



(51) International Patent Classification:
H04W 24/00 (2009.01)

(21) International Application Number:
PCT/CN2017/070312

(22) International Filing Date:
05 January 2017 (05.01.2017)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: **MOTOROLA MOBILITY LLC** [US/US];
222 West Merchandise Mart Plaza, Suite 1800, Chicago,
Illinois 60654 (US).

(72) Inventors: **ZHU, Chenxi**; 11452 Mallard Creek Trail, Fairfax,
Virginia 22033 (US). **LING, Wei**; 18-3-202, Shuangying
West Road 78, Changping District, Beijing 102299
(CN).

(74) Agent: **CHINA SINDA INTELLECTUAL PROPERTY LTD.**; B11th Floor, Focus Place, 19 Financial Street, Xi-
cheng District, Beijing 100033 (CN).

(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, DJ, 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, KH, KN, KP, KR,
KW, KZ, LA, LC, LK, LR, LS, 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, ST, 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,

(54) Title: BEAM QUALITY DETERMINATION

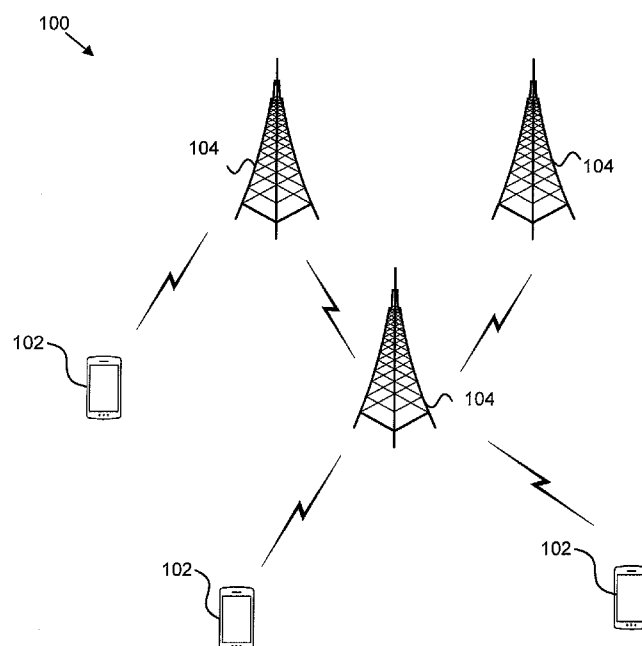


FIG. 1

(57) Abstract: Apparatuses, methods, and systems are disclosed for beam quality determination. One apparatus (200) includes a receiver (212) that receives (602) two adjacent reference signal symbols sent from a transmit beam. The apparatus (200) also includes a processor (202) that determines (604) a beam quality of the transmit beam based on one or more of the two adjacent reference signal symbols. The beam quality includes a reference signal received power. The apparatus (200) includes a transmitter (210) that transmits (606) data indicating the beam quality.



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).

Published:

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

BEAM QUALITY DETERMINATION

FIELD

[0001] The subject matter disclosed herein relates generally to wireless communications and more particularly relates to beam quality determination.

BACKGROUND

[0002] The following abbreviations are herewith defined, at least some of which are referred to within the following description: Third Generation Partnership Project (“3GPP”), Positive-Acknowledgment (“ACK”), Binary Phase Shift Keying (“BPSK”), Clear Channel Assessment (“CCA”), Cyclic Prefix (“CP”), Channel State Information (“CSI”), Common Search Space (“CSS”), Discrete Fourier Transform Spread (“DFTS”), Downlink Control Information (“DCI”), Downlink (“DL”), Downlink Pilot Time Slot (“DwPTS”), Enhanced Clear Channel Assessment (“eCCA”), Enhanced Mobile Broadband (“eMBB”), Evolved Node B (“eNB”), European Telecommunications Standards Institute (“ETSI”), Frame Based Equipment (“FBE”), Frequency Division Duplex (“FDD”), Frequency Division Multiple Access (“FDMA”), Guard Period (“GP”), Hybrid Automatic Repeat Request (“HARQ”), Internet-of-Things (“IoT”), Licensed Assisted Access (“LAA”), Load Based Equipment (“LBE”), Listen-Before-Talk (“LBT”), Long Term Evolution (“LTE”), Multiple Access (“MA”), Modulation Coding Scheme (“MCS”), Machine Type Communication (“MTC”), Multiple Input Multiple Output (“MIMO”), Multi User Shared Access (“MUSA”), Narrowband (“NB”), Negative-Acknowledgment (“NACK”) or (“NAK”), Next Generation Node B (“gNB”), Non-Orthogonal Multiple Access (“NOMA”), Orthogonal Cover Code (“OCC”), Orthogonal Frequency Division Multiplexing (“OFDM”), Primary Cell (“PCell”), Physical Broadcast Channel (“PBCH”), Physical Downlink Control Channel (“PDCCH”), Physical Downlink Shared Channel (“PDSCH”), Pattern Division Multiple Access (“PDMA”), Physical Hybrid ARQ Indicator Channel (“PHICH”), Physical Random Access Channel (“PRACH”), Physical Resource Block (“PRB”), Physical Uplink Control Channel (“PUCCH”), Physical Uplink Shared Channel (“PUSCH”), Quality of Service (“QoS”), Quadrature Phase Shift Keying (“QPSK”), Radio Resource Control (“RRC”), Random Access Procedure (“RACH”), Random Access Response (“RAR”), Reference Signal (“RS”), Resource Spread Multiple Access (“RSMA”), Round Trip Time (“RTT”), Receive (“RX”), Sparse Code Multiple Access (“SCMA”), Scheduling Request (“SR”), Single Carrier Frequency Division Multiple Access (“SC-FDMA”), Secondary Cell (“SCell”), Shared Channel (“SCH”), Signal-to-Interference-Plus-Noise Ratio (“SINR”), System Information Block (“SIB”), Transport Block (“TB”), Transport Block Size (“TBS”), Time-Division Duplex (“TDD”), Time Division

Multiplex (“TDM”), Transmission Time Interval (“TTI”), Transmit (“TX”), Uplink Control Information (“UCI”), User Entity/Equipment (Mobile Terminal) (“UE”), Uplink (“UL”), Universal Mobile Telecommunications System (“UMTS”), Uplink Pilot Time Slot (“UpPTS”), Ultra-reliability and Low-latency Communications (“URLLC”), and Worldwide Interoperability
5 for Microwave Access (“WiMAX”). As used herein, “HARQ-ACK” may represent collectively the Positive Acknowledge (“ACK”) and the Negative Acknowledge (“NAK”). ACK means that a TB is correctly received while NAK means a TB is erroneously received.

[0003] In certain wireless communications networks, a high frequency range is used, such as a millimeter wave (“mmW”) range. Transmission in the mmW range may have a higher
10 path loss than a microwave range (e.g., typically an additional loss of 20 to 30dB). Without increasing the transmission power, the additional path loss may be compensated for by deploying a large number of antenna elements and transmission and reception beamforming at a gNB and UE. The number of antenna elements at a gNB may be up to one hundred or higher. Transmission beamforming with a large number of antenna elements may focus the transmission
15 energy in a certain direction (e.g., with a narrow angle) to compensate for the additional path loss. A large directional gain may be achieved in the transmission. A large number of antenna elements may also be used for transmission in the microwave range in massive-MIMO systems in order to achieve high system capacity.

[0004] In certain configurations, because of the large number of antenna elements, the
20 cost of implementing an all-digital transceiver may be high. In various configurations, a separate radio frequency (“RF”) chain may be used for each antenna element (e.g., either TX or RX) resulting in high cost and/or high power consumption. Various configurations may use hybrid analog/digital beamforming in which a small number of RF chains may be used to power a large number of antenna elements. Relative phases between antenna elements may be controlled by a
25 separate power distribution (e.g., at the TX side), combining (e.g., at the RX side), and phase shift network (e.g., RF precoder). Generation of an analog beam (e.g., TX or RX) may be controlled by a RF precoder, and only 1 TX and RX analog beam may be applied at any given time.

[0005] Some configurations may operation in a high frequency band (e.g., > 6GHz) and
30 may be multi-beam based systems. Such configurations may have large path loss and large penetration loss and may use multiple narrow beams to cover one cell. The beams may be an analog beam formed through a phase shifter in an RF chain or a composite beam formed through analog beamforming and digital beamforming. In multi-beam based system, a gNB uses each beam to cover one part of the cell. For downlink transmission to a UE, the gNB may use one TX

beam for the UE so the downlink signal may reach the UE with strong power. Similarly, a UE may choose one Rx beam to receive the downlink transmission and one TX beam to send an uplink transmission. It may be challenging to select a TX beam of a gNB for transmitting to a UE.

