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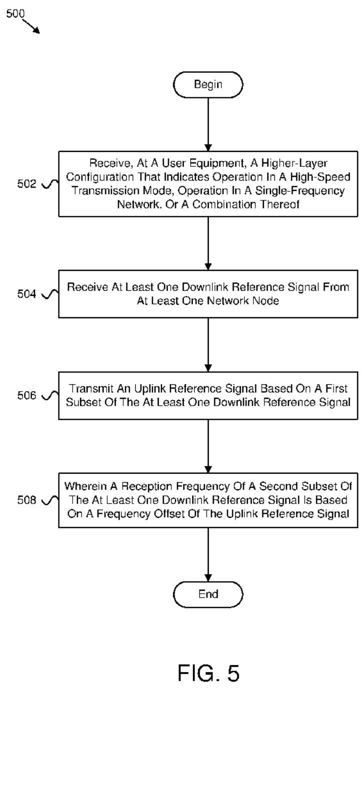

FIG. 5

(57) **Abstract:** Apparatuses, methods, and systems are disclosed for frequency correlation based on a frequency offset. One method (500) includes receiving (502), at a user equipment, a higher-layer configuration that indicates operation in a high-speed transmission mode, operation in a single-frequency network, or a combination thereof. The method (500) includes receiving (504) at least one downlink reference signal from at least one network node. The method (500) includes transmitting (506) an uplink reference signal based on a first subset of the at least one downlink reference signal. A reception frequency of a second subset of the at least one downlink reference signal is based (508) on a frequency offset of the uplink reference signal.

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FREQUENCY CORRELATION BASED ON A FREQUENCY OFFSET

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to United States Patent Application Serial Number 63/062,327 entitled "APPARATUSES, METHODS, AND SYSTEMS FOR REFERENCE SIGNALING ENHANCEMENTS FOR HIGH SPEED SCENARIOS UNDER SINGLE FREQUENCY NETWORKS" and filed on August 6, 2020 for Ahmed Hindy, which is incorporated herein by reference in its entirety.

FIELD

[0002] The subject matter disclosed herein relates generally to wireless communications and more particularly relates to frequency correlation based on a frequency offset.

BACKGROUND

[0003] In certain wireless communications networks, high speed vehicles may make and receive transmissions. However, the transmissions made and received may not be synchronized.

BRIEF SUMMARY

[0004] Methods for frequency correlation based on a frequency offset are disclosed. Apparatuses and systems also perform the functions of the methods. One embodiment of a method includes receiving, at a user equipment, a higher-layer configuration that indicates operation in a high-speed transmission mode, operation in a single-frequency network, or a combination thereof. In some embodiments, the method includes receiving at least one downlink reference signal from at least one network node. In certain embodiments, the method includes transmitting an uplink reference signal based on a first subset of the at least one downlink reference signal. In various embodiments, a reception frequency of a second subset of the at least one downlink reference signal is based on a frequency offset of the uplink reference signal.

[0005] One apparatus for frequency correlation based on a frequency offset includes a user equipment. In some embodiments, the apparatus includes a receiver that: receives a higher-layer configuration that indicates operation in a high-speed transmission mode, operation in a single-frequency network, or a combination thereof; and receives at least one downlink reference signal from at least one network node. In various embodiments, the apparatus includes a transmitter that transmits an uplink reference signal based on a first subset of the at least one downlink reference signal. In certain embodiments, a reception frequency of a second subset of the at least one downlink reference signal is based on a frequency offset of the uplink reference signal.

[0006] Another embodiment of a method for frequency correlation based on a frequency offset includes transmitting, from a network device, a higher-layer configuration that indicates operation in a high-speed transmission mode, operation in a single-frequency network, or a combination thereof. In some embodiments, the method includes transmitting at least one downlink reference signal to a user equipment. In certain embodiments, the method includes receiving an uplink reference signal based on a first subset of the at least one downlink reference signal. In various embodiments, a transmission frequency of a second subset of the at least one downlink reference signal is based on a frequency offset of the uplink reference signal.

[0007] Another apparatus for frequency correlation based on a frequency offset includes a network device. In certain embodiments, the apparatus includes a transmitter that: transmits a higher-layer configuration that indicates operation in a high-speed transmission mode, operation in a single-frequency network, or a combination thereof; and transmits at least one downlink reference signal to a user equipment. In some embodiments, the apparatus includes a receiver that receives an uplink reference signal based on a first subset of the at least one downlink reference signal. In various embodiments, a transmission frequency of a second subset of the at least one downlink reference signal is based on a frequency offset of the uplink reference signal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] 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:

[0009] Figure 1 is a schematic block diagram illustrating one embodiment of a wireless communication system for frequency correlation based on a frequency offset;

[0010] Figure 2 is a schematic block diagram illustrating one embodiment of an apparatus that may be used for frequency correlation based on a frequency offset;

[0011] Figure 3 is a schematic block diagram illustrating one embodiment of an apparatus that may be used for frequency correlation based on a frequency offset;

[0012] Figure 4 is a schematic block diagram illustrating one embodiment of communications for frequency correlation based on a frequency offset;

[0013] Figure 5 is a flow chart diagram illustrating one embodiment of a method for frequency correlation based on a frequency offset; and

[0014] Figure 6 is a flow chart diagram illustrating another embodiment of a method for frequency correlation based on a frequency offset.

DETAILED DESCRIPTION

[0015] 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.

[0016] 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.

[0017] 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.

[0018] 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.

[0019] 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.

[0020] 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.

[0021] 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).

[0022] 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.

[0023] 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.

[0024] 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. The code may be provided to a processor of a general purpose computer, special purpose 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.

[0025] The code may also be stored in a storage device that can direct a computer, other 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.

[0026] The code may also be loaded onto a computer, other programmable data 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.

[0027] The schematic flowchart diagrams and/or schematic block diagrams in the Figures 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 instructions of the code for implementing the specified logical function(s).

[0028] 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 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.

[0029] 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.

[0030] 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.

[0031] Figure 1 depicts an embodiment of a wireless communication system 100 for frequency correlation based on a frequency offset. In one embodiment, the wireless communication system 100 includes remote units 102 and network units 104. Even though a specific number of remote units 102 and network units 104 are depicted in Figure 1, one of skill in the art will recognize that any number of remote units 102 and network units 104 may be included in the wireless communication system 100.

