more subframes, time slots, or symbols.

44. The UE according to claim 42, wherein a beam carrying the downlink signal or downlink channel originates from one or more nodes.

45. The UE according to any one of claims 42-44, further comprising:

a measurement module configured to measure initial access signals and broadcast channels that the node transmits in the beam-sweeping mode to obtain a measurement result and generate a beam-training result based on the measurement result; and

a feedback module configured to send the beam-training result back to the node, so that the node selects one or more serving beams for the UE according to the beam-training result.

46. The UE according to claim 42, wherein the initial access signals and the broadcast channels are carried in one time unit by at least two levels of beam sets respectively, each level of beam set comprising one or more beams, at least one beam in a lower-level beam set being a sub-beam of a beam in an immediate upper-level beam set, and the beams in all of the beam sets using a same set of TXRU virtualization matrices during their beamforming process; and

the measurement module is configured to measure the at least two levels of beam sets according to an order from top level to bottom level, and estimate a beam selection result of each level, wherein when measuring the lower-level beam set, only the sub-beams of the beams in the immediate upper-level beam selection result are measured, the beam-training result being the beam-selection result at the lowest level.

47. A node comprising a processor and a transceiver coupled to the processor, the processor being configured to:

transmit via the transceiver a downlink signal and/or downlink channel in beam-sweeping mode, where in the beam-sweeping mode the downlink signal or downlink channel is carried by at least two beams and is transmitted in at least two time units in one cycle, wherein formation of the beams at least uses analog beamforming.

48. The node according to claim 47, wherein each time unit comprises one or more subframes, time slots, or symbols.

49. The node according to claim 47, wherein the processor is configured to transmit the downlink signal and/or downlink channel in the beam-sweeping mode in accordance with a beam configuration, the beam configuration comprising at least one of a number of beams, a length of the time unit, a length of the cycle, and a sweeping pattern.

50. The node according to claim 49, wherein the sweeping pattern comprises a consecutive or inconsecutive time allocation for the beams of which directions lie in one or several same predetermined ranges and which make up a beam group.

51. The node according to claim 49, wherein the processor is further configured to receive via the transceiver an uplink signal and/or uplink channel from a UE in beamforming manner.

52. The node according to claim 51, wherein there is a time dependency between the transmission and reception of the beams of which directions lie in one or several same predetermined ranges, the beam configuration further comprising the time dependency.

53. The node according to claim 51, wherein the transmission and reception of the beams of which directions lie in one or several same predetermined ranges are performed in a same time slot or subframe.

54. The node according to any one of claims 49-53, wherein the processor is further configured to transmit via the transceiver the beam configuration to the UE using L1/L2 signaling or higher-layer signaling.

55. The node according to any one of claims 47-53, wherein the processor is configured to transmit via the transceiver initial access signals and broadcast channels in the beam-sweeping mode, the initial access signals and the broadcast channels being jointly used for beam training.

56. The node according to claim 55, wherein the processor is further configured to: receive via the transceiver a beam-training result fed back from the UE; and select one or more serving beams for the UE according to the beam-training result.

57. The node according to claim 55, wherein the processor is configured to transmit via the transceiver the initial access signals and the broadcast channels in the first time unit of each beam group in time domain, the beam group consisting of beams of which the directions lie in the one or several same predetermined ranges.

58. The node according to claim 55, wherein the processor is configured to transmit the initial access signals and the broadcast channels using the beams in all directions sequentially during a training period.

59. The node according to claim 55, wherein the training period is located at an initial position of a cycle.

60. The node according to claim 55, wherein the processor is configured to transmit via the transceiver the initial access signals and the broadcast channels in one time unit using at least two levels of beam sets respectively, each level of beam set comprising one or more beams, at least one beam in a lower-level beam set being a sub-beam of a beam in an

immediate upper-level beam set, and the beams in all of the beam sets using a same set of TXRU virtualization matrices during their beamforming process.

61. The node according to claim 60, wherein the initial access signals and the broadcast channels comprise synchronization signals, BRS, and PBCH, the synchronization signals being carried by a first-level beam set, and the BRS and the PBCH being carried by a second-level beam set.

62. The node according to claim 61, wherein the synchronization signals comprise PSS and SSS.

63. The node according to claim 62, wherein the synchronization signals further comprise ESS, the ESS being used to indicate a time location of the synchronization signals.

64. The node according to claim 62, wherein the initial access signals and the broadcast channels further comprise eBRS and ePBCH that are carried by a third-level beam set.

65. The node according to claim 64, wherein PSS, SSS, PBCH, or ePBCH is further used to indicate a time location of the synchronization signals.

66. The node according to claim 64, wherein eBRS and ePBCH have a different periodicity from BRS and PBCH.

67. The node according to claim 64, wherein eBRS and ePBCH are transmitted on demand.

68. The node according to claim 60, wherein RE allocations of different beams in the same beam set are multiplexed in at least one of time domain, frequency domain, and code domain.

69. The node according to claim 60, wherein RE allocations of different beams in different beam sets are multiplexed in time domain and/or frequency domain.

70. The node according to claim 60, wherein there is a dependency for RE allocation between the beams in different levels of beam sets.

71. The node according to any one of claims 47-53, wherein the node is a base station, DU, TP, TRP, or RRH.

72. A UE comprising a processor and a communication circuit coupled to the processor, the processor being configured to:

receive via the communication circuit a downlink signal and/or downlink channel that are transmitted from a node in beam-sweeping mode, where in the beam-sweeping mode the downlink signal or downlink channel is carried by at least two beams and is transmitted in at least two time units in one cycle, wherein formation of the beams at least uses analog beamforming.