BRIEF SUMMARY

[0006] Apparatuses for beam quality determination are disclosed. Methods and systems also perform the functions of the apparatus. In one embodiment, the apparatus includes a receiver that receives two adjacent reference signal symbols sent from a transmit beam. The apparatus also includes a processor that determines a beam quality of the transmit beam based on one or more of the two adjacent reference signal symbols. The beam quality includes a reference signal received power. In certain embodiments, the apparatus includes a transmitter that transmits data indicating the beam quality.

[0007] In one embodiment, the two adjacent reference signal symbols are the same. In a further embodiment, the two adjacent reference signal symbols are different. In certain embodiments, a first reference signal symbol of the two adjacent reference signal symbols and a second reference signal symbol of the two adjacent reference signal symbols have a length 2 orthogonal cover code applied. In some embodiments, the processor determines the beam quality of the transmit beam by performing channel estimation jointly on the two adjacent reference signal symbols. In various embodiments, the receiver receives a first reference signal symbol of the two adjacent reference signal symbols via a first receive beam and a second reference signal symbol of the two adjacent reference signal symbols via a second receive beam. In some embodiments, the processor determines the beam quality of the transmit beam by estimating a phase offset of the two adjacent reference signal symbols.

[0008] In one embodiment, the beam quality comprises a phase noise, and the processor estimates the phase noise of the two adjacent reference signal symbols. In a further embodiment, the processor determines the beam quality of the transmit beam by determining a first reference signal received power on a first reference signal symbol of the two adjacent reference signal symbols received via a first receive beam and determining a second reference signal received power on a second reference signal symbol of the two adjacent reference signal symbols received via a second receive beam. In various embodiments, the transmitter transmits data indicating the beam quality by transmitting a phase noise measurement feedback message. In some embodiments, the transmitter transmits data indicating the beam quality by transmitting an indicator that indicates a width of bandwidth used for measurements. In certain embodiments,

the transmitter transmits data indicating the beam quality by transmitting a message including a normalized reference signal received power.

[0009] A method for beam quality determination, in one embodiment, includes receiving two adjacent reference signal symbols sent from a transmit beam. The method also includes
5 determining a beam quality of the transmit beam based on one or more of the two adjacent reference signal symbols. The beam quality includes a reference signal received power. The method includes transmitting data indicating the beam quality.

[0010] In one embodiment, an apparatus includes a transmitter that transmits two adjacent reference signal symbols using a first transmit beam. In various embodiments, the
10 apparatus includes a receiver that receives data indicating a beam quality determined based on one or more of the two adjacent reference signal symbols. The beam quality includes a reference signal received power.

[0011] In one embodiment, the transmitter transmits the two adjacent reference signal symbols using the first transmit beam by transmitting a first multiple two adjacent reference
15 signal symbols using the first transmit beam. In a further embodiment, the transmitter transmits the first multiple two adjacent reference signal symbols by transmitting a first portion of the first multiple two adjacent reference signal symbols in a center bandwidth, a second portion of the first multiple two adjacent reference signal symbols in a first side bandwidth, and a third portion of the first multiple two adjacent reference signal symbols in a second side bandwidth. In certain
20 embodiments, a density of the first portion of the first multiple two adjacent reference signal symbols is higher than a density of the second and third portions of the first multiple two adjacent reference signal symbols.

[0012] In some embodiments, a sequence transmitted in the first portion of the first multiple two adjacent reference signal symbols is different than a sequence transmitted in the
25 second and third portions of the first multiple two adjacent reference signal symbols. In various embodiments, the transmitter transmits a second multiple two adjacent reference signal symbols using a second transmit beam. In some embodiments, the two adjacent reference signal symbols are the same. In one embodiment, the two adjacent reference signal symbols are different. In a further embodiment, the apparatus includes a processor that applies an orthogonal cover code to
30 a first reference signal symbol of the two adjacent reference signal symbols and a second reference signal symbol of the two adjacent reference signal symbols.

[0013] A method for beam quality determination, in one embodiment, includes transmitting two adjacent reference signal symbols using a first transmit beam. The method also

includes receiving data indicating a beam quality determined based on one or more of the two adjacent reference signal symbols. The beam quality includes a reference signal received power.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] A more particular description of the embodiments briefly described above will be rendered by reference to specific embodiments that are illustrated in the appended drawings. Understanding that these drawings depict only some embodiments and are not therefore to be considered to be limiting of scope, the embodiments will be described and explained with additional specificity and detail through the use of the accompanying drawings, in which:

[0015] Figure 1 is a schematic block diagram illustrating one embodiment of a wireless communication system for beam quality determination;

[0016] Figure 2 is a schematic block diagram illustrating one embodiment of an apparatus that may be used for beam quality determination;

[0017] Figure 3 is a schematic block diagram illustrating one embodiment of an apparatus that may be used for beam quality determination;

[0018] Figure 4 illustrates one embodiment of communications for beam quality determination;

[0019] Figure 5 is a schematic block diagram illustrating one embodiment of communications for beam quality determination;

[0020] Figure 6 is a schematic flow chart diagram illustrating one embodiment of a method for beam quality determination; and

[0021] Figure 7 is a schematic flow chart diagram illustrating another embodiment of a method for beam quality determination.

DETAILED DESCRIPTION

[0022] As will be appreciated by one skilled in the art, aspects of the embodiments may be embodied as a system, apparatus, method, or program product. Accordingly, embodiments may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a “circuit,” “module” or “system.” Furthermore, embodiments may take the form of a program product embodied in one or more computer readable storage devices storing machine readable code, computer readable code, and/or program code, referred hereafter as code. The storage devices may be tangible, non-transitory, and/or non-transmission. The storage devices may not embody signals. In a certain embodiment, the storage devices only employ signals for accessing code.

[0023] Certain of the functional units described in this specification may be labeled as modules, in order to more particularly emphasize their implementation independence. For example, a module may be implemented as a hardware circuit comprising custom very-large-scale integration (“VLSI”) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A module may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices or the like.

[0024] Modules may also be implemented in code and/or software for execution by various types of processors. An identified module of code may, for instance, include one or more physical or logical blocks of executable code which may, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified module need not be physically located together, but may include disparate instructions stored in different locations which, when joined logically together, include the module and achieve the stated purpose for the module.

[0025] Indeed, a module of code may be a single instruction, or many instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data may be identified and illustrated herein within modules, and may be embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set, or may be distributed over different locations including over different computer readable storage devices. Where a module or portions of a module are implemented in software, the software portions are stored on one or more computer readable storage devices.

[0026] Any combination of one or more computer readable medium may be utilized. The computer readable medium may be a computer readable storage medium. The computer readable storage medium may be a storage device storing the code. The storage device may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, holographic, micromechanical, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing.

[0027] More specific examples (a non-exhaustive list) of the storage device would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access memory (“RAM”), a read-only memory (“ROM”), an erasable programmable read-only memory (“EPROM” or Flash memory), a portable compact disc read-only memory (“CD-ROM”), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer readable

storage medium may be any tangible medium that can contain, or store a program for use by or in connection with an instruction execution system, apparatus, or device.

[0028] Code for carrying out operations for embodiments may be any number of lines and may be written in any combination of one or more programming languages including an object oriented programming language such as Python, Ruby, Java, Smalltalk, C++, or the like, and conventional procedural programming languages, such as the "C" programming language, or the like, and/or machine languages such as assembly languages. The code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network ("LAN") or a wide area network ("WAN"), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

[0029] Reference throughout this specification to "one embodiment," "an embodiment," or similar language means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, appearances of the phrases "in one embodiment," "in an embodiment," and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment, but mean "one or more but not all embodiments" unless expressly specified otherwise. The terms "including," "comprising," "having," and variations thereof mean "including but not limited to," unless expressly specified otherwise. An enumerated listing of items does not imply that any or all of the items are mutually exclusive, unless expressly specified otherwise. The terms "a," "an," and "the" also refer to "one or more" unless expressly specified otherwise.

[0030] Furthermore, the described features, structures, or characteristics of the embodiments may be combined in any suitable manner. In the following description, numerous specific details are provided, such as examples of programming, software modules, user selections, network transactions, database queries, database structures, hardware modules, hardware circuits, hardware chips, etc., to provide a thorough understanding of embodiments. One skilled in the relevant art will recognize, however, that embodiments may be practiced without one or more of the specific details, or with other methods, components, materials, and so forth. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of an embodiment.

[0031] Aspects of the embodiments are described below with reference to schematic flowchart diagrams and/or schematic block diagrams of methods, apparatuses, systems, and

program products according to embodiments. It will be understood that each block of the schematic flowchart diagrams and/or schematic block diagrams, and combinations of blocks in the schematic flowchart diagrams and/or schematic block diagrams, can be implemented by code. These code may be provided to a processor of a general purpose computer, special purpose
5 computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the schematic flowchart diagrams and/or schematic block diagrams block or blocks.