[0032] 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), aerial vehicles, drones, 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 network units 104 via UL communication signals. In certain embodiments, the remote units 102 may communicate directly with other remote units 102 via sidelink communication.

[0033] The network units 104 may be distributed over a geographic region. In certain embodiments, a network unit 104 may also be referred to and/or may include one or more of an access point, an access terminal, a base, a base station, a location server, a core network ("CN"), a radio network entity, a Node-B, an evolved node-B ("eNB"), a 5G node-B ("gNB"), a Home Node-B, a relay node, a device, a core network, an aerial server, a radio access node, an access point ("AP"), new radio ("NR"), a network entity, an access and mobility management function ("AMF"), a unified data management ("UDM"), a unified data repository ("UDR"), a UDM/UDR, a policy control function ("PCF"), a radio access network ("RAN"), a network slice selection function ("NSSF"), an operations, administration, and management ("OAM"), a session management function ("SMF"), a user plane function ("UPF"), an application function, an authentication server function ("AUSF"), security anchor functionality ("SEAF"), trusted non-3GPP gateway function ("TNGF"), or by any other terminology used in the art. The network units 104 are generally part of a radio access network that includes one or more controllers communicably coupled to one or more corresponding network 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.

[0034] In one implementation, the wireless communication system 100 is compliant with NR protocols standardized in third generation partnership project ("3GPP"), wherein the network unit 104 transmits using an OFDM modulation scheme on the downlink ("DL") and the remote units 102 transmit on the uplink ("UL") using a single-carrier frequency division multiple access ("SC-FDMA") scheme or an orthogonal frequency division multiplexing ("OFDM") scheme. More generally, however, the wireless communication system 100 may implement some other open or proprietary communication protocol, for example, WiMAX, institute of electrical and electronics engineers ("IEEE") 802.11 variants, global system for mobile communications ("GSM"), general packet radio service ("GPRS"), universal mobile telecommunications system ("UMTS"), long term evolution ("LTE") variants, code division multiple access 2000 ("CDMA2000"), Bluetooth®, ZigBee, Sigfoxx, among other protocols. The present disclosure is not intended to be limited to the implementation of any particular wireless communication system architecture or protocol.

[0035] The network 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 network units 104 transmit DL communication signals to serve the remote units 102 in the time, frequency, and/or spatial domain.

[0036] In various embodiments, a remote unit 102 may receive a higher-layer configuration that indicates operation in a high-speed transmission mode, operation in a single-frequency network, or a combination thereof. In some embodiments, the remote unit 102 may receive at least one downlink reference signal from at least one network node. In certain embodiments, the remote unit 102 may transmit an uplink reference signal based on a first subset of the at least one downlink reference signal. In various embodiments, a reception frequency of a second subset of the at least one downlink reference signal is based on a frequency offset of the uplink reference signal. Accordingly, the remote unit 102 may be used for frequency correlation based on a frequency offset.

[0037] In certain embodiments, a network unit 104 may transmit a higher-layer configuration that indicates operation in a high-speed transmission mode, operation in a single-frequency network, or a combination thereof. In some embodiments, the network unit 104 may transmit at least one downlink reference signal to a user equipment. In certain embodiments, the network unit 104 may receive an uplink reference signal based on a first subset of the at least one downlink reference signal. In various embodiments, a transmission frequency of a second subset of the at least one downlink reference signal is based on a frequency offset of the uplink reference signal. Accordingly, the network unit 104 may be used for frequency correlation based on a frequency offset.

[0038] Figure 2 depicts one embodiment of an apparatus 200 that may be used for frequency correlation based on a frequency offset. 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 and/or the display 208.

[0039] 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 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. The processor 202 is communicatively coupled to the memory 204, the input device 206, the display 208, the transmitter 210, and the receiver 212.

[0040] 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 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 also stores program code and related data, such as an operating system or other controller algorithms operating on the remote unit 102.

[0041] 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 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.

[0042] 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, a liquid crystal display ("LCD"), a light emitting diode ("LED") display, an organic light emitting diode ("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.

[0043] 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.

[0044] In some embodiments, the receiver 212: receives a higher-layer configuration that indicates operation in a high-speed transmission mode, operation in a single-frequency network, or a combination thereof; and receives at least one downlink reference signal from at least one network node. In various embodiments, the transmitter 210 transmits an uplink reference signal based on a first subset of the at least one downlink reference signal. In certain embodiments, a reception frequency of a second subset of the at least one downlink reference signal is based on a frequency offset of the uplink reference signal.

[0045] 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. 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.

[0046] Figure 3 depicts one embodiment of an apparatus 300 that may be used for frequency correlation based on a frequency offset. The apparatus 300 includes one embodiment of the network unit 104. Furthermore, the network 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.

[0047] In certain embodiments, the transmitter 310: transmits a higher-layer configuration that indicates operation in a high-speed transmission mode, operation in a single-frequency network, or a combination thereof; and transmits at least one downlink reference signal to a user equipment. In some embodiments, the receiver 312 receives an uplink reference signal based on a first subset of the at least one downlink reference signal. In various embodiments, a transmission frequency of a second subset of the at least one downlink reference signal is based on a frequency offset of the uplink reference signal.

[0048] In certain embodiments, high speed rail transportation is expanding and a number of passengers with smart devices like laptops and mobile phones are growing. Current technologies support data ranges from tens of kbps to tens of Mbps which may not be enough to handle demand for high-data-rates and increased reliability and/or latency for on-board broadband services. Some embodiments found herein include enhancements to support high speed train (“HST”) and/or single frequency network (“SFN”) configurations.

[0049] In some embodiments, such as in SFN configurations (e.g., all cells operate at the same frequency), multiple remote radio heads may be located along a railway and connected to a central unit via fiber. The radio heads may share a same cell identifier (“ID”). If the transmissions from transmission and reception points (“TRPs”) within a cell are synchronized, SFN deployment may enlarge a cell coverage, reduce a frequency of handovers, and achieve transmission diversity and power gain. In various embodiments, based on a 6 dB pathloss difference between any two remote radio heads (“RRHs”), a train may take advantage of simultaneous two RRH transmissions for sessions of at least 4 seconds long (e.g., for high speed rail configurations having a train speed of 500 km/hr).