73. The UE according to claim 72, wherein each time unit comprises one or more subframes, time slots, or symbols.

74. The UE according to claim 72, wherein a beam carrying the downlink signal or downlink channel originates from one or more nodes.

75. The UE according to claim 72, wherein the processor is further configured to receive via the communication circuit a beam configuration that the node sends using L1/L2 signaling or higher-layer signaling.

76. The UE according to any one of claims 72-75, wherein the processor is configured to receive via the communication circuit initial access signals and broadcast channels that are transmitted from the node in the beam-sweeping mode, the initial access signals and the broadcast channels being jointly used for beam training.

77. The UE according to claim 76, wherein the processor is further configured to: measure via the communication circuit the initial access signals and the broadcast channels to obtain a measurement result, and generate a beam-training result based on the measurement result; and send via the communication circuit the beam-training result back to the node, so that the node selects one or more serving beams for the UE according to the beam-training result.

78. The UE according to claim 77, wherein the processor is configured to measure via the communication circuit all of the beams carrying the initial access signals and the broadcast channels to obtain the measurement result, the measurement result containing signal strength/quality of each measured beam; and select one or more beams with the best signal quality or the highest signal power from all of the measured beams as the beam-training result.

79. The UE according to claim 77, wherein the processor is configured to: measure via the communication circuit a beam carrying the initial access signals and the broadcast

channels to obtain the measurement result, the measurement result containing signal strength/quality of the measured beam; and determine whether the signal strength/quality of the measured beam is greater than a preset threshold, and if yes, add the beam to the beam-training result.

80. The UE according to claim 77, wherein the initial access signals and the broadcast channels are carried in one time unit by at least two levels of beam sets respectively, each level of beam set comprising one or more beams, at least one beam in a lower-level beam set being a sub-beam of a beam in an immediate upper-level beam set, and the beams in all of the beam sets using a same set of TXRU virtualization matrices during their beamforming process; and

the processor is configured to measure via the communication circuit the at least two levels of beam sets according to an order from top level to bottom level, and estimate a beam selection result of each level, wherein when measuring the lower-level beam set, only the sub-beams of the beams in the immediate upper-level beam selection result are measured, the beam-training result being the beam-selection result at the lowest level.

