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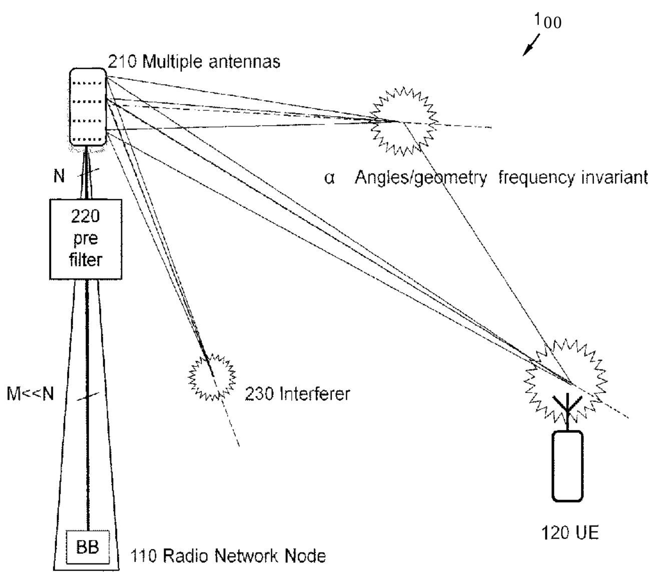

Fig. 2

(57) Abstract: Radio network node (110) and method (400) in a radio network node (110), for wireless communication with a UE (120) in a wireless communication system (100) in antenna streams. The radio network node (110) comprises a multiple antenna array (210) configured for beamforming, spatial multiplexing and MIMO transmission. The method (400) comprises receiving (401) wireless signals, spatial analysing (402) the received (401) signals, selecting (403) signals, based on the spatial analysis (402), determining (404) AoA for the selected (403) signals, determining (405) VRoA for the selected (403) signals, designing (406) a receiver pre-filter, for isolating signals received (401) from the determined (404, 405) AoA and VRoA, designing (407) a transmitter pre-filter, reciprocal to the designed (406) receiver pre-filter, transmitting (408) wireless signals, pre-filtered through the designed (407) transmitter pre-filter, in antenna streams in an AoD corresponding to the determined (404) AoA as the selected (403) signals.

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METHODS AND NODES IN A WIRELESS COMMUNICATION NETWORK

FIELD OF INVENTION

Implementations described herein relate generally to a radio network node and a method in a radio network node. In particular is herein described a mechanism for communicating wireless signals in antenna streams in a multiple antenna environment.

BACKGROUND OF INVENTION

A User Equipment (UE), also known as a mobile station, wireless terminal and/or mobile terminal is enabled to communicate wirelessly in a wireless communication network, sometimes also referred to as a cellular radio system. The communication may be made, e.g., between UEs, between a UE and a wire connected telephone and/or between a UE and a server via a Radio Access Network (RAN) and possibly one or more core networks.

The wireless communication may comprise various communication services such as voice, messaging, packet data, video, broadcast, etc.

The UE may further be referred to as mobile telephone, cellular telephone, computer tablet or laptop with wireless capability, etc. The UE in the present context may be, for example, portable, pocket-storable, hand-held, computer-comprised, or vehicle-mounted mobile devices, enabled to communicate voice and/or data, via the radio access network, with another entity, such as another UE or a server.

The wireless communication network covers a geographical area which is divided into cell areas, with each cell area being served by a radio network node, or base station, e.g., a Radio Base Station (RBS), which in some networks may be referred to as "eNB", "eNodeB", "NodeB" or "B node", depending on the technology and/ or terminology used.

Sometimes, the expression "cell" may be used for denoting the radio network node itself. However, the cell may also in normal terminology be used for the geographical area where radio coverage is provided by the radio network node at a base station site. One radio network node, situated on the base station site, may serve one or several cells. The radio network nodes may communicate over the air interface operating on radio frequencies with any UE within range of the respective radio network node.

In some radio access networks, several radio network nodes may be connected, e.g., by landlines or microwave, to a Radio Network Controller (RNC), e.g., in Universal Mobile Telecommunications System (UMTS). The RNC, also sometimes termed Base Station Controller (BSC), e.g., in GSM, may supervise and coordinate various activities of the plural radio network nodes connected thereto. GSM is an abbreviation for Global System for Mobile Communications (originally: Groupe Special Mobile).

In 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) radio network nodes, which may be referred to as eNodeBs or eNBs, may be connected to a gateway, e.g., a radio access gateway, to one or more core networks.

In the present context, the expressions downlink, downstream link or forward link may be used for the transmission path from the radio network node to the UE. The expression uplink, upstream link or reverse link may be used for the transmission path in the opposite direction, i.e., from the UE to the radio network node.

Beyond 3G mobile communication systems, such as e.g., 3GPP LTE, offer high data rate in the downlink by employing mult-iple antenna systems utilising Multiple-Input and Multiple-Output (MIMO) .

Massive MIMO is a new technology that uses large Antenna Arr-ays Systems (AAS) with individual transceivers to dramatically improve throughput of wireless communication systems. The benefit of these large arrays is the ability to spatially re-solve and separate received and transmitted signals with very high resolution.

The resolution is determined by the number of antenna ele-ments, and their spacing. Typically the number of transceivers may be as high as lOx the maximum rank of the system. The rank is defined as the total number of parallel (same time and fre-quency) transmissions, including both wanted and unwanted sig-nals (i.e. interference). Massive MIMO is sometimes loosely defined as a system using comprising 100 or more transceivers. Various investigations in this community have shown Massive MIMO systems that benefit from several hundred' s of transce-ivers .

In theory it may be enough having the same number of antennas as the rank in the massive MIMO system, if these antennas were ideally adapted/ designed for each specific scenario. In prac-tice this is impossible.

The physical number of antennas is typically lOx the number of spatial layers, which sometimes also may be referred to as ranks, or logical antennas. The complexity of baseband receive and transmit MIMO algorithms scales exponentially with number of antennas, leading to high requirements for computational ability, which may require additional dedicated hardware in form of very high capacity processing platforms. Further, computational complexity adds processing time, delaying the transmission/ reception, and consume power, leading to high energy costs and additional heating.

Further, prior art schemes are limited to Time Division Duplex (TDD), while it is desired to support also Frequency Division Duplex (FDD).

The main limiting factors of prior art massive MIMO comprises:

1. The overwhelming computational complexity.

2: Calibration requirements.

3: The Channel State Information (CSI). The latter in particular for downlink, where it is deemed not feasibility to have mobile terminals report channel measurements for base station antennas. Further, prior art schemes requires TDD to assess the downlink channel based on uplink measurements since the radio channel in TDD is reciprocal, i.e. the same in both uplink and downlink since they operate on the same frequencies.

It appears that massive MIMO requires further development for becoming feasible for practical implementation.

SUMMARY OF INVENTION

It is therefore an object to obviate at least some of the above mentioned disadvantages and to improve the performance in a wireless communication network.

According to a first aspect, the object is achieved by a method in a radio network node. The method is configured for wireless communication with a user equipment in a wireless communication system in antenna streams. The radio network node comprises a multiple antenna array configured for beam-forming, spatial multiplexing and MIMO transmission. The method comprises receiving wireless signals from the user equipment. Also, the method also comprises spatial analysing the received signals. Further, the method also comprises selecting signals, based on the spatial analysis. In further addition, the method moreover comprises determining angles of arrival for the selected signals. Additionally, the method further also comprises determining visibility range of arrival for the selected signals. The method moreover comprises designing a receiver pre-filter, for isolating signals received from the determined angles of arrival and visibility range of arrival. Also, the method in addition comprises designing a transmitter pre-filter, reciprocal to the designed receiver pre-filter. Finally the method additionally also comprises transmitting wireless signals, pre-filtered through the designed transmitter pre-filter, in antenna streams in an angle of departure corresponding to the determined angle of arrival as the selected signals, to be received by the user equipment.