[0050] In certain embodiments, such as for SFN transmission, a physical downlink shared channel (“PDSCH”) transmission may be repeated from two TRPs using a single scheduling downlink control information (“DCI”) indicating a single demodulation reference signal (“DMRS”) port and a single transmission configuration indicator (“TCI”) state. In some embodiments, a doppler shift for a transmission a first RRH may be different than a doppler shift from a second RRH. If a receiver uses long-term channel statistics associated with an indicated TCI state to estimate the aggregate channel, there may be estimation errors and performance degradation.

[0051] In various embodiments, a single DCI multi-TRP transmission may be used. The DCI may indicate DMRS ports from different code division multiplexing (“CDM”) groups along with a TCI codepoint indicating two TCI states. Some layers of a transmitted transport block (“TB”) may be sent from a first RRH and some layers may be sent from a second RRH. This may cause interlayer interference and may not achieve a power gain resulting in no cell coverage increase. Also, due to a varying proximity of two RRHs to a UE, a signal-to-noise (“SNR”) ratio gap between signals from two TRPs may lead to constraining a modulation and coding scheme (“MCS”) level (e.g., via a channel quality indicator (“CQI”)) to the worst of both transmissions, assuming a single codeword (“CW”).

[0052] Embodiments described herein enable a UE to receive data from the same ports from each TRP of a set of TRPs to achieve a power gain while estimating independently a channel from each TRP to improve performance.

[0053] In certain embodiments, a sounding reference signal ("SRS") transmitted from a UE may be used to provide an estimate of a Doppler shift for each UE-RRH channel link. In some embodiments, let a Doppler shift computed at a RRH k be Δfk. Since Doppler shift is reciprocal (e.g., the Doppler shift between two transceivers (e.g., UE and RRH, or transmitter ("TX") and receiver ("RX") for time division duplexing ("TDD") and approximately the same for frequency division duplexing ("FDD") (e.g., carrier frequency much larger than a duplex spacing)) may be the same regardless of which node is transmitting), RRH k may use the Doppler shift computed for uplink ("UL") to pre-compensate a downlink ("DL") Doppler shift. For example, a frequency offset of -Δfk may be applied prior to the transmitting the DL reference signals ("RSs") and data and/or control signaling over a PDSCH and/or a physical downlink control channel ("PDCCH").

[0054] In various embodiments, RRH k may pre-compensate a DL Doppler shift via applying a frequency offset of Δfj -Δfk (e.g., aligning its offset with that of another RRH j), prior to transmitting a DL RSs and data and/or control signaling over a PDSCH and/or a PDCCH.

[0055] It should be noted that, for Doppler reciprocity to hold, it may be required that a spatial-domain transmit filter used for transmission of a SRS be similar to a spatial-domain filter used for reception of a subsequent tracking reference signal ("TRS") and/or PDSCH DMRS, which may be applied if a UE is configured with a higher layer parameter related to high speed users (e.g., highSpeedEnhancedDemodulationFlag, highSpeedFlag, or highSpeedEnhDemodFlag-r17). As may be appreciated, flags with other names that indicate a high-speed user are not precluded.

[0056] In certain embodiments, an equation may be used to indicate a validity of a spatial relation (e.g., if a UE receives DCI triggering an SRS in slot n). In such embodiments, the spatial-domain filter used for transmitting a target SRS at slot $n + k0$ may be the same as the receive spatial filter used for the TRS that is received in the time window from slot $n + k1$ up to slot $n + k2$, where k0, k1, and k2 are arbitrary positive integer values that are either set by a rule or are higher-layer configured, and satisfy $k0 < k1 \leq k2$.

[0057] In some embodiments, an equation may be used to indicate a validity of a spatial relation (e.g., if a UE transmits an SRS in slot n). In such embodiments, the spatial-domain filter used for receiving a TRS for up to slot $n + k3$ may be the same as the spatial-domain filter used for transmitting a target SRS, where k3 is a positive integer value.

[0058] In various embodiments, no equation is used to indicate a validity of a spatial relation. In such embodiments, the spatial-domain filter for TRS reception is the same as the spatial-domain filter of a prior SRS transmission if a UE is configured with a flag that indicates high speed (e.g., highSpeedEnhDemodFlag-r17). In certain embodiments, the same spatial relation information may apply to all SRS resources in the same SRS resource set.

[0059] In certain embodiments, some UEs may track multiple (e.g., up to 8) TRS resource sets simultaneously. In such embodiments, each TRS may indicate a different beam transmitted from a network side (e.g., TRP, RRH). Each of the TRSs may be quasi-co-located (“QCLed”) with a synchronization signal (“SS”) and/or physical broadcast channel (“PBCH”) block with respect to Type C, as well as Type-D QCL with a non-zero power (“NZP”) channel state information (“CSI”) RS (“CSI-RS”) configured with higher-layer parameter repetition (e.g., CSI-RS for beam management (e.g., transmitted with a narrower beam width than the SS and/or PBCH block)).

[0060] In some embodiments, a UE reports an index indicating a beam with best channel characteristics to a network. The UE reports the index in an indicator called CSI-RS resource indicator (“CRI”) in a corresponding CSI report. In a high speed train (“HST”) SFN (“HST-SFN”) deployment, more than one TRS may be transmitted from RRHs in a system so that a UE may estimate a Doppler shift of each RRH independently. In a HST-SFN configuration, it may be beneficial for the UE to report a CRI with an appropriate Doppler shift in addition to other considerations including received power and signal to interference and noise ratio (“SINR”) values.

[0061] In various embodiments, a UE feeds back one or more CRI values in a CSI report that corresponds to (e.g., has a QCL relationship with) one or more different TRS resources. At least one of the one or more TRS resources may be a periodic TRS or an aperiodic TRS which may be triggered by reception of DCI.

[0062] In certain embodiments, a UE feeds back one codepoint referring to one or more CRI values in a CSI report that correspond to (e.g., has a QCL relationship with) one or more different TRS resources. At least one of the one or more TRS resources may be a periodic TRS or an aperiodic TRS which may be triggered by reception of DCI.

[0063] In some embodiments, a UE feeds back a CSI report corresponding to each TRS resource of one or more TRS resources. In such embodiments, at least one TRS resource of the one or more TRS resources may be a periodic TRS or an aperiodic TRS which may be triggered by reception of DCI.

