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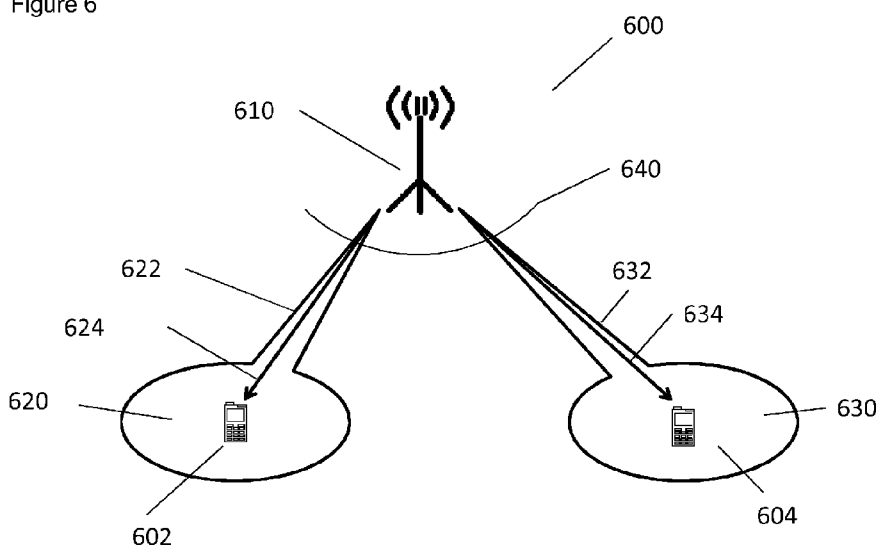
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(54) **Title:** METHOD, APPARATUS AND SYSTEM

Figure 6



(57) **Abstract:** There is provided a method comprising: receiving, at a user equipment, at least one beam, said beam including a first reference signal associated with that beam, receiving at the user equipment a second reference signal for a cell and determining channel state information in dependence on the first reference signal and the second reference signal.

METHOD, APPARATUS AND SYSTEM

Field

The present application relates to a method, apparatus and system and in particular but not exclusively, to feedback design for massive MIMO (Multiple-Input and Multiple-Output) antennas.

Background

A communication system can be seen as a facility that enables communication sessions between two or more entities such as user terminals, base stations and/or other nodes by providing carriers between the various entities involved in the communications path. A communication system can be provided for example by means of a communication network and one or more compatible communication devices. The communications may comprise, for example, communication of data for carrying communications such as voice, electronic mail (email), text message, multimedia and/or content data and so on. Non-limiting examples of services provided include two-way or multi-way calls, data communication or multimedia services and access to a data network system, such as the Internet.

20

In a wireless communication system at least a part of communications between at least two stations occurs over a wireless link. Examples of wireless systems include public land mobile networks (PLMN), satellite based communication systems and different wireless local networks, for example wireless local area networks (WLAN). The wireless systems can typically be divided into cells, and are therefore often referred to as cellular systems.

25

A user can access the communication system by means of an appropriate communication device or terminal. A communication device of a user is often referred to as user equipment (UE). A communication device is provided with an appropriate signal receiving and transmitting apparatus for enabling communications, for example enabling access to a communication network or communications directly with other users. The communication device may access

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a carrier provided by a station, for example a base station of a cell, and transmit and/or receive communications on the carrier.

The communication system and associated devices typically operate in accordance with a given standard or specification which sets out what the various entities associated with the system are permitted to do and how that should be achieved. Communication protocols and/or parameters which shall be used for the connection are also typically defined. An example of attempts to solve the problems associated with the increased demands for capacity is an architecture that is known as the long-term evolution (LTE) of the Universal Mobile Telecommunications System (UMTS) radio-access technology. The LTE is being standardized by the 3rd Generation Partnership Project (3GPP). The various development stages of the 3GPP LTE specifications are referred to as releases.

Summary

In a first aspect there is provided a method comprising receiving, at a user equipment, at least one beam, said beam including a first reference signal associated with that beam, receiving at the user equipment a second reference signal for a cell and determining channel state information in dependence on the first reference signal and the second reference signal.

The method may comprise receiving a plurality of beams at the user equipment, each beam comprising a first reference signal associated with that beam, and selecting at least one beam in dependence on beam signal information.

The method may comprise causing beam selection information to be transmitted to an access point.

Beam signal information may comprise at least one of signal to interference plus noise ratio and received reference signal power.

Determining channel state information in dependence on the first reference signal and the second reference signal may comprise deriving channel state information based on the second reference and updating it according to the first reference signal measurement.

5

The method may comprise causing channel state information to be transmitted to an access point.

10 The channel state information may comprise at least one of a channel quality indicator, a precoding matrix indicator and a rank indicator.

The first reference signal may represent the vertical domain of a two-dimensional antenna array.

15 Each beam may be precoded by a weighting vector.

The weighting vector may be predefined.

20 In a second aspect there is provided a method comprising causing at least one beam to be transmitted to a user equipment, said beam including a first reference signal associated with that beam and causing a second reference signal for a cell to be transmitted to the user equipment.

25 The method may comprise receiving channel state information, said channel state information determined in dependence on the first reference signal and the second reference signal.

30 The method may comprise causing a plurality of beams to be transmitted to the user equipment, each beam comprising a first reference signal associated with that beam.

The method may comprise receiving beam selection information from the user equipment, said beam selection determined in dependence on beam signal information.

- 5 The channel state information may comprise at least one of a channel quality indicator, a precoding matrix indicator and a rank indicator.

The first reference signal may represent the vertical domain of a two-dimensional antenna array.

10

The method may comprise precoding each beam by a weighting vector.

The weighting vector may be predefined.

- 15 In a third aspect there is provided an apparatus comprising means for receiving, at a user equipment, at least one beam, said beam including a first reference signal associated with that beam, receiving at the user equipment a second reference signal for a cell and determining channel state information in dependence on the first reference signal and the second reference signal.

20

The apparatus may comprise means for receiving a plurality of beams at the user equipment, each beam comprising a first reference signal associated with that beam, and selecting at least one beam in dependence on beam signal information.

- 25 The apparatus may comprise means for causing beam selection information to be transmitted to an access point.

Beam signal information may comprise at least one of signal to interference plus noise ratio and received reference signal power.

30

Means for determining channel state information in dependence on the first reference signal and the second reference signal may comprise means for deriving

channel state information based on the second reference and updating it according to the first reference signal measurement.

5 The apparatus may comprise means for causing channel state information to be transmitted to an access point.

The channel state information may comprise at least one of a channel quality indicator, a precoding matrix indicator and a rank indicator.

10 The first reference signal may represent the vertical domain of a two-dimensional antenna array.

Each beam may be precoded by a weighting vector.

15 The weighting vector may be predefined.

In a fourth aspect there is provided an apparatus comprising means for causing at least one beam to be transmitted to a user equipment, said beam including a first reference signal associated with that beam and causing a second reference signal
20 for a cell to be transmitted to the user equipment.

The apparatus may comprise means for receiving channel state information, said channel state information determined in dependence on the first reference signal and the second reference signal.
25

The apparatus may comprise means for causing a plurality of beams to be transmitted to the user equipment, each beam comprising a first reference signal associated with that beam.

30 The apparatus may comprise means for receiving beam selection information from the user equipment, said beam selection determined in dependence on beam signal information.

The channel state information may comprise at least one of a channel quality indicator, a precoding matrix indicator and a rank indicator.

5 The first reference signal may represent the vertical domain of a two-dimensional antenna array.

The apparatus may comprise means for precoding each beam by a weighting vector.