According to a second aspect, the object is achieved by a radio network node configured for wireless communication with a user equipment in a wireless communication system in antenna streams. The radio network node comprises a multiple antenna array configured for beamforming, spatial multiplexing and MIMO transmission. The radio network node further comprises a receiver, configured for receiving wireless signals from the user equipment. Further, the radio network node also in addition comprises a processing circuit, configured for spatial analysis of the received signals. The processing circuit is also configured for selecting signals, based on the spatial analysis. In addition the processing circuit is configured also for determining angles of arrival for the selected signals. Furthermore, the processing circuit is in addition configured for determining visibility range of arrival for the selected signals. The processing circuit is moreover also configured for designing a receiver pre-filter, for isolating signals received from the determined angles of arrival and visibility range of arrival for the selected signals. Additionally, the processing circuit is also configured for designing a transmitter pre-filter, reciprocal to the designed receiver pre-filter. The radio network node also in addition comprises a transmitter, configured for transmitting wireless signals, pre-filtered through the designed transmitter pre-filter, in antenna streams in an angle of departure corresponding to the determined angle of arrival as the selected signals, to be received by the user equipment.

A general concept according to embodiments of the invention is the insight that large scale fading may be considered independent from the frequency of transmitted signals. A way of mapping the physical antennas into ideal logical antennas is presented in some embodiments. By adding an independent and seemingly transparent processing stage in the antenna array subsystem, it is possible to access ideal antennas, always adapted to match each instantaneous scenario. Thereby, complexity of baseband reception- and transmission MIMO algorithms is simplified, leading to less computation and also less downlink interference. Further, reuse of legacy systems, including both implementations and governing standards e.g. LTE is facilitated. Also, transmission in FDD is enabled in some embodiments .

Thereby an improved performance within the wireless communication network is provided.

Other objects, advantages and novel features of the embodiments of the invention will become apparent from the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention are described in more detail with reference to attached drawings illustrating examples of embodiments of the invention in which:

Figure 1 is a block diagram illustrating a wireless communication network according to some embodiments.

Figure 2 is a block diagram illustrating a wireless communication network according to some embodiments.

Figure 3A is a block diagram illustrating a radio network node architecture according to an embodiment.

Figure 3B is a block diagram illustrating a radio network node architecture according to an embodiment.

Figure 4 is a flow chart illustrating a method in a radio network node according to an embodiment of the invention.

Figure 5 is a block diagram illustrating a radio network node according to an embodiment of the invention.

DETAILED DESCRIPTION OF INVENTION

Embodiments of the invention described herein are defined as a radio network node and a method in a radio network node, which may be put into practice in the embodiments described below.

These embodiments may, however, be exemplified and realised in many different forms and are not to be considered as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete.

Still other objects and features may become apparent from the following detailed description considered in conjunction with the accompanying drawings. It is to be understood, however, that the drawings are designed solely for purposes of illustration and not as a definition of the limits of the herein disclosed embodiments, for which reference is to be made to the appended claims. Further, the drawings are not necessarily drawn to scale and, unless otherwise indicated, they are merely intended to conceptually illustrate the structures and procedures described herein.

Figure 1 is a schematic illustration over a wireless communication network **100** comprising a radio network node **110** and a User Equipment (UE) **120.**

The wireless communication network 100 may at least partly be based on radio access technologies such as, e.g., 3GPP LTE, LTE-Advanced, Evolved Universal Terrestrial Radio Access Network (E-UTRAN), Universal Mobile Telecommunications System (UMTS), Global System for Mobile Communications (originally: Groupe Special Mobile) (GSM)/ Enhanced Data rate for GSM Evolution (GSM/EDGE), Wideband Code Division Multiple Access (WCDMA), Time Division Multiple Access (TDMA) networks, Frequency Division Multiple Access (FDMA) networks, Orthogonal FDMA (OFDMA) networks, Single-Carrier FDMA (SC-FDMA) networks, Worldwide Interoperability for Microwave Access (WiMax), or Ultra Mobile Broadband (UMB), High Speed Packet Access (HSPA) Evolved Universal Terrestrial Radio Access (E-UTRA), Universal

Terrestrial Radio Access (UTRA), GSM EDGE Radio Access Network (GERAN), 3GPP2 CDMA technologies, e.g., CDMA2000 lx RTT and High Rate Packet Data (HRPD), just to mention some few options. The expressions "wireless communication network" and "wireless communication system" may within the technological context of this disclosure sometimes be utilised interchangeably.

The wireless communication network 100 may be configured to operate according to the Time Division Duplex (TDD) and/ or the Frequency Division Duplex (FDD) principle, according to different embodiments.

TDD is an application of time-division multiplexing to separate uplink and downlink signals in time, possibly with a Guard Period (GP) situated in the time domain between the uplink and downlink signalling. FDD means that the transmitter and receiver operate at different carrier frequencies.

Further, the wireless communication network 100 may be configured for massive MIMO and AAS, according to some embodiments.

The purpose of the illustration in Figure 1 is to provide a simplified, general overview of the wireless communication network 100 and the involved methods and nodes, such as the radio network node 110 and UE 120 herein described, and the functionalities involved. The methods, radio network node 110 and UE 120 will subsequently, as a non-limiting example, be described in a 3GPP LTE/ LTE-Advanced environment, but the embodiments of the disclosed methods, radio network node 110 and UE 120 may operate in a wireless communication network 100 based on another access technology such as, e.g., any of the above already enumerated. Thus, although the embodiments of the invention are described based on, and using the lingo of, 3GPP LTE systems, it is by no means limited to 3GPP LTE.

The illustrated wireless communication network 100 comprises the radio network node 110, which may send radio signals to be received by the UE 120.

It is to be noted that the illustrated network setting of one radio network node 110 and one UE 120 in Figure 1 is to be regarded as a non-limiting example of an embodiment only. The wireless communication network 100 may comprise any other number and/ or combination of radio network nodes 110 and/ or UEs 120. A plurality of UEs 120 and another configuration of radio network nodes 110 may thus be involved in some embodiments of the disclosed invention.

Thus whenever "one" or "a/ an" UE 120 and/ or radio network node 110 is referred to in the present context, a plurality of UEs 120 and/ or radio network nodes 110 may be involved, according to some embodiments.

The radio network node 110 may according to some embodiments be configured for downlink transmission and may be referred to, respectively, as e.g., a base station, NodeB, evolved Node Bs (eNB, or eNode B), base transceiver station, Access Point Base Station, base station router, Radio Base Station (RBS), micro base station, pico base station, femto base station, Home eNodeB, sensor, beacon device, relay node, repeater or any other network node configured for communication with the UE 120 over a wireless interface, depending, e.g., of the radio access technology and/ or terminology used.

The UE 120 may correspondingly be represented by, e.g. a wireless communication terminal, a mobile cellular phone, a Personal Digital Assistant (PDA), a wireless platform, a mobile station, a tablet computer, a portable communication device, a laptop, a computer, a wireless terminal acting as a relay, a relay node, a mobile relay, a Customer Premises Equipment

(CPE), a Fixed Wireless Access (FWA) nodes or any other kind of device configured to communicate wirelessly with the radio network node 110, according to different embodiments and different vocabulary.

In wireless communication between the radio network node 110 and the UE 120, in particular during communication in non-line of sight, scattering and fading may occur. Fading is deviation of the attenuation affecting the transmitted signal. The fading may vary with time, geographical position and/ or radio frequency.