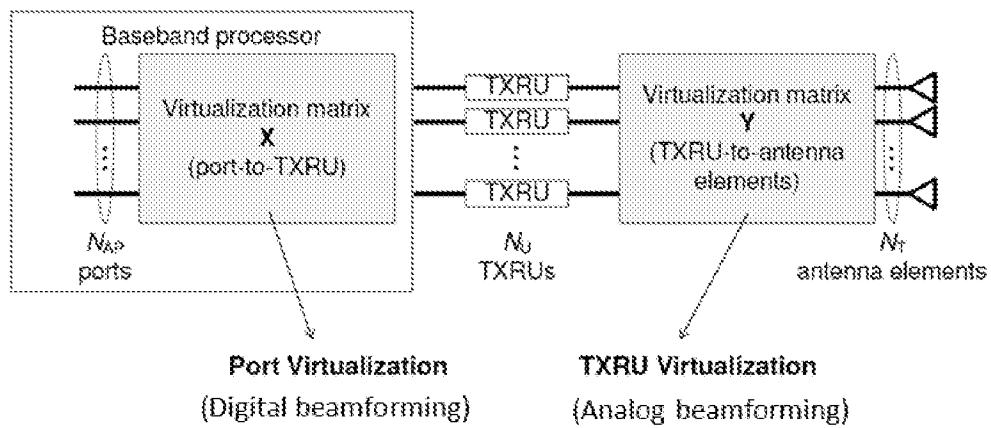


FIG. 1

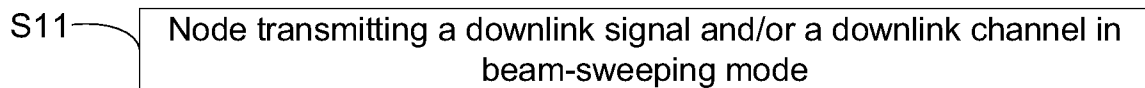


FIG. 2

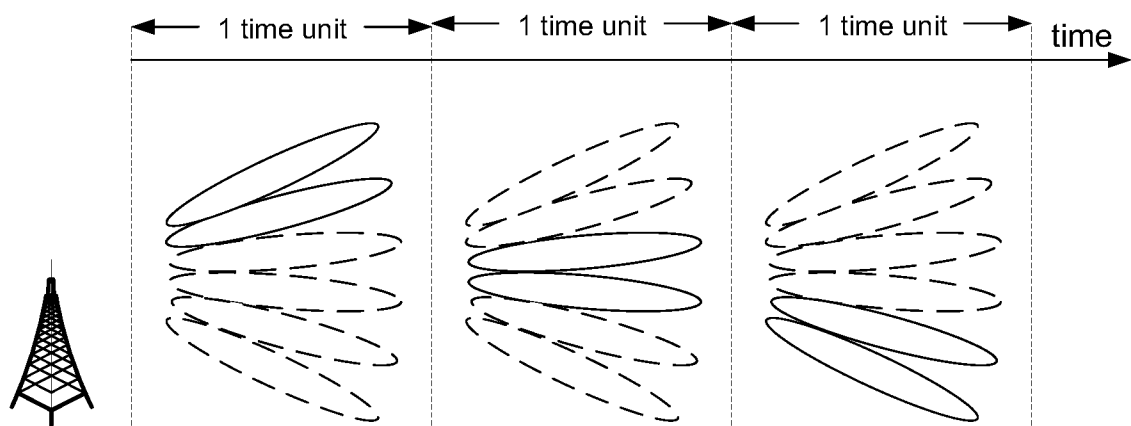


FIG. 3

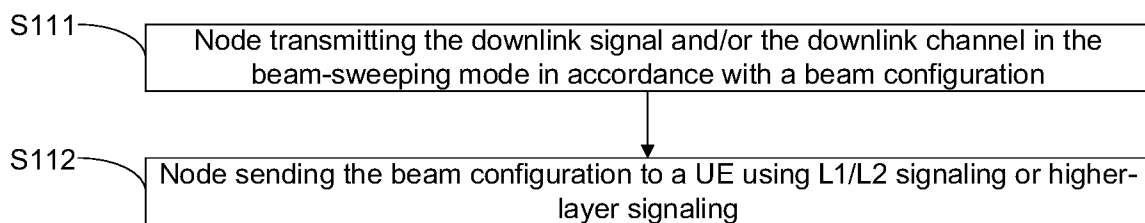
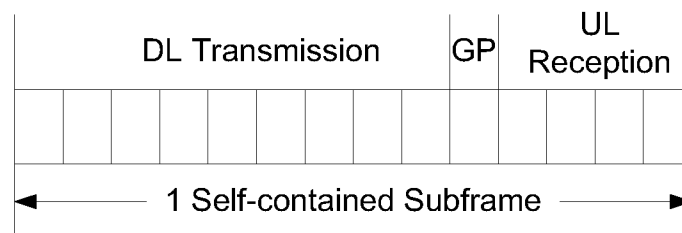
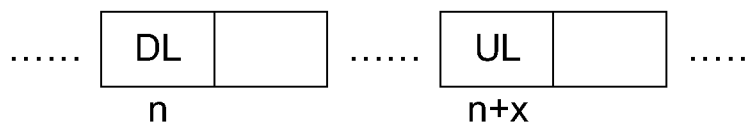
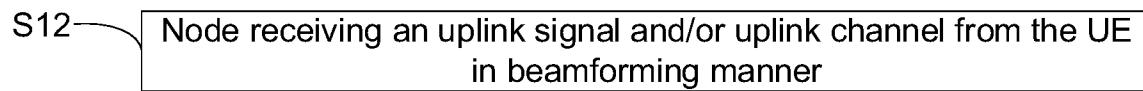
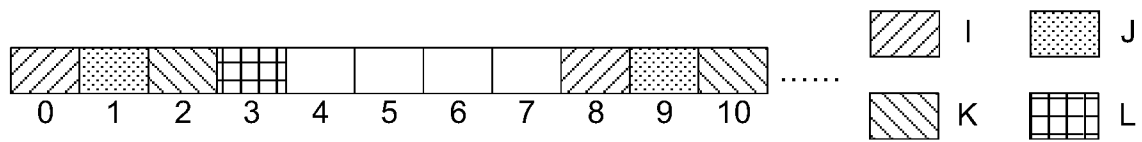
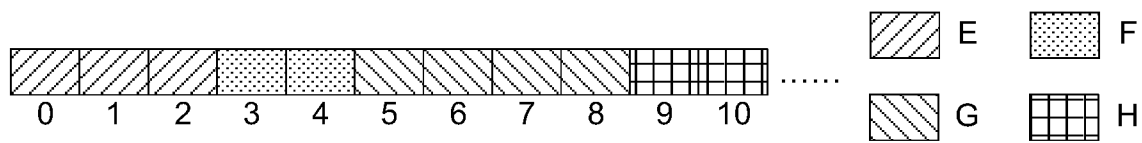
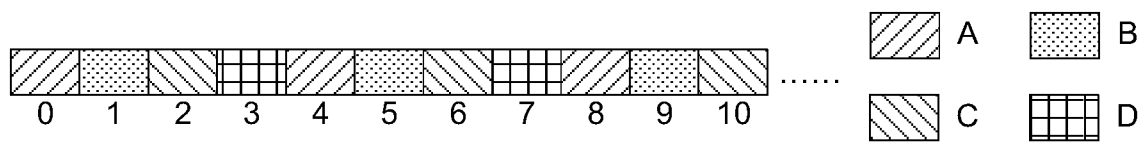