[0064] In various embodiments, a UE may be configured with an SRS resource set with one or more SRS resources for SRS transmission. The SRS resource set applicability may be determined by a usage parameter (e.g., 'beamManagement'). In one example, a single SRS resource may be configured. In another example, a single port SRS may be configured within an SRS resource. The SRS resource may be configured with spatial relation information (e.g., higher layer parameter spatialRelationInfo) indicating a spatial relation between a reference RS and a target SRS by indicating an identifier ("ID") of the reference RS. The reference RS may be a SS and/or PBCH block, CSI-RS, or an SRS configured on the same or different component carrier and/or serving cell and/or bandwidth part as the target SRS.

[0065] In one example, a reference RS may be a SS and/or PBCH block or CSI-RS configured on a serving cell indicated by higher layer parameter servingCellId (e.g., if present), a same serving cell as the target SRS, or an SRS configured on an uplink BWP indicated by a higher layer parameter uplinkBWP, and the serving cell indicated by the higher layer parameter servingCellId (e.g., if present) or the same serving cell as the target SRS. The UE may transmit the target SRS resource with the same spatial domain transmission filter used for the reception of the reference RS. If a reference RS is an SRS (e.g., higher layer parameter spatialRelationInfo containing the ID of a reference 'srs'), the UE transmits the target SRS resource with the same spatial domain transmission filter used for the transmission of the reference periodic SRS.

[0066] In another example, the reference RS is a first TRS (e.g., first NZP CSI-RS resource set configured with trs-info - also known as CSI-RS - for tracking). The TRS may be a single antenna port. The first TRS may be transmitted by a first RRH or may be SFN transmitted from one or more RRHs, and may be transmitted without Doppler pre-compensation at the first RRH or any of the RRHs. The UE may perform frequency tracking (e.g., may also perform time tracking) (e.g., estimate frequency offsets, Doppler shift, etc.) based on the first TRS. The UE may transmit the target SRS based on the determined frequency tracking and based on the measurements on the first TRS. The UE may be configured with a second TRS (e.g., second NZP CSI-RS resource set configured with trs-info). The second TRS may be SFN transmitted from one or more RRHs and may be transmitted with Doppler pre-compensation from at least one of the RRHs (e.g., first RRH). The RRH may determine the Doppler pre-compensation value (e.g., sign and magnitude) based on the received target SRS. The UE may receive a DL scheduling assignment DCI scheduling a PDSCH and indicating a codepoint in a TCI state bit field indicating one TCI state with a QCL relationship between the second TRS and the PDSCH DMRS antenna ports. The QCL relation may at least be a QCL Type-A. The TCI state may also indicate a QCL Type-D with the same TRS or another CSI-RS resource (e.g., CSI-RS for beam management or CSI-RS for CSI acquisition). The one or more PDSCH DMRS ports may belong to the same DMRS CDM group. The UE receives the PDSCH based on the indicated TCI state and QCL relationships. The UE may receive the PDSCH assuming an SFN transmission for the PDSCH transmitted over an aggregate or composite channel composed and/or constructed of a channel from the individual RRHs (e.g., H1 from first RRH, H2 from second RRH - H1 + H2).

[0067] In another example, the first TRS may be transmitted from the first RRH (or first group of RRH, or RRHs with a first (e.g., same) unidirectional antenna beam pattern), and the SFN second TRS transmission includes an TRS transmission from the first RRH with Doppler pre-compensated, and a TRS transmission from the second RRH (or second group of RRH, or RRHs with a second (e.g., same) using a unidirectional antenna beam pattern, the second unidirectional antenna beam pattern being different than the first unidirectional antenna beam pattern) that is not Doppler pre-compensated. An RRH may comprise bi-directional antennas or only unidirectional antennas. The first TRS and/or the second TRS may be periodic TRS or aperiodic TRS.

[0068] In some embodiments, based on a trajectory of a UE in a train, a received power and/or a SINR from different RRHs may vary significantly. For instance, whenever the UE is within close proximity to one RRH, it may be beneficial that the UE receives control and/or data signaling from this RRH, while the other RRHs are switched off (e.g., with respect to a particular UE). Thereby, it may be beneficial if the network toggles between the SFN mode and non-SFN mode (e.g., dynamic point selection ("DPS") or single-point transmission throughout a period of communication). Such approach may improve network efficiency and may reduce a complexity at the UE if special considerations are required by the UE if the transmission is in the SFN mode. The UE may provide assistance information (e.g., CSI reporting, measurements) to assist the network in selecting between the SFN mode and the non-SFN mode.

[0069] In various embodiments, a transmission mode toggles between a SFN and a non-SFN based on a layer 1 ("L1") RSRP ("L1-RSRP") and/or L1 SINR ("L1-SINR") and/or CQI reported in one or more CSI reports.

[0070] In certain embodiments, a transmission mode toggles between a SFN and a non-SFN based on a flag included in DCI triggering a UE that indicates signaling with a high-speed UE.

[0071] In some embodiments, a transmission mode toggles between a SFN and a non-SFN based on an SRS RSRP.

[0072] In various embodiments, a transmission mode toggles between a SFN and a non-SFN based on an indicator reported by a UE.

[0073] In some embodiments, the terms antenna, panel, and antenna panel are used interchangeably. An antenna panel may be hardware that is used for transmitting and/or receiving radio signals at frequencies lower than 6 GHz (e.g., frequency range 1 ("FR1")0, or higher than 6 GHz (e.g., frequency range 2 ("FR2") or millimeter wave ("mmWave")). In certain embodiments, an antenna panel may include an array of antenna elements. Each antenna element may be connected to hardware, such as a phase shifter, that enables a control module to apply spatial parameters for transmission and/or reception of signals. The resulting radiation pattern may be called a beam, which may or may not be unimodal and may allow the device to amplify signals that are transmitted or received from spatial directions.

[0074] In various embodiments, an antenna panel may or may not be virtualized as an antenna port. An antenna panel may be connected to a baseband processing module through a radio frequency ("RF") chain for each transmission (e.g., egress) and reception (e.g., ingress) direction. A capability of a device in terms of a number of antenna panels, their duplexing capabilities, their beamforming capabilities, and so forth, may or may not be transparent to other devices. In some embodiments, capability information may be communicated via signaling or capability information may be provided to devices without a need for signaling. If information is available to other devices the information may be used for signaling or local decision making.

