(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
10 December 2015 (10.12.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/187130 A1

(51) International Patent Classification: *H04B 7/26* (2006.01)

(21) International Application Number: PCT/US2014/040693

(22) International Filing Date: 3 June 2014 (03.06.2014)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: **HITACHI, LTD.** [JP/JP]; 6-6 Marunouchi 1-chome, Chiyoda-ku, Tokyo 100-8220 (JP).

(72) Inventors; and
(71) Applicants : **ACHARYA, Joydeep** [IN/US]; 718 Old San Francisco Rd., Apt 231, Sunnyvale, California 94086 (US). **AKOUM, Salam** [LB/US]; 20 Descanso Dr., Apt 1367, San Jose, California 95134 (US). **GAO, Long** [CN/US]; 4654 Alex Dr., San Jose, California 95130 (US).

(74) Agents: **HUANG, Ernest C.** et al.; c/o Procopio, Cory, Hargreaves & Savitch LLP, 525 B street, suite 2200, San Diego, California 92101 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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

Declarations under Rule 4.17:
— *of inventorship (Rule 4.17(iv))*

Published:
— *with international search report (Art. 21(3))*

(54) Title: ADAPTIVE ANTENNA RESPONSE AT THE UE FOR LTE-ADVANCED AND BEYOND

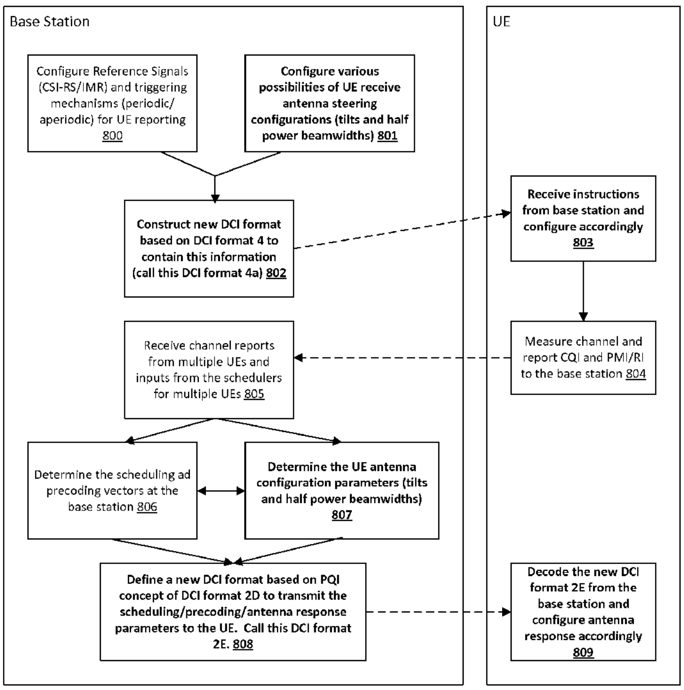


FIG. 8

(57) Abstract: Example implementations described herein are directed to systems and methods that utilize adaptive antenna arrays that include one or more antennas at the user equipment (UE) to dynamically steer the antenna response at the UE to improve system performance. The improvement is achievable in both downlink and uplink. The example implementations described herein also involve details of the associated signaling. The UE sends feedback measurement signals related to the position and orientation of the UE to the base station, wherein the base station calculates and provides antenna response parameters for the UE based on the received feedback.

WO 2015/187130 A1

ADAPTIVE ANTENNA RESPONSE AT THE UE FOR LTE-ADVANCED AND BEYOND

BACKGROUND

Field

[0001] The present disclosure relates generally to communication systems, and more specifically, to antenna responses for wireless systems.

Related art

[0002] FIG. 1 illustrates a related art configuration involving transmitter and receiver antenna responses for the downlink of wireless networks. For purposes of explanation, a channel with no fading has been shown. The orientation of the line of sight ray from the base station to the user equipment (UE) is given by azimuth angle φ and elevation angle Θ. The base station transmitter has a directional antenna which is characterized by the antenna response function ATX(φ,Θ). Through using sectorization, mechanical tilt, remote electrical tilt (RET) and more recently electrical tilt which is enabled by Active Antenna Systems (AAS) and Full Dimensional (FD) multiple input multiple output (MIMO), the base station antenna response ATX(φ,Θ) can be dynamically steered along the desired spatial direction.

[0003] The antenna response function at the UE side is configured to be isotropic or omnidirectional without the feature of dynamic steering. Thus in the related art $A_{UE}(\phi,\theta)=1$.

[0004] FIG. 2 illustrates a fading multipath channel. Instead of a single line of sight (LoS) ray as in the no-fading case depicted in FIG. 1, there are multiple rays. All of these rays depart from the transmitter and arrive at the receiver at angles that are distributed around the mean LoS angles φ and Θ. The extents of deviations from the mean angles are given by the angular spreads of the channel. For a channel with low/medium angular spread, the base station antenna response can be tilted by AAS and FD-MIMO to predominantly transmit/receive signals to/from an intended spatial direction.

[0005] FIG. 3 illustrates an instance of a MIMO channel where the transmitter and receiver are equipped with multiple antenna ports. The antenna responses at each transmit (receive) port can be modeled the same way. Further, there is an additional array factor which is given by the spacing and polarization of the antenna ports. The response of each antenna port depends on the type of antenna elements used and the number of antenna elements that form a port.

SUMMARY

[0006] For related art systems, there is no adaptation or steering of receiver side antenna responses. The concept of dynamic beamsteering at the UE side can be understood from the related art literature of analog beamsteering. The present disclosure is directed to methods to implement adaptive antenna response at receivers using Third Generation Partnership Project (3GPP) protocols and signaling.

[0007] The channel response between a transmitter and a receiver is proportional to the transmitter and receiver antenna responses. Related art efforts have focused on optimizing the antenna response functions at the base station using horizontal sectorization and more recently sectorized antennas with electrical downtilts and Active Antenna Systems (AAS). However the optimization of the antenna response function at the UE side has not been considered in commercial systems. The present disclosure addresses adapting or steering the antenna response function at the UE to improve the overall system performance.

[0008] Example implementations described herein utilize adaptive antenna arrays that include one or more antennas, at the UE to dynamically steer the antenna response at the UE to improve system performance. The improvement is achievable in both downlink and uplink. The example implementations described herein also involve details of the associated signaling.

[0009] Aspects of the present disclosure include a base station, which may involve a memory configured to manage one or more feedback measurements of an associated UE; and a processor, configured to calculate one or more directional antenna response parameters of the associated UE, based on the one or more feedback measurements in the memory, wherein the

one or more directional antenna response parameters are associated with a half power beam width (HPBW) and a tilt configuration of the associated UE; and transmit the calculated one or more antenna response parameters to the associated UE. The one or more feedback measurements may be associated with a position and orientation of the associated UE.

[0010] Aspects of the present disclosure include a computer program having instructions for executing a process. The instructions may involve managing one or more feedback measurements of an associated UE; calculating one or more directional antenna response parameters of the associated UE, based on the one or more feedback measurements, wherein the one or more directional antenna response parameters are associated with a half power beam width (HPBW) and a tilt configuration of the associated UE; and transmitting the calculated one or more antenna response parameters to the associated UE. The computer program may be stored on a non-transitory computer readable medium as described herein, wherein the instructions may be executed by a processor. The one or more feedback measurements may be associated with a position and orientation of the associated UE

[0011] Aspects of the present disclosure include a method, which may involve managing one or more feedback measurements of an associated UE; calculating one or more directional antenna response parameters of the associated UE, based on the one or more feedback measurements, wherein the one or more directional antenna response parameters are associated with a half power beam width (HPBW) and a tilt configuration of the associated UE; and transmitting the calculated one or more antenna response parameters to the associated UE. The one or more feedback measurements may be associated with a position and orientation of the associated UE

[0012] Aspects of the present disclosure include a user equipment (UE), which can involve one or more antennas, a memory configured to manage one or more feedback measurements of the UE; and a processor, configured to send the one or more feedback measurements of the UE to an associated base station, receive one or more directional antenna response parameters for the UE from the base station wherein the one or more directional antenna response parameters are associated with a half power beam width (HPBW) and a tilt configuration of the UE; and configure the one or more antennas based on the received one or more directional antenna response parameters. The one or more antenna response parameters may also be configured for a base station within a coordinated multipoint (CoMP) set, wherein the processor configures the one or more antennas based on the one or more antenna response parameters when the UE is associated with the base station within the CoMP set. The processor may also be configured to receive an instruction to change from a directional configuration to an isotropic configuration; and configure the one or more antennas based on the instruction. The instruction may be received during a measurement gap. The memory may also be configured to store one or more possible UE steering configurations, which the processor is configured to transmit to the base station. The feedback measurements may involve at least one of measurements associated with the position and orientation of the UE, such as downlink reference signals (DL-RS), uplink reference signals (UL-RS), and so forth. The DL-RS may also include position reference signals (PRS).

BRIEF DESCRIPTION OF DRAWINGS

[0013] .FIG. 1 illustrates a related art configuration of a base station and UE antennas for a cellular downlink.

[0014] FIG. 2 illustrates a related art example of a multipath channel.

[0015] FIG. 3 illustrates a related art example of a MIMO channel.

[0016] FIGS. 4A and 4B illustrate example details of the algorithm to adapt the UE antenna function for both the downlink and uplink, in accordance with an example implementation.

[0017] FIG. 5 illustrates received signal power characteristics at a UE with an initial isotropic pattern configuration, in accordance with an example implementation.

[0018] FIG. 6 illustrates received signal power at a UE with a directional pattern after base station instructed beamsteering, in accordance with an example implementation.

[0019] FIG. 7 illustrates an Enhanced UE Measurement Configuration Module for facilitating receive antenna beamsteering, in accordance with an example implementation.

[0020] FIG. 8 illustrates the flow diagram for the base station for implementing downlink CoMP when UE receiver antenna response is adapted, in accordance with an example implementation.

[0021] FIGS. 9A and 9B illustrates an example of how UE antenna response adaptation can be applied for coordinate scheduling/beamforming (CS/CB) CoMP, in accordance with an example implementation.

[0022] FIGS. 10A and 10B illustrate an example of how UE antenna response adaptation can be applied for dynamic point selection (DPS) CoMP, in accordance with an example implementation.

[0023] FIG. 11 illustrates a flow diagram for adapting the UE antenna response with the optimization conducted at the UE, in accordance with an example implementation.

[0024] FIG. 12 illustrates an example base station upon which example implementations can be implemented.

[0025] FIG. 13 illustrates an example user equipment upon which example implementations can be implemented.