10 The weighting vector may be predefined.

In a fifth aspect there is provided a computer program product for a computer, comprising software code portions for performing the steps of the methods
15 described above when said product is run on the computer.

In a sixth aspect there is provided an apparatus comprising at least one processor and at least one memory including a computer program code, the at least one memory and the computer program code configured to, with the at least one
20 processor, cause the apparatus at least to: receive, at a user equipment, at least one beam, said beam including a first reference signal associated with that beam, receive at the user equipment a second reference signal for a cell and determine channel state information in dependence on the first reference signal and the second reference signal.

25

The at least one memory and the computer program code may be configured to, with the at least one processor, cause the apparatus to receive a plurality of beams at the user equipment, each beam comprising a first reference signal associated with that beam, and selecting at least one beam in dependence on
30 beam signal information.

The at least one memory and the computer program code may be configured to, with the at least one processor, cause the apparatus to cause beam selection information to be transmitted to an access point.

- 5 Beam signal information may comprise at least one of signal to interference plus noise ratio and received reference signal power.

The at least one memory and the computer program code may be configured to, with the at least one processor, cause the apparatus to derive channel state
10 information based on the second reference and updating it according to the first reference signal measurement.

The at least one memory and the computer program code may be configured to, with the at least one processor, cause the apparatus to cause channel state
15 information to be transmitted to an access point.

The channel state information may comprise at least one of a channel quality indicator, a precoding matrix indicator and a rank indicator.

- 20 The first reference signal may represent the vertical domain of a two-dimensional antenna array.

Each beam may be precoded by a weighting vector.

- 25 The weighting vector may be predefined.

In a seventh aspect there is provided an apparatus comprising at least one processor and at least one memory including a computer program code, the at least one memory and the computer program code configured to, with the at least
30 one processor, cause the apparatus to cause at least one beam to be transmitted to a user equipment, said beam including a first reference signal associated with that beam and causing a second reference signal for a cell to be transmitted to the user equipment.

5 The at least one memory and the computer program code may be configured to, with the at least one processor, cause the apparatus to receive channel state information, said channel state information determined in dependence on the first reference signal and the second reference signal.

10 The at least one memory and the computer program code may be configured to, with the at least one processor, cause the apparatus to cause a plurality of beams to be transmitted to the user equipment, each beam comprising a first reference signal associated with that beam.

15 The at least one memory and the computer program code may be configured to, with the at least one processor, cause the apparatus to receive beam selection information from the user equipment, said beam selection determined in dependence on beam signal information.

The channel state information may comprise at least one of a channel quality indicator, a precoding matrix indicator and a rank indicator.

20 The first reference signal may represent the vertical domain of a two-dimensional antenna array.

25 The apparatus may comprise means for precoding each beam by a weighting vector.

The weighting vector may be predefined.

30 In an eighth aspect there is provided a computer program embodied on a computer-readable storage medium, the computer program comprising program code for controlling a process to execute a process, the process comprising: receiving, at a user equipment, at least one beam, said beam including a first reference signal associated with that beam, receiving at the user equipment a

second reference signal for a cell and determining channel state information in dependence on the first reference signal and the second reference signal.

5 The process may comprise receiving a plurality of beams at the user equipment, each beam comprising a first reference signal associated with that beam, and selecting at least one beam in dependence on beam signal information.

10 The process may comprise causing beam selection information to be transmitted to an access point.

Beam signal information may comprise at least one of signal to interference plus noise ratio and received reference signal power.

15 Determining channel state information in dependence on the first reference signal and the second reference signal may comprise deriving channel state information based on the second reference and updating it according to the first reference signal measurement.

20 The process may comprise causing channel state information to be transmitted to an access point.

The channel state information may comprise at least one of a channel quality indicator, a precoding matrix indicator and a rank indicator.

25 The first reference signal may represent the vertical domain of a two-dimensional antenna array.

Each beam may be precoded by a weighting vector.

30 The weighting vector may be predefined.

In a ninth aspect there is provided a computer program embodied on a computer-readable storage medium, the computer program comprising program code for

controlling a process to execute a process, the process comprising: causing at least one beam to be transmitted to a user equipment, said beam including a first reference signal associated with that beam and causing a second reference signal for a cell to be transmitted to the user equipment.

5

The process may comprise receiving channel state information, said channel state information determined in dependence on the first reference signal and the second reference signal.

10 The process may comprise causing a plurality of beams to be transmitted to the user equipment, each beam comprising a first reference signal associated with that beam.

The process may comprise receiving beam selection information from the user
15 equipment, said beam selection determined in dependence on beam signal information.

The channel state information may comprise at least one of a channel quality indicator, a precoding matrix indicator and a rank indicator.

20

The first reference signal may represent the vertical domain of a two-dimensional antenna array.

The process may comprise precoding each beam by a weighting vector.

25

The weighting vector may be predefined.

In the above, many different embodiments have been described. It should be appreciated that further embodiments may be provided by the combination of any
30 two or more of the embodiments described above.

List of Drawings

Embodiments will now be described, by way of example only, with reference to the accompanying Figures in which:

5 Figure 1 shows a schematic diagram of an example communication system comprising a base station and a plurality of communication devices;

Figure 2 shows a schematic diagram of an example mobile communication device;

10 Figure 3 shows a schematic view of example MIMO antenna applying a two-dimensional array;

Figure 4 shows a flow chart of an example method of feedback design for massive MIMO;

15 Figure 5 shows a flow chart of an example method of feedback design for massive MIMO;

20 Figure 6 shows a schematic view of an example communication system comprising an access point and a plurality of communication devices;

Figure 7 shows an example of a schematic view of hybrid beamforming apparatus

Figure 8 shows a schematic diagram of an example control apparatus;

Description of Embodiments

25 In the following certain exemplifying embodiments are explained with reference to a wireless or mobile communication system serving mobile communication devices. Before explaining in detail the exemplifying embodiments, certain general principles of a wireless communication system and mobile communication devices are briefly explained with reference to Figures 1 and 2 to assist in understanding
30 the technology underlying the described examples. It should be appreciated that the Long Term Evolution Advanced (LTE-Advanced) system is used herein only as a non-limiting example. Embodiments may be applied to any other

communications system, such as a 5G system which may have a similar architecture to that of the LTE-Advanced system.

In a wireless communication system 100, such as that shown in figure 1, mobile communication devices or user equipment (UE) 102, 104, 105 are provided wireless access via at least one base station or similar wireless transmitting and/or receiving node or point.

Base stations are typically controlled by at least one appropriate controller apparatus so as to enable operation thereof and management of mobile communication devices in communication with the base stations. In Figure 1 control apparatus 108 and 109 is shown to control the respective macro level base stations 106 and 107. The control apparatus of a base station can be interconnected with other control entities. The control apparatus is typically provided with memory capacity and at least one data processor. The control apparatus and functions may be distributed between a plurality of control units. The control apparatus may be as shown in Figure 8 which is discussed later.

The controller apparatus may be located in a radio access network (e.g. wireless communication system 100) or in a core network (not shown) and may be implemented as one central apparatus or its functionality may be distributed over several apparatus. The controller apparatus may be part of the base station and/or provided by a separate entity such as a Radio Network Controller. In Figure 1 control apparatus 108 and 109 are shown to control the respective macro level base stations 106 and 107. The control apparatus of a base station can be interconnected with other control entities. The control apparatus is typically provided with memory capacity and at least one data processor. The control apparatus and functions may be distributed between a plurality of control units. In some systems, the control apparatus may additionally or alternatively be provided in a radio network controller.