[0075] In some embodiments, a UE antenna panel may be a physical or logical antenna array including a set of antenna elements or antenna ports that share a common or a significant portion of a radio frequency ("RF") chain (e.g., in-phase and/or quadrature ("I/Q") modulator, analog to digital ("A/D") converter, local oscillator, phase shift network). The UE antenna panel or UE panel may be a logical entity with physical UE antennas mapped to the logical entity. The mapping of physical UE antennas to the logical entity may be up to UE implementation. Communicating (e.g., receiving or transmitting) on at least a subset of antenna elements or antenna ports active for radiating energy (e.g., active elements) of an antenna panel may require biasing or powering on of an RF chain which results in current drain or power consumption in a UE associated with the antenna panel (e.g., including power amplifier and/or low noise amplifier ("LNA") power consumption associated with the antenna elements or antenna ports). The phrase "active for radiating energy," as used herein, is not meant to be limited to a transmit function but also encompasses a receive function. Accordingly, an antenna element that is active for radiating energy may be coupled to a transmitter to transmit radio frequency energy or to a receiver to receive radio frequency energy, either simultaneously or sequentially, or may be coupled to a transceiver in general, for performing its intended functionality. Communicating on the active elements of an antenna panel enables generation of radiation patterns or beams.

[0076] In certain embodiments, depending on a UE's own implementation, a "UE panel" may have at least one of the following functionalities as an operational role of unit of antenna group to control its transmit ("TX") beam independently, unit of antenna group to control its transmission power independently, and/pr unit of antenna group to control its transmission timing independently. The "UE panel" may be transparent to a gNB. For certain conditions, a gNB or network may assume that a mapping between a UE's physical antennas to the logical entity "UE panel" may not be changed. For example, a condition may include until the next update or report from UE or include a duration of time over which the gNB assumes there will be no change to mapping. A UE may report its UE capability with respect to the "UE panel" to the gNB or network. The UE capability may include at least the number of "UE panels." In one embodiment, a UE may support UL transmission from one beam within a panel. With multiple panels, more than one beam (e.g., one beam per panel) may be used for UL transmission. In another embodiment, more than one beam per panel may be supported and/or used for UL transmission.

[0077] In some embodiments, an antenna port may be defined such that a channel over which a symbol on the antenna port is conveyed may be inferred from the channel over which another symbol on the same antenna port is conveyed.

[0078] In certain embodiments, two antenna ports are said to be quasi co-located ("QCL") if large-scale properties of a channel over which a symbol on one antenna port is conveyed may be inferred from the channel over which a symbol on another antenna port is conveyed. Large-scale properties may include one or more of delay spread, Doppler spread, Doppler shift, average gain, average delay, and/or spatial receive ("RX") parameters. Two antenna ports may be quasi co-located with respect to a subset of the large-scale properties and different subset of large-scale properties may be indicated by a QCL Type. For example, a qcl-Type may take one of the following values: 1) 'QCL-TypeA': {Doppler shift, Doppler spread, average delay, delay spread}; 2) 'QCL-TypeB': {Doppler shift, Doppler spread}; 3) 'QCL-TypeC': {Doppler shift, average delay}; and 4) 'QCL-TypeD': {Spatial Rx parameter}.

[0079] In various embodiments, spatial RX parameters may include one or more of: angle of arrival ("AoA"), dominant AoA, average AoA, angular spread, power angular spectrum ("PAS") of AoA, average angle of departure ("AoD"), PAS of AoD, transmit and/or receive channel correlation, transmit and/or receive beamforming, and/or spatial channel correlation.

[0080] In certain embodiments, the QCL-TypeA, QCL-TypeB, and QCL-TypeC may be applicable for all carrier frequencies, but the QCL-TypeD may be applicable only in higher carrier frequencies (e.g., mmWave, FR2, and beyond), where essentially a UE may not be able to perform omni-directional transmission (e.g., the UE may need to form beams for directional transmission). For a QCL-TypeD between two reference signals A and B, the reference signal A is considered to be spatially co-located with reference signal B and the UE may assume that the reference signals A and B can be received with the same spatial filter (e.g., with the same RX beamforming weights).

[0081] In some embodiments, an "antenna port" may be a logical port that may correspond to a beam (e.g., resulting from beamforming) or may correspond to a physical antenna on a device. In certain embodiments, a physical antenna may map directly to a single antenna port in which an antenna port corresponds to an actual physical antenna. In various embodiments, a set of physical antennas, a subset of physical antennas, an antenna set, an antenna array, or an antenna sub-array may be mapped to one or more antenna ports after applying complex weights and/or a cyclic delay to the signal on each physical antenna. The physical antenna set may have antennas from a single module or panel or from multiple modules or panels. The weights may be fixed as in an antenna virtualization scheme, such as cyclic delay diversity ("CDD"). A procedure used to derive antenna ports from physical antennas may be specific to a device implementation and transparent to other devices.

[0082] In various embodiments, a transmission configuration indicator ("TCI") state associated with a target transmission may indicate a quasi-collocation relationship between a target transmission (e.g., target RS of demodulation reference signal ("DM-RS") ports of the target transmission during a transmission occasion) and source reference signals (e.g., synchronization signal block ("SSB"), channel state information reference signal ("CSI-RS"), and/or sounding reference signal ("SRS")) with respect to quasi co-location type parameters indicated in a corresponding TCI state. A device may receive a configuration of multiple transmission configuration indicator states for a serving cell for transmissions on the serving cell.

[0083] In some embodiments, spatial relation information associated with a target transmission may indicate a spatial setting between a target transmission and a reference RS (e.g., SSB, CSI-RS, and/or SRS). For example, a UE may transmit a target transmission with the same spatial domain filter used for receiving a reference RS (e.g., DL RS such as SSB and/or CSI-RS). In another example, a UE may transmit a target transmission with the same spatial domain transmission filter used for the transmission of a RS (e.g., UL RS such as SRS). A UE may receive a configuration of multiple spatial relation information configurations for a serving cell for transmissions on a serving cell.

[0084] Figure 4 is a schematic block diagram illustrating one embodiment of communications 400 for frequency correlation based on a frequency offset. The communications 400 include messages transmitted between one or more TRPs 402 and a UE 404. As may be appreciated, each of the communications 400 may include one or more messages.

[0085] In a first communications 406 transmitted from the one or more TRPs 402 to the UE 404, the one or more TRPs 402 may transmit a higher-layer configuration that indicates operation in a high-speed transmission mode and/or operation in a single-frequency network to the

UE 404. In a second communication 408 transmitted from the one or more TRPs 402 to the UE 404, the one or more TRPs 402 may transmit at least one downlink reference signal to the UE 404. In a third communications 412 transmitted from the UE 404 to the one or more TRPs 402, the UE 404 may transmit an uplink reference signal based on a first subset of the at least one downlink reference signal to the one or more TRPs 402. In some embodiments, a reception frequency of a second subset of the at least one downlink reference signal is based on a frequency offset of the uplink reference signal.