DETAILED DESCRIPTION

[0026] The following detailed description provides further details of the figures and example implementations of the present application. Reference numerals and descriptions of redundant elements between figures are omitted for clarity. Terms used throughout the description are provided as examples and are not intended to be limiting. For example, the use of the term “automatic” may involve fully automatic or semi-automatic implementations involving user or administrator control over certain aspects of the implementation, depending on the desired implementation of one of ordinary skill in the art practicing implementations of the present application. The terms enhanced node B (eNodeB), small cell (SC), base station (BS) and pico cell may be utilized interchangeably throughout the example implementations. The terms traffic and data may also be utilized interchangeably throughout the example implementations. The implementations described herein are also not intended to be limiting, and can be implemented in various ways, depending on the desired implementation.

[0027] Example implementations involve methods for adapting the antenna response at the UE based on UE feedback and base station assistance. Example implementations may also involve methods for initial antenna response adaptation after UE association to base station, methods for the subsequent handover process which will be affected by the newly proposed UE antenna response adaptation, and methods for operating downlink base station coordination (CoMP) which will be affected by the UE antenna response adaptation.

[0028] Example implementations involve adaptive and dynamic antenna arrays at the UE. This can be achieved through exploiting AAS for FD-MIMO and elevation beamforming. FIGS. 4A and 4B illustrate example details of the algorithm to adapt the UE antenna function for both the downlink and uplink, in accordance with an example implementation. In particular, text indicated in bold is directed to example implementations for the new messaging scheme and adjustment of antenna response parameters of the UE.

[0029] When the UE powers on, the UE measures the various synchronization signals, such as the primary synchronization signals/secondary synchronization signals (PSS/SSS) that are transmitted by the base stations nearby as shown at 400. The UE associates itself with a base station (will be henceforth called as the serving base station) based on the signals measured from multiple base stations at 401. At this stage the UE downlink antenna pattern is isotropic as shown in FIG. 5 and the UE can capture power received from all spatial directions. As shown in FIG. 5, the UE antenna has the same gain for the serving base station and another base station which is not serving the UE (and hence is acting as an interfering base station for the downlink transmission) even through the two signals are coming from different spatial directions.

[0030] After association the base station transmits downlink reference symbols (DL-RS) such as position reference signals (PRS) at 402.

[0031] The UE decodes the DL-RS and makes measurements at 403. The UE then sends back the measurement report to the base station at 404, which is received by the base station at 405.

In this example, PRS measurements are transmitted, however, any UE feedback measurement signals may be transmitted to the base station that are associated with the position and orientation of the respective UE. For example, the UE may also transmit uplink reference symbols (UL-RS), and DL-RS measurements other than PRS.

[0032] Upon receiving the UL-RS and DL-RS decoded information from the UE, the base station combines this information with information of locations of other base stations in the vicinity at 406. This information can be obtained from X2 based information exchange. Note that these other base stations may be interfering base stations for the UE for the downlink communication. The serving base station builds up a spatial signal and interference map for the given UE.

[0033] The serving base station calculates the parameters of the UE antenna response at 407. For understanding of what parameters can be used, recall that the use of AAS at the UE side was implemented to enable adaptive antenna response steering. AAS has been used at base station side and form factor considerations have to be made when implementing it at the UE.

[0034] At 408, a new Radio Resource Control (RRC) message is configured to transmit the calculated optimized antenna response parameters to the UE. At 409, the UE receives the antenna response parameters from the base station and configures the antenna response accordingly.

[0035] The problem of packing antennas in a small form factor has been investigated in the related art, albeit not in the context of AAS at the UE. Depending on the operating frequency, and the type of antennas, and the type of antenna array configuration, more and more antennas can be packed on a mobile device while ensuring that the effect of mutual coupling and antenna correlation can be reduced through additional circuitry and signal processing.

[0036] Following the methods for AAS at the base station, allow a UE to be equipped with a 2D antenna grid array (e.g. a planar grid of antenna elements) that constitute an antenna port. The response of this antenna port can be made to steer in any direction by adjusting the parameters of the beamformer weighting matrix. For example, by using AAS and FD-MIMO the UE antenna response (in dB) can be modeled such that it is proportional to

$$A_{UE}(\phi,\theta) \propto \left(\frac{\phi-\phi_{scan}}{\phi_{3,dB}}\right)^2 + \left(\frac{\theta-\theta_{tilt}}{\theta_{3,dB}}\right)^2$$

[0037] The serving base station can optimize the parameters $\phi_{scan}, \phi_{3,dB}, \theta_{tilt}, \theta_{3,dB}$ and transmit the parameters to the UE. The parameters $\phi_{scan}, \theta_{tilt}$ decide the orientation or tilt of the receiver side antenna response while the parameters $\phi_{3,dB}, \theta_{3,dB}$ decide the half power beamwidths of the antenna responses. The antenna pattern and orientation at the UE has been limited in the related art (which by extension is reflects on the types of UE receivers commercially available at present) to considering either isotropic or omnidirectional antenna pattern at the UE. It has been shown that a dipole antenna structure at the UE (non-isotropic) provides an improvement in the average and cell edge throughput.

[0038] Note that separate optimizations can be done for the downlink receive UE antenna and the uplink transmit UE antenna. FIG. 4B illustrates a flow diagram that incorporates the separate optimizations, in accordance with an example implementation. The flow is the same as in FIG. 4A, except that at 404-1 the DL-RS measurements along with the UL-RS are transmitted to the base station. As described above, any UE feedback measurement signals may be transmitted to the base station that are associated with the position and orientation of the respective UE.

[0039] In an example implementation, the serving base station can decide that the downlink UE receive antenna should tilt in a direction towards the serving base station in order to maximize the received signal energy in the desired direction and reject interference energy which may be originating from another spatial direction. Similarly the uplink UE transmit antenna can be tilted towards the receiving base station, so as to maximize the received signal energy in the uplink. FIG. 6 graphically depicts the UE antenna response adaptation process, applied to the set-up of FIG. 5. Thus in the downlink the received energy from the interfering base station B is reduced. In both downlink and uplink the received signal energy is maximized.

[0040] In an example implementation, assume that the serving base station has determined that the angular spread of the channel is low (e.g., below a threshold). In that case, if the UE is pointing towards the base station, the base station may further choose the half power beamwidths to be narrower.

[0041] Changes to some of the Long Term Evolution (LTE) procedures and signal processing as a result of UE antenna response adaptation can be implemented. Consider that Radio Resource Monitoring/Radio Link Monitoring (RRM/RLM) measurements and handover will be affected by the UE antenna response adaptation. In LTE implementations, a UE continuously measures the channel of the serving base station and other base stations in the vicinity and reports the occurrence of various measurement events such as “neighbor cell becomes offset better than serving cell (measurement Event A3). This implies that the following event has taken place:

$$RSRP_{Serving\ Cell} + R_{Threshold} < RSRP_{Neighbor\ Cell}$$

[0042] This event may trigger a handover. Now consider the example given in FIG. 6, where the serving cell is A and the neighbor is B. After the UE has associated with the serving cell, when it measures Reference Signal Received Power (RSRP), the receiving antenna of the UE is pointed towards base station A. Thus the received RSRP from base station B is less than what would have been if there was an isotropic UE antenna configuration as in FIG. 5. While this configuration may be beneficial as long as base station B is emitting interference, the configuration can prove detrimental for RRM/RLM measurements. This is because the measured RSRP between UE and base station B, when the UE antenna is oriented towards base station A, is not the true indication of the received signal power had base station B been the serving base station. This is because if base station B were the serving base station, the UE would have changed the antenna orientation towards base station B and thus improved the received signal.

[0043] Thus the problem is to estimate the UE to base station B channel without receive antenna gain (without actually steering the UE antenna towards base station B). In example implementations, an enhanced UE measurement configuration module is provided that may be implemented at the base station side for measurement parameters of the UEs that are capable of receiver beamsteering. This is illustrated in FIG. 7, which illustrates an Enhanced UE Measurement Configuration Module 700, in accordance with an example implementation. The module 700 can involve the following two flows.

[0044] At 701, the threshold value $R_{Threshold}$ is set to a lower value than related art implementations which would increase the chance of handover for a lower value of $RSRP_{Neighbor\ Cell}$ than before. This is justified as after handover, UE beamsteering would boost up $RSRP_{Neighbor\ Cell}$.

[0045] LTE defines a measurement gap which is a period of time where the UE is not scheduled for UL or DL transmission/receptions and the UE can perform inter frequency RRM measurements. In example implementations and as shown at 702, the scope of the measurement gap can be increased to include the following aspects.

[0046] Application of the increased scope only to the UEs capable of receiver beamsteering and not to the legacy UEs. This example implementation can thereby maintain backward compatibility. In another example implementation, the UEs perform RRM/RLM measurements for both intra and inter frequency cells. The UEs can also change their antenna pattern to isotropic for purposes of the RRM/RLM measurements. Note that they still use the directional antenna pattern for data reception/channel quality indicator (CQI) reporting, and other functions. In this manner, the UE can measure the channel strengths without introducing the bias due to the directional antenna response adaptation (i.e. without the antenna gain at the receiver). Thus, the UE can change from an isotropic configuration to a directional configuration and vice versa according to the desired implementation.

[0047] In example implementations, downlink base station coordination (CoMP) may be affected from the implementations of the UE antenna response, thus additional methods may be utilized to implement downlink CoMP with LTE signaling. If the UE is capable of steering the antenna response towards increasing the desired received signal strength and minimizing interference, then the performance of base station coordination where one base station is serving one or more UEs and coordinating with other base stations to mitigate interference (coordinated scheduling/coordinated beamforming, dynamic point scheduling (DPS), etc.) can be improved.

[0048] FIG. 8 illustrates the flow diagram for the base station for implementing downlink CoMP when UE receiver antenna response is adapted, in accordance with an example implementation. In particular, text indicated in bold is directed to example implementations that may involve additional schemes for the implementation of downlink CoMP for UE receiver antenna response.

[0049] As before the serving base station configures the various parameters for UE feedback. Parameters are defined such as configuration of reference symbols such as CSI-RS and interference measurement (IMR) which are used to measure the channel and interference respectively at 800. The base station configures the UE to report difference combinations of signal and interference hypotheses. To facilitate the UE receiver antenna response, the base station also configures the UE to a set of antenna response parameters (such as tilt and half power beamwidths) at 801.

[0050] Thus the base station defines new feedback hypotheses which are a combination of signal + interference + UE antenna response parameters (instead of only signal + interference as in the related art). To convey this to the UE for aperiodic feedback trigger, the base station defines a new downlink control information (DCI) format based on DCI format 4, which is denoted as DCI format 4a for FIG. 8, as shown at 802.

[0051] At 803, the UE receives these new feedback hypotheses by decoding DCI format 4a. At 804, the UE performs channel estimation based on the configured hypotheses and feeds back the channel state information parameters (such as CQI and Pre-coding matrix indicator/Rank Indicator (PMI/RI)) to the base station as shown at 805.