FIG. 4



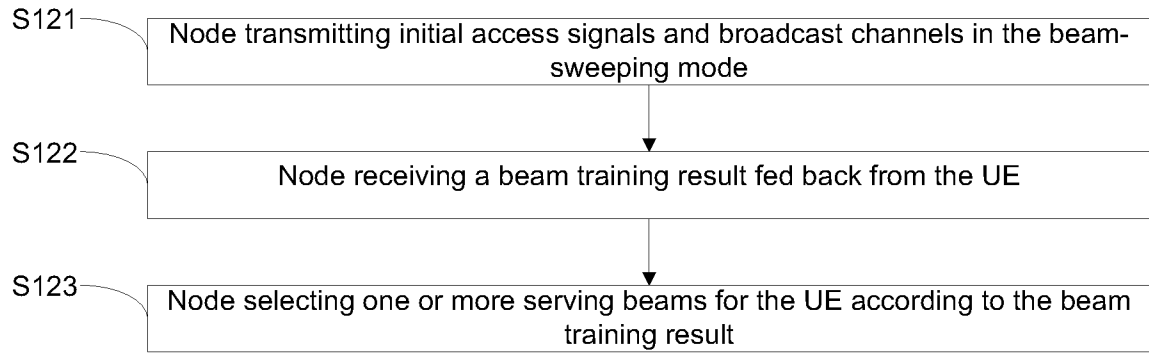


FIG. 11

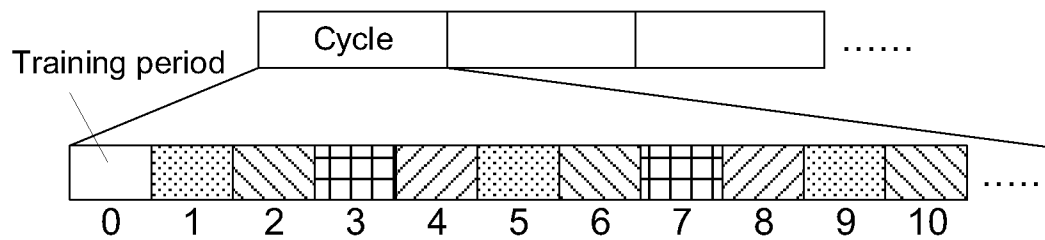


FIG. 12

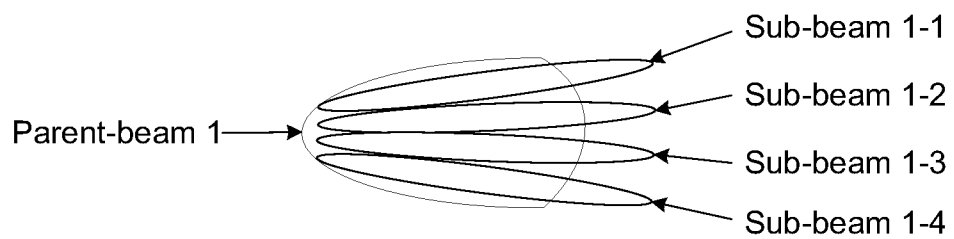


FIG. 13