LTE systems may however be considered to have a so-called “flat” architecture, without the provision of RNCs; rather the (e)NB is in communication with a system

architecture evolution gateway (SAE-GW) and a mobility management entity (MME), which entities may also be pooled meaning that a plurality of these nodes may serve a plurality (set) of (e)NBs. Each UE is served by only one MME and/or S-GW at a time and the (e)NB keeps track of current association. SAE-GW is a
5 “high-level” user plane core network element in LTE, which may consist of the S-GW and the P-GW (serving gateway and packet data network gateway, respectively). The functionalities of the S-GW and P-GW are separated and they are not required to be co-located.

10 In Figure 1 base stations 106 and 107 are shown as connected to a wider communications network 113 via gateway 112. A further gateway function may be provided to connect to another network.

The smaller base stations 116, 118 and 120 may also be connected to the network
15 113, for example by a separate gateway function and/or via the controllers of the macro level stations. The base stations 116, 118 and 120 may be pico or femto level base stations or the like. In the example, stations 116 and 118 are connected via a gateway 111 whilst station 120 connects via the controller apparatus 108. In some embodiments, the smaller stations may not be provided.

20 Each mobile communication device and station may have one or more radio channels open at the same time and may send signals to and/or receive signals from more than one source. It is noted that the radio service area borders or edges are schematically shown for illustration purposes only in Figure 1. It shall also be
25 understood that the sizes and shapes of radio service areas may vary considerably from the shapes of Figure 1. A base station site can provide one or more cells. A base station can also provide a plurality of sectors, for example three radio sectors, each sector providing a cell or a subarea of a cell. All sectors within a cell can be served by the same base station.

30 A base station may comprise at least one base band unit (BBU) which can perform system operations such as communicating with a core network. In some embodiments the base transceiver station comprises at least one RF unit (RU) or

remote RF unit (RRU). The base band unit communicates with a radio frequency units (RU)/ remote radio units (RRU) over a defined interface. The radio frequency unit is configured to convert base band signals into a format suitable for transmission over a wireless network. The radio frequency unit may send signals
5 for wireless transmissions to an antenna system. The antenna system may comprise a plurality of antennas. In some embodiments the radio frequency unit is separate from the base band unit, however alternatively the radio frequency unit and the base band unit may be comprised in the same network entity. In some other embodiments the antenna system and the radio frequency unit may be
10 comprised in the same network entity. The plurality of antennas may be used together for the purposes of beam forming wireless transmissions.

A possible mobile communication device will now be described in more detail with reference to Figure 2 showing a schematic, partially sectioned view of a
15 communication device 200. Such a communication device is often referred to as user equipment (UE) or terminal. An appropriate mobile communication device may be provided by any device capable of sending and receiving radio signals. Non-limiting examples include a mobile station (MS) or mobile device such as a mobile phone or what is known as a 'smart phone', a computer provided with a
20 wireless interface card or other wireless interface facility (e.g., USB dongle), personal data assistant (PDA) or a tablet provided with wireless communication capabilities, or any combinations of these or the like. A mobile communication device may provide, for example, communication of data for carrying communications such as voice, electronic mail (email), text message, multimedia
25 and so on. Users may thus be offered and provided numerous services via their communication devices. Non-limiting examples of these services include two-way or multi-way calls, data communication or multimedia services or simply an access to a data communications network system, such as the Internet. Users may also be provided broadcast or multicast data. Non-limiting examples of the content
30 include downloads, television and radio programs, videos, advertisements, various alerts and other information.

The mobile device 200 may receive signals over an air or radio interface 207 via appropriate apparatus for receiving and may transmit signals via appropriate apparatus for transmitting radio signals. In Figure 2 transceiver apparatus is designated schematically by block 206. The transceiver apparatus 206 may be
5 provided for example by means of a radio part and associated antenna arrangement. The antenna arrangement may be arranged internally or externally to the mobile device.

A mobile device is typically provided with at least one data processing entity 201,
10 at least one memory 202 and other possible components 203 for use in software and hardware aided execution of tasks it is designed to perform, including control of access to and communications with access systems and other communication devices. The data processing, storage and other relevant control apparatus can be provided on an appropriate circuit board and/or in chipsets. This feature is denoted
15 by reference 204. The user may control the operation of the mobile device by means of a suitable user interface such as key pad 205, voice commands, touch sensitive screen or pad, combinations thereof or the like. A display 208, a speaker and a microphone can be also provided. Furthermore, a mobile communication device may comprise appropriate connectors (either wired or wireless) to other
20 devices and/or for connecting external accessories, for example hands-free equipment, thereto.

The communication devices 102, 104, 105 may access the communication system based on various access techniques, such as code division multiple access
25 (CDMA), or wideband CDMA (WCDMA). Other non-limiting examples comprise time division multiple access (TDMA), frequency division multiple access (FDMA) and various schemes thereof such as the interleaved frequency division multiple access (IFDMA), single carrier frequency division multiple access (SC-FDMA) and orthogonal frequency division multiple access (OFDMA), space division multiple
30 access (SDMA) and so on.

An example of wireless communication systems are architectures standardized by the 3rd Generation Partnership Project (3GPP). A latest 3GPP based development

is often referred to as the long term evolution (LTE) of the Universal Mobile Telecommunications System (UMTS) radio-access technology. The various development stages of the 3GPP specifications are referred to as releases. More recent developments of the LTE are often referred to as LTE Advanced (LTE-A).

5 The LTE employs a mobile architecture known as the Evolved Universal Terrestrial Radio Access Network (E-UTRAN). Base stations of such systems are known as evolved or enhanced Node Bs (eNBs) and provide E-UTRAN features such as user plane Radio Link Control/Medium Access Control/Physical layer protocol (RLC/MAC/PHY) and control plane Radio Resource Control (RRC) protocol
10 terminations towards the communication devices. Other examples of radio access system include those provided by base stations of systems that are based on technologies such as wireless local area network (WLAN) and/or WiMax (Worldwide Interoperability for Microwave Access). A base station can provide coverage for an entire cell or similar radio service area.

15 A wireless communication device can be provided with a Multiple Input / Multiple Output (MIMO) antenna system. MIMO systems use multiple antennas at the transmitter and receiver along with advanced digital signal processing to improve link quality and capacity. Although not shown in Figures 1 and 2, multiple antennas
20 can be provided, for example at base stations and mobile stations, and the transceiver apparatus 206 of Figure 2 can provide a plurality of antenna ports. More data can be received and/or sent where there are more antenna elements. A station may comprise an array of multiple antennas. Signalling and muting patterns can be associated with transmitter antenna numbers or receiver port numbers of
25 MIMO arrangements. Massive MIMO antennas are used, particularly in 5G technologies, as they can bring increased throughput and enhance user experience. Feedback mechanism designs for massive MIMOs are considered.

Through vertical domain beamforming and spatial multiplexing, the MIMO
30 capability of a cellular network may be further developed. In LTE Rel-8 and R10, horizontal domain MIMO may be applied. Vertical domain MIMO is being discussed in the context of 3GPP Rel-12/13.

As can be seen in figure 3, in LTE 3D-MIMO, an antenna array will apply a two-dimensional array, including a vertical domain element and a horizontal domain element, also referred to as azimuth domain and elevation domain, respectively. In order to assist UE feedback and eNB precoding, solutions based on vertical domain RS (Reference Signal) and horizontal domain RS are proposed to provide UE measurement and CSI (Channel State Information) feedback. In the relevant solutions, vertical antenna element and horizontal antenna element are separately virtualized, and each domain owns independent RS mapping and CSI feedback, as shown in the figure 3.