[0052] Based on the UE feedback the base station determines the various transmission parameters of the UE for subsequent downlink transmission. In the related art, the base station had to choose the scheduling assignment and transmit precoders as shown at 806. However in example implementations, the base station also has to decide the antenna response parameters (such as tilt and half power beamwidths) as shown at 807.

[0053] The base station includes the information from 806 and 807 in a new DCI format which is based on the Physical downlink shared channel rate matching and Quasi colocation Indicator (PQI) bits of DCI format 2D. In example implementations, the PQI bits will also carry information about the antenna response parameters. Since the total amount of possible information hypotheses to convey is more than what was conveyed in DCI format 2D (since it did not convey antenna response parameter information), example implementations incorporate more bits than the two used in DCI format 2D. Thus, example implementations may utilize a new DCI format, which is deonted as DCI format 2E. Note that this format does not have to be a simple PQI bit extension over DCI format 2D, but could also be implemented as a new and more intelligent representation of information.

[0054] The UE decodes DCI format 2E and thereby knows how to decode the received CoMP signal as shown at 809.

[0055] FIGS. 9A and 9B illustrate an example of how UE antenna response adaptation can be applied for coordinate scheduling/beamforming (CS/CB) CoMP, in accordance with an example implementation. In particular, FIG. 9A illustrates an example of CS/CB without UE antenna response adaptation, and FIG. 9B illustrates an example of CS/CB with UE antenna response adaptation. In the related art, base stations A and B schedule their UEs simultaneously in CS/CB and interference is managed by choosing the precoders or the UEs in a coordinated way. In example implementations of the present disclosure, base stations A and B also coordinate to decide the antenna response parameters (tilt and beamwidths) of the two UEs together.

[0056] FIGS. 10A and 10B illustrate an example of how UE antenna response adaptation can be applied for dynamic point selection (DPS) CoMP, in accordance with an example implementation. In particular, FIG. 10A illustrates DPS without UE antenna response adaptation, and FIG. 10B illustrates DPS with UE antenna response adaptation. At a given time instant ‘t’ the UE may be scheduled by base station A and in the next instant by a different base station B. In the related art, the antenna response of the UE is isotropic at both time instants. However in example implementations, the parameters of the antenna response (tilt and beamwidths) can be adapted as the serving base station changes from base station A to base station B.

[0057] FIG. 11 illustrates a flow diagram for adapting the UE antenna response with the optimization conducted at the UE, in accordance with an example implementation. The flow diagram of FIG. 11 illustrates another example implementation of the algorithm that had previously been shown in FIG. 4. In contrast to FIG. 4, the antenna parameter optimization is present in the UE. In this example implementation, since the UE has full channel information and the base station only has quantized information, the UE may be able to perform the optimization better than the base station. The flows of 407 and 408 of FIG. 4A are implemented at the UE as shown at the flows at 1104 and 1105, respectively in FIG. 11, whereupon the UE can utilize the optimize antenna response parameters according to the desired implementation. At 1106, the base station can receive the antenna response information from the UE and store the information in memory for future transmissions.

[0058] In the example implementations above, variations in the antenna pattern parameters can be stored as management information in the memory of either the base station or the UE, along with possible steering configurations of the UE. For example, Table I shows possible variations in the antenna pattern parameters of a UE as a result of the example implementations, in which the parameters may change based on the situation in time (e.g., measurement gap, handover, etc.).

Time	**Event**	ϕ_{scan}	$\phi_{3,dB}$	θ_{tilt}	$\theta_{3,dB}$	**Explanation**
T0 – T10	Initial Association	0	360	0	360	Isotropic pattern initially
T10-T100	Association with BS A and data from BS	30	70	102	45	Aligned towards spatial direction of BS A

	A					
T100-T140	Association with BS A and data from CoMP BS B by DPS CoMP	45	55	96	45	Aligned towards spatial direction of BS B while still associated with BS A
T140-T150	Measurement gap	0	360	0	360	Isotropic pattern
T150-T250	Handover and Association with BS B	55	55	92	45	Aligned towards spatial direction of BS B

Table I: Time Evolution of UE antenna parameters

[0059] FIG. 12 illustrates an example base station upon which example implementations can be implemented. The block diagram of a base station 1200 in the example implementations is shown in FIG. 12, which could be a macro base station, a pico base station, an enhanced node B and so forth. The base station 1200 may include the following modules: the Central Processing Unit (CPU) 1201, the baseband processor 1202, the transmission/receiving (Tx/Rx) array 1203, the X2/Xn interface 1204, and the memory 1205. The CPU 1201 is configured to execute one or more modules or flows as described, for example, in FIGS. 4A, 4B, 7 and 11. The baseband processor 1202 generates baseband signaling including the reference signal and the system information such as the cell-ID information. The Tx/Rx array 1203 contains an array of antennas which are configured to facilitate communications with associated UEs. The antennas may be grouped arbitrarily to form one or more active antenna ports. Associated UEs may communicate with the Tx/Rx array to transmit UE feedback measurements associated with the position and orientation of the UE as described with respect to FIGS. 4A and 4B, antenna response information, handover information when the UE is switching to a different base station in the CoMP set, and so forth. The X2/Xn interface 1204 is used to exchange traffic and interference information between one or more base stations via a backhaul to transmit instructions for antenna steering configurations, configuration parameters, scheduling information and so forth to and from other base stations within the CoMP set, which can be in the formats as described above. The memory 1205 can be configured to store and manage the UE feedback measurements of the associated UE and other management information, such as the information described in Table I above. Memory 1205 may take the form of a computer readable storage medium or can be replaced with a computer readable signal medium as described below.

[0060] FIG. 13 illustrates an example user equipment upon which example implementations can be implemented. The UE 1300 may involve the following modules: the CPU module 1301, the Tx/Rx array 1302, the baseband processor 1303, and the memory 1304. The CPU module 1301 can be configured to perform one or more functions, such as execution of the flows as described, for example, in FIGS. 4A, 4B, 7 and 11. The Tx/RX array 1302 may be implemented as an array of one or more antennas and can be configured to be in an isotropic or directional configuration based on the antenna response parameters as described above. The memory 1304 can be configured to store possible steering configurations for the UE as well as the antenna response parameters for the serving base station as well as one or more base stations in a CoMP set. The baseband digital signal processing (DSP) module can be configured to perform one or more functions, such as to conduct measurements to generate the feedback measurements associated with the position and orientation of the UE for the serving base station to estimate the location of the UE as described with respect to FIGS. 4A and 4B. The memory 1304 can be configured to store the most recent channel estimate.

[0061] Some portions of the detailed description are presented in terms of algorithms and symbolic representations of operations within a computer. These algorithmic descriptions and symbolic representations are the means used by those skilled in the data processing arts to most effectively convey the essence of their innovations to others skilled in the art. An algorithm is a series of defined steps leading to a desired end state or result. In example implementations, the steps carried out require physical manipulations of tangible quantities for achieving a tangible result.

[0062] Unless specifically stated otherwise, as apparent from the discussion, it is appreciated that throughout the description, discussions utilizing terms such as “processing,” “computing,” “calculating,” “determining,” “displaying,” or the like, can include the actions and processes of a computer system or other information processing device that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system's memories or registers or other information storage, transmission or display devices.

[0063] Example implementations may also relate to an apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may include one or more general-purpose computers selectively activated or reconfigured by one or more computer programs. Such computer programs may be stored in a computer-readable medium, such as a non-transitory medium or a storage medium, or a computer-readable signal medium. Non-transitory media or non-transitory computer-readable media can be tangible media such as, but are not limited to, optical disks, magnetic disks, read-only memories, random access memories, solid state devices and drives, or any other types of tangible media suitable for storing electronic information. A computer readable signal medium may any transitory medium, such as carrier waves. The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Computer programs can involve pure software implementations that involve instructions that perform the operations of the desired implementation.

[0064] Various general-purpose systems and devices and/or particular/specialized systems and devices may be used with programs and modules in accordance with the examples herein, or it may prove convenient to construct a more specialized apparatus to perform desired method steps. In addition, the example implementations are not described with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of the example implementations as described herein. The instructions of the programming language(s) may be executed by one or more processing devices, e.g., central processing units (CPUs), processors, or controllers.

[0065] As is known in the art, the operations described above can be performed by hardware, software, or some combination of software and hardware. Various aspects of the example implementations may be implemented using circuits and logic devices (hardware), while other aspects may be implemented using instructions stored on a machine-readable medium (software), which if executed by a processor, would cause the processor to perform a method to carry out implementations of the present application. Further, some example implementations of the present application may be performed solely in hardware, whereas other example implementations may be performed solely in software. Moreover, the various functions described can be performed in a single unit, or can be spread across a number of components in any number of ways. When performed by software, the methods may be executed by a processor, such as a general purpose computer, based on instructions stored on a computer-readable medium. If desired, the instructions can be stored on the medium in a compressed and/or encrypted format.

[0066] Moreover, other implementations of the present application will be apparent to those skilled in the art from consideration of the specification and practice of the teachings of the present application. Various aspects and/or components of the described example implementations may be used singly or in any combination. It is intended that the specification and example implementations be considered as examples only, with the true scope and spirit of the present application being indicated by the following claims.

CLAIMS

What is claimed is:

1. A base station, comprising:

a memory configured to manage one or more feedback measurements of an associated user equipment (UE), the one or more feedback measurements associated with a position and orientation of the associated UE; and

a processor, configured to:

calculate one or more directional antenna response parameters of the associated UE, based on the one or more feedback measurements in the memory, wherein the one or more directional antenna response parameters are associated with a half power beam width (HPBW) and a tilt configuration of the associated UE; and

transmit the calculated one or more antenna response parameters to the associated UE.

2. The base station of claim 1, wherein the processor is configured to:

calculate the one or more antenna response parameters for the associated UE receiving from each base station in a coordinated multipoint (CoMP) set that serves the associated UE; and

transmit the calculated one or more antenna response parameters to the associated UE when the associated UE is receiving from at least one of the each base station in the CoMP set.

3. The base station of claim 1, wherein the processor is configured to:

send an instruction to the associated UE to change from a directional configuration to an isotropic configuration; and calculate handover measurements while the associated UE is configured in the isotropic configuration.

4. The base station of claim 3, wherein the base station is configured to send the instruction to the associated UE during a measurement gap.

5. The base station of claim 1, wherein the memory is configured to store one or more possible UE steering configurations for the associated UE, and wherein the processor is configured to calculate the one or more directional antenna response parameters of the associated UE based on the possible UE steering configurations.