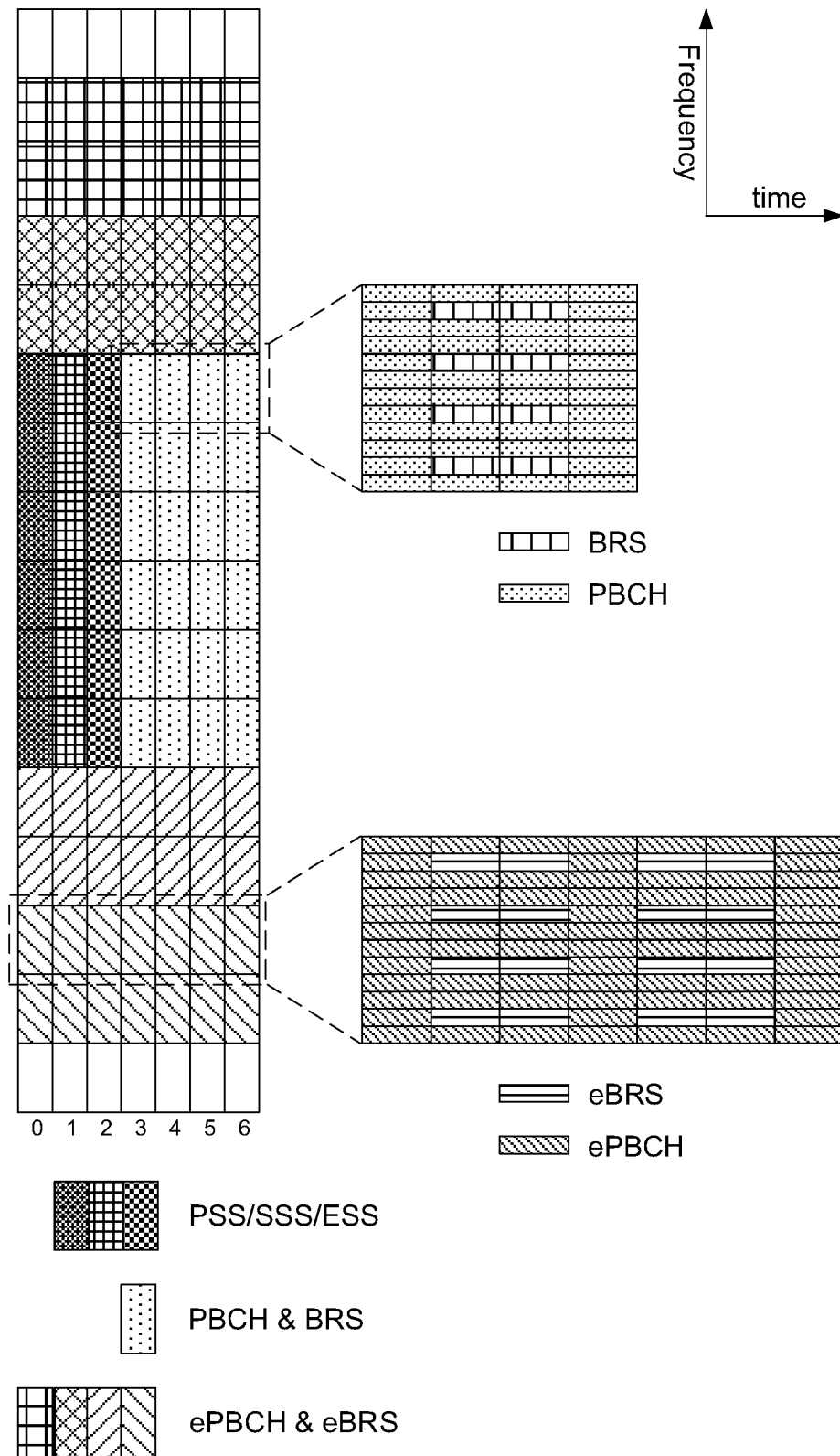


FIG. 14

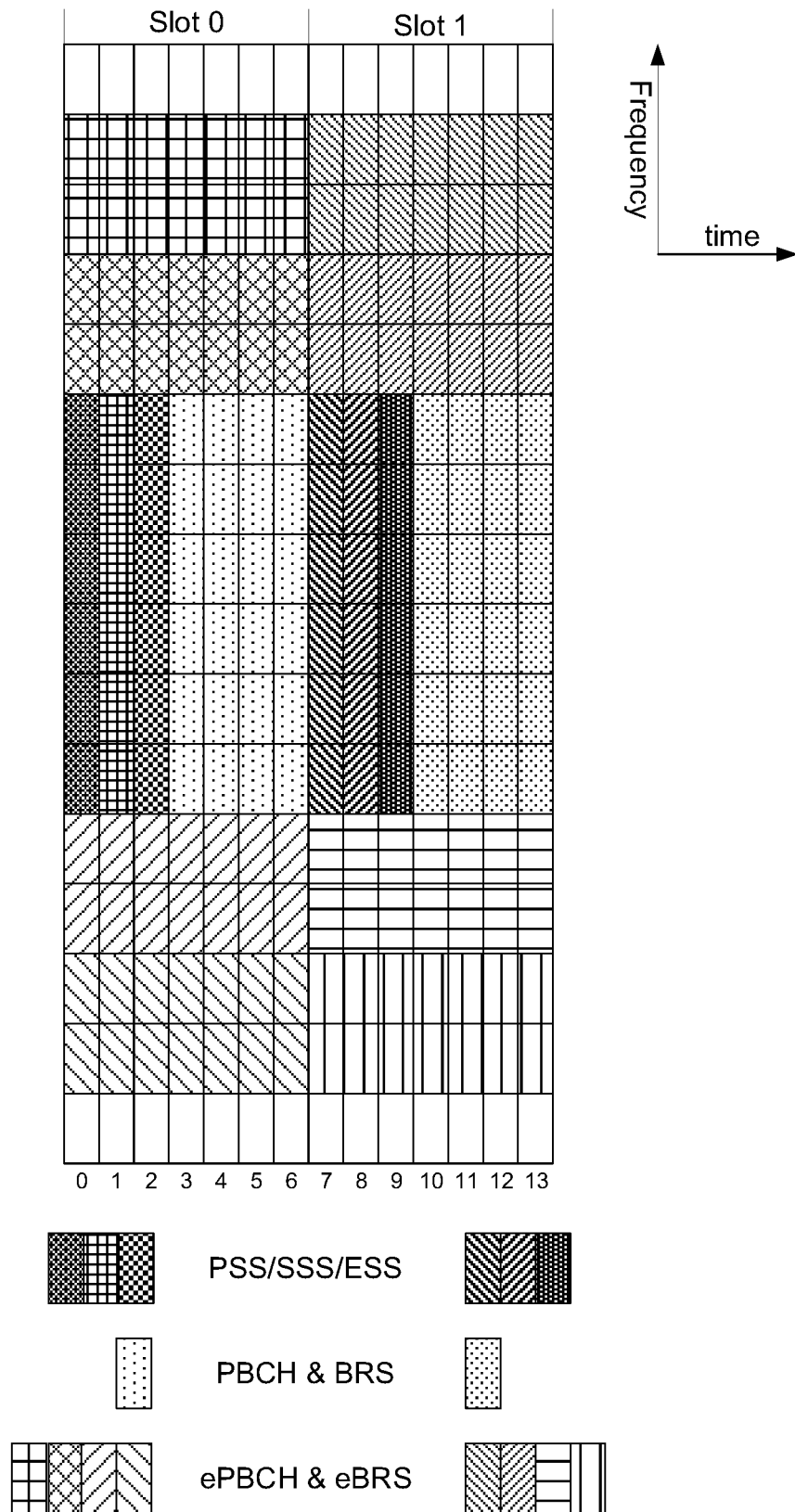


FIG. 15

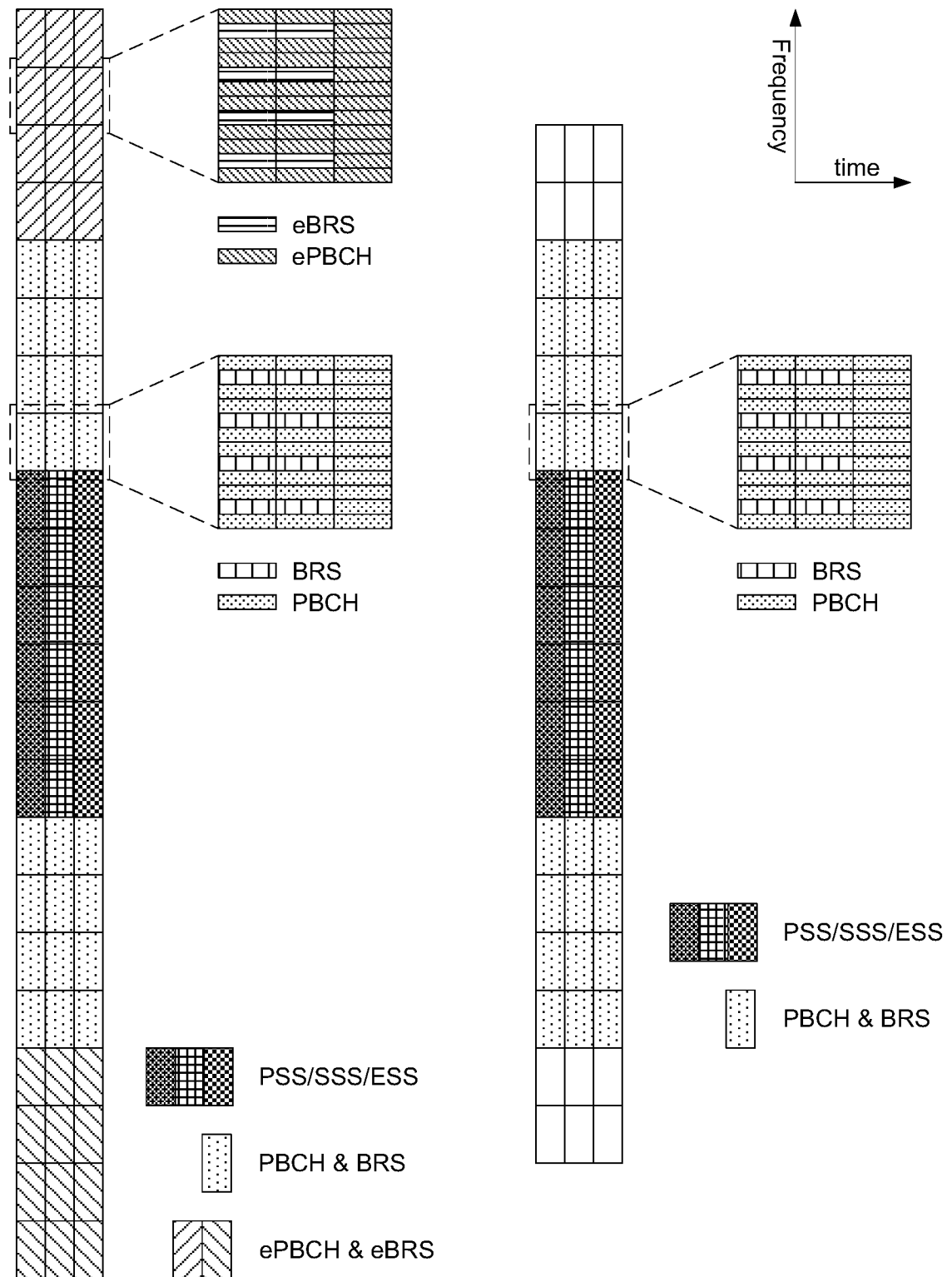


FIG. 16