[0086] Figure 5 is a flow chart diagram illustrating one embodiment of a method 500 for frequency correlation based on a frequency offset. In some embodiments, the method 500 is performed by an apparatus, such as the remote unit 102. In certain embodiments, the method 500 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.

[0087] In various embodiments, the method 500 includes receiving 502, at a user equipment, a higher-layer configuration that indicates operation in a high-speed transmission mode, operation in a single-frequency network, or a combination thereof. In some embodiments, the method 500 includes receiving 504 at least one downlink reference signal from at least one network node. In certain embodiments, the method 500 includes transmitting 506 an uplink reference signal based on a first subset of the at least one downlink reference signal. In various embodiments, a reception frequency of a second subset of the at least one downlink reference signal is based 508 on a frequency offset of the uplink reference signal.

[0088] In certain embodiments, the uplink reference signal is a sounding reference signal. In some embodiments, the at least one downlink reference signal includes a timing reference signal or a demodulation reference signal for a physical downlink shared channel. In various embodiments, a spatial relation of the uplink reference signal is based on the at least one downlink reference signal.

[0089] In one embodiment, a time between the uplink reference signal transmission and the at least one downlink reference signal reception comprises a configured threshold time. In certain embodiments, the at least one downlink reference signal comprises two tracking reference signal resources. In some embodiments, the method 500 further comprises reporting a channel state information reference signal resource indicator corresponding to the two tracking reference signal resources.

[0090] In various embodiments, the method 500 further comprises receiving a downlink scheduling assignment downlink control information scheduling a physical downlink shared channel and indicating a codepoint in a transmission configuration indicator bit field, wherein the transmission configuration indicator bit field indicates two transmission configuration indicator states, a first transmission configuration indicator state of the two transmission configuration indicator states indicate a quasi-co-location relationship between a first tracking reference signal of the two tracking reference signals and a physical downlink shared channel demodulation reference signal resource, and a second transmission configuration indicator state of the two transmission configuration indicator states indicate a quasi-co-location relationship between a second tracking reference signal of the two tracking reference signals and the physical downlink shared channel demodulation reference signal resource.

[0091] In one embodiment, the quasi-co-location relationship indicated by at least one transmission configuration indicator state of the two transmission configuration indicator states comprises a Type-A relationship, a Type-D relationship, or a combination thereof between a tracking reference signal resource and the physical downlink shared channel demodulation reference signal resource. In certain embodiments, all ports of a set of ports associated with the physical downlink shared channel demodulation reference signal ports belong to a same code division multiplexing group. In some embodiments, the higher-layer configuration comprises downlink control information that indicates whether the user equipment operates in the high-speed transmission mode, a non-high-speed transmission mode, a dynamic point selection mode, or some combination thereof.

[0092] Figure 6 is a flow chart diagram illustrating one embodiment of a method 600 for frequency correlation based on a frequency offset. In some embodiments, the method 600 is performed by an apparatus, such as the network unit 104. 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.

[0093] In various embodiments, the method 600 includes transmitting 602, from a network device, a higher-layer configuration that indicates operation in a high-speed transmission mode, operation in a single-frequency network, or a combination thereof. In some embodiments, the method 600 includes transmitting 604 at least one downlink reference signal to a user equipment. In certain embodiments, the method 600 includes receiving 606 an uplink reference signal based on a first subset of the at least one downlink reference signal. In various embodiments, a transmission frequency of a second subset of the at least one downlink reference signal is based 608 on a frequency offset of the uplink reference signal.

[0094] In certain embodiments, the uplink reference signal is a sounding reference signal. In some embodiments, the at least one downlink reference signal includes a timing reference signal or a demodulation reference signal for a physical downlink shared channel. In various embodiments, a spatial relation of the uplink reference signal is based on the at least one downlink reference signal.

[0095] In one embodiment, a time between the uplink reference signal transmission and the at least one downlink reference signal reception comprises a configured threshold time. In certain embodiments, the at least one downlink reference signal comprises two tracking reference signal resources. In some embodiments, the method 600 further comprises receiving a channel state information reference signal resource indicator corresponding to the two tracking reference signal resources.

[0096] In various embodiments, the method 600 further comprises transmitting a downlink scheduling assignment downlink control information scheduling a physical downlink shared channel and indicating a codepoint in a transmission configuration indicator bit field, wherein the transmission configuration indicator bit field indicates two transmission configuration indicator states, a first transmission configuration indicator state of the two transmission configuration indicator states indicate a quasi-co-location relationship between a first tracking reference signal of the two tracking reference signals and a physical downlink shared channel demodulation reference signal resource, and a second transmission configuration indicator state of the two transmission configuration indication states indicate a quasi-co-location relationship between a second tracking reference signal of the two tracking reference signals and the physical downlink shared channel demodulation reference signal resource.

[0097] In one embodiment, the quasi-co-location relationship indicated by at least one transmission configuration indicator state of the two transmission configuration indicator states comprises a Type-A relationship, a Type-D relationship, or a combination thereof between a tracking reference signal resource and the physical downlink shared channel demodulation reference signal resource. In certain embodiments, all ports of a set of ports associated with the physical downlink shared channel demodulation reference signal ports belong to a same code division multiplexing group. In some embodiments, the higher-layer configuration comprises downlink control information that indicates whether the user equipment operates in the high-speed transmission mode, a non-high-speed transmission mode, a dynamic point selection mode, or some combination thereof.

[0098] In one embodiment, a method comprises: receiving, at a user equipment, a higher-layer configuration that indicates operation in a high-speed transmission mode, operation in a single-frequency network, or a combination thereof; receiving at least one downlink reference signal from at least one network node; and transmitting an uplink reference signal based on a first subset of the at least one downlink reference signal; wherein a reception frequency of a second subset of the at least one downlink reference signal is based on a frequency offset of the uplink reference signal.

[0099] In certain embodiments, the uplink reference signal is a sounding reference signal.

[0100] In some embodiments, the at least one downlink reference signal includes a timing reference signal or a demodulation reference signal for a physical downlink shared channel.