Fading may be either due to multipath propagation, sometimes also referred to as multipath induced fading, or due to shadowing from obstacles affecting the wave propagation, sometimes referred to as shadow fading.

Further, the fading may be divided into large scale fading and small scale fading.

In large scale fading the amplitude and phase change imposed by the channel may be considered roughly constant over a period of time. In small scale fading, the amplitude and phase change imposed by the channel may vary considerably over the period of time.

A general concept according to embodiments of the invention is the insight that large scale fading may be considered independent from the frequency of transmitted signals. Thereby, thanks to reciprocity in the communication directions, the same large scale fading may be considered in the downlink, as has been measured in the uplink. Thereby, signals may be transmitted to the UE 120 in the downlink, in antenna streams in the same directions as signals has been received in the uplink. It is thereby possible to beam-form the transmitted signal, leading to less computations and also less downlink interference. This will be further discussed under the presentation of **Figure 2**.

Figure 2 discloses an embodiment of the wireless communication network 100 comprising a radio network node 110 and a UE 120. The radio network node 110 comprises, or is connected to, a multiple antenna array **210**; or antenna array as it also may be referred to as, which may be configured for massive MIMO. The multiple antenna array 210 comprises multiple antenna elements, such as e.g. 100 antenna elements, just to mention an example. The radio network node 110 further comprises a pre-filter **220**, for mapping some significant clusters of signals to logical antennas. The number of logical antennas may be smaller, or much smaller, than the number of antenna elements comprised in the multiple antenna array 210. Signals received in the uplink may be received from the UE 120, or from an interferer **230**. The interferer 230 may comprise another UE, or any other arbitrary device configured for transmission of wireless signals.

Signals received by the radio network node 110 in the uplink from the UE 120 and possibly from one or more interferers 230, are divided into clusters, which clusters are either generating or scattering wireless signals. According to the previously made discussion concerning large scale fading, the cluster location may be considered frequency and time invariant, when the cluster is not moving. When the cluster is moving, it may be considered stationary for at least one or some Transmission Time Intervals (TTIs), which may be approximately e.g. 1, 2, 10, 20, 40 or 80 ms according to different standards and/ or protocols; or some other similar time period comprising a subset, or multiple respectively, of any of the enumerated time periods.

As an illustrative example, it may be estimated that a UE 120, even when travelling at a rather speedy velocity of 300 m/s (1080 km/h) relative to the radio network node 110, moves approximately a modest 30 cm during one TTI (1 ms in LTE). The UE 120 may thereby be considered as stationary at least during that TTI, even when travelling at such rather extraordinary high velocity.

Beamforming and/ or spatial multiplexing may be based on orthogonal propagation paths between the radio network node 110 and the UE 120 through these detected and selected clusters, sometimes referred to as rank M of the link. The rank M may typically be smaller, or much smaller than the number of antenna elements N comprised in the multiple antenna array 210. The rank M may be e.g. approximately 8, 16 or similar. In some embodiments, the multiple antenna array 210 may comprise at least ten times more antenna elements N than the rank M of the system 100; i.e. may comprise e.g. 100 or more antenna elements in some embodiments. The clusters may carry any combination of desired signal and interference in some embodiments. Thus the rank M of the system 100 also may comprise interferers.

Some embodiments utilises the fact that the received signals on neighbouring elements of the multiple antenna array 210 are correlated. This correlation unveils the Angle of Arrival (AoA) of each individual propagation path arriving at the array. The AoA may sometimes be referred to as Direction of Arrival (DoA), or just "direction", of the received uplink signal.

AoA measurement is a method for determining the direction of propagation of a radio-frequency wave incident on the multiple antennas 210. AoA may be determined by measuring the Time Difference of Arrival (TDOA) at individual elements of the multiple antennas 210; and based on these delays the AoA may be calculated. Generally such TDOA measurement may comprise measuring the difference in received phase at each element in the multiple antenna array 210. This may be thought of as beamforming in reverse. In downlink beamforming, the signal from each element is delayed by some weight to steer the gain of the antenna array in relation to a particular UE 120. In AoA, the delay of arrival at each element may be measured directly and converted to an AoA measurement.

The number of propagation paths is related to the rank M of the system 100, while the angular resolution of the system 100 is defined by the number of antenna elements N, and their spacing. A spatial analysis and a selection of significant AoAs may be performed, i.e. angles with significant propagation paths, and a mapping of logical antennas to selected significant AoAs is established. As the AoAs essentially are constant in time and frequency as previously discussed, at least for a short period of time, the set of AoA may also be used for downlink Angle of Departures (AoD) in downlink transmission, in particular in FDD mode.

Further, in some embodiments, Visibility Range of Arrival (VRoA) may be determined. The Visibility Range of Arrival is a determination of which antenna elements in the multiple antenna array 210 that actually receives the uplink signal. Due to shading etc., the received signal may be received only on a subset of the antenna elements comprised in the multiple antenna array 210.

Thus, in some embodiments, the determined AoA and/ or VRoA differences may be utilised to separate incoming signals spatially.

Utilising VRoA enables an improved separation of uplink signals in comparison with only using AoA. However, another advantage is that transmission of downlink signals intended for the UE 120 could be inhibited. It may thereby be avoided that signals are transmitted in vain from antenna elements that are shaded for the UE 120, which saves energy and reduces downlink interference for other UEs within the cell.

The pre-filter design is intended to be reused for both uplink reception and downlink transmission, regardless if the directions are separated by time (TDD in TDMA), frequency (FDD in FDMA), code (CDMA) or space, as may be the case.

Figure 3A discloses an embodiment of spatial pre-filtering in the spatial pre-filter 220 in the radio network node 110, configured for wireless communication in FDD mode.

Signals are received from the UE 120 over the multiple antenna array 210. A Fast Fourier Transformation (FFT) may be made on the received signals.

The spatial pre-filtering may be regarded as a manipulation of the transmission channel. The channel may be regarded as a combination of the radio channel, antenna properties, transmitter properties (Analog and Digital) and the spatial pre-filter. Further, the pre-filter may be recalculated continuously, or at a predetermined time interval, such as e.g. every TTI, e.g. approximately every 1, 2, 10, 20, 40 or 80 ms, or some other similar time period.

The FFT may keep the processing complexity linear, i.e. to scale with the number of antenna elements N within the multiple antennas 210. The number N need not be a base 2 number according to some embodiments. Zero padding allows for using a larger transform. A slightly larger transform may make the spatial profile interpolated and may make subsequent processing more accurate, in analogy with a UMTS finger searcher, according to some embodiments.

Acquisition and discrimination of spatial profile may then be made. The acquisition may be blind, based on received signal, or based on a model such as a matched filter tuned for known reference signals according to different embodiments.

An advantage of using blind estimations/ statistics may be that any received signals may be utilised for the pre-filtering.

An advantage of using a matched filter tuned for known reference signals such as pilot signals is that interferers 230 may be filtered out, according to some embodiments. Thereby, an improved signal quality of the signal received in the uplink from the UE 120 may be achieved.

Explicit or implicit schedule information used for addressing of a pre-filter database, e.g. pairing received signal streams with transmitted signal streams. Further, a filtering may be made for filtering out weak signals. Thus received signals having a signal strength below a threshold value may be filtered out. The AoA of the remaining, selected signals may then be determined and a receiver pre-filter, for isolating signals received from the determined AoA, may be determined. The other signals/ AoAs may be discarded. Further, a number of M antenna streams may be mapped on Angles of Departure AoDs, possibly adjusted for FDD distance in some embodiments.