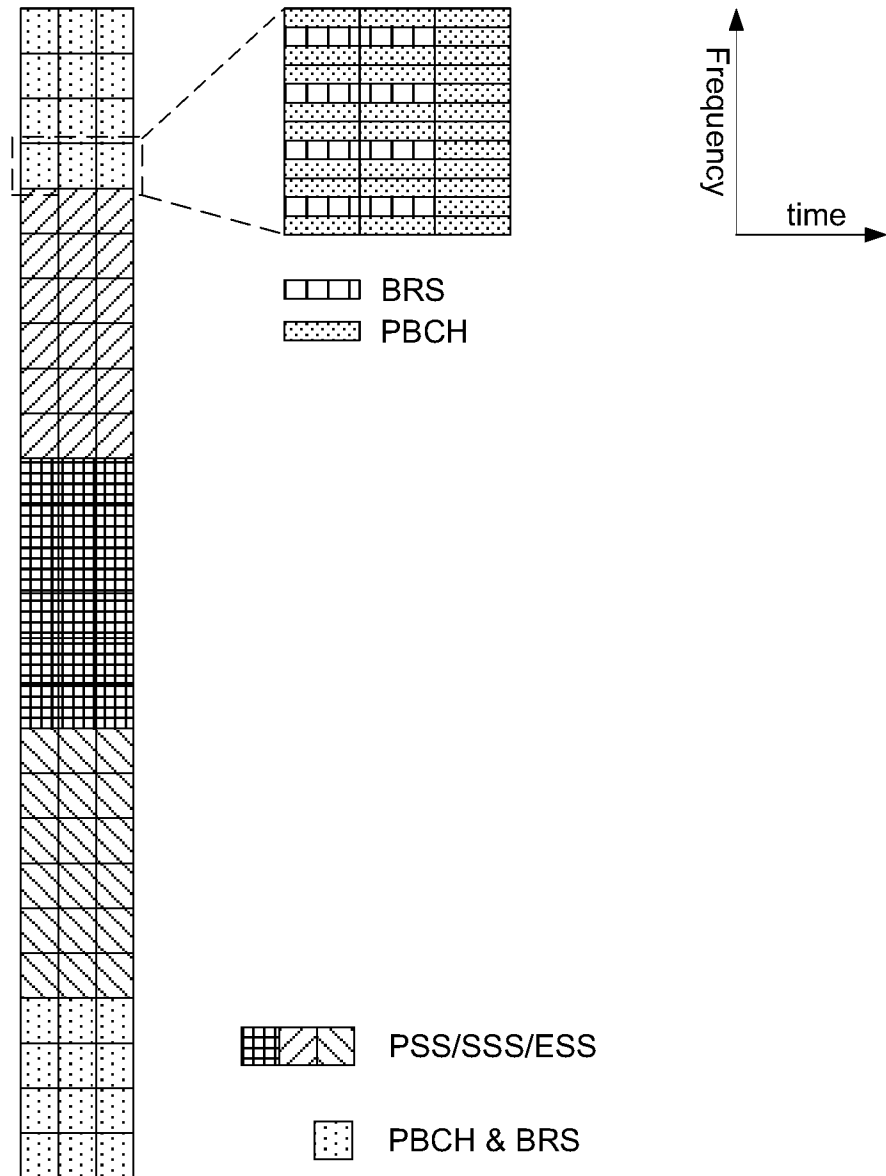


FIG. 17

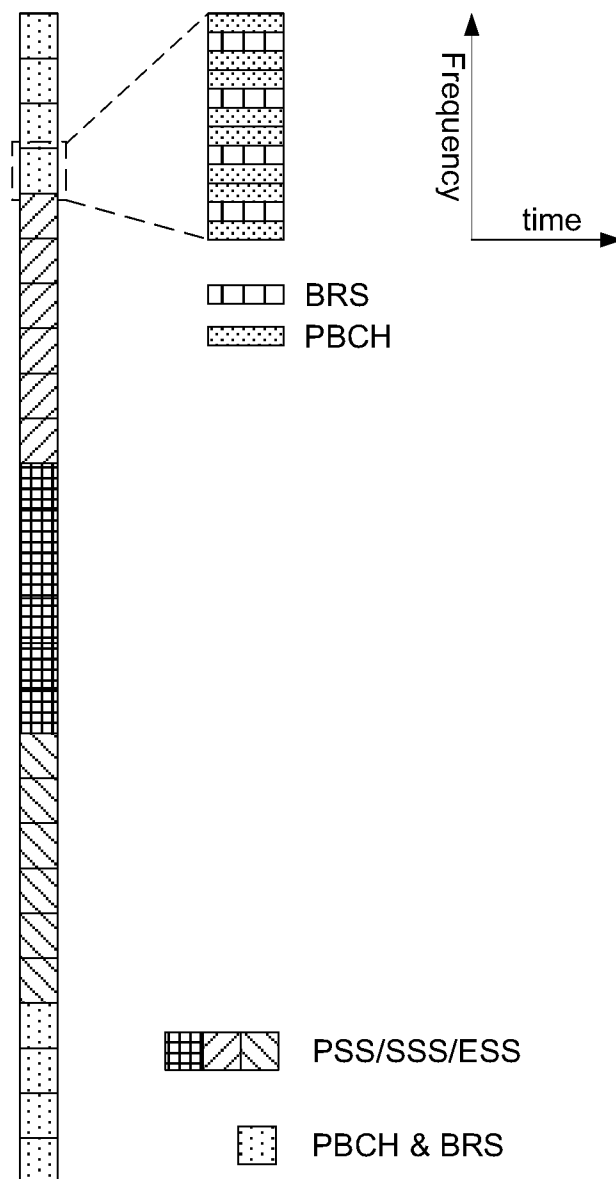


FIG. 18

S21— A UE receiving a downlink signal and/or downlink channel that a node transmits in beam-sweeping mode

FIG. 19

S22— The UE receiving a beam configuration that the node sends using L1/L2 signaling or higher-layer signaling