[0032] The code may also be stored in a storage device that can direct a computer, other
10 programmable data processing apparatus, or other devices to function in a particular manner, such that the instructions stored in the storage device produce an article of manufacture including instructions which implement the function/act specified in the schematic flowchart diagrams and/or schematic block diagrams block or blocks.

[0033] The code may also be loaded onto a computer, other programmable data
15 processing apparatus, or other devices to cause a series of operational steps to be performed on the computer, other programmable apparatus or other devices to produce a computer implemented process such that the code which execute on the computer or other programmable apparatus provide processes for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

[0034] The schematic flowchart diagrams and/or schematic block diagrams in the Figures
20 illustrate the architecture, functionality, and operation of possible implementations of apparatuses, systems, methods and program products according to various embodiments. In this regard, each block in the schematic flowchart diagrams and/or schematic block diagrams may represent a module, segment, or portion of code, which includes one or more executable
25 instructions of the code for implementing the specified logical function(s).

[0035] It should also be noted that, in some alternative implementations, the functions
noted in the block may occur out of the order noted in the Figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. Other
30 steps and methods may be conceived that are equivalent in function, logic, or effect to one or more blocks, or portions thereof, of the illustrated Figures.

[0036] Although various arrow types and line types may be employed in the flowchart and/or block diagrams, they are understood not to limit the scope of the corresponding embodiments. Indeed, some arrows or other connectors may be used to indicate only the logical

flow of the depicted embodiment. For instance, an arrow may indicate a waiting or monitoring period of unspecified duration between enumerated steps of the depicted embodiment. It will also be noted that each block of the block diagrams and/or flowchart diagrams, and combinations of blocks in the block diagrams and/or flowchart diagrams, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and code.

[0037] The description of elements in each figure may refer to elements of proceeding figures. Like numbers refer to like elements in all figures, including alternate embodiments of like elements.

[0038] Figure 1 depicts an embodiment of a wireless communication system 100 for beam quality determination. In one embodiment, the wireless communication system 100 includes remote units 102 and base units 104. Even though a specific number of remote units 102 and base units 104 are depicted in Figure 1, one of skill in the art will recognize that any number of remote units 102 and base units 104 may be included in the wireless communication system 100.

[0039] In one embodiment, the remote units 102 may include computing devices, such as desktop computers, laptop computers, personal digital assistants (“PDAs”), tablet computers, smart phones, smart televisions (e.g., televisions connected to the Internet), set-top boxes, game consoles, security systems (including security cameras), vehicle on-board computers, network devices (e.g., routers, switches, modems), or the like. In some embodiments, the remote units 102 include wearable devices, such as smart watches, fitness bands, optical head-mounted displays, or the like. Moreover, the remote units 102 may be referred to as subscriber units, mobiles, mobile stations, users, terminals, mobile terminals, fixed terminals, subscriber stations, UE, user terminals, a device, or by other terminology used in the art. The remote units 102 may communicate directly with one or more of the base units 104 via UL communication signals.

[0040] The base units 104 may be distributed over a geographic region. In certain embodiments, a base unit 104 may also be referred to as an access point, an access terminal, a base, a base station, a Node-B, an eNB, a gNB, a Home Node-B, a relay node, a device, or by any other terminology used in the art. The base units 104 are generally part of a radio access network that includes one or more controllers communicably coupled to one or more corresponding base units 104. The radio access network is generally communicably coupled to one or more core networks, which may be coupled to other networks, like the Internet and public switched telephone networks, among other networks. These and other elements of radio access

and core networks are not illustrated but are well known generally by those having ordinary skill in the art.

[0041] In one implementation, the wireless communication system 100 is compliant with the LTE of the 3GPP protocol, wherein the base unit 104 transmits using an OFDM modulation scheme on the DL and the remote units 102 transmit on the UL using a SC-FDMA scheme or an OFDM scheme. More generally, however, the wireless communication system 100 may implement some other open or proprietary communication protocol, for example, WiMAX, among other protocols. The present disclosure is not intended to be limited to the implementation of any particular wireless communication system architecture or protocol.

[0042] The base units 104 may serve a number of remote units 102 within a serving area, for example, a cell or a cell sector via a wireless communication link. The base units 104 transmit DL communication signals to serve the remote units 102 in the time, frequency, and/or spatial domain.

[0043] In one embodiment, a base unit 104 may transmit two adjacent reference signal symbols using a first transmit beam (e.g., a single transmit beam). The two adjacent reference signal symbols may be two symbols that are transmitted consecutively. In some embodiments, the base unit 104 may receive data indicating a beam quality determined based on one or more of the two adjacent reference signal symbols. The beam quality may include a reference signal received power. In one example, the beam quality may be based on a first reference signal of the two adjacent reference signals and/or a second reference signal of the two adjacent reference signals. Accordingly, a base unit 104 may be used for beam quality determination.

[0044] In another embodiment, a remote unit 102 may receive two adjacent reference signal symbols sent from a transmit beam (e.g., a single transmit beam). The two adjacent reference signal symbols may be two symbols that are received consecutively. The remote unit 102 may determine a beam quality of the transmit beam based on one or more of the two adjacent reference signal symbols. The beam quality may include a reference signal received power. In one example, the beam quality may be based on a first reference signal of the two adjacent reference signals and/or a second reference signal of the two adjacent reference signals. The remote unit 102 may transmit data indicating the beam quality. Accordingly, a remote unit 102 may be used for beam quality determination.

[0045] Figure 2 depicts one embodiment of an apparatus 200 that may be used for beam quality determination. The apparatus 200 includes one embodiment of the remote unit 102. Furthermore, the remote unit 102 may include a processor 202, a memory 204, an input device 206, a display 208, a transmitter 210, and a receiver 212. In some embodiments, the input device

206 and the display 208 are combined into a single device, such as a touchscreen. In certain embodiments, the remote unit 102 may not include any input device 206 and/or display 208. In various embodiments, the remote unit 102 may include one or more of the processor 202, the memory 204, the transmitter 210, and the receiver 212, and may not include the input device 206
5 and/or the display 208.

[0046] The processor 202, in one embodiment, may include any known controller capable of executing computer-readable instructions and/or capable of performing logical operations. For example, the processor 202 may be a microcontroller, a microprocessor, a central processing unit (“CPU”), a graphics processing unit (“GPU”), an auxiliary processing
10 unit, a field programmable gate array (“FPGA”), or similar programmable controller. In some embodiments, the processor 202 executes instructions stored in the memory 204 to perform the methods and routines described herein. In certain embodiments, the processor 202 may determine a beam quality of a transmit beam based on one or more of two adjacent reference signal symbols. The beam quality may include a reference signal received power. The processor
15 202 is communicatively coupled to the memory 204, the input device 206, the display 208, the transmitter 210, and the receiver 212.

[0047] The memory 204, in one embodiment, is a computer readable storage medium. In some embodiments, the memory 204 includes volatile computer storage media. For example, the memory 204 may include a RAM, including dynamic RAM (“DRAM”), synchronous dynamic
20 RAM (“SDRAM”), and/or static RAM (“SRAM”). In some embodiments, the memory 204 includes non-volatile computer storage media. For example, the memory 204 may include a hard disk drive, a flash memory, or any other suitable non-volatile computer storage device. In some embodiments, the memory 204 includes both volatile and non-volatile computer storage media. In some embodiments, the memory 204 stores data relating to beam quality. In some
25 embodiments, the memory 204 also stores program code and related data, such as an operating system or other controller algorithms operating on the remote unit 102.

[0048] The input device 206, in one embodiment, may include any known computer input device including a touch panel, a button, a keyboard, a stylus, a microphone, or the like. In some embodiments, the input device 206 may be integrated with the display 208, for example, as
30 a touchscreen or similar touch-sensitive display. In some embodiments, the input device 206 includes a touchscreen such that text may be input using a virtual keyboard displayed on the touchscreen and/or by handwriting on the touchscreen. In some embodiments, the input device 206 includes two or more different devices, such as a keyboard and a touch panel.

[0049] The display 208, in one embodiment, may include any known electronically controllable display or display device. The display 208 may be designed to output visual, audible, and/or haptic signals. In some embodiments, the display 208 includes an electronic display capable of outputting visual data to a user. For example, the display 208 may include, but is not limited to, an LCD display, an LED display, an OLED display, a projector, or similar display device capable of outputting images, text, or the like to a user. As another, non-limiting, example, the display 208 may include a wearable display such as a smart watch, smart glasses, a heads-up display, or the like. Further, the display 208 may be a component of a smart phone, a personal digital assistant, a television, a table computer, a notebook (laptop) computer, a personal computer, a vehicle dashboard, or the like.