6. A computer program having instructions for executing a process, the instructions comprising:

managing one or more feedback measurements of an associated user equipment (UE), the one or more feedback measurements associated with a position and orientation of the associated UE;

calculating one or more directional antenna response parameters of the associated UE, based on the one or more feedback measurements, wherein the one or more directional antenna response parameters are associated with a half power beam width (HPBW) and a tilt configuration of the associated UE; and

transmitting the calculated one or more antenna response parameters to the associated UE.

7. The computer program of claim 6, wherein the instructions comprise:

calculating the one or more antenna response parameters for the associated UE receiving from each base station in a coordinated multipoint (CoMP) set that serves the associated UE; and

transmitting the calculated one or more antenna response parameters to the associated UE when the associated UE is receiving from at least one of the each base station in the CoMP set.

8. The computer program of claim 6, wherein the instructions comprise:

sending an instruction to the associated UE to change from a directional configuration to an isotropic configuration; and

calculating handover measurements while the associated UE is configured in the isotropic configuration.

9. The computer program of claim 8, wherein the instructions comprise sending the instruction to the associated UE during a measurement gap.

10. The computer program of claim 6, wherein the instructions comprise managing one or more possible UE steering configurations for the associated UE, and calculating the one or more directional antenna response parameters of the associated UE based on the possible UE steering configurations.

11. A method, comprising:

managing one or more feedback measurements of an associated user equipment (UE), the one or more feedback measurements associated with a position and orientation of the associated UE;

calculating one or more directional antenna response parameters of the associated UE, based on the one or more feedback measurements, wherein the one or more directional antenna response parameters are associated with a half power beam width (HPBW) and a tilt configuration of the associated UE; and

transmitting the calculated one or more antenna response parameters to the associated UE.

12. The method of claim 11, further comprising:

calculating the one or more antenna response parameters for the associated UE receiving from each base station in a coordinated multipoint (CoMP) set that serves the associated UE; and transmitting the calculated one or more antenna response parameters to the associated UE when the associated UE is receiving from at least one of the each base station in the CoMP set.

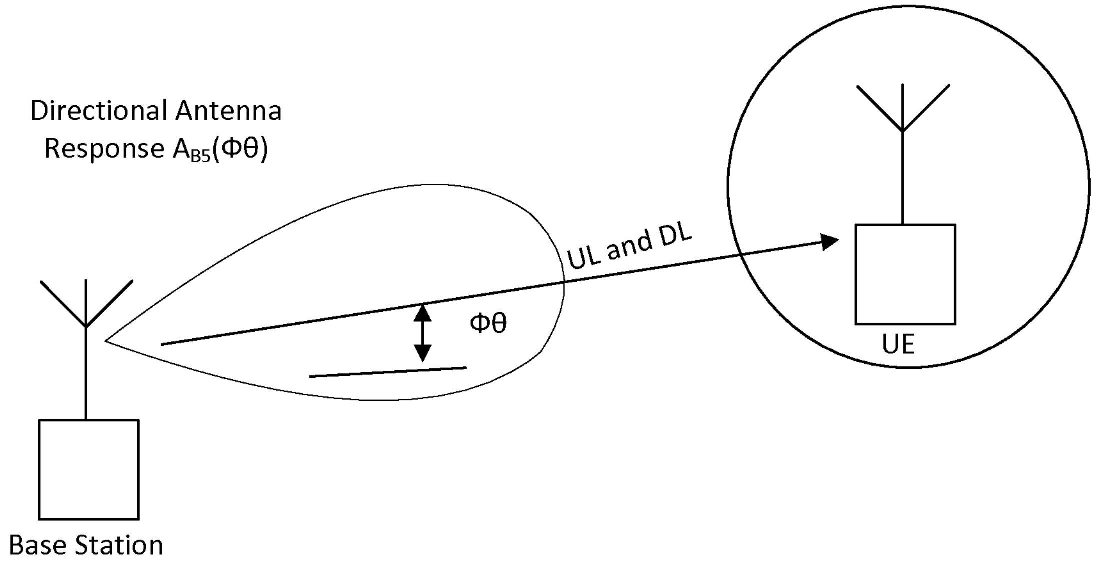
13. The method of claim 11, further comprising:

sending an instruction to the associated UE to change from a directional configuration to an isotropic configuration; and

calculating handover measurements while the associated UE is configured in the isotropic configuration.

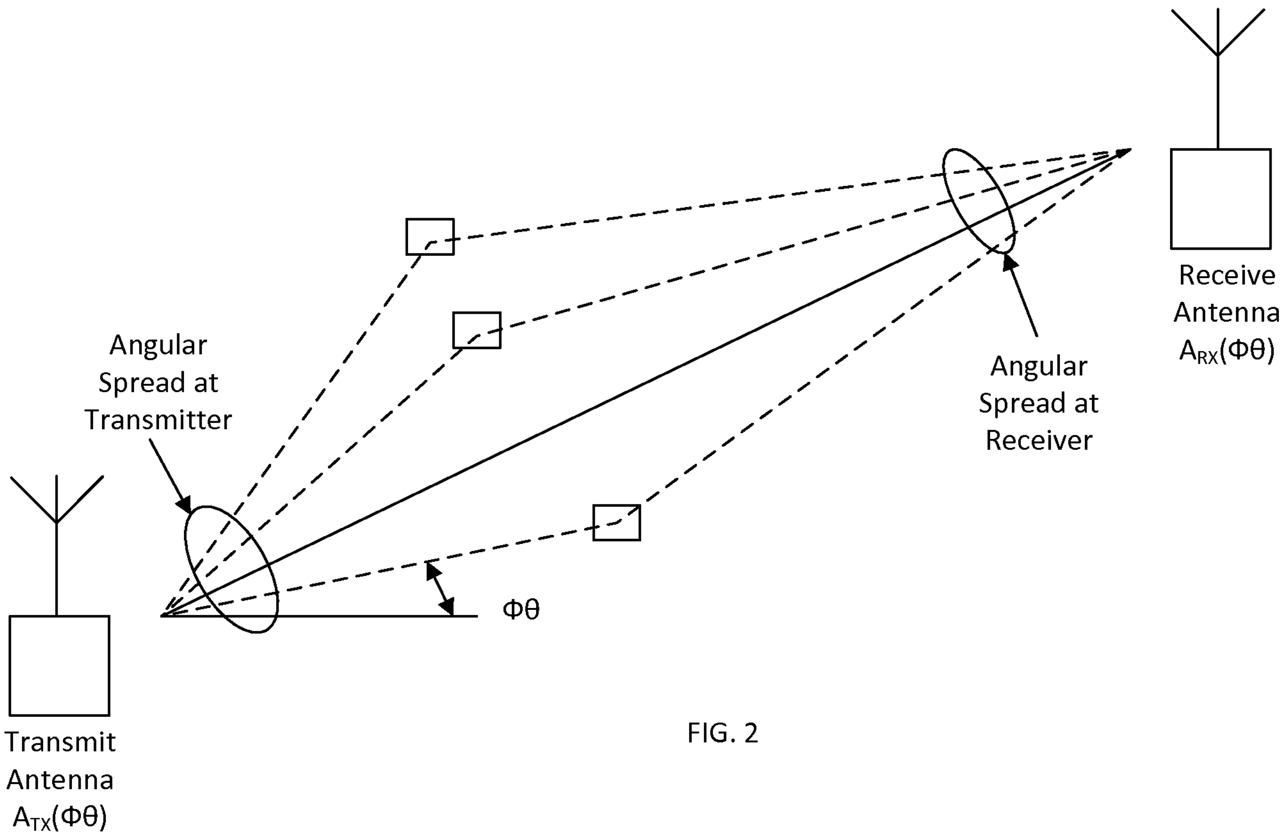
14. The method of claim 13, further comprising sending the instruction to the associated UE during a measurement gap.

15. The method of claim 11, further comprising managing one or more possible UE steering configurations for the associated UE, and calculating the one or more directional antenna response parameters of the associated UE based on the possible UE steering configurations.



Directional Antenna
Response $A_{B5}(\Phi\theta)$
UL and DL
$\Phi\theta$
UE
Base Station

FIG. 1



Angular
Spread at
Transmitter
Angular
Spread at
Receiver
Receive
Antenna
$A_{RX}(\Phi\theta)$
$\Phi\theta$
Transmit
Antenna
$A_{TX}(\Phi\theta)$