FIG. 20

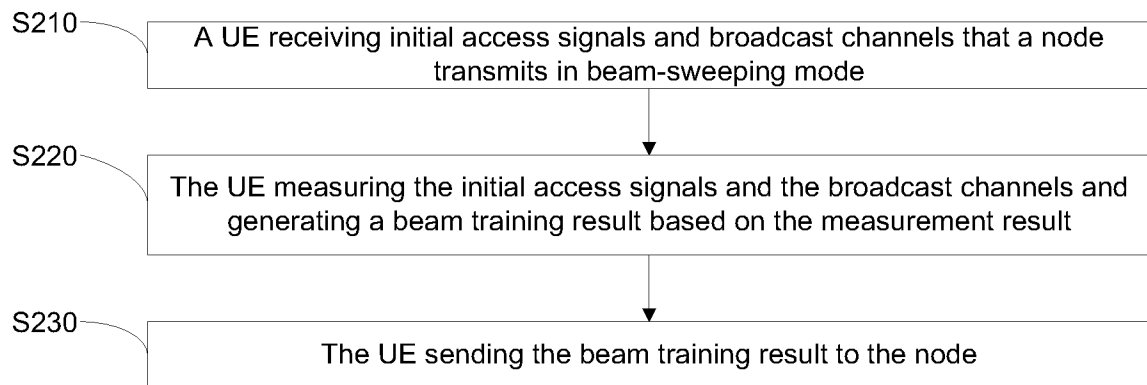


FIG. 21

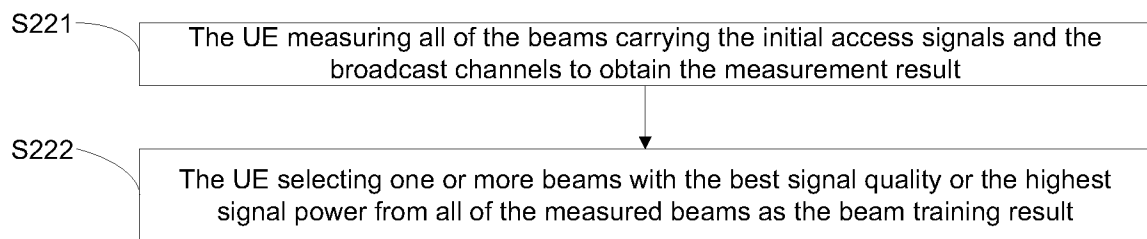


FIG. 22

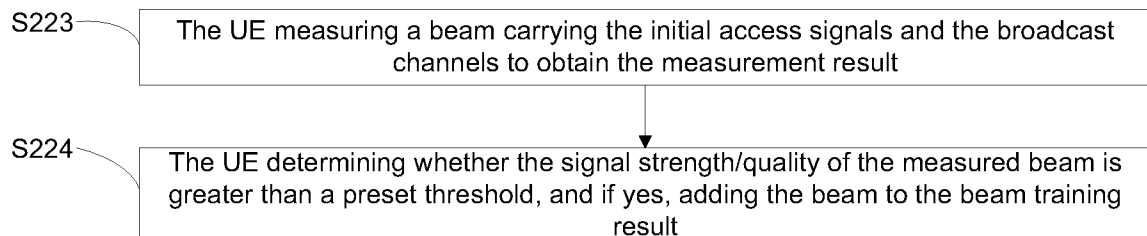


FIG. 23



FIG. 24

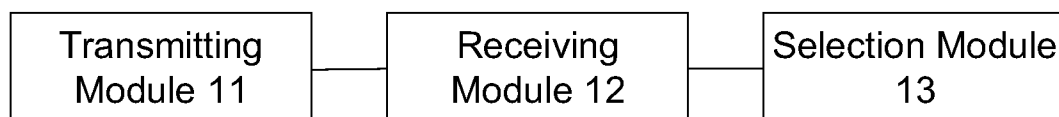


FIG. 25

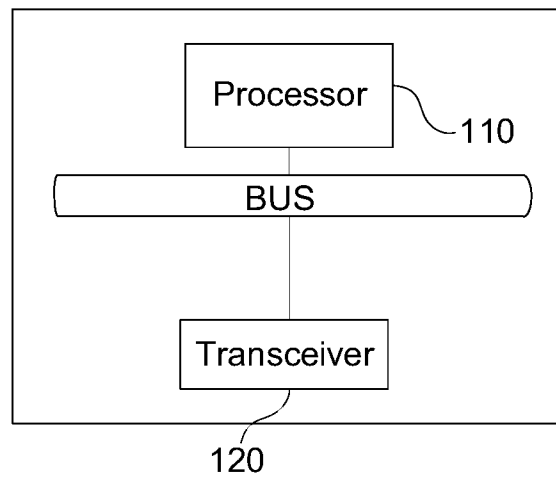


FIG. 26

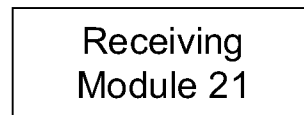


FIG. 27

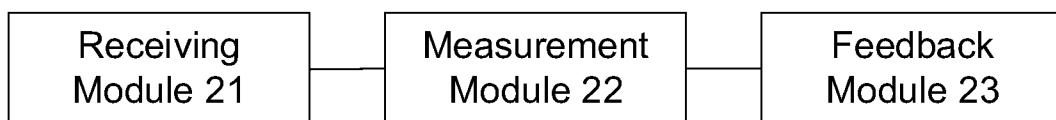


FIG. 28

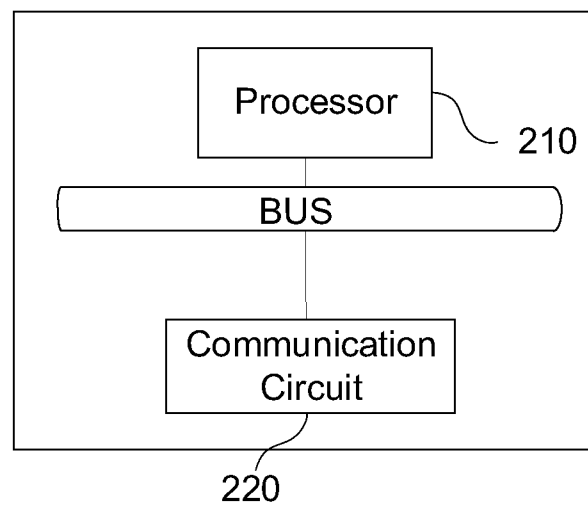


FIG. 29

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2016/103728

A. CLASSIFICATION OF SUBJECT MATTER

H04B 7/06(2006.01)i; H04B 7/08(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)

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)

CNPAT, CNKI, WPI, EPODOC, GOOGLE, 3GPP: beamforming, downlink, signal, channel, sweep+, transmi+, formation, analog, digital, subframe, slot, pattern, broadcast

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 101459457 A (TD TECH LTD.) 17 June 2009 (2009-06-17) description, page 1, paragraphs 2-3, page 4, paragraph 7 to page 6, paragraph 6	1-80
A	US 2013102345 A1 (SAMSUNG ELECTRONICS CO., LTD.) 25 April 2013 (2013-04-25) the whole document	1-80
A	US 2014198681 A1 (SAMSUNG ELECTRONICS CO., LTD.) 17 July 2014 (2014-07-17) the whole document	1-80
A	WO 2016032104 A1 (LG ELECTRONICS INC.) 03 March 2016 (2016-03-03) the whole document	1-80



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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“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

08 June 2017

Date of mailing of the international search report

30 June 2017

Name and mailing address of the ISA/CN

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Facsimile No. (86-10)62019451

Telephone No. (86-10)62413257

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2016/103728

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	20130043078	A	29 April 2013
				CN	103891161	A	25 June 2014
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				EP	2946586	A1	25 November 2015
				KR	20140092165	A	23 July 2014
				CN	104937972	A	23 September 2015
				WO	2014112789	A1	24 July 2014
WO	2016032104	A1	03 March 2016	CN	106575990	A	19 April 2017
				KR	2017044645	A	25 April 2017