The rank M may be much smaller than the number of antenna elements N comprised among the multiple antennas 210 in some embodiments, and may be different per slot time, e.g. in a Time Division Multiple Access (TDMA) system.

Figure 3B discloses an embodiment of spatial pre-filtering in the spatial pre-filter 220 in the radio network node 110, configured for wireless communication in FDD mode and Frequency-Division Multiple Access (FDMA).

Signals are received from the UE 120 over the multiple antenna array 210. A Fast Fourier Transformation (FFT) may be made on the received signals. Cyclic Prefix (CP) may be removed in some embodiments. Acquisition and discrimination of spatial profile may then be made within scheduled FDMA frequencies. The acquisition may be blind, based on received signal, or based on a model such as a matched filter tuned for known reference signals according to different embodiments.

An advantage of using blind estimations/ statistics may be that any received signals may be utilised for the pre-filtering.

An advantage of using a matched filter tuned for known reference signals such as pilot signals is that interferers 230 may be filtered out.

Explicit or implicit schedule information used for addressing of a pre-filter database, e.g. pairing received signal streams with transmitted signal streams. Further, a filtering may be made for filtering out weak signals. Thus received signals having a signal strength below a threshold value may be filtered out. The AoA of the remaining, selected signals may then be determined and a receiver pre-filter, for isolating signals received from the determined AoA, may be determined. The other signals/ AoAs may be discarded. Further, a number of M antenna streams may be mapped on Angles of Departure AoDs, possibly adjusted for FDD distance in some embodiments.

The rank M may be much smaller than the number of antenna elements N comprised among the multiple antenna array 210 in some embodiments, and may be different per allocation, e.g. in a FDMA system.

Figure 4 is a flow chart illustrating embodiments of a method **400** in a radio network node 110, for wireless communication with a User Equipment (UE) 120 in a wireless communication system 100 in antenna streams. The radio network node 110 comprises, or is connected to; a multiple antenna array 210 configured for beamforming, spatial multiplexing and Multiple Input Multiple Output (MIMO) transmission. The multiple antenna array 210 comprises a multitude of antenna elements, such as e.g. 100 or more antenna elements. The wireless communication system 100 thus may be configured for massive MIMO, according to some embodiments. The multitude of antenna elements may in some embodiments be mounted at a distance from each other, within the multiple antenna array 210, such that some, several or even all of the antenna elements may be able to receive the same signal from the UE 120.

The wireless communication network 100 may be based on 3rd Generation Partnership Project Long Term Evolution (3GPP LTE). Further, the wireless communication system 100 may be based on FDD. The radio network node 110 may comprise an evolved NodeB (eNodeB) according to some embodiments.

To appropriately communicate in antenna streams with the UE 120, the method 400 may comprise a number of actions **401-408.**

It is however to be noted that any, some or all of the described actions 401-408, may be performed in a somewhat different chronological order than the enumeration indicates, be performed simultaneously or even be performed in reversed order. Further, it is to be noted that some actions may be performed in a plurality of alternative manners according to different embodiments. The method 400 may comprise the following actions:

Action 401

Wireless signals are received.

The wireless signals may be uplink signals, received directly from the UE 120, or may be received indirectly from the UE 120 via scattering reflections. Further, the received wireless signals may be received from interferers 230, i.e. other UEs within range, and/ or reflections from signals transmitted by other interferers 230/ UEs.

Action 402

The received 401 signals are spatially analysed.

The spatial analysis of the received 401 signals may comprise a comparison of the received signal strength/ quality with a predetermined threshold value, or a predetermined number of directions in some embodiments.

Action 403

Signals are selected, based on the spatial analysis 402.

According to some embodiments, the signals having a signal strength/ quality exceeding a predetermined threshold value may be selected.

Action 404

Angles of Arrival (AoAs) for the selected 403 signals are determined.

The AoAs may be determined by measuring the Time Difference of Arrival (TDOA) at individual antenna elements N of the multiple antenna array 210, according to some embodiments.

Action 405

Visibility Range of Arrival (VRoA) for the selected 403 signals is determined. Thereby it may be determined which antenna elements that are receiving the uplink signal.

According to some embodiments, it may be determined which antenna elements in the multiple antenna array 210, i.e. a subset of the multitude of antenna elements comprised in the multiple antenna array 210, that are receiving an uplink signal having a signal strength/ quality exceeding a predetermined threshold value.

Action 406

A receiver pre-filter is designed, for isolating signals received 401 on the determined 404, 405 AoA and VRoA.

The signals may be received from certain clusters, which are generating and/ or scattering wireless signals.

The design of the receiver pre-filter may be based on blind estimations and/ or statistics according to some embodiments.

However, the design of the receiver pre-filter may be model based, e.g. based on matched filter signal strength measurements on pilot signals received from the UE 120, in some embodiments .

Action 407

A transmitter pre-filter is designed, which is reciprocal to the designed 406 receiver pre-filter.

Thus an Angle of Departure (AoD) for signals to be transmitted may be determined, which AoD is corresponding to the previously determined AoA and/ or VRoA of the selected uplink signals. The AoD may thus comprise an approximately the same, or similar, angle as the previously determined AoA of the selected uplink signals, according to some embodiments, due to reciprocity .

Action 408

Wireless signals, which have been pre-filtered through the designed 407 transmitter pre-filter, are transmitted in antenna streams in an AoD corresponding to the determined 404 AoA as the selected 403 signals, to be received by the UE 120.

The wireless signals may be transmitted from the antenna elements determined by the VRoA.

The rank M of the transmission may be specified, known or determined and the number of antenna streams may be determined by the rank M of the transmission.

The spatial resolution of the transmission may according to some embodiments be known or determined and the number of physical antenna streams may be determined by the spatial resolution .

Figure 5 is a block diagram illustrating a radio network node 110 in a wireless communication network 100. The radio network node 110 is configured for performing the above mentioned method 400 according to any, some or all of the actions 401-408 for wireless communication with a UE 120 in a wireless communication system 100, in antenna streams.

The radio network node 110 comprises, or is connected to, a multiple antenna array 210 configured for beamforming, spatial multiplexing and MIMO transmission. The multiple antenna array 210 comprises a multitude of antenna elements, i.e. transceivers, such as e.g. 100 or more antenna elements. The wireless communication system 100 may be configured for massive MIMO, according to some embodiments. The multitude of antenna elements may in some embodiments be mounted at a distance from each other, within the multiple antenna array 210, such that some, several or even all of the antenna elements in the multiple antenna array 210 may be able to receive the same signal from the UE 120.

The wireless communication network 100 may be based on 3GPP LTE in some embodiments. Further, the wireless communication system 100 may be based on FDD. The radio network node 110 may comprise an eNodeB according to some embodiments.

For enhanced clarity, any internal electronics or other components of the radio network node 110, not entirely essential for understanding the herein described embodiments have been omitted from Figure 5.

The radio network node 110 comprises a receiver **510**, configured for receiving wireless signals. The signals may be received from the UE 120 directly or indirectly via scattering/ reflections on one or on a multitude of paths in different embodiments. Further, the signals may be received from interferers 230, i.e. other UEs.

Also, the radio network node 110 comprises a processing circuit **520.** The processing circuit 520 is configured for spatial analysis of the received signals. Further, the processing circuit 520 is also configured for selecting signals, based on the performed spatial analysis. In addition the processing circuit 520 is further configured for determining AoA and VRoA for the selected signals. Furthermore, the processing circuit

520 is configured in addition for designing a receiver pre-filter, for isolating signals received from the determined AoA and VRoA. The processing circuit 520 is further configured for designing a transmitter pre-filter, reciprocal to the designed receiver pre-filter.