In a large scale antenna array, such as that used in 5G architectures, conventional RS design and CSI feedback may be more complex. Antenna arrays may define different shapes, such that horizontal and vertical beams are harder to define. Massive MIMO hardware implementation based on large scale antenna array may exhibit new beam forms. For example, hybrid beamforming, where the transmitted antenna number is bigger than the baseband transceiver number, as shown in figure 7, may be used. In this context, conventional vertical domain beamforming and horizontal beamforming needs further extending, for example, introducing universal beamforming concept, not only in dependence on beam direction and/or beam height, but also addressing a specific geographical zone.

Two-layer feedback is proposed, the first layer being reporting the quadrant index associated with UE location and the second is reporting the Precoding Matrix Indicator (PMI)/Rank Indicator (RI)/Channel Quality Indicator (CQI) based on quadrant specific CSI-RS (Channel State Information Reference Signal). Requiring one unique CSI-RS set to map each quadrant may increase overhead requirements.

One related concept is using beam reference signal (RS). In this scheme, a UE will select one favoured beam RS and report the selected beam RS to an access point (AP), such as an eNB. Then the AP will perform beamforming according to the UE feedback. However, this feedback design only comprises one layer of feedback and may not be suitable to perform rank adaptation.

CSI-RS overhead and feedback design are considered, particularly in 5G as antenna arrays become larger and the number of antenna elements may exceed 32 or 64. An efficient feedback design having low overhead is desirable. A simple and effective feedback scheme, which may be applied in 5G massive MIMO, is proposed.

Figure 4 shows a method of providing feedback. The method may be suitable for massive MIMO, in which a two-layer feedback scheme comprising two different reference signals is used.

The method comprises, in step 1, receiving 410, at a user equipment, at least one beam, said beam including a first reference signal associated with that beam. In step 2, a second reference signal for a cell is received 420 at a user equipment and in step 3, channel information is determined 430 in dependence on the first reference signal and the second reference signal.

A method feedback design is shown in figure 5, which comprises, in step 1 causing 510 at least one beam to be transmitted to a user equipment, said beam including a first reference signal associated with that beam. In step 2, a second reference signal for a cell is caused 520 to be transmitted to the user equipment. In step 3, channel state information may be received 530, said channel state information determined in dependence on the first reference signal and the second reference signal.

Figure 6 shows an example system architecture 600 for a method of feedback, for example that of figure 4 and/or figure 5. The system 600 comprises an AP 610, for example a base station such as an eNB; a first mobile communication device 602 and a second mobile communication device 604. The first mobile communication device 602 is situated in a first beam zone 620, i.e. a zone that receives a directional beam 622 from the AP 610, and the second mobile communication device 604 may be situated in a second beam zone 630, i.e. a zone that receives a directional beam 632 from the AP 610. Two mobile communication devices and

two beam zones are shown by way of example. However any suitable number of beam zones and mobile communication devices may be present.

5 One cell may correspond to one sector, supposing one cell includes 120 degrees coverage. Eight zones in the horizontal domain can be defined to divide a cell. Alternatively, considering the height component of a cell, four horizontal zones and two vertical zones can be assigned, to also define eight zones.

In the following, embodiments of the method are described in further detail.

10 AP 610 may transmit at least one beam to be transmitted to a user equipment, said beam including a first reference signal associated with that beam. For example, AP 610 may transmit a first beam reference signal (RS) precoded by beam weights, where one RS port corresponds to one beam zone and one cell is divided into multiple beam zones. The beam weights may be predefined, they may
15 be calculated and/or generated, and/or they may be selected, for example in dependence of circumstances, from a number of beam weights.

AP 610 may transmit a first reference signal 624 to beam zone 620 and a second reference signal 634 to second beam zone 630.

20

To generate beam weights, a weighting vector, which may be predefined, for example a DFT (Discrete Fourier Transform) vector, may be used to represent beam weights. If a three-dimensional zone is covered, a Kronecker product may be performed on two separate vectors to form one combined weight vector.

25

A UE may select a favoured beam zone RS port. The UE may select a favoured beam zone RS according to one of SINR (Signal to Interference plus Noise Ratio) or received RS signal power. Other properties may be used to select a favoured beam zone RS port. The UE may cause the beam zone selection to be transmitted
30 to the AP.

AP 610 may transmit a second reference signal 640, for example a CSI-RS (Channel State Information Reference Signal) set, to a UE. Within the CSI-RS set,

one or multiple RS ports are represented. The second reference signal, e.g. CSI-RS, may cover the whole cell, with a cell specific transmission mode. Since the antenna array is concentrated, one CSI-RS set is enough to represent one set of antenna ports.

5

The UE may determine channel state information in dependence on the first reference signal and the second reference signal. For example, the UE may measure a CSI-RS and may derive a Precoding Matrix Indicator (PMI)/Rank Indicator (RI)/Channel Quality Indicator (CQI) in combination with the latest beam
10 RS selection. A UE measures the received CSI-RS, and may firstly derive one set of RI/PMI/CQI values without taking into account specific beam gain. When calculating CQI according to one cell specific CSI-RS, beam gain may not be reflected, as it is not matched to real PDSCH transmission. In real data transmission, AP 610 will perform beamforming to a desired user. High CQI may
15 cause high Rank. Hence, it may also be desirable to update RI. The beam zone RS may help UE to determine accurate beam gain under specific beam direction. Based on beam gain information, UE can recalculate RI and CQI.

Since the UE is aware of which beam zone RS corresponds to which weighting
20 vector, the UE may adjust a CQI calculation by aggregating beam weighting vector.

The UE may then cause the final channel state information, for example, PMI/CQI/RI, to AP 610.

25

The AP 610 may send the PDSCH to the UE according to a reported beam zone index and PMI/RI/CQI.

The reported beam index may correspond to the beam weighting vector of the UE
30 location, so the AP can use the weighting vector to generate a location specific beam. The AP may use combined beam index and weighting vector to perform beamforming and precoding to desired UE.

The beam zone division may help to conduct accurate beamforming with a large scale antenna array.

Combining long term beam zone information and short term channel information
5 may be used to ensure accurate enough CSI feedback and flexible rank/link adaption.

Feedback overhead and RS overhead may be reduced even as a number of antenna elements in an antenna increases. Since CSI-RS is cell specific, CSI-RS
10 is not precoded by a location or UE specific weighting vector, but by one cell specific weighting vector. Since only one CSI-RS set is used, the RS overhead is may be reduced.

A hybrid beamforming diagram is shown in figure 7. In this figure, data streams are
15 precoded firstly by digital beamformer 710 with precoding vector w_1 , and further precoded by analog beamformer 720 with precoding vector w_2 . w_1 precoding is performed in digital baseband, the basedband path number may be limited dependent on cost but may have flexibility in weighting vector generation. However, w_2 precoding is performed in the RF part after the mixer, where each
20 transmitted path corresponds to each real antenna element. So in analog beamforming, the weighting vector generation may be more complex but the branch number could be larger. In the case of hybrid beam forming, one cell specific weighting vector may be used in an analog beamformer to transmit CSI-RS. One beam RS corresponding to each analog beam weighted by one specific
25 beam vector may be transmitted. A UE may calculate and feedback the beam zone index and PMI/RI/CQI depending on beam zone and CSI-RS information

An AP may generate an analog beam with a corresponding beam zone specific weighting vector and perform precoding with the reported PMI. An AP may send
30 PDSCH (Physical Downlink Shared Channel) to UE with above beam and precoding information.

In a LTE 3D-MIMO with a regular 2D antenna array, the method may be implemented as follows.

5 In the vertical domain, the beam zone RS may be used to represent the vertical beam. In the horizontal domain, one legacy CSI-RS set is used to assist UE horizontal domain feedback.