[0050] In certain embodiments, the display 208 includes one or more speakers for producing sound. For example, the display 208 may produce an audible alert or notification (e.g., a beep or chime). In some embodiments, the display 208 includes one or more haptic devices for producing vibrations, motion, or other haptic feedback. In some embodiments, all or portions of the display 208 may be integrated with the input device 206. For example, the input device 206 and display 208 may form a touchscreen or similar touch-sensitive display. In other embodiments, the display 208 may be located near the input device 206.

[0051] The transmitter 210 is used to provide UL communication signals to the base unit 104 and the receiver 212 is used to receive DL communication signals from the base unit 104. In one embodiment, the receiver 212 may be used to receive two adjacent reference signal symbols sent from a transmit beam. In certain embodiments, the transmitter 210 transmits data indicating a beam quality. The beam quality may include a reference signal received power. Although only one transmitter 210 and one receiver 212 are illustrated, the remote unit 102 may have any suitable number of transmitters 210 and receivers 212. In some embodiments, the transmitter 210 may transmit multiple beams. In various embodiments, the receiver 212 may receive multiple beams. The transmitter 210 and the receiver 212 may be any suitable type of transmitters and receivers. In one embodiment, the transmitter 210 and the receiver 212 may be part of a transceiver.

[0052] Figure 3 depicts one embodiment of an apparatus 300 that may be used for beam quality determination. The apparatus 300 includes one embodiment of the base unit 104. Furthermore, the base unit 104 may include a processor 302, a memory 304, an input device 306, a display 308, a transmitter 310, and a receiver 312. As may be appreciated, the processor 302, the memory 304, the input device 306, the display 308, the transmitter 310, and the receiver 312

may be substantially similar to the processor 202, the memory 204, the input device 206, the display 208, the transmitter 210, and the receiver 212 of the remote unit 102, respectively.

[0053] In various embodiment, the transmitter 310 is used to transmit two adjacent reference signal symbols using a first transmit beam. In certain embodiments, the receiver 312 may receive data indicating a beam quality determined based on one or more of the two adjacent reference signal symbols. The beam quality may include a reference signal received power. Although only one transmitter 310 and one receiver 312 are illustrated, the base unit 104 may have any suitable number of transmitters 310 and receivers 312. In some embodiments, the transmitter 310 may transmit multiple beams. In various embodiments, the receiver 312 may receive multiple beams. The transmitter 310 and the receiver 312 may be any suitable type of transmitters and receivers. In one embodiment, the transmitter 310 and the receiver 312 may be part of a transceiver.

[0054] Figure 4 illustrates one embodiment of communications 400 for beam quality determination. Specifically, communications 400 between a UE 402 and a gNB 404 are illustrated. A first communication 406 may include pairs of adjacent reference signal symbols transmitted from the gNB 404. The pairs of adjacent reference signal symbols may be transmitted using multiple transmit beams and/or using multiple frequencies. The UE 402 may receive one or more pairs of adjacent reference signal symbols transmitted in the first communication 406 using one or more receive beams. Moreover, the UE 402 may determine a beam quality of a transmit beam of the gNB 404 based on one or more of a pair of adjacent reference signal symbols. The beam quality may include a reference signal received power. Moreover, a second communication 408 may include a message sent from the UE 402 to the gNB 404 indicating the beam quality determined by the UE 402. A third communication 410 may include a message sent from the gNB 404 to the UE 402 using a transmit beam determined based on one or more beam qualities received by the gNB 404.

[0055] Figure 5 is a schematic block diagram illustrating one embodiment of communications 500 for beam quality determination. Specifically, the communications 500 illustrate transmissions from the gNB 404. Moreover, the communications 500 includes multiple transmit beams 502 each including at least one beam management reference signal (“BRS”). In certain embodiments, the multiple transmit beams 502 include a first transmit beam 504, a second transmit beam 506, a third transmit beam 508, and an nth transmit beam 510. As may be appreciated, the multiple transmit beams 502 may include any number (“M”) of transmit beams. Each of the first transmit beam 504, the second transmit beam 506, the third transmit beam 508, and the nth transmit beam 510 include at least one BRS. Each BRS is indicated as a shaded

symbol in the transmit beams. As illustrated, each BRS is transmitted as part of a pair of adjacent reference signal symbols. Each of the transmit beams of the multiple transmit beams 502 includes a center bandwidth 512, a first side bandwidth 514, and a second side bandwidth 516.

5 [0056] In various embodiments, each BRS may be transmitted repeatedly in a pair of adjacent OFDM symbols. For a gNB 404 transmitting M distinct beams via TDM, a BRS resource may be configured with M pairs of RS symbols in which each pair is used to transmit the BRS with a same TX beam. In some embodiments, the gNB 404 may periodically transmit with different beams with a period $M \cdot T$, where T is the time between two RS transmissions. A
10 gNB 404 may transmit these M RSs using the same sequence because they may be distinguished from their transmission time. In certain embodiments, a UE 402 may not obtain the system timing from BRSs, but may acquire system timing from synchronization signals. When multiple numerologies are supported by the gNB 404, BRS may be transmitted using the same numerology of the synchronization signals.

15 [0057] In certain embodiments, a length 2 OCC can be applied to the resource elements in the two adjacent reference signal symbols. In one embodiment, a length 2 OCC may be $([1 \ 1], [1 \ -1])$. In various embodiments, with or without length 2 OCC, channel estimation may be done independently at each BRS symbol, and phase noise may be estimated from the channel estimation at the two symbols. In some embodiments, a UE 402 with poor received signal
20 strength may perform channel estimation jointly in two adjacent reference signal symbols.

[0058] Different gNBs may, in certain embodiments, transmit RSs with different sequences to reduce their mutual interference and for the UE 402 to distinguish different RSs from different gNBs. Since BRS are gNB-specific, they may be configured as part of a system information block ("SIB"). In certain embodiments, BRS may be configured either per cell or
25 per UE. For example, BRS may be configured in an RRC message for UE specific BRS, or in an SIB message or RRC for a cell-specific configuration.

[0059] A UE 402 with digital beamforming capability may, in certain embodiments, be able to receive with all of its digital beams simultaneously. Accordingly, in such embodiments, there may be no additional time needed for switching different RX beams. In some
30 embodiments, a UE 402 may measure an RS pair in two adjacent symbols to estimate a carrier frequency offset and/or phase noise to facilitate adjusting its receiver and/or improving receive quality. The UE 402 may report its measurement of phase noise to the gNB 404 in a separate feedback message (e.g., a phase noise measurement feedback message).

[0060] In some embodiments, for a UE 402 with analog or hybrid beamforming capability, the UE 402 may use two different RX beams to receive two adjacent RS symbols. In such embodiments, in each BRS instance the UE 402 may measure a TX beam reference signal received power ("RSRP") with two RX beams. In certain embodiments, for a UE 402 with N analog beams, it may take up to $M \cdot N/2$ RS instances to find the TX/RX beam combination with the largest RSRP. In various embodiments, a UE 402 may use the same RX beam to receive two adjacent RS symbol (e.g., an RS pair). In such embodiments, the UE 402 may conduct phase noise measurement with a delay. For example, the UE 402 may use $M \cdot N$ RS instances to find the best TX/RX beam combination.

[0061] In one embodiment, a BRS may have different densities in the frequency domain. For example, near the center of the carrier or near the frequency location of the synchronization signals (e.g., the center bandwidth 512), the RS may be dense, and may be sparse at the two sides of the center bandwidth 512 (e.g., the first side bandwidth 514, the second side bandwidth 516) or zero towards the edge of the carrier. In some embodiments, a bandwidth with a higher RS density may cover at least a minimum RX bandwidth of any UEs, so that UEs with the minimum RX bandwidth may receive enough RS to measure the channel/beam quality and/or track the phase noise. In certain embodiments, UEs with wider RX bandwidth may use the RS beyond the minimum bandwidth to enhance measurement quality. In various embodiments, to reduce power consumption, a UE 402 (e.g., especially a UE without active traffic) may receive with a bandwidth smaller than a maximum bandwidth it supports. Because a measured RSRP is dependent on the UE 402 measured bandwidth, when the UE 402 reports to the gNB 404 the RSRP of the RS, the UE 402 may include an indicator of the width of the bandwidth it uses for measurement.

[0062] In various embodiments, UE feedback of its BRS measurement may have the following format: RS sequence identification ("ID") (or beam/gNB ID derived from the sequence), RS time index (e.g., the position of the symbol pair where it receives the RS), RS measurement bandwidth indicator, and BRS RSRP.