[0101] In various embodiments, a spatial relation of the uplink reference signal is based on the at least one downlink reference signal.

[0102] In one embodiment, a time between the uplink reference signal transmission and the at least one downlink reference signal reception comprises a configured threshold time.

[0103] In certain embodiments, the at least one downlink reference signal comprises two tracking reference signal resources.

[0104] In some embodiments, the method further comprises reporting a channel state information reference signal resource indicator corresponding to the two tracking reference signal resources.

[0105] In various embodiments, the method further comprises receiving a downlink scheduling assignment downlink control information scheduling a physical downlink shared channel and indicating a codepoint in a transmission configuration indicator bit field, wherein the transmission configuration indicator bit field indicates two transmission configuration indicator states, a first transmission configuration indicator state of the two transmission configuration indicator states indicate a quasi-co-location relationship between a first tracking reference signal of the two tracking reference signals and a physical downlink shared channel demodulation reference signal resource, and a second transmission configuration indicator state of the two transmission configuration indicator states indicate a quasi-co-location relationship between a second tracking reference signal of the two tracking reference signals and the physical downlink shared channel demodulation reference signal resource.

[0106] In one embodiment, the quasi-co-location relationship indicated by at least one transmission configuration indicator state of the two transmission configuration indicator states comprises a Type-A relationship, a Type-D relationship, or a combination thereof between a tracking reference signal resource and the physical downlink shared channel demodulation reference signal resource.

[0107] In certain embodiments, all ports of a set of ports associated with the physical downlink shared channel demodulation reference signal ports belong to a same code division multiplexing group.

[0108] In some embodiments, the higher-layer configuration comprises downlink control information that indicates whether the user equipment operates in the high-speed transmission mode, a non-high-speed transmission mode, a dynamic point selection mode, or some combination thereof.

[0109] In one embodiment, an apparatus comprises a user equipment. The apparatus further comprises: a receiver that: receives a higher-layer configuration that indicates operation in a high-speed transmission mode, operation in a single-frequency network, or a combination thereof; and receives at least one downlink reference signal from at least one network node; and a transmitter that transmits an uplink reference signal based on a first subset of the at least one downlink reference signal; wherein a reception frequency of a second subset of the at least one downlink reference signal is based on a frequency offset of the uplink reference signal.

[0110] In certain embodiments, the uplink reference signal is a sounding reference signal.

[0111] In some embodiments, the at least one downlink reference signal includes a timing reference signal or a demodulation reference signal for a physical downlink shared channel.

[0112] In various embodiments, a spatial relation of the uplink reference signal is based on the at least one downlink reference signal.

[0113] In one embodiment, a time between the uplink reference signal transmission and the at least one downlink reference signal reception comprises a configured threshold time.

[0114] In certain embodiments, the at least one downlink reference signal comprises two tracking reference signal resources.

[0115] In some embodiments, the apparatus further comprises a processor that reports a channel state information reference signal resource indicator corresponding to the two tracking reference signal resources.

[0116] In various embodiments, the receiver receives a downlink scheduling assignment downlink control information scheduling a physical downlink shared channel and indicating a codepoint in a transmission configuration indicator bit field, the transmission configuration indicator bit field indicates two transmission configuration indicator states, a first transmission configuration indicator state of the two transmission configuration indicator states indicate a quasi-co-location relationship between a first tracking reference signal of the two tracking reference signals and a physical downlink shared channel demodulation reference signal resource, and a second transmission configuration indicator state of the two transmission configuration indicator states indicate a quasi-co-location relationship between a second tracking reference signal of the two tracking reference signals and the physical downlink shared channel demodulation reference signal resource.

[0117] In one embodiment, the quasi-co-location relationship indicated by at least one transmission configuration indicator state of the two transmission configuration indicator states comprises a Type-A relationship, a Type-D relationship, or a combination thereof between a tracking reference signal resource and the physical downlink shared channel demodulation reference signal resource.

[0118] In certain embodiments, all ports of a set of ports associated with the physical downlink shared channel demodulation reference signal ports belong to a same code division multiplexing group.

[0119] In some embodiments, the higher-layer configuration comprises downlink control information that indicates whether the user equipment operates in the high-speed transmission mode, a non-high-speed transmission mode, a dynamic point selection mode, or some combination thereof.

[0120] In one embodiment, a method comprises: transmitting, from a network device, a higher-layer configuration that indicates operation in a high-speed transmission mode, operation in a single-frequency network, or a combination thereof; transmitting at least one downlink reference signal to a user equipment; and receiving an uplink reference signal based on a first subset of the at least one downlink reference signal; wherein a transmission frequency of a second subset of the at least one downlink reference signal is based on a frequency offset of the uplink reference signal.

[0121] In certain embodiments, the uplink reference signal is a sounding reference signal.

[0122] In some embodiments, the at least one downlink reference signal includes a timing reference signal or a demodulation reference signal for a physical downlink shared channel.

[0123] In various embodiments, a spatial relation of the uplink reference signal is based on the at least one downlink reference signal.

[0124] In one embodiment, a time between the uplink reference signal transmission and the at least one downlink reference signal reception comprises a configured threshold time.

[0125] In certain embodiments, the at least one downlink reference signal comprises two tracking reference signal resources.

[0126] In some embodiments, the method further comprises receiving a channel state information reference signal resource indicator corresponding to the two tracking reference signal resources.

[0127] In various embodiments, the method further comprises transmitting a downlink scheduling assignment downlink control information scheduling a physical downlink shared channel and indicating a codepoint in a transmission configuration indicator bit field, wherein the transmission configuration indicator bit field indicates two transmission configuration indicator states, a first transmission configuration indicator state of the two transmission configuration indicator states indicate a quasi-co-location relationship between a first tracking reference signal of the two tracking reference signals and a physical downlink shared channel demodulation reference signal resource, and a second transmission configuration indicator state of the two transmission configuration indicator states indicate a quasi-co-location relationship between a second tracking reference signal of the two tracking reference signals and the physical downlink shared channel demodulation reference signal resource.

[0128] In one embodiment, the quasi-co-location relationship indicated by at least one transmission configuration indicator state of the two transmission configuration indicator states comprises a Type-A relationship, a Type-D relationship, or a combination thereof between a tracking reference signal resource and the physical downlink shared channel demodulation reference signal resource.

[0129] In certain embodiments, all ports of a set of ports associated with the physical downlink shared channel demodulation reference signal ports belong to a same code division multiplexing group.