FIG. 2

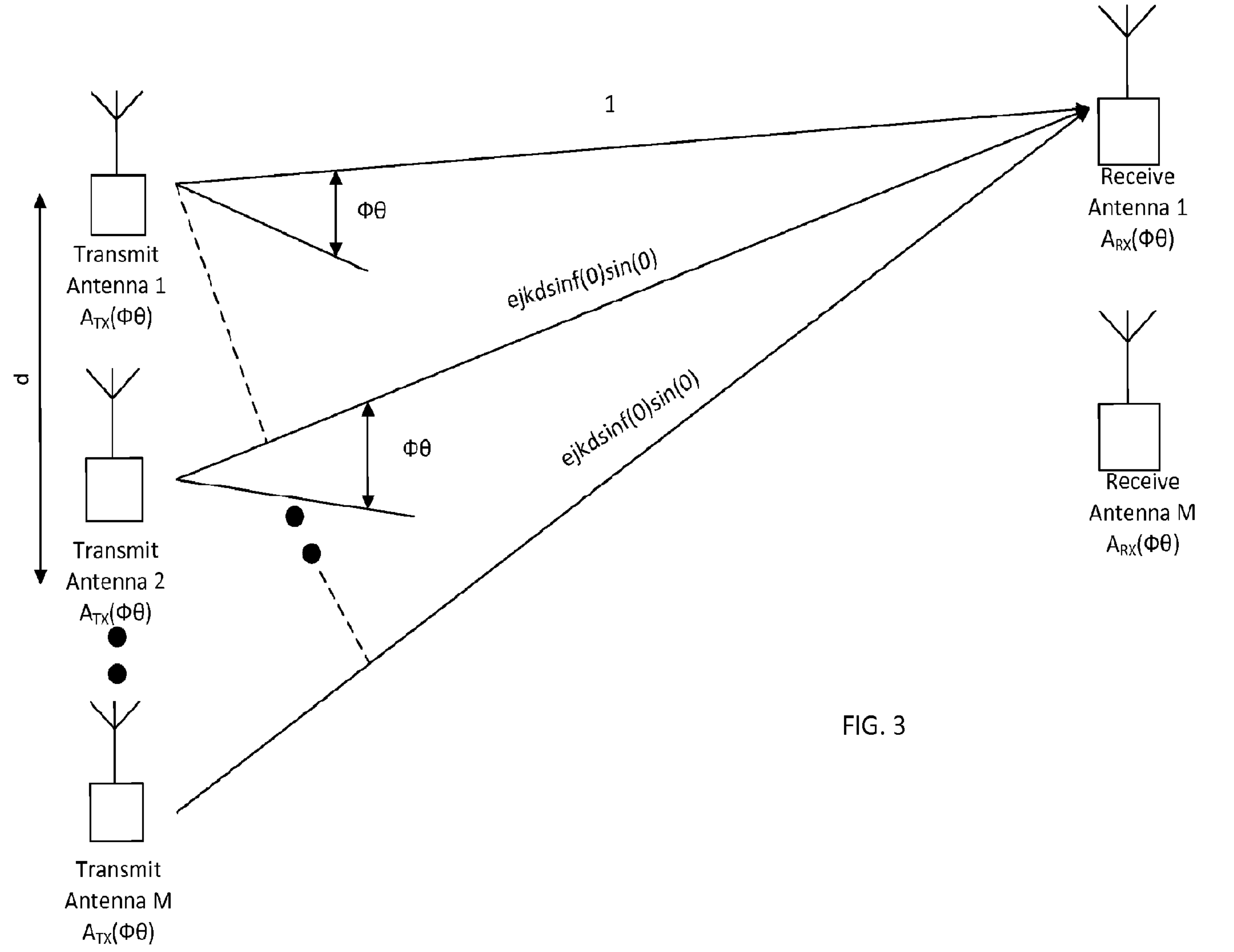

1
Φθ
ejkdsinf(0)sin(0)
Φθ
ejkdsinf(0)sin(0)
d
Transmit
Antenna 1
ATX(Φθ)
Transmit
Antenna 2
ATX(Φθ)
Transmit
Antenna M
ATX(Φθ)
Receive
Antenna 1
ARX(Φθ)
Receive
Antenna M
ARX(Φθ)

FIG. 3

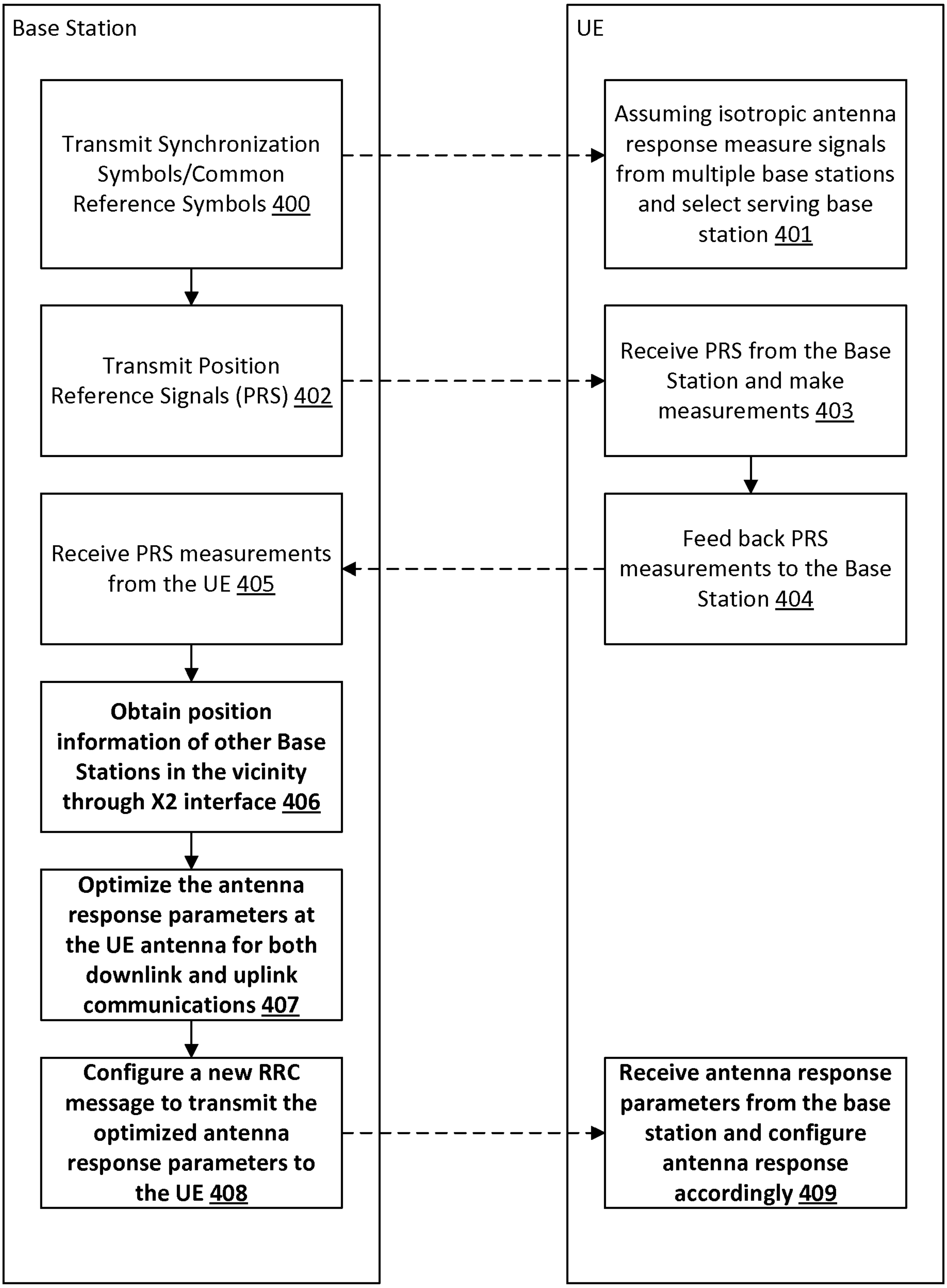

Base Station
UE
Transmit Synchronization Symbols/Common Reference Symbols 400
Assuming isotropic antenna response measure signals from multiple base stations and select serving base station 401
Transmit Position Reference Signals (PRS) 402
Receive PRS from the Base Station and make measurements 403
Receive PRS measurements from the UE 405
Feed back PRS measurements to the Base Station 404
Obtain position information of other Base Stations in the vicinity through X2 interface 406
Optimize the antenna response parameters at the UE antenna for both downlink and uplink communications 407
Configure a new RRC message to transmit the optimized antenna response parameters to the UE 408
Receive antenna response parameters from the base station and configure antenna response accordingly 409

FIG. 4A

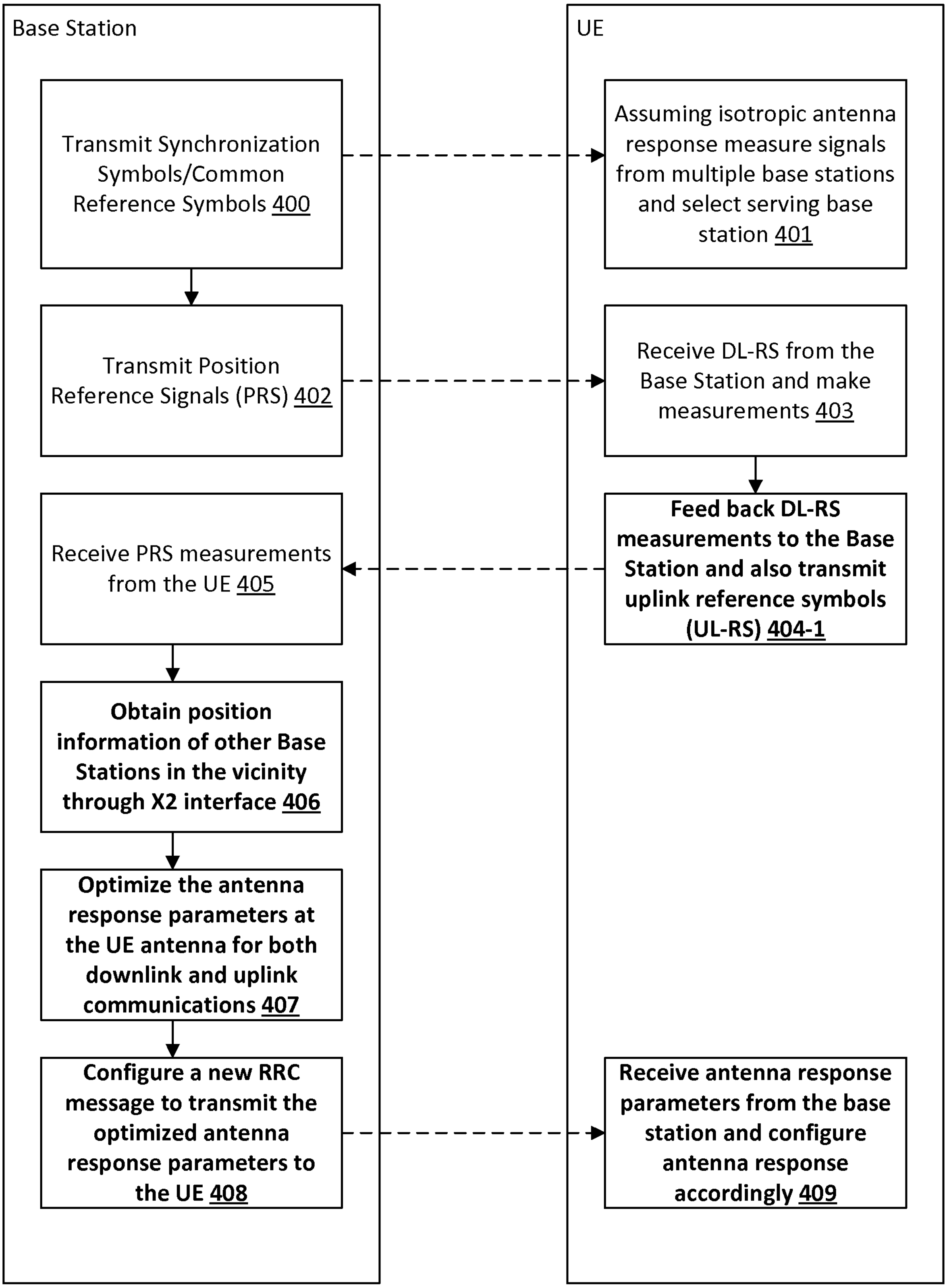

Base Station
Transmit Synchronization Symbols/Common Reference Symbols 400
Transmit Position Reference Signals (PRS) 402
Receive PRS measurements from the UE 405
Obtain position information of other Base Stations in the vicinity through X2 interface 406
Optimize the antenna response parameters at the UE antenna for both downlink and uplink communications 407
Configure a new RRC message to transmit the optimized antenna response parameters to the UE 408
UE
Assuming isotropic antenna response measure signals from multiple base stations and select serving base station 401
Receive DL-RS from the Base Station and make measurements 403
Feed back DL-RS measurements to the Base Station and also transmit uplink reference symbols (UL-RS) 404-1
Receive antenna response parameters from the base station and configure antenna response accordingly 409