[0063] In certain embodiments, a UE 402 may report the RSRP of the BRS normalized with respect to the number of BRS REs within its RX bandwidth. For example, suppose the BRS is transmitted in a uniform power spectrum density in its occupied REs, this makes the normalized RSRP independent of the RX bandwidth. In this example, the UE 402 may feedback its BRS measurement as: RS sequence ID (or beam/gNB ID derived from the sequence), RS time index (e.g., the position of the symbol pair where it receives the RS), and normalized BRS RSRP.

[0064] In some embodiments, RS sequences may have zero or small cross-correlation without regard to a RX bandwidth used by a UE 402 for measurement. For example, suppose a UE 402 measures the BRS with one of two different bandwidths, a UE measuring with narrow bandwidth covers only the center bandwidth 512, and a UE measuring with wide bandwidth covers the center bandwidth 512, the first side bandwidth 514, and the second side bandwidth 516. In such an example, the RS transmitted by different gNBs, if they share the same time and frequency resources, may have small correlations, both in the center bandwidth 512 and in the first and second side bandwidths 514 and 516. The small correlations may be realized by using two separate sequences (e.g., a first sequence in the center bandwidth 512, and a second sequence in the first and second side bandwidths 514 and 516). In certain embodiments, the same sequence may be used in the first and second side bandwidths 514 and 516. In other embodiments, different sequences may be used in the first and second side bandwidths 514 and 516. In some embodiments, the sequences used in the center bandwidth 512, the first side bandwidth 514, and/or the second side bandwidth 516 may have different lengths, depending on the width of the center bandwidth 512, the first side bandwidth 514, and/or the second side bandwidth 516, and/or their RS densities. In some embodiments, pseudo-random sequences may be generated with using the gNB ID or another ID.

[0065] In various embodiments, a BRS signal may include: a gNB 404 transmitting BRS through multiple beams periodically for TX beam sweeping in which the BRS may be cell-specific and configured via a SIB message; a BRS transmitted by a same beam in two adjacent symbols for UE 402 RX beamsweeping or phase noise measurement; a length 2 OCC may be applied to the BRs in the two adjacent symbols; a BRS may have variable density in the frequency domain to accommodate different UEs RX bandwidth; a UE 402 may report BRS RSRP either with a RX bandwidth indicator or report the normalized RSRP; separate sequences may be applied to the RS in different frequency ranges to provide good correlation properties observed by UEs with different RX bandwidth; and/or phase noise measurement from BRS may be sent by a UE 402 in separate messages.

[0066] Figure 6 is a schematic flow chart diagram illustrating one embodiment of a method 600 for beam quality determination. In some embodiments, the method 600 is performed by an apparatus, such as the remote unit 102. In certain embodiments, the method 600 may be performed by a processor executing program code, for example, a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0067] The method 600 may include receiving 602 two adjacent reference signal symbols sent from a transmit beam. The method 600 also includes determining 604 a beam quality of the

transmit beam combined with the receive beam based on one or more of the two adjacent reference signal symbols. The beam quality may include a reference signal received power. In one embodiment, the method 600 includes transmitting 606 data indicating the beam quality. In one embodiment, the beam quality includes a RX beam ID, while in another embodiment, the beam quality does not include a RX beam ID.

[0068] In one embodiment, the two adjacent reference signal symbols are the same. In a further embodiment, the two adjacent reference signal symbols are different. In certain embodiments, a first reference signal symbol of the two adjacent reference signal symbols and a second reference signal symbol of the two adjacent reference signal symbols have a length 2 orthogonal cover code applied. In some embodiments, the method 600 includes determining the beam quality of the transmit beam by performing channel estimation jointly on the two adjacent reference signal symbols. In various embodiments, the method 600 includes receiving a first reference signal symbol of the two adjacent reference signal symbols via a first receive beam and a second reference signal symbol of the two adjacent reference signal symbols via a second receive beam. In some embodiments, the method 600 includes determining the beam quality of the transmit beam by estimating a phase offset of the two adjacent reference signal symbols.

[0069] In one embodiment, the beam quality includes a phase noise, and the phase noise of the two adjacent reference signal symbols is estimated. In a further embodiment, the method 600 includes determining the beam quality of the transmit beam by determining a first reference signal received power on a first reference signal symbol of the two adjacent reference signal symbols received via a first receive beam and determining a second reference signal received power on a second reference signal symbol of the two adjacent reference signal symbols received via a second receive beam. In various embodiments, the method 600 includes transmitting data indicating the beam quality by transmitting a phase noise measurement feedback message. In some embodiments, the method 600 includes transmitting data indicating the beam quality by transmitting an indicator that indicates a width of bandwidth used for measurements. In certain embodiments, the method 600 includes transmitting data indicating the beam quality by transmitting a message including a normalized reference signal received power.

[0070] Figure 7 is a schematic flow chart diagram illustrating one embodiment of a method 700 for beam quality determination. In some embodiments, the method 700 is performed by an apparatus, such as the base unit 104. In certain embodiments, the method 700 may be performed by a processor executing program code, for example, a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0071] The method 700 may include transmitting 702 two adjacent reference signal symbols using a first transmit beam. The method 700 also includes receiving 704 data indicating a beam quality determined based on one or more of the two adjacent reference signal symbols. The beam quality may include a reference signal received power.

5 [0072] In one embodiment, the method 700 includes transmitting the two adjacent reference signal symbols using the first transmit beam by transmitting a first multiple two adjacent reference signal symbols using the first transmit beam. In a further embodiment, the method 700 includes transmitting the first multiple two adjacent reference signal symbols by transmitting a first portion of the first multiple two adjacent reference signal symbols in a center
10 bandwidth, a second portion of the first multiple two adjacent reference signal symbols in a first side bandwidth, and a third portion of the first multiple two adjacent reference signal symbols in a second side bandwidth. In certain embodiments, a density of the first portion of the first multiple two adjacent reference signal symbols is higher than a density of the second and third portions of the first multiple two adjacent reference signal symbols.

15 [0073] In some embodiments, a sequence transmitted in the first portion of the first multiple two adjacent reference signal symbols is different than a sequence transmitted in the second and third portions of the first multiple two adjacent reference signal symbols. In various embodiments, the method 700 includes transmitting a second multiple two adjacent reference signal symbols using a second transmit beam. In some embodiments, the two adjacent reference
20 signal symbols are the same. In various embodiments, the method 700 may include transmitting any predetermined number of two adjacent reference signal symbols using any predetermined number of transmit beams. As may be appreciated, a UE receiving multiple two adjacent reference signal symbols may only report the beam quality of beams having a good reference signal received power.

25 [0074] In one embodiment, the two adjacent reference signal symbols are different. In a further embodiment, the method 700 includes applying an orthogonal cover code to a first reference signal symbol of the two adjacent reference signal symbols and a second reference signal symbol of the two adjacent reference signal symbols.

30 [0075] Embodiments may be practiced in other specific forms. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

CLAIMS

1. An apparatus comprising:
a receiver that receives two adjacent reference signal symbols sent from a transmit beam;
a processor that determines a beam quality of the transmit beam based on one or more of
5 the two adjacent reference signal symbols, wherein the beam quality comprises a
reference signal received power; and
a transmitter that transmits data indicating the beam quality.
2. The apparatus of claim 1, wherein the two adjacent reference signal symbols are the same.
3. The apparatus of claim 1, wherein the two adjacent reference signal symbols are different.
- 10 4. The apparatus of claim 1, wherein a first reference signal symbol of the two adjacent
reference signal symbols and a second reference signal symbol of the two adjacent
reference signal symbols have a length 2 orthogonal cover code applied.
5. The apparatus of claim 1, wherein the processor determines the beam quality of the
transmit beam by performing channel estimation jointly on the two adjacent reference
15 signal symbols.
6. The apparatus of claim 1, wherein the receiver receives a first reference signal symbol of
the two adjacent reference signal symbols via a first receive beam and a second reference
signal symbol of the two adjacent reference signal symbols via a second receive beam.
7. The apparatus of claim 1, wherein the processor determines the beam quality of the
20 transmit beam by estimating a phase offset of the two adjacent reference signal symbols.
8. The apparatus of claim 1, wherein the beam quality comprises a phase noise, and the
processor estimates the phase noise of the two adjacent reference signal symbols.