The processing circuit 520 may comprise, e.g., one or more instances of a Central Processing Unit (CPU), a processing unit, a processing circuit, a processor, an Application Specific Integrated Circuit (ASIC), a microprocessor, or other processing logic that may interpret and execute instructions. The herein utilised expression "processing circuit" may thus represent a processing circuitry comprising a plurality of processing circuits, such as, e.g., any, some or all of the ones enumerated above.

The processing circuit 520 may further perform data processing functions for inputting, outputting, and processing of data comprising data buffering and device control functions, such as call processing control, user interface control, or the like.

Also, the radio network node 110 comprises a transmitter **530**, configured for transmitting signals, which have been pre-filtered through the designed transmitter pre-filter, in antenna streams in an AoD corresponding to the determined AoA as the selected signals, to be received by the UE 120.

The antenna elements comprised in the multiple antenna array 210 may be mounted at a distance from each other such that at least some, or all, of the multiple antenna array 210 may be able to receiving the same signal from the UE 120 in some embodiments.

Furthermore, the radio network node 110 may comprise at least one memory **525**, according to some embodiments. The memory 525 may comprise a physical device utilised to store data or programs, i.e., sequences of instructions, on a temporary or permanent basis. According to some embodiments, the memory 525 may comprise integrated circuits comprising silicon-based transistors. Further, the memory 525 may be volatile or non-volatile.

The previously described actions 401-408 to be performed in the radio network node 110 may be implemented through the one or more processing circuits 520 in the radio network node 110, together with computer program code for performing the functions of the actions 401-408. Thus a computer program product, comprising instructions for performing the actions 401-408 in the radio network node 110 may perform the method 400 for wireless communication with a UE 120 in a wireless communication system 100 in antenna streams, when the computer program product is loaded in a processing circuit 520 of the radio network node 110.

The computer program product mentioned above may be provided for instance in the form of a data carrier carrying computer program code for performing any, at least some, or all of the actions 401-408 according to some embodiments when being loaded into the processing circuit 520. The data carrier may be, e.g., a hard disk, a CD ROM disc, a memory stick, an optical storage device, a magnetic storage device or any other appropriate medium such as a disk or tape that may hold machine readable data in a non transitory manner. The computer program product may furthermore be provided as computer program code on a server and downloaded to the radio network node 110 remotely, e.g., over an Internet or an intranet connection.

The terminology used in the detailed description of the embodiments as illustrated in the accompanying drawings is not intended to be limiting of the described method 400 and/ or radio network node 110, which instead are limited by the enclosed claims.

As used herein, the term "and/ or" comprises any and all combinations of one or more of the associated listed items. In addition, the singular forms "a", "an" and "the" are to be interpreted as "at least one", thus also possibly comprising a plurality of entities of the same kind, unless expressly stated otherwise. It will be further understood that the terms "includes", "comprises", "including" and/ or "comprising", specifies the presence of stated features, actions, integers, steps, operations, elements, and/ or components, but do not preclude the presence or addition of one or more other features, actions, integers, steps, operations, elements, components, and/ or groups thereof.

CLAIMS

1. A method (400) in a radio network node (110), for wireless communication with a user equipment (120) in a wireless communication system (100) in antenna streams, which radio network node (110) comprises a multiple antenna array (210) configured for beamforming, spatial multiplexing and Multiple Input Multiple Output, MIMO, transmission, the method (400) comprising :

receiving (401) wireless signals from the user equipment (120);

spatial analysing (402) the received (401) signals;

selecting (403) signals, based on the spatial analysis (402) ;

determining (404) angles of arrival for the selected (403) signals;

designing (406) a receiver pre-filter, for isolating signals received (401) from the determined (404) angle of arrival ;

designing (407) a transmitter pre-filter, reciprocal to the designed (406) receiver pre-filter; and

transmitting (408) wireless signals, pre-filtered through the designed (407) transmitter pre-filter, in antenna streams in an angle of departure corresponding to the determined (404) angle of arrival as the selected (403) signals, to be received by the user equipment (120) .

2. The method (400) according to claim 1, further comprising :

determining (405) visibility range of arrival for the selected (403) signals; and wherein the design (406) of the receiver pre-filter is further made for isolating signals received (401) from the determined (405) visibility range of arrival.

3. The method (400) according to claim 1, wherein the spatial analysis (402) of the received (401) signals comprises a comparison of the received signal strength with a predetermined threshold value or a predetermined number of directions, and wherein the signals having a signal strength exceeding the predetermined threshold value are selected (403).

4. The method (400) according to claim 1, wherein the rank of the transmission is specified, known or determined and the number of antenna streams is determined by the rank of the transmission.

5. The method (400) according to claim 1, wherein the spatial resolution of the transmission is specified, known or determined and the number of physical antenna streams is determined by the spatial resolution.

6. The method (400) according to claim 1, wherein the design (406) of the receiver pre-filter is based on blind estimations and/ or statistics.

7. The method (400) according to claim 1, wherein the design (406) of the receiver pre-filter is model based, e.g. based on matched filter signal strength measurements on pilot signals received from the user equipment (120).

8. The method (400) according to claim 1, wherein the wireless communication system (100) is based on Frequency Division Duplex, FDD.

9. The method (400) according to claim 1, wherein the multiple antenna array (210) comprises a multitude of antenna elements, mounted at a distance from each other such that at least some of the antenna elements are able to receiving the same signal from the user equipment (120).

10. The method (400) according to claim 1, wherein the radio network node (110) comprises an evolved NodeB, eNodeB; and wherein the wireless communication network (100) is based on 3rd Generation Partnership Project Long Term Evolution, 3GPP LTE.

11. A radio network node (110) configured for wireless communication with a user equipment (120) in a wireless communication system (100) in antenna streams, which radio network node (110) comprises a multiple antenna array (210) configured for beamforming, spatial multiplexing and Multiple Input Multiple Output, MIMO, transmission, the radio network node (110) further comprising:

a receiver (510), configured for receiving wireless signals from the user equipment (120);

a processing circuit (520), configured for spatial analysis of the received signals, and also configured for selecting signals, based on the spatial analysis, and in addition configured for determining angles of arrival for the selected signals, and also configured for determining visibility range of arrival for the selected signals, and also configured for designing a receiver pre-filter, for isolating signals received from the determined angles of arrival and visibility range of arrival for the selected signals, and additionally also configured for designing a transmitter pre-filter, reciprocal to the designed receiver pre-filter; and a transmitter (530), configured for transmitting wireless signals, pre-filtered through the designed transmitter pre-filter, in antenna streams in an angle of departure corresp–onding to the determined angle of arrival as the selected sig-nals, to be received by the user equipment (120) .

12. The radio network node (110) according to claim 11, wherein the multiple antenna array (210) comprises a multitude of antenna elements mounted at a distance from each other such that at least some of the antenna elements are able to receiv-ing the same signal from the user equipment (120) .

13. A computer program product in a radio network node (110), according to claim 11, configured for performing the method (400) according to claim 1, for wireless communication with a user equipment (120) in a wireless communication system (100) in antenna streams, when the computer program product is load–ed in a processing circuit (520) of the radio network node (110) .