FIG. 4B

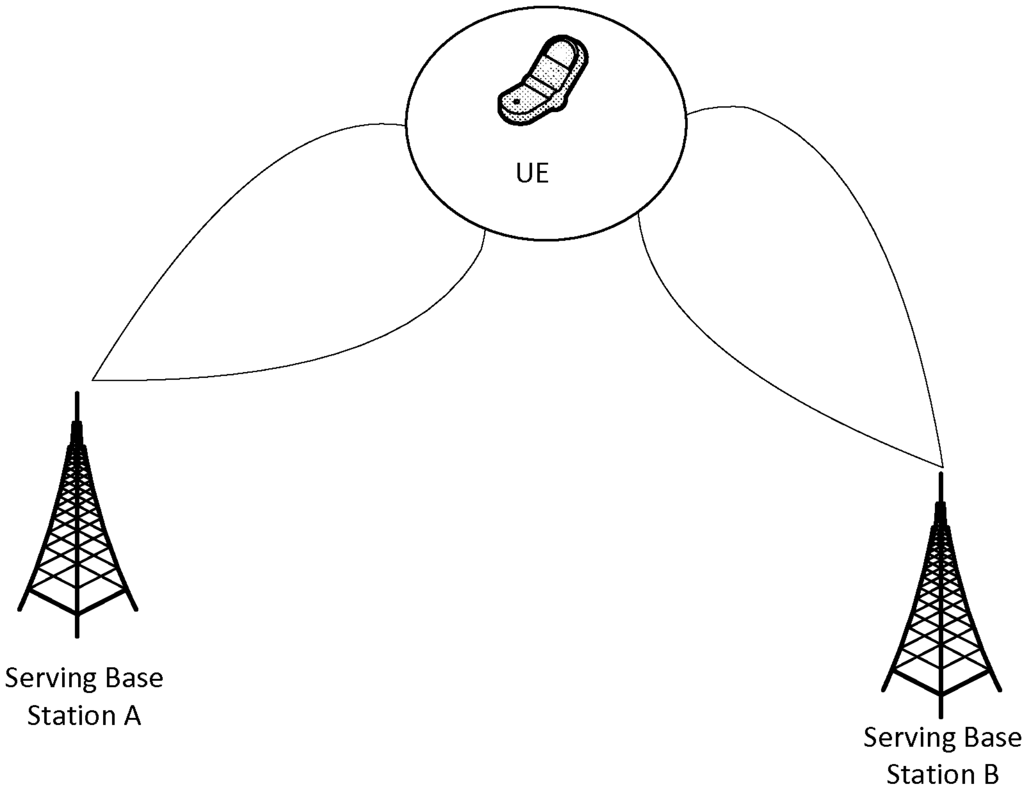


FIG. 5

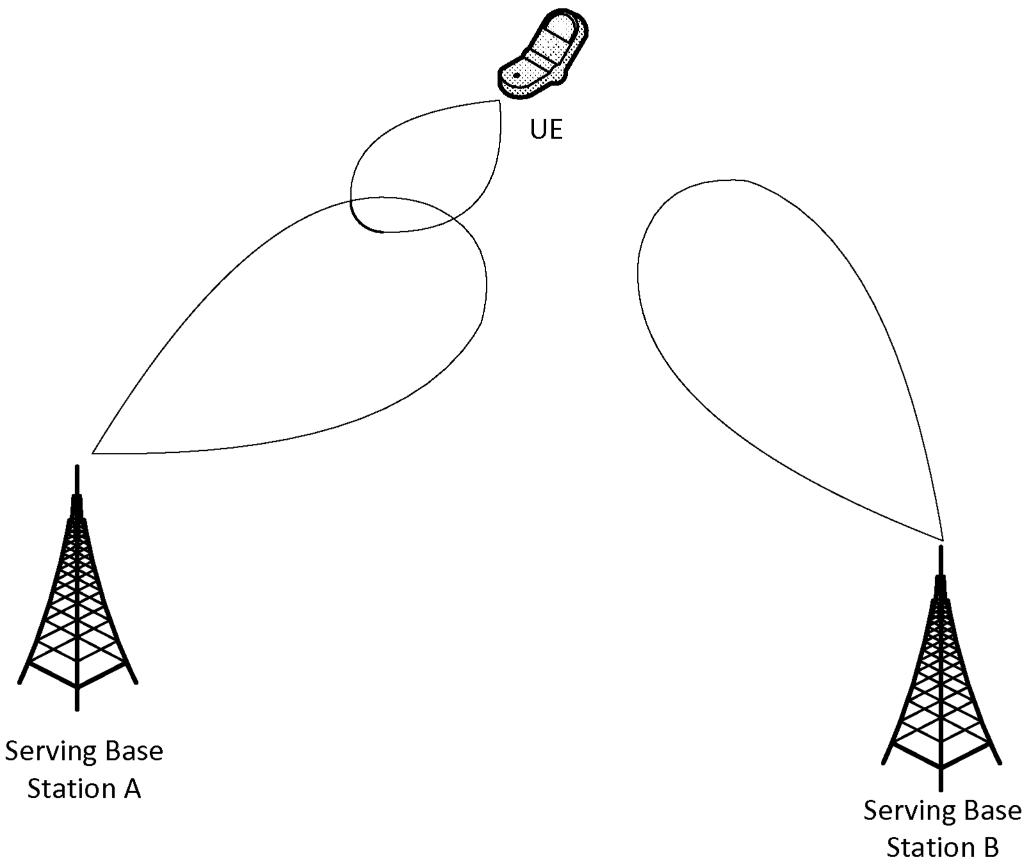


FIG. 6

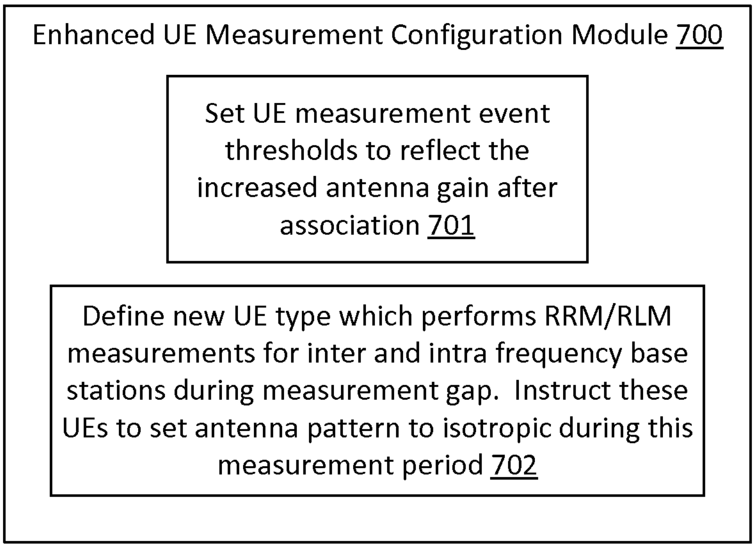

Enhanced UE Measurement Configuration Module 700
Set UE measurement event thresholds to reflect the increased antenna gain after association 701
Define new UE type which performs RRM/RLM measurements for inter and intra frequency base stations during measurement gap. Instruct these UEs to set antenna pattern to isotropic during this measurement period 702

FIG. 7

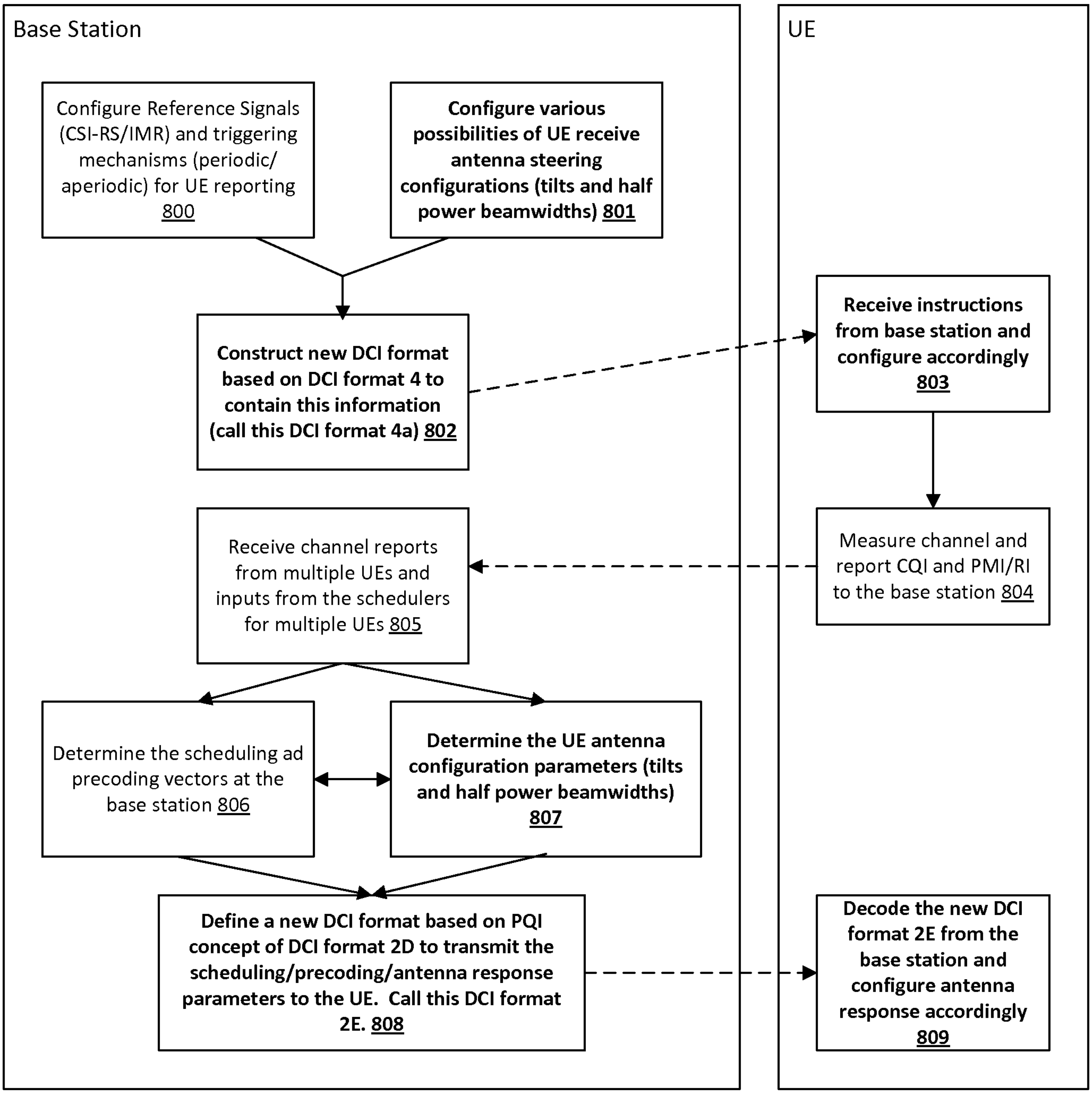

Base Station
UE
Configure Reference Signals (CSI-RS/IMR) and triggering mechanisms (periodic/ aperiodic) for UE reporting 800
Configure various possibilities of UE receive antenna steering configurations (tilts and half power beamwidths) 801
Construct new DCI format based on DCI format 4 to contain this information (call this DCI format 4a) 802
Receive instructions from base station and configure accordingly 803
Measure channel and report CQI and PMI/RI to the base station 804
Receive channel reports from multiple UEs and inputs from the schedulers for multiple UEs 805
Determine the scheduling ad precoding vectors at the base station 806
Determine the UE antenna configuration parameters (tilts and half power beamwidths) 807
Define a new DCI format based on PQI concept of DCI format 2D to transmit the scheduling/precoding/antenna response parameters to the UE. Call this DCI format 2E. 808
Decode the new DCI format 2E from the base station and configure antenna response accordingly 809