A UE determines and feeds back the vertical beam index and PMI/RI/CQI depending on both vertical and horizontal information. An AP will send PDSCH to
10 UE according to the reported beam index and PMI/RI/CQI.

It should be understood that each block of the flowchart of Figures 4 and 5 and any combination thereof may be implemented by various means or their combinations, such as hardware, software, firmware, one or more processors
15 and/or circuitry.

Embodiments disclosed above in relation to Figures 3 to 7 may be implemented on a control apparatus as shown in figure 8. Figure 8 shows an example of a control apparatus for a communication system, for example to be coupled to and/or for
20 controlling a station of an access system, such as a base station or (e) node B, or a server or host. In some embodiments, base stations comprise a separate control apparatus unit or module. In other embodiments, the control apparatus can be another network element such as a radio network controller or a spectrum controller. In some embodiments, each base station may have such a control
25 apparatus as well as a control apparatus being provided in a radio network controller. The control apparatus 109 can be arranged to provide control on communications in the service area of the system. The control apparatus 109 comprises at least one memory 301, at least one data processing unit 302, 303 and an input/output interface 304. Via the interface the control apparatus can be
30 coupled to a receiver and a transmitter of the base station. The receiver and/or the transmitter may be implemented as a radio front end or a remote radio head. For example the control apparatus 109 can be configured to execute an appropriate software code to provide the control functions.

More specifically, the control apparatus may comprise at least one unit, module or circuitry to receive, at a user equipment, at least one beam, said beam including a first reference signal associated with that beam, receive at the user equipment a
5 second reference signal for a cell and determine channel state information in dependence on the first reference signal and the second reference signal.

The control apparatus may comprise at least one unit, module or circuitry to cause at least one beam to be transmitted to a user equipment, said beam including a
10 first reference signal associated with that beam and cause a second reference signal for a cell to be transmitted to the user equipment.

An example of an apparatus comprises means for receiving, at a user equipment, at least one beam, said beam including a first reference signal associated with
15 that beam, receive at the user equipment a second reference signal for a cell and determine channel state information in dependence on the first reference signal and the second reference signal.

An example of an apparatus comprises means for causing at least one beam to be
20 transmitted to a user equipment, said beam including a first reference signal associated with that beam and causing a second reference signal for a cell to be transmitted to the user equipment.

It should be understood that the apparatuses may include or be coupled to other
25 units or modules etc., such as radio parts or radio heads, used in or for transmission and/or reception. Although the apparatuses have been described as one entity, different modules and memory may be implemented in one or more physical or logical entities.

30 It is noted that whilst embodiments have been described in relation to LTE, similar principles can be applied to any other communication system where MIMO antennas are supported. Therefore, although certain embodiments were described above by way of example with reference to certain example architectures for

wireless networks, technologies and standards, embodiments may be applied to any other suitable forms of communication systems than those illustrated and described herein.

- 5 It is also noted herein that while the above describes example embodiments, there are several variations and modifications which may be made to the disclosed solution without departing from the scope of the present invention.

10 In general, the various embodiments may be implemented in hardware or special purpose circuits, software, logic or any combination thereof. Some aspects of the invention may be implemented in hardware, while other aspects may be implemented in firmware or software which may be executed by a controller, microprocessor or other computing device, although the invention is not limited thereto. While various aspects of the invention may be illustrated and described
15 as block diagrams, flow charts, or using some other pictorial representation, it is well understood that these blocks, apparatus, systems, techniques or methods described herein may be implemented in, as non-limiting examples, hardware, software, firmware, special purpose circuits or logic, general purpose hardware or controller or other computing devices, or some combination thereof.

20

The embodiments of this invention may be implemented by computer software executable by a data processor of the mobile device, such as in the processor entity, or by hardware, or by a combination of software and hardware. Computer software or program, also called program product, including software routines,
25 applets and/or macros, may be stored in any apparatus-readable data storage medium and they include program instructions to perform particular tasks. A computer program product may comprise one or more computer-executable components which, when the program is run, are configured to carry out embodiments. The one or more computer-executable components may be at least
30 one software code or portions of it. The computer program may be stored in the apparatus or it may be downloadable into the apparatus.

Further in this regard it should be noted that any blocks of the logic flow as in the Figures 4 and 5 (and/or further details disclosed in relation to Figure 6) may represent program steps, or interconnected logic circuits, blocks and functions, or a combination of program steps and logic circuits, blocks and functions. The software may be stored on such physical media as memory chips, or memory blocks implemented within the processor, magnetic media such as hard disk or floppy disks, and optical media such as for example DVD and the data variants thereof, CD. The physical media may be a non-transitory media.

The memory may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The data processors may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs), application specific integrated circuits (ASIC), FPGA, gate level circuits and processors based on multi core processor architecture, as non limiting examples.

Embodiments of the inventions may be practiced in various components such as integrated circuit modules. The design of integrated circuits is by and large a highly automated process. Complex and powerful software tools are available for converting a logic level design into a semiconductor circuit design ready to be etched and formed on a semiconductor substrate.

In the above, many different embodiments have been described. It should be appreciated that further embodiments may be provided by the combination of any two or more of the embodiments described above.

The foregoing description has provided by way of non-limiting examples a full and informative description of the exemplary embodiment of this invention. However, various modifications and adaptations may become apparent to those skilled in the relevant arts in view of the foregoing description, when read in conjunction with the

accompanying drawings and the appended claims. However, all such and similar modifications of the teachings of this invention will still fall within the scope of this invention as defined in the appended claims. Indeed there is a further embodiment comprising a combination of one or more embodiments with any of the other

5 embodiments previously discussed.

CLAIMS

1. A method comprising:

5 receiving, at a user equipment, at least one beam, said beam including a first reference signal associated with that beam;
receiving at the user equipment a second reference signal for a cell; and
determining channel state information in dependence on the first reference
signal and the second reference signal.

10 2. The method according to claim 1 comprising receiving a plurality of beams at the user equipment, each beam comprising a first reference signal associated with that beam, and selecting at least one beam in dependence on beam signal information.

15 3. The method according to claim 2 comprising causing beam selection information to be transmitted to an access point.

20 4. The method according to claim 2 or claim 3, wherein beam signal information comprises at least one of signal to interference plus noise ratio and received reference signal power.

25 5. The method according to any preceding claim, wherein determining channel state information in dependence on the first reference signal and the second reference signal comprises deriving channel state information based on the second reference and updating it according to the first reference signal measurement.

30 6. The method according to any preceding claim comprising causing channel state information to be transmitted to an access point.

7. The method according to any preceding claim, wherein the channel state information comprises at least one of a channel quality indicator, a precoding matrix indicator and a rank indicator.

5 8. The method according to any preceding claim, wherein the first reference signal represents the vertical domain of a two-dimensional antenna array.

9. A method comprising:

10 causing at least one beam to be transmitted to a user equipment, said beam including a first reference signal associated with that beam; and causing a second reference signal for a cell to be transmitted to the user equipment.

10. The method according to claim 9, comprising:

15 receiving channel state information, said channel state information determined in dependence on the first reference signal and the second reference signal.

11. The method according to claim 9 or claim 10 comprising:

20 causing a plurality of beams to be transmitted to the user equipment, each beam comprising a first reference signal associated with that beam.

12. The method according to any one of claims 9 to 11 comprising:

25 receiving beam selection information from the user equipment, said beam selection determined in dependence on beam signal information.

13. The method according to any one of claims 9 to 12, wherein the channel state information comprises at least one of a channel quality indicator, a precoding matrix indicator and a rank indicator.