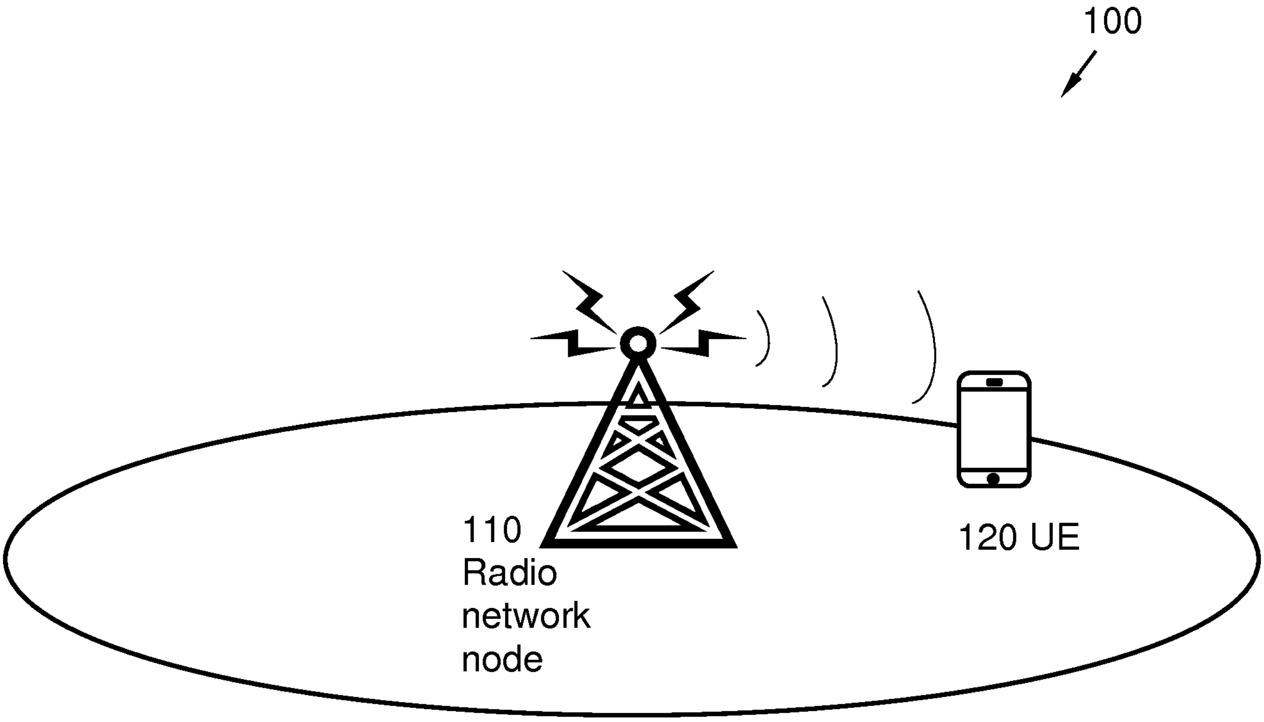

Fig. 1

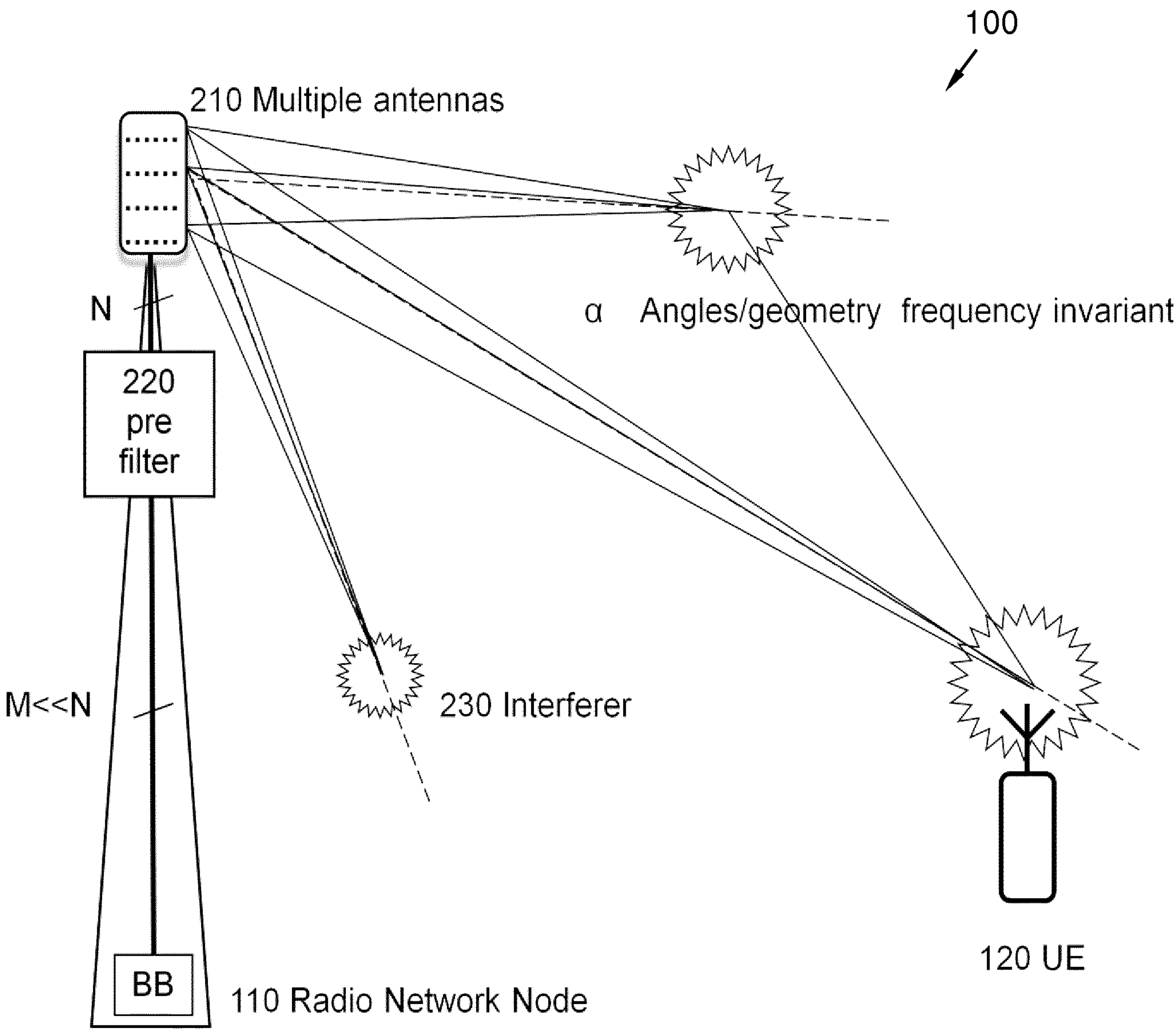
100
210 Multiple antennas
N
220
pre
filter
α Angles/geometry frequency invariant
M<<N
230 Interferer
BB
110 Radio Network Node
120 UE