FIG. 8

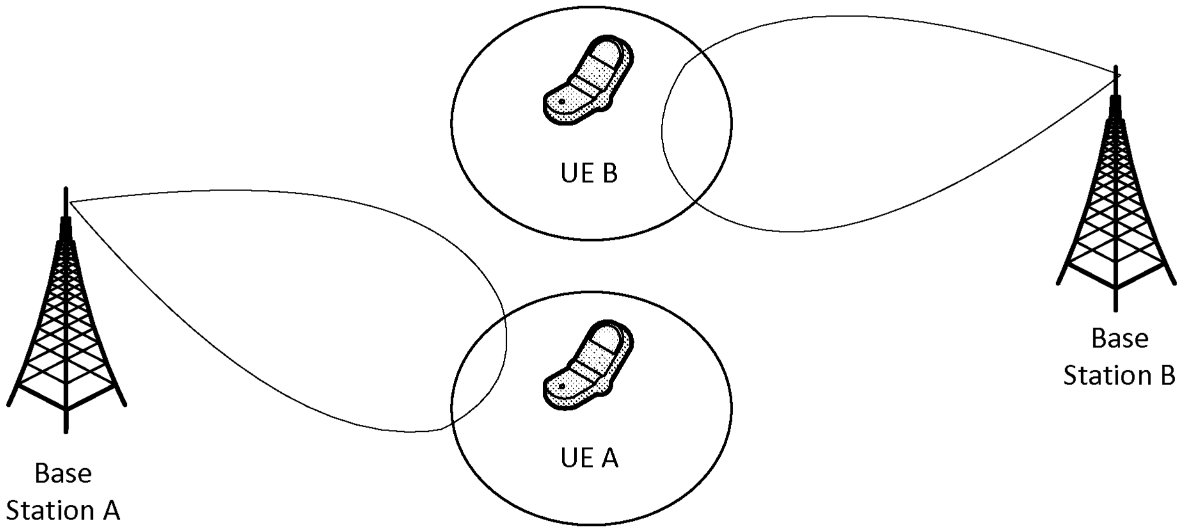

UE B
Base
Station B
UE A
Base
Station A

FIG. 9A

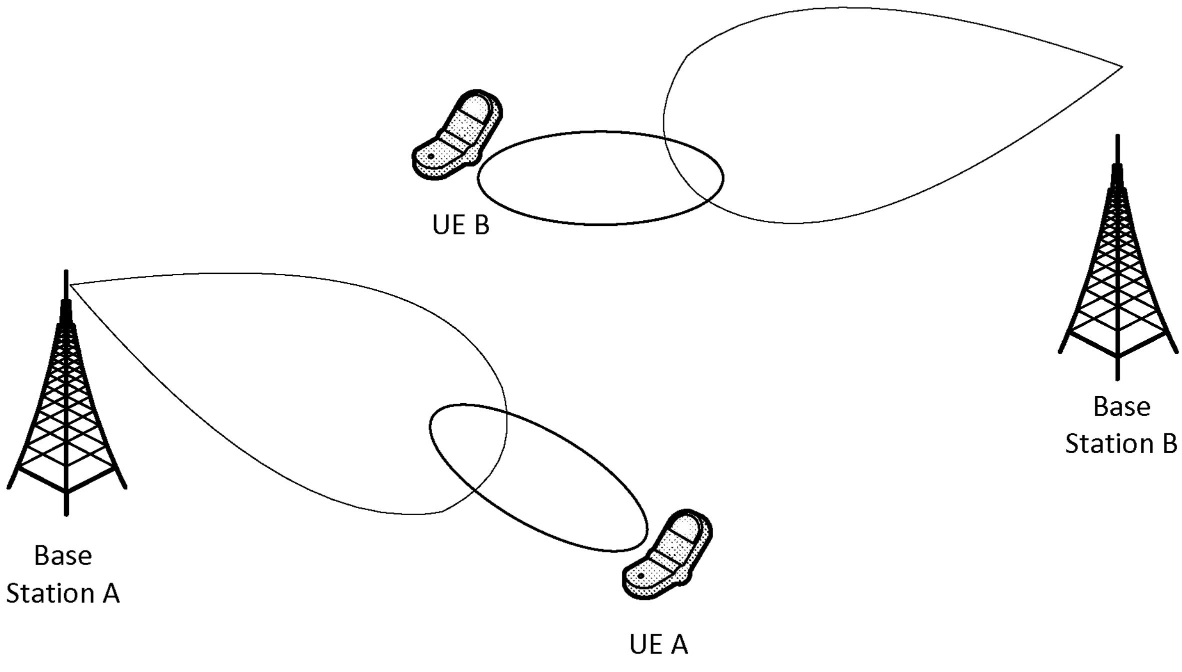

UE B
Base
Station B
Base
Station A
UE A

FIG. 9B

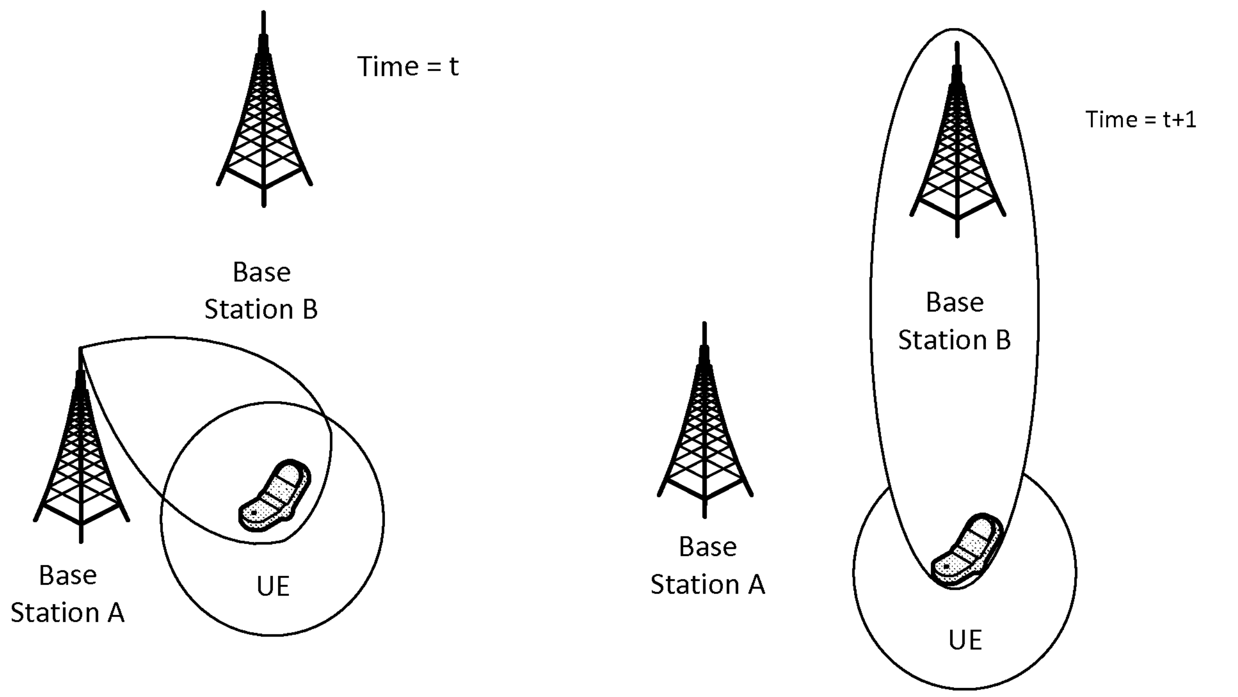


FIG. 10A

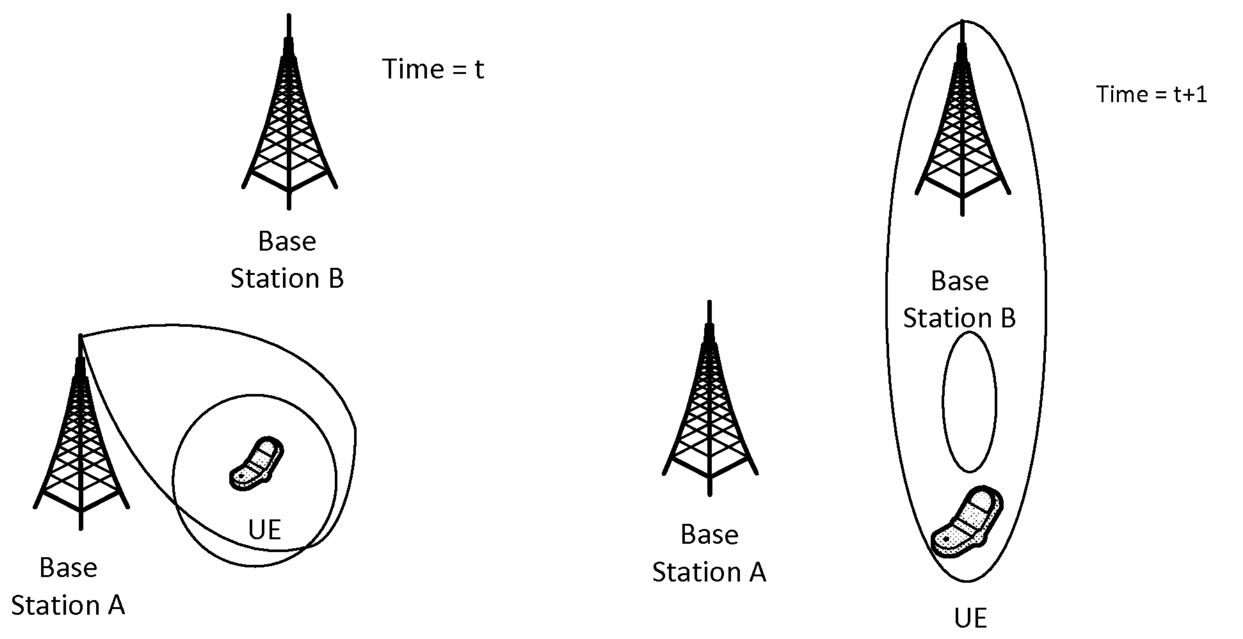


FIG. 10B

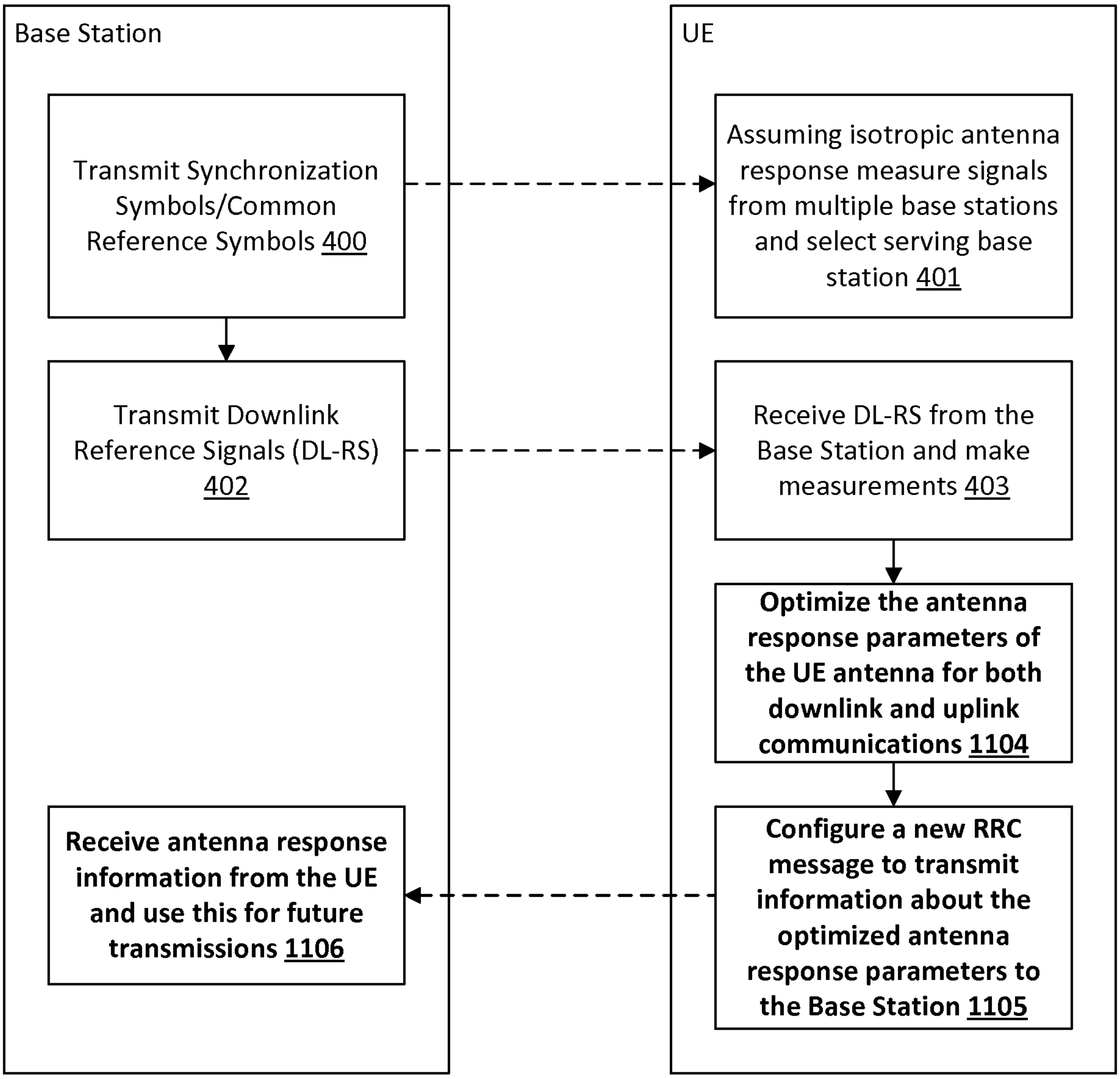

Base Station
UE
Transmit Synchronization Symbols/Common Reference Symbols 400
Assuming isotropic antenna response measure signals from multiple base stations and select serving base station 401
Transmit Downlink Reference Signals (DL-RS) 402
Receive DL-RS from the Base Station and make measurements 403
Optimize the antenna response parameters of the UE antenna for both downlink and uplink communications 1104
Receive antenna response information from the UE and use this for future transmissions 1106
Configure a new RRC message to transmit information about the optimized antenna response parameters to the Base Station 1105

FIG. 11

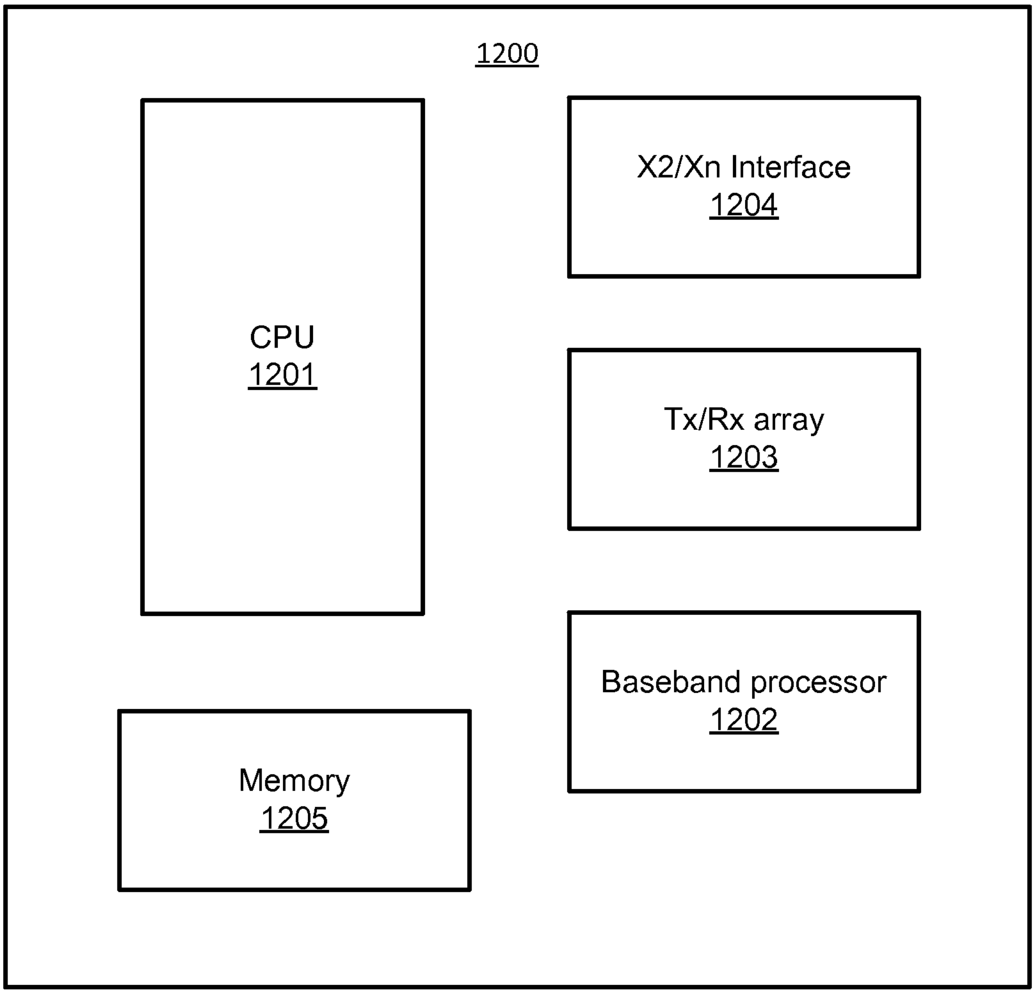

1200
CPU
1201
X2/Xn Interface
1204
Tx/Rx array