30

14. The method according to any one of claims 9 to 13, wherein the first reference signal represents the vertical domain of a two-dimensional antenna array.

15. The method according to any one of claims 9 to 14, comprising precoding each beam by a weighting vector.

5 16. An apparatus comprising means for carrying out the method according to any one of claims 1 to 15.

17. A computer program product for a computer, comprising software code portions for performing the steps of any of claims 1 to 15, when said product
10 is run on the computer.

18. An apparatus comprising:

at least one processor and at least one memory including a computer program code, the at least one memory and the computer program code
15 configured to, with the at least one processor, cause the apparatus at least to receive, at a user equipment, at least one beam, said beam including a first reference signal associated with that beam;
receive at the user equipment a second reference signal for a cell; and
determine channel state information in dependence on the first reference
20 signal and the second reference signal.

19. An apparatus comprising:

at least one processor and at least one memory including a computer program code, the at least one memory and the computer program code
25 configured to, with the at least one processor, cause the apparatus at least to: cause at least one beam to be transmitted to a user equipment, said beam including a first reference signal associated with that beam; and
cause a second reference signal for a cell to be transmitted to the user equipment
30

20. A computer program embodied on a computer-readable storage medium, the computer program comprising program code for controlling a process to execute a process, the process comprising:

receiving, at a user equipment, at least one beam, said beam including a first reference signal associated with that beam; and
receiving at the user equipment a second reference signal for a cell;
determining channel state information in dependence on the first reference
5 signal and the second reference signal.

21. A computer program embodied on a computer-readable storage medium,
the computer program comprising program code for controlling a process to
execute a process, the process comprising: causing at least one beam to
10 be transmitted to a user equipment, said beam including a first reference
signal associated with that beam; and
causing a second reference signal for a cell to be transmitted to the user
equipment.