Fig. 2

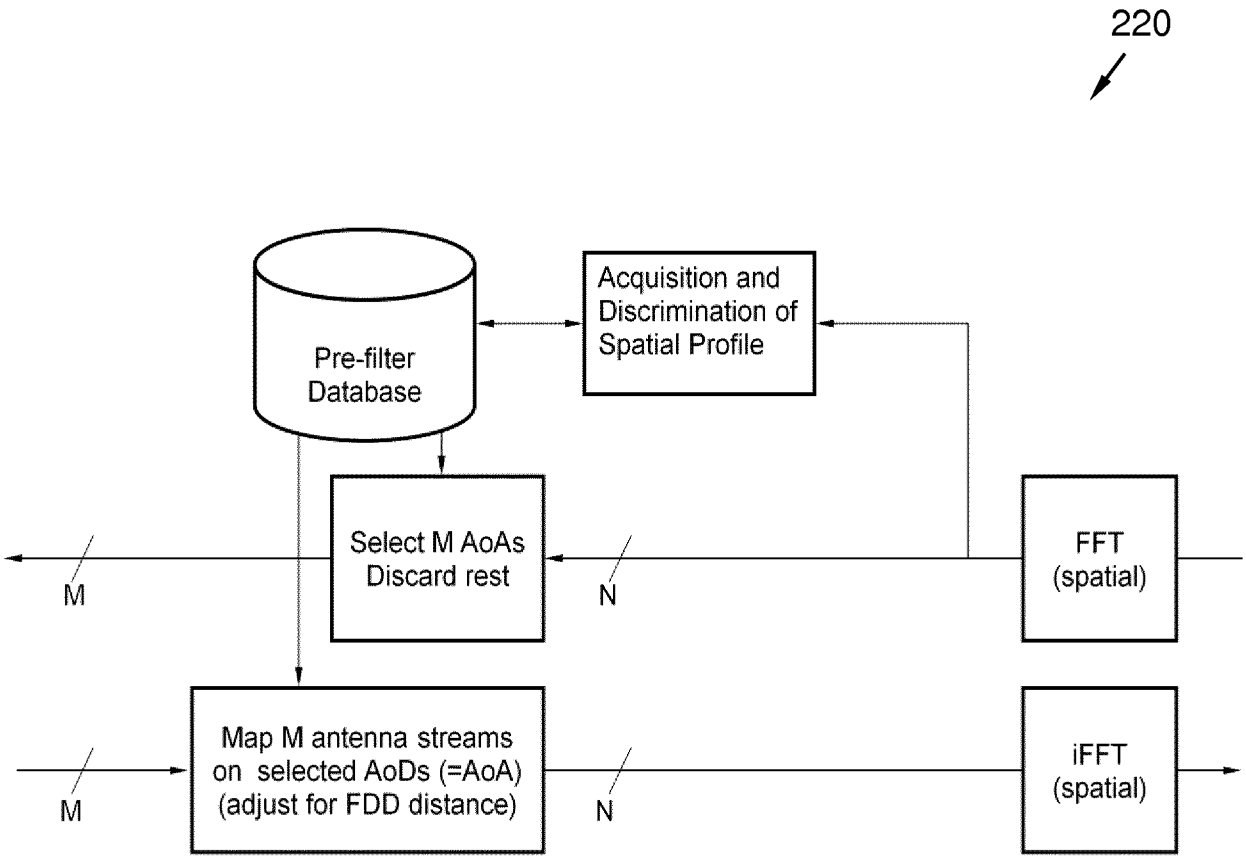
220
Pre-filter Database
Acquisition and Discrimination of Spatial Profile
Select M AoAs Discard rest
M
N
FFT (spatial)
Map M antenna streams on selected AoDs (=AoA) (adjust for FDD distance)
M
N
iFFT (spatial)

Fig. 3A

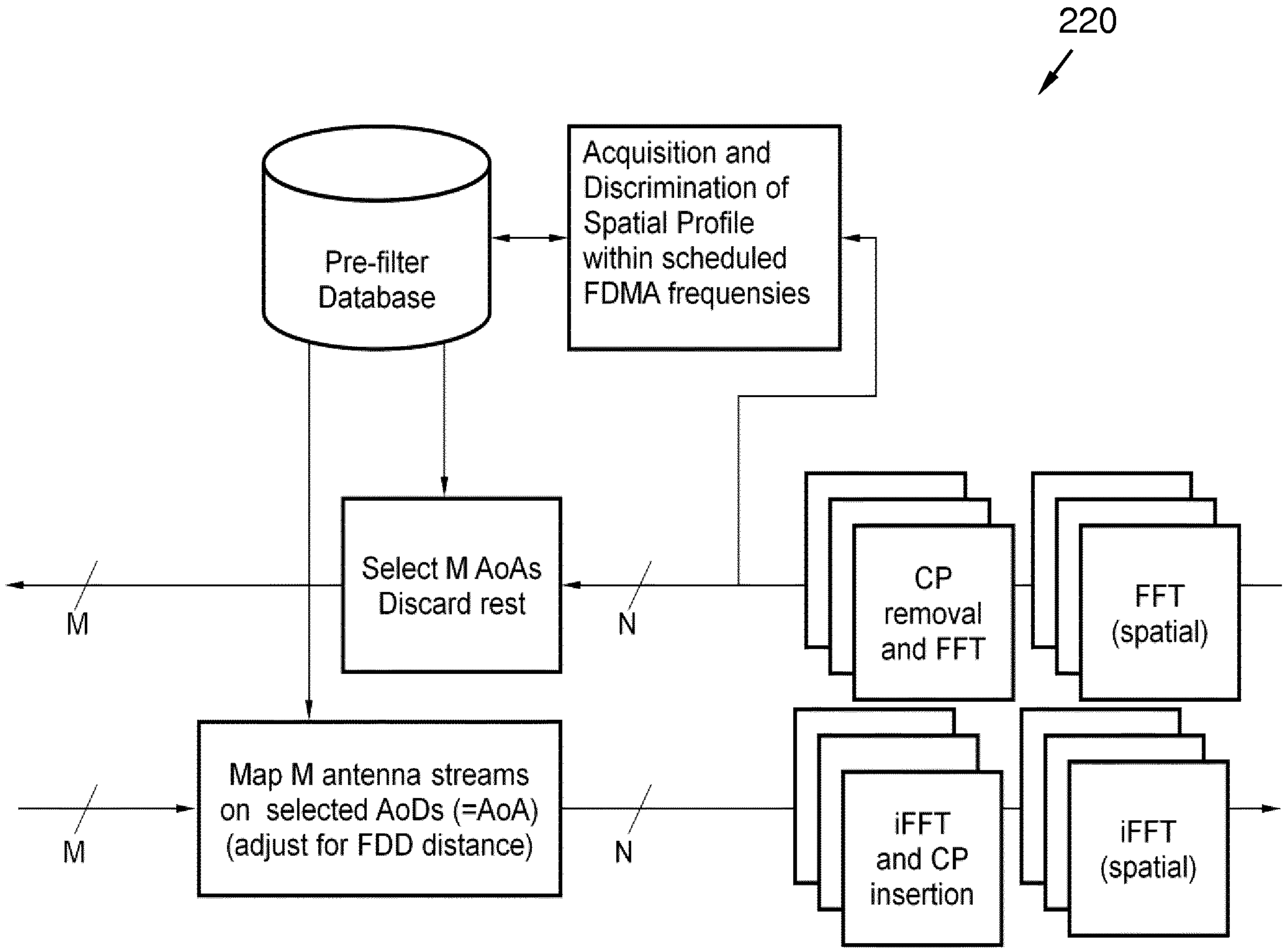
220
Pre-filter Database
Acquisition and Discrimination of Spatial Profile within scheduled FDMA frequensies
Select M AoAs Discard rest
M
N
CP removal and FFT
FFT (spatial)
Map M antenna streams on selected AoDs (=AoA) (adjust for FDD distance)
M
N
iFFT and CP insertion
iFFT (spatial)