1203
Baseband processor
1202
Memory
1205

FIG. 12

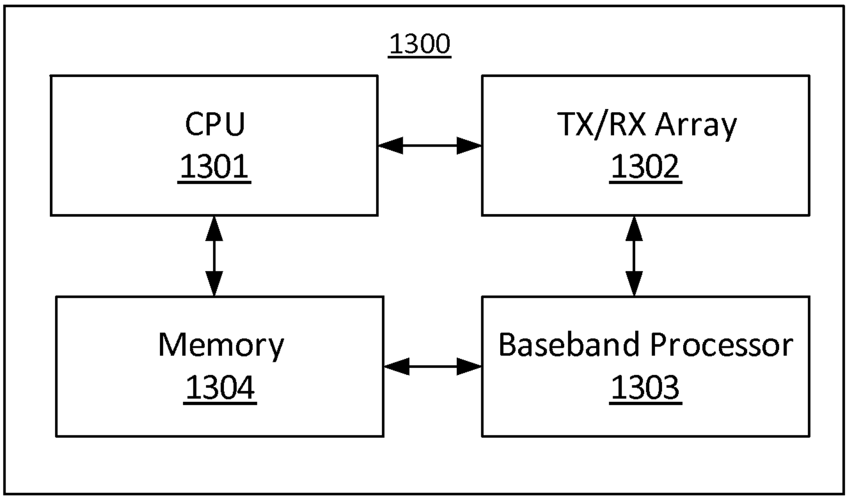

1300
CPU
1301
TX/RX Array
1302
Memory
1304
Baseband Processor
1303

FIG. 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/040693

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H04B 7/26 (2014.01)
CPC - H04B 7/26 (2014.09)
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)
IPC(8) - H04B 7/00, 7/24, 7/26 (2014.01)
USPC -455/39, 500, 507

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - H04B 7/00, 7/24, 7/26 (2014.09)

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2011/0070908 A1 (GARCIA CABEZAS et al) 24 March 2011 (24.03.2011) entire document	1-15
Y	US 2010/0112996 A1 (HO et al) 06 May 2010 (06.05.2010) entire document	1-15
Y	US 2013/0286960 A1 (LI et al) 31 October 2013 (31.10.2013) entire document	2-5, 7-10, 12-15
A	WO 2013/181850 A1 (ZHANG et al) 12 December 2013 (12.12.2013) entire document	1-15

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 September 2014	15 OCT 2014

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774