Figure 1

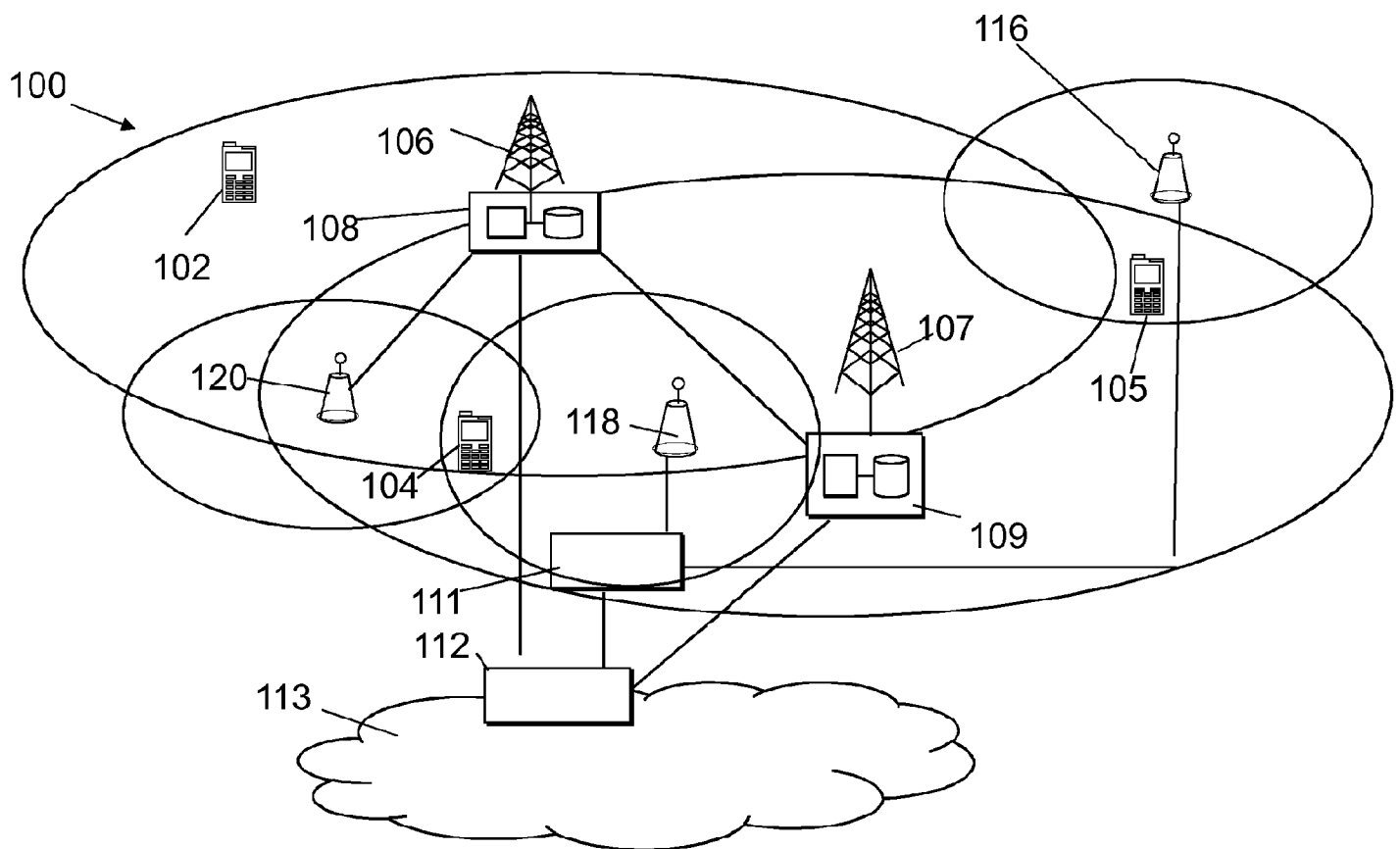


Figure 2

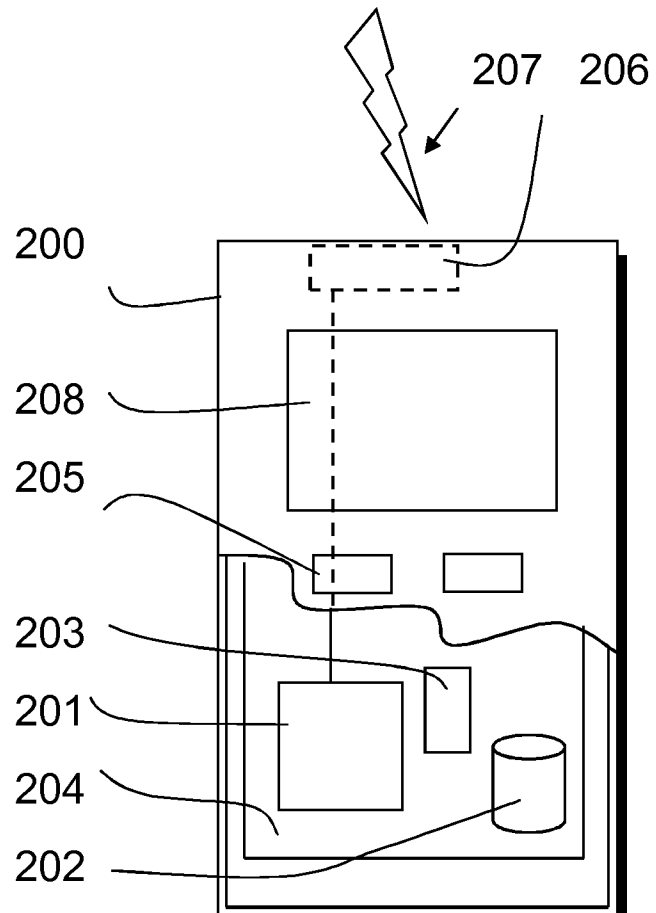


Figure 3

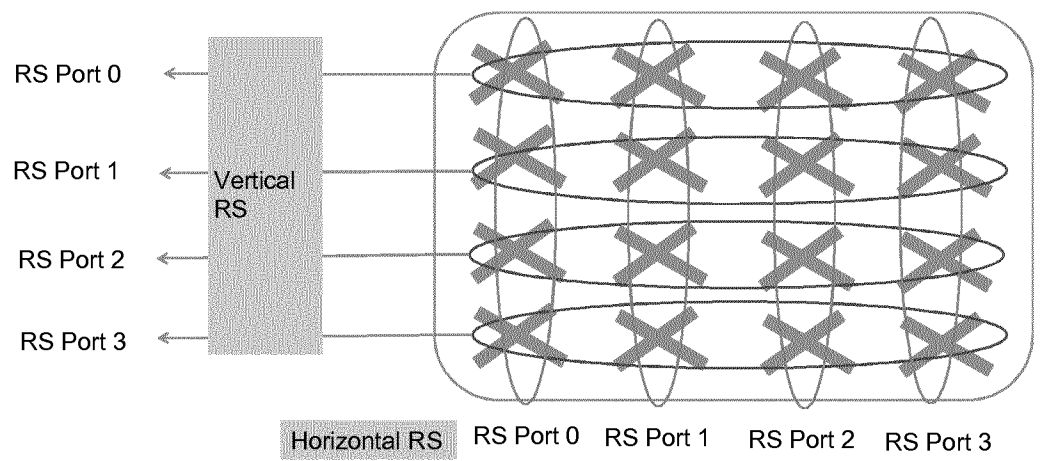


Figure 4

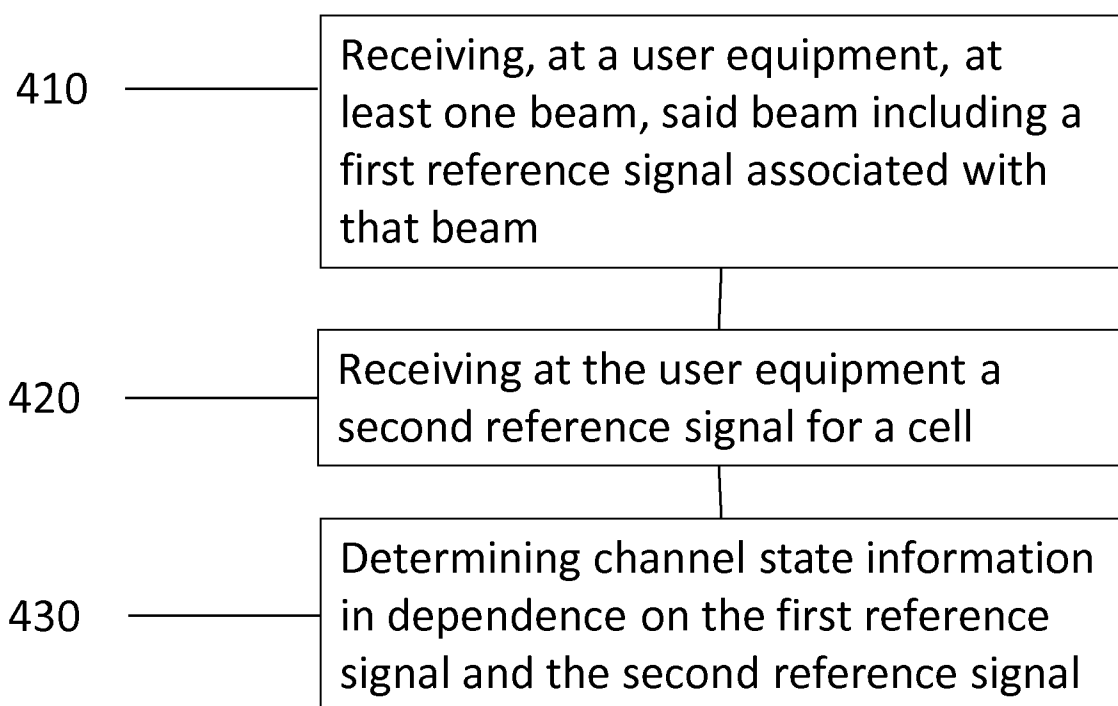


Figure 5

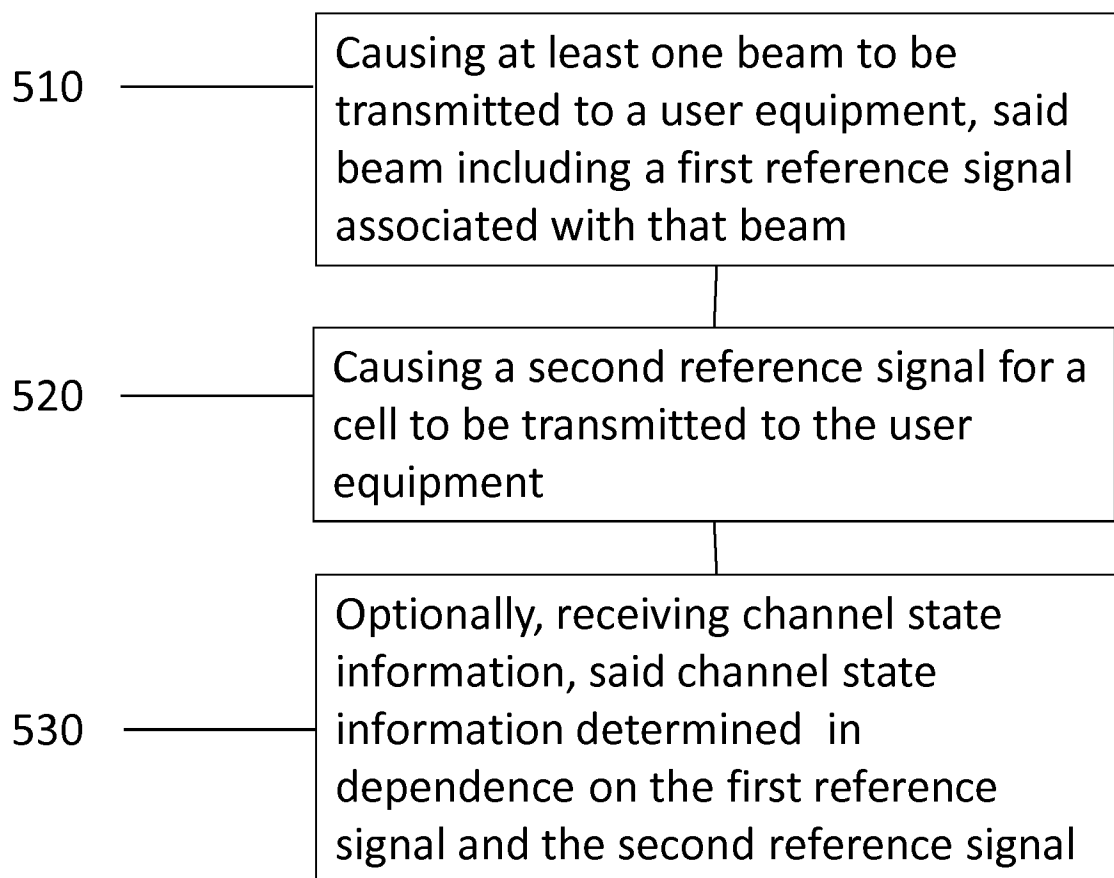


Figure 6

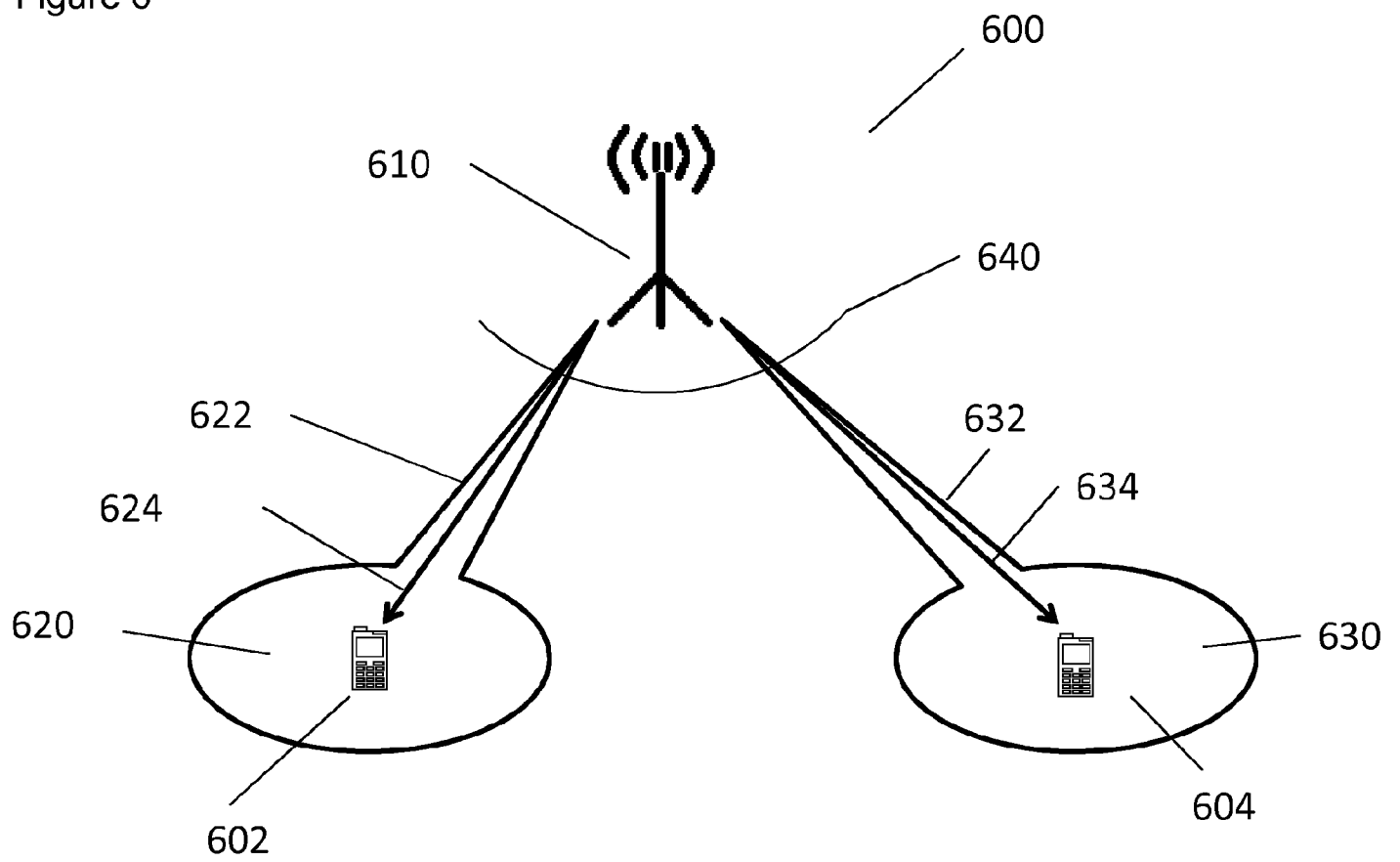


Figure 7

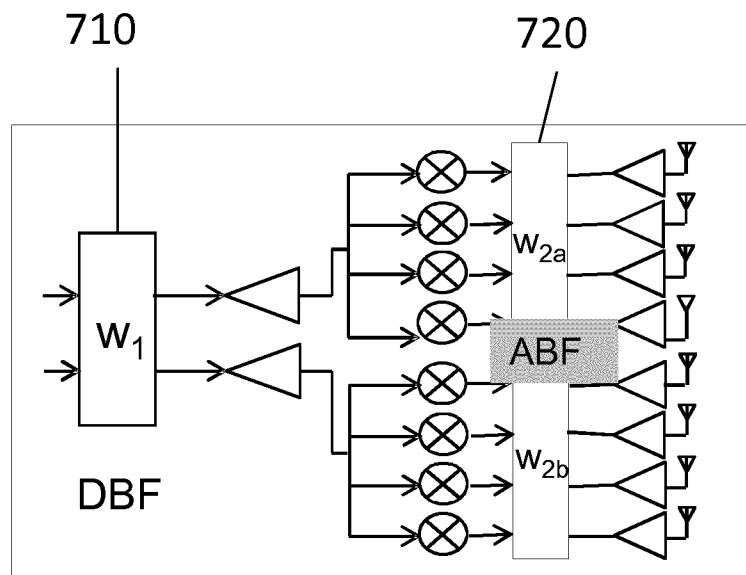
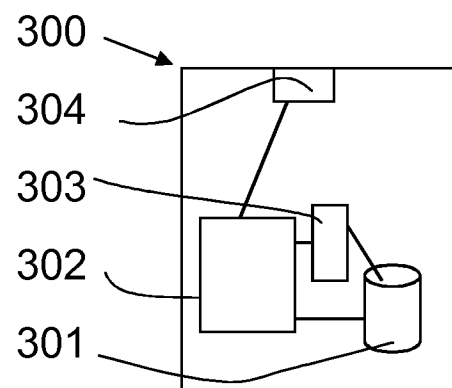


Figure 8



INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2014/065324

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W24/10 H04W16/28
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04B H04W

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/308715 A1 (NAM YOUNG-HAN [US] ET AL) 21 November 2013 (2013-11-21)	1,3-10, 13,14, 16-21
Y	paragraphs [0062], [0063] - [0068] paragraphs [0070], [0071], [0073], [0074], [0077] paragraphs [0114], [0117] - [0119] paragraphs [0120], [0123], [0124] paragraph [0164]	2,11,12, 15
Y	----- US 2014/177745 A1 (KRISHNAMURTHY SANDEEP H [US] ET AL) 26 June 2014 (2014-06-26) paragraphs [0035] - [0039] -----	2,11,12, 15
A	EP 2 685 755 A1 (ALCATEL LUCENT [FR]) 15 January 2014 (2014-01-15) abstract ----- -/-	1-21



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

2 September 2014

Date of mailing of the international search report

10/09/2014

Name and mailing address of the ISA/

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Authorized officer

Mele, Marco

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2014/065324

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013/272151 A1 (THOMAS TIMOTHY A [US] ET AL) 17 October 2013 (2013-10-17) abstract -----	1-21

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2014/065324

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013308715 A1	21-11-2013	EP 2665203 A1	20-11-2013
		US 2013308715 A1	21-11-2013
		WO 2013172692 A1	21-11-2013

US 2014177745 A1	26-06-2014	US 2014177745 A1	26-06-2014
		WO 2014099341 A1	26-06-2014

EP 2685755 A1	15-01-2014	EP 2685755 A1	15-01-2014
		TW 201404194 A	16-01-2014
		WO 2014009036 A1	16-01-2014

US 2013272151 A1	17-10-2013	US 2013272151 A1	17-10-2013
		WO 2013144365 A1	03-10-2013