Fig. 3B

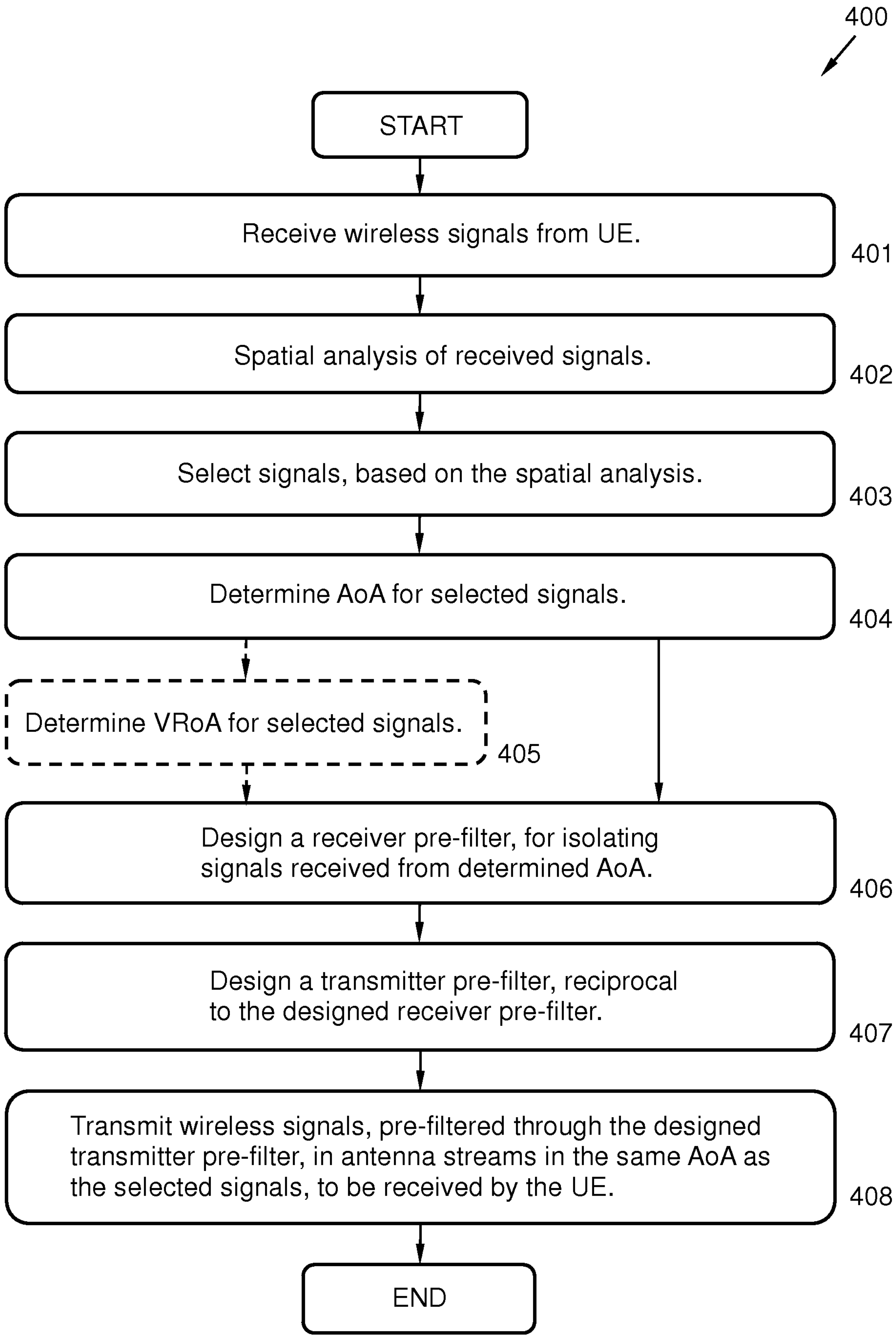
400
START
Receive wireless signals from UE.
401
Spatial analysis of received signals.
402
Select signals, based on the spatial analysis.
403
Determine AoA for selected signals.
404
Determine VRoA for selected signals.
405
Design a receiver pre-filter, for isolating signals received from determined AoA.
406
Design a transmitter pre-filter, reciprocal to the designed receiver pre-filter.
407
Transmit wireless signals, pre-filtered through the designed transmitter pre-filter, in antenna streams in the same AoA as the selected signals, to be received by the UE.
408
END

Fig. 4

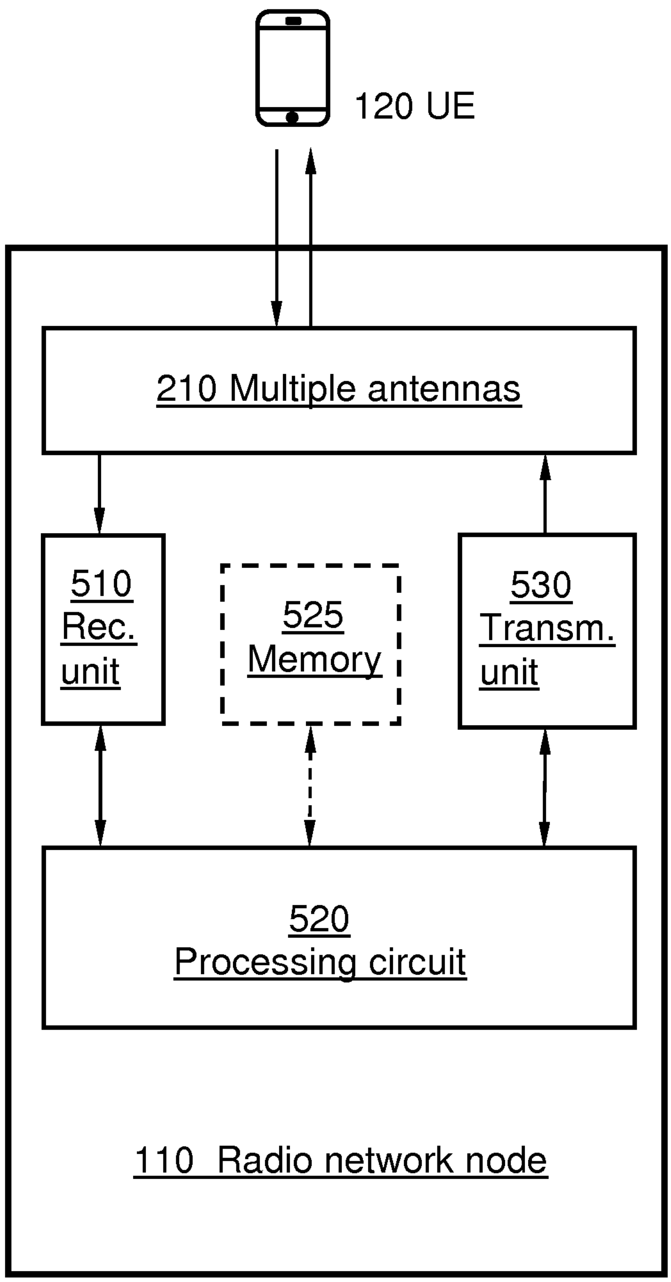
120 UE
210 Multiple antennas
510
Rec.
unit
525
Memory
530
Transm.
unit
520
Processing circuit
110 Radio network node

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/06Q294

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B7/Q6 H04B7/08
ADD.

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 091 788 A (KESKITALO ILKKA [FI] ET AL) 18 July 2000 (2000-07-18) abstract column 1, lines 12-47 column 2, lines 52-67 column 4, line 59 - column 15, line 54 figures l-6b -----	1-13
X	US 2011/013711 AI (WANG GENYUAN [US] ET AL) 20 January 2011 (2011-01-20) abstract paragraphs [0014], [0023] - [0029] figures 1, 4, 5 -----	1-13

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 January 2014	24/01/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Helms, Jochen

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/040337 Al (YLITALO JUHA [FI]) 27 February 2003 (2003-02-27) abstract paragraphs [0028] - [0045] figures 1-5 -----	1-13
A	US 2012/119953 Al (HOSOYA KENICHI [JP] ET AL) 17 May 2012 (2012-05-17) abstract paragraph [0112] figure 4 -----	1-13

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2013/06Q294

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