9. The apparatus of claim 1, wherein the processor determines the beam quality of the transmit beam by determining a first reference signal received power on a first reference signal symbol of the two adjacent reference signal symbols received via a first receive beam and determining a second reference signal received power on a second reference signal symbol of the two adjacent reference signal symbols received via a second receive beam.
10. The apparatus of claim 1, wherein the transmitter transmits data indicating the beam quality by transmitting a phase noise measurement feedback message.
11. The apparatus of claim 1, wherein the transmitter transmits data indicating the beam quality by transmitting an indicator that indicates a width of bandwidth used for measurements.
12. The apparatus of claim 1, wherein the transmitter transmits data indicating the beam quality by transmitting a message comprising a normalized reference signal received power.
13. A method comprising:
receiving two adjacent reference signal symbols sent from a transmit beam;
determining a beam quality of the transmit beam based on one or more of the two adjacent reference signal symbols, wherein the beam quality comprises a reference signal received power; and
transmitting data indicating the beam quality.
14. The method of claim 13, wherein the two adjacent reference signal symbols are the same.
15. The method of claim 13, wherein the two adjacent reference signal symbols are different.
16. The method of claim 13, wherein a first reference signal symbol of the two adjacent reference signal symbols and a second reference signal symbol of the two adjacent reference signal symbols have a length 2 orthogonal cover code applied.

17. The method of claim 13, wherein determining the beam quality of the transmit beam comprises performing channel estimation jointly on the two adjacent reference signal symbols.
18. The method of claim 13, wherein receiving the two adjacent reference signal symbols comprises receiving a first reference signal symbol of the two adjacent reference signal symbols via a first receive beam and receiving a second reference signal symbol of the two adjacent reference signal symbols via a second receive beam.
19. The method of claim 13, wherein determining the beam quality of the transmit beam comprises estimating a phase offset of the two adjacent reference signal symbols.
20. The method of claim 13, wherein the beam quality comprises a phase noise, and the phase noise of the two adjacent reference signal symbols is estimated.
21. The method of claim 13, wherein determining the beam quality of the transmit beam comprises determining a first reference signal received power on a first reference signal symbol of the two adjacent reference signal symbols received via a first receive beam and determining a second reference signal received power on a second reference signal symbol of the two adjacent reference signal symbols received via a second receive beam.
22. The method of claim 13, wherein transmitting data indicating the beam quality comprises transmitting a phase noise measurement feedback message.
23. The method of claim 13, wherein transmitting data indicating the beam quality comprises transmitting an indicator that indicates a width of bandwidth used for measurements.
24. The method of claim 13, wherein transmitting data indicating the beam quality comprises transmitting a message comprising a normalized reference signal received power.
25. An apparatus comprising:
a transmitter that transmits two adjacent reference signal symbols using a first transmit beam; and

a receiver that receives data indicating a beam quality determined based on one or more of the two adjacent reference signal symbols, wherein the beam quality comprises a reference signal received power.

26. The apparatus of claim 25, wherein the transmitter transmits the two adjacent reference signal symbols using the first transmit beam by transmitting a first plurality of two adjacent reference signal symbols using the first transmit beam.
27. The apparatus of claim 26, wherein the transmitter transmits the first plurality of two adjacent reference signal symbols by transmitting a first portion of the first plurality of two adjacent reference signal symbols in a center bandwidth, a second portion of the first plurality of two adjacent reference signal symbols in a first side bandwidth, and a third portion of the first plurality of two adjacent reference signal symbols in a second side bandwidth.
28. The apparatus of claim 27, wherein a density of the first portion of the first plurality of two adjacent reference signal symbols is higher than a density of the second and third portions of the first plurality of two adjacent reference signal symbols.
29. The apparatus of claim 27, wherein a sequence transmitted in the first portion of the first plurality of two adjacent reference signal symbols is different than a sequence transmitted in the second and third portions of the first plurality of two adjacent reference signal symbols.
30. The apparatus of claim 26, wherein the transmitter transmits a second plurality of two adjacent reference signal symbols using a second transmit beam.
31. The apparatus of claim 25, wherein the two adjacent reference signal symbols are the same.
32. The apparatus of claim 25, wherein the two adjacent reference signal symbols are different.

33. The apparatus of claim 25, further comprising a processor that applies an orthogonal cover code to a first reference signal symbol of the two adjacent reference signal symbols and a second reference signal symbol of the two adjacent reference signal symbols.
34. A method comprising:
5 transmitting two adjacent reference signal symbols using a first transmit beam; and receiving data indicating a beam quality determined based on one or more of the two adjacent reference signal symbols, wherein the beam quality comprises a reference signal received power.
35. The method of claim 34, wherein transmitting the two adjacent reference signal symbols
10 using the first transmit beam comprises transmitting a first plurality of two adjacent reference signal symbols using the first transmit beam.
36. The method of claim 35, wherein transmitting the first plurality of two adjacent reference signal symbols comprises transmitting a first portion of the first plurality of two adjacent reference signal symbols in a center bandwidth, a second portion of the first plurality of
15 two adjacent reference signal symbols in a first side bandwidth, and a third portion of the first plurality of two adjacent reference signal symbols in a second side bandwidth.
37. The method of claim 36, wherein a density of the first portion of the first plurality of two adjacent reference signal symbols is higher than a density of the second and third portions of the first plurality of two adjacent reference signal symbols.
- 20 38. The method of claim 36, wherein a sequence transmitted in the first portion of the first plurality of two adjacent reference signal symbols is different than a sequence transmitted in the second and third portions of the first plurality of two adjacent reference signal symbols.
- 25 39. The method of claim 35, further comprising transmitting a second plurality of two adjacent reference signal symbols using a second transmit beam.
40. The method of claim 34, wherein the two adjacent reference signal symbols are the same.

41. The method of claim 34, wherein the two adjacent reference signal symbols are different.
42. The method of claim 34, further comprising applying an orthogonal cover code to a first reference signal symbol of the two adjacent reference signal symbols and a second reference signal symbol of the two adjacent reference signal symbols.

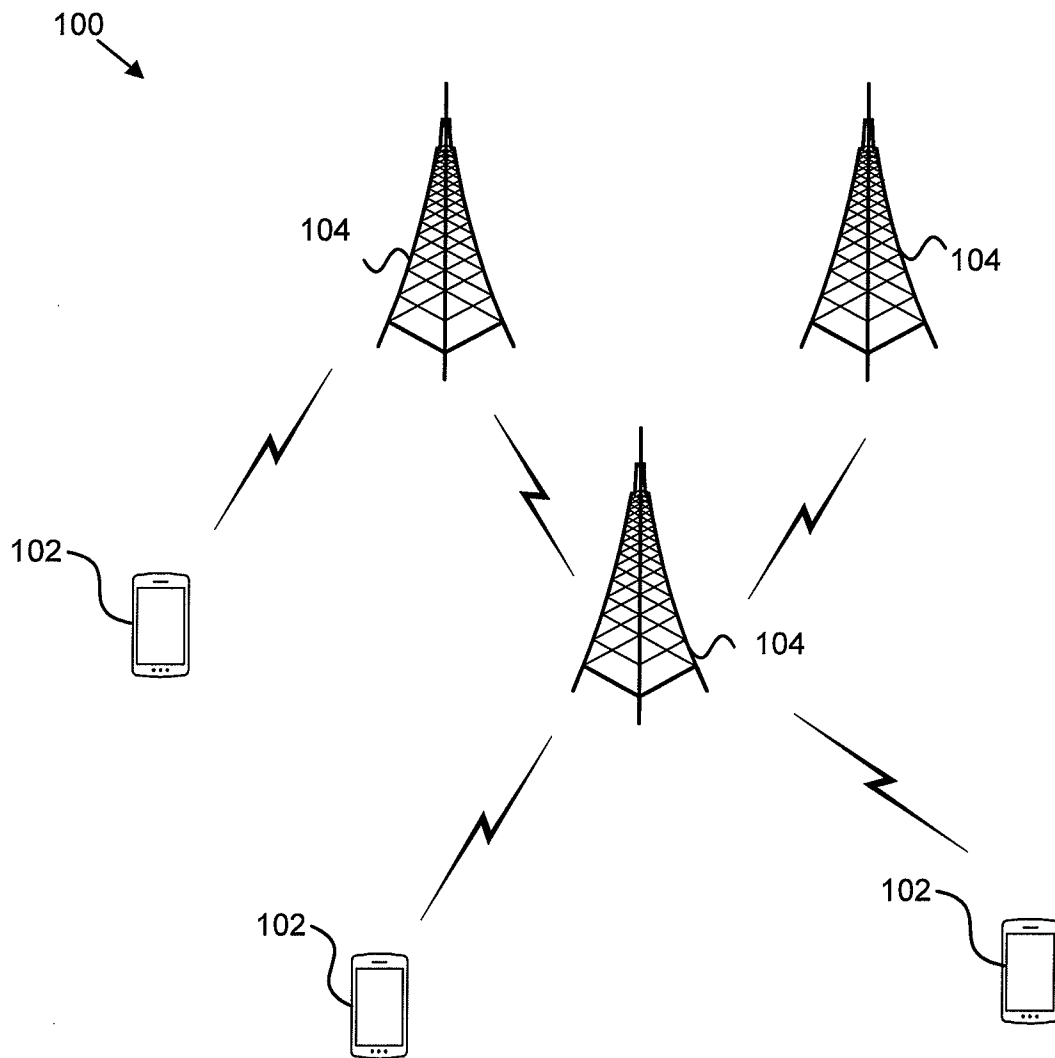


FIG. 1

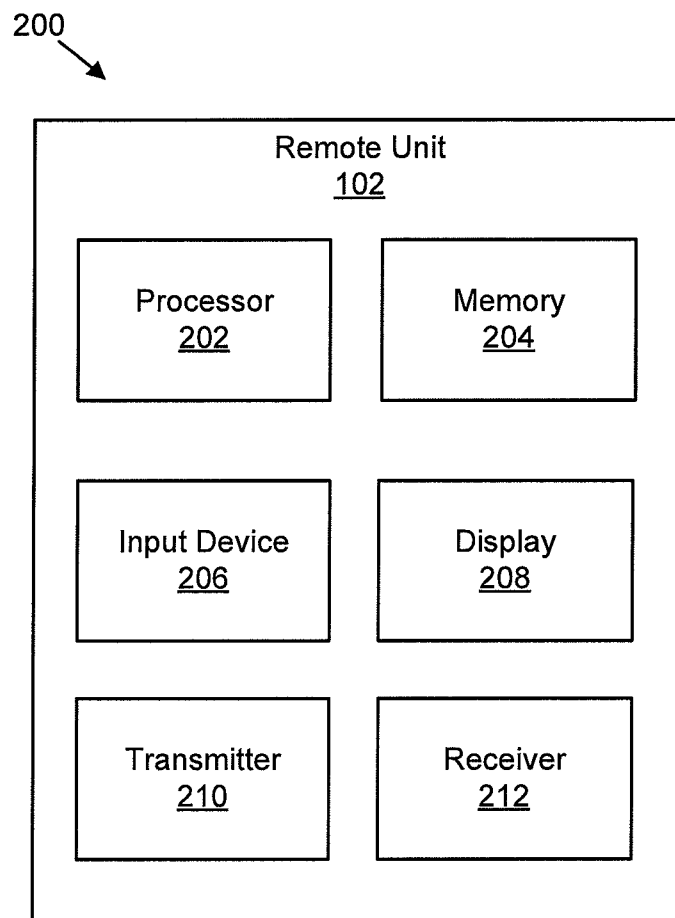


FIG. 2

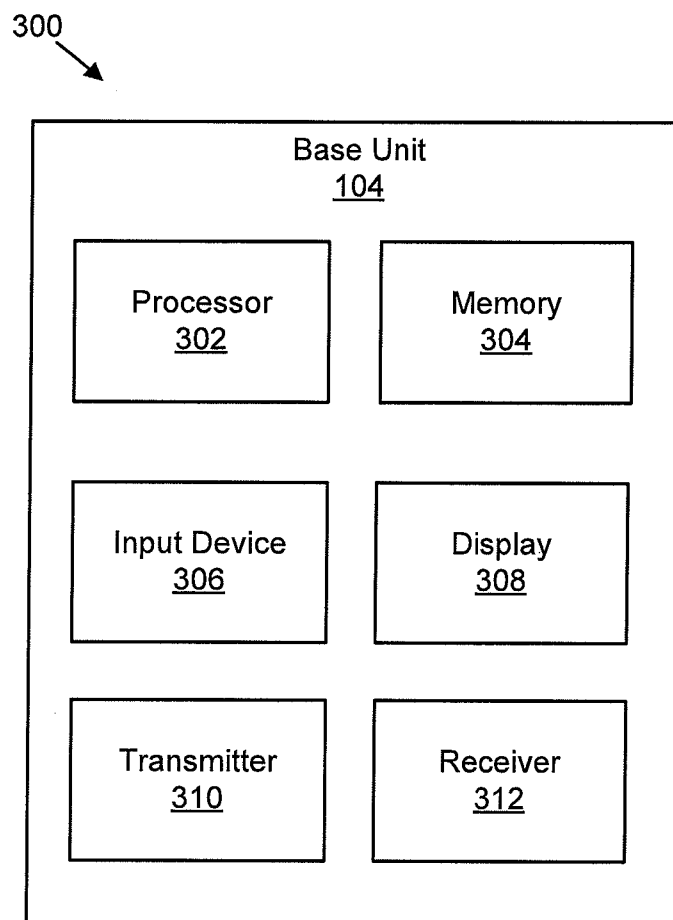


FIG. 3

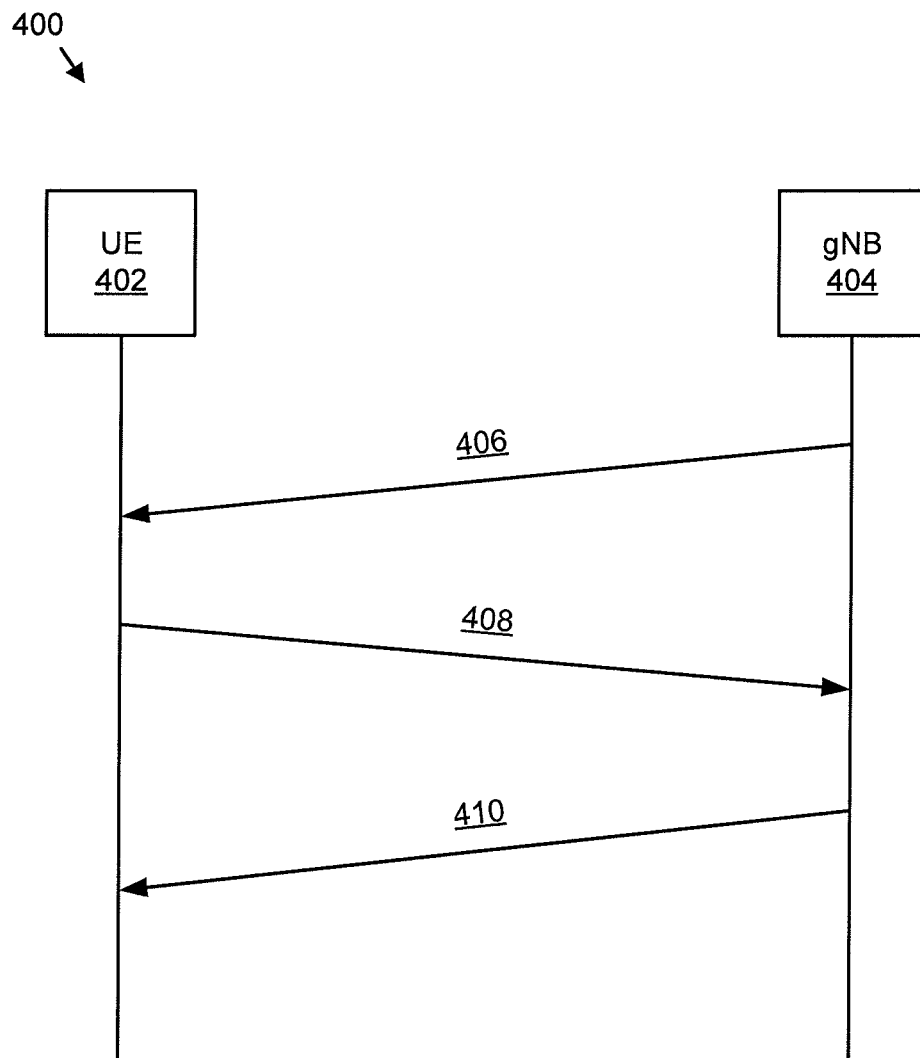


FIG. 4

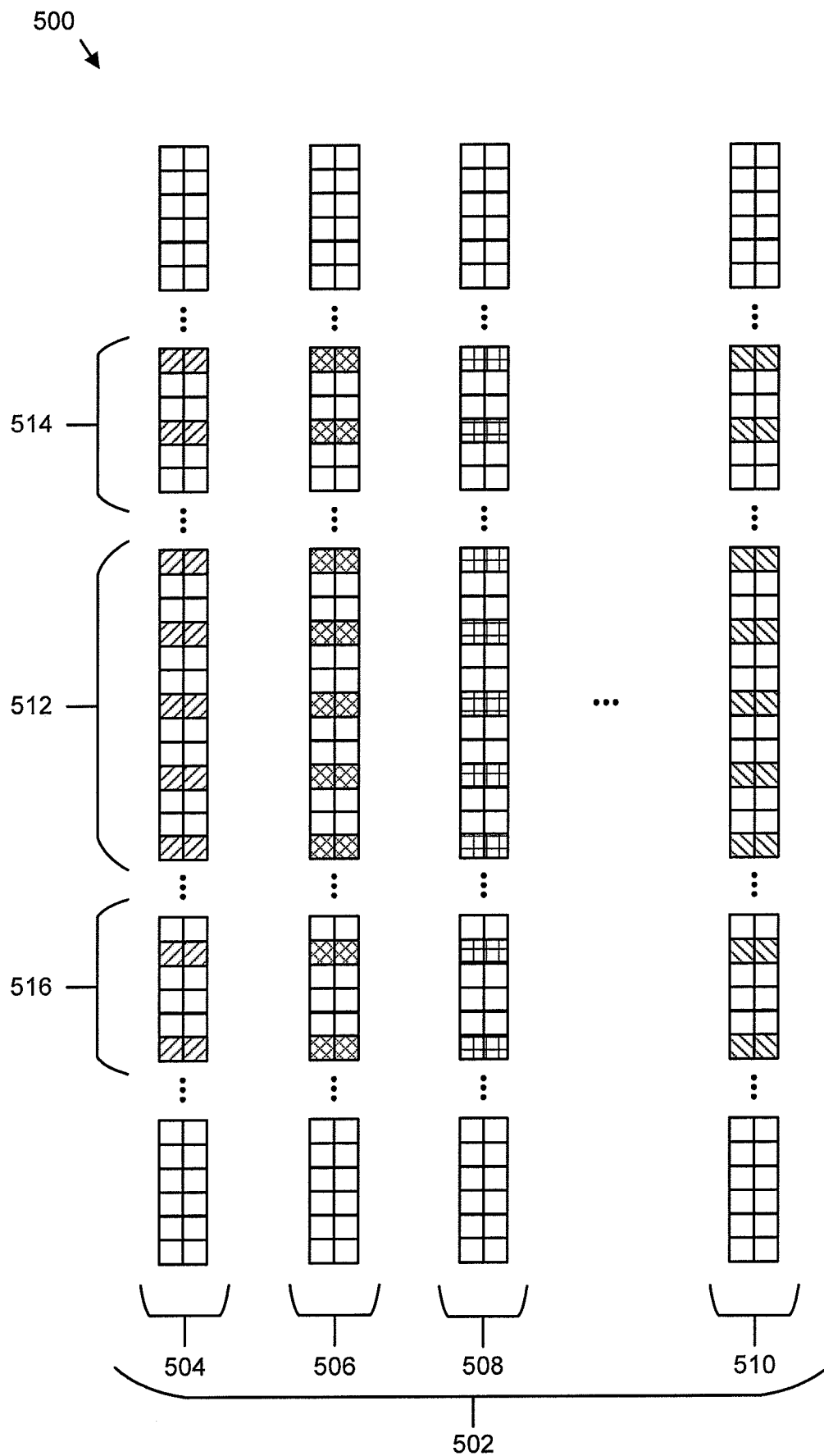


FIG. 5

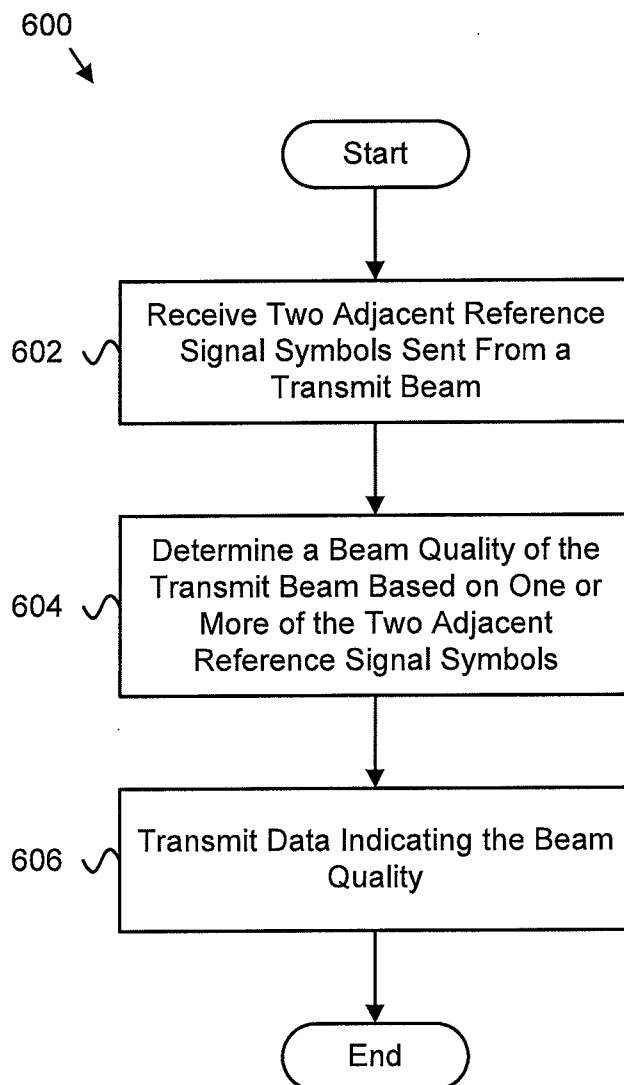


FIG. 6

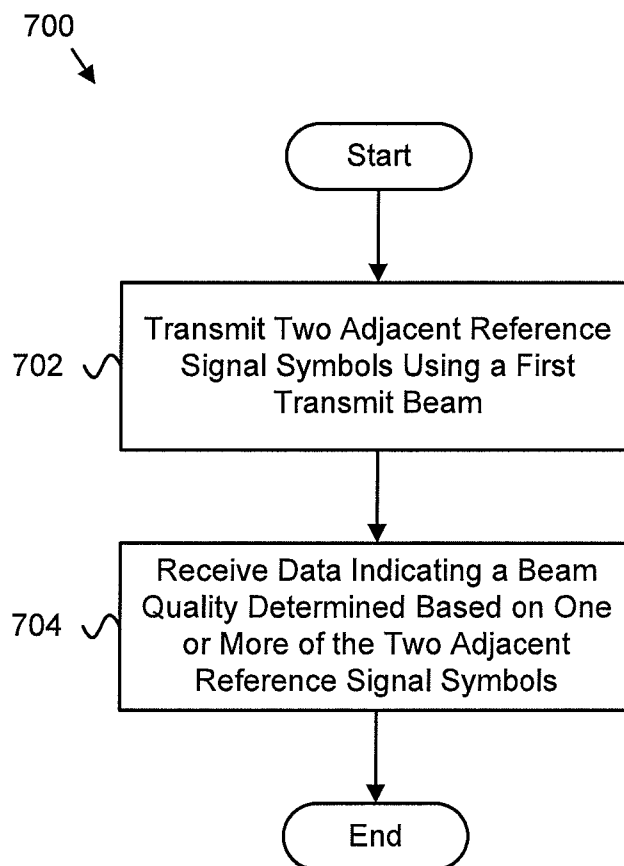


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2017/070312

A. CLASSIFICATION OF SUBJECT MATTER

H04W 24/00(2009.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W

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

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

CNPAT, CNKI, WPI, EPODOC, 3GPP: adjacent, consecutive, continuous, successive, sequential, reference signal symbol, RSS, beam, quality, RSRP, reference signal received power

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013223256 A1 (QUALCOMM INC.) 29 August 2013 (2013-08-29) description, paragraphs 0033-0034, 0044-0081 and figures 6-13	1-42
X	CN 102783062 A (NEC CORPORATION ET AL.) 14 November 2012 (2012-11-14) description, paragraphs 0029-0069	1-42
A	CN 103929772 A (ZHANXUN COMMUNICATION SHANGHAI CO., LTD.) 16 July 2014 (2014-07-16) the whole document	1-42



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

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

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

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

“&” document member of the same patent family

Date of the actual completion of the international search

04 September 2017

Date of mailing of the international search report

11 October 2017

Name and mailing address of the ISA/CN

STATE INTELLECTUAL PROPERTY OFFICE OF THE
P.R.CHINA
6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing
100088
China

Authorized officer

HE,Xijia

Facsimile No. (86-10)62019451

Telephone No. (86-10)62413281

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2017/070312

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
US	2013223256	A1	29 August 2013	TW	201342839	A	16 October 2013
				WO	2013130886	A1	06 September 2013
				EP	2820810	A1	07 January 2015
				KR	20140130730	A	11 November 2014
				JP	2015513843	A	14 May 2015
				CN	104160670	A	19 November 2014
CN	102783062	A	14 November 2012	TW	201214985	A	01 April 2012
				EP	2538589	A1	26 December 2012
				WO	2011102289	A1	25 August 2011
				US	2013034191	A1	07 February 2013
				JP	2012500570	X	17 June 2013
				IN7	935CHENP2012	A	18 December 2015
CN	103929772	A	16 July 2014	None			