[0130] In some embodiments, the higher-layer configuration comprises downlink control information that indicates whether the user equipment operates in the high-speed transmission mode, a non-high-speed transmission mode, a dynamic point selection mode, or some combination thereof.

[0131] In one embodiment, an apparatus comprises a network device. The apparatus further comprises: a transmitter that: transmits a higher-layer configuration that indicates operation in a high-speed transmission mode, operation in a single-frequency network, or a combination thereof; and transmits at least one downlink reference signal to a user equipment; and a receiver that receives an uplink reference signal based on a first subset of the at least one downlink reference signal; wherein a transmission frequency of a second subset of the at least one downlink reference signal is based on a frequency offset of the uplink reference signal.

[0132] In certain embodiments, the uplink reference signal is a sounding reference signal.

[0133] In some embodiments, the at least one downlink reference signal includes a timing reference signal or a demodulation reference signal for a physical downlink shared channel.

[0134] In various embodiments, a spatial relation of the uplink reference signal is based on the at least one downlink reference signal.

[0135] In one embodiment, a time between the uplink reference signal transmission and the at least one downlink reference signal reception comprises a configured threshold time.

[0136] In certain embodiments, the at least one downlink reference signal comprises two tracking reference signal resources.

[0137] In some embodiments, the receiver receives a channel state information reference signal resource indicator corresponding to the two tracking reference signal resources.

[0138] In various embodiments, the transmitter transmits a downlink scheduling assignment downlink control information scheduling a physical downlink shared channel and indicating a codepoint in a transmission configuration indicator bit field, the transmission configuration indicator bit field indicates two transmission configuration indicator states, a first transmission configuration indicator state of the two transmission configuration indicator states indicate a quasi-co-location relationship between a first tracking reference signal of the two tracking reference signals and a physical downlink shared channel demodulation reference signal resource, and a second transmission configuration indicator state of the two transmission configuration indicator states indicate a quasi-co-location relationship between a second tracking reference signal of the two tracking reference signals and the physical downlink shared channel demodulation reference signal resource.

[0139] In one embodiment, the quasi-co-location relationship indicated by at least one transmission configuration indicator state of the two transmission configuration indicator states comprises a Type-A relationship, a Type-D relationship, or a combination thereof between a tracking reference signal resource and the physical downlink shared channel demodulation reference signal resource.

[0140] In certain embodiments, all ports of a set of ports associated with the physical downlink shared channel demodulation reference signal ports belong to a same code division multiplexing group.

[0141] In some embodiments, the higher-layer configuration comprises downlink control information that indicates whether the user equipment operates in the high-speed transmission mode, a non-high-speed transmission mode, a dynamic point selection mode, or some combination thereof.

[0142] 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. A method comprising:
receiving, at a user equipment, a higher-layer configuration that indicates operation in a high-speed transmission mode, operation in a single-frequency network, or a combination thereof;
receiving at least one downlink reference signal from at least one network node; and
transmitting an uplink reference signal based on a first subset of the at least one downlink reference signal;
wherein a reception frequency of a second subset of the at least one downlink reference signal is based on a frequency offset of the uplink reference signal.

2. An apparatus comprising a user equipment, the apparatus further comprising:
a receiver that:
receives a higher-layer configuration that indicates operation in a high-speed transmission mode, operation in a single-frequency network, or a combination thereof; and
receives at least one downlink reference signal from at least one network node; and
a transmitter that transmits an uplink reference signal based on a first subset of the at least one downlink reference signal;
wherein a reception frequency of a second subset of the at least one downlink reference signal is based on a frequency offset of the uplink reference signal.

3. The apparatus of claim 2, wherein the uplink reference signal is a sounding reference signal.

4. The apparatus of claim 2, wherein the at least one downlink reference signal includes a timing reference signal or a demodulation reference signal for a physical downlink shared channel.

5. The apparatus of claim 2, wherein a spatial relation of the uplink reference signal is based on the at least one downlink reference signal.

6. The apparatus of claim 5, wherein a time between the uplink reference signal transmission and the at least one downlink reference signal reception comprises a configured threshold time.

7. The apparatus of claim 2, wherein the at least one downlink reference signal comprises two tracking reference signal resources.

8. The apparatus of claim 7, further comprising a processor that reports a channel state information reference signal resource indicator corresponding to the two tracking reference signal resources.

9. The apparatus of claim 7, wherein the receiver receives a downlink scheduling assignment downlink control information scheduling a physical downlink shared channel and indicating a codepoint in a transmission configuration indicator bit field, the transmission configuration indicator bit field indicates two transmission configuration indicator states, a first transmission configuration indicator state of the two transmission configuration indicator states indicate a quasi-co-location relationship between a first tracking reference signal of the two tracking reference signals and a physical downlink shared channel demodulation reference signal resource, and a second transmission configuration indicator state of the two transmission configuration indicator states indicate a quasi-co-location relationship between a second tracking reference signal of the two tracking reference signals and the physical downlink shared channel demodulation reference signal resource.

10. The apparatus of claim 9, wherein the quasi-co-location relationship indicated by at least one transmission configuration indicator state of the two transmission configuration indicator states comprises a Type-A relationship, a Type-D relationship, or a combination thereof between a tracking reference signal resource and the physical downlink shared channel demodulation reference signal resource.

11. The apparatus of claim 9, wherein all ports of a set of ports associated with the physical downlink shared channel demodulation reference signal ports belong to a same code division multiplexing group.

12. The apparatus of claim 2, wherein the higher-layer configuration comprises downlink control information that indicates whether the user equipment operates in the high-speed transmission mode, a non-high-speed transmission mode, a dynamic point selection mode, or some combination thereof.

13. An apparatus comprising a network device, the apparatus further comprising:
a transmitter that:
transmits a higher-layer configuration that indicates operation in a high-speed transmission mode, operation in a single-frequency network, or a combination thereof; and
transmits at least one downlink reference signal to a user equipment; and
a receiver that receives an uplink reference signal based on a first subset of the at least one downlink reference signal;
wherein a transmission frequency of a second subset of the at least one downlink reference signal is based on a frequency offset of the uplink reference signal.

14. The apparatus of claim 13, wherein the at least one downlink reference signal comprises two tracking reference signal resources.

15. The apparatus of claim 14, wherein the receiver receives a channel state information reference signal resource indicator corresponding to the two tracking reference signal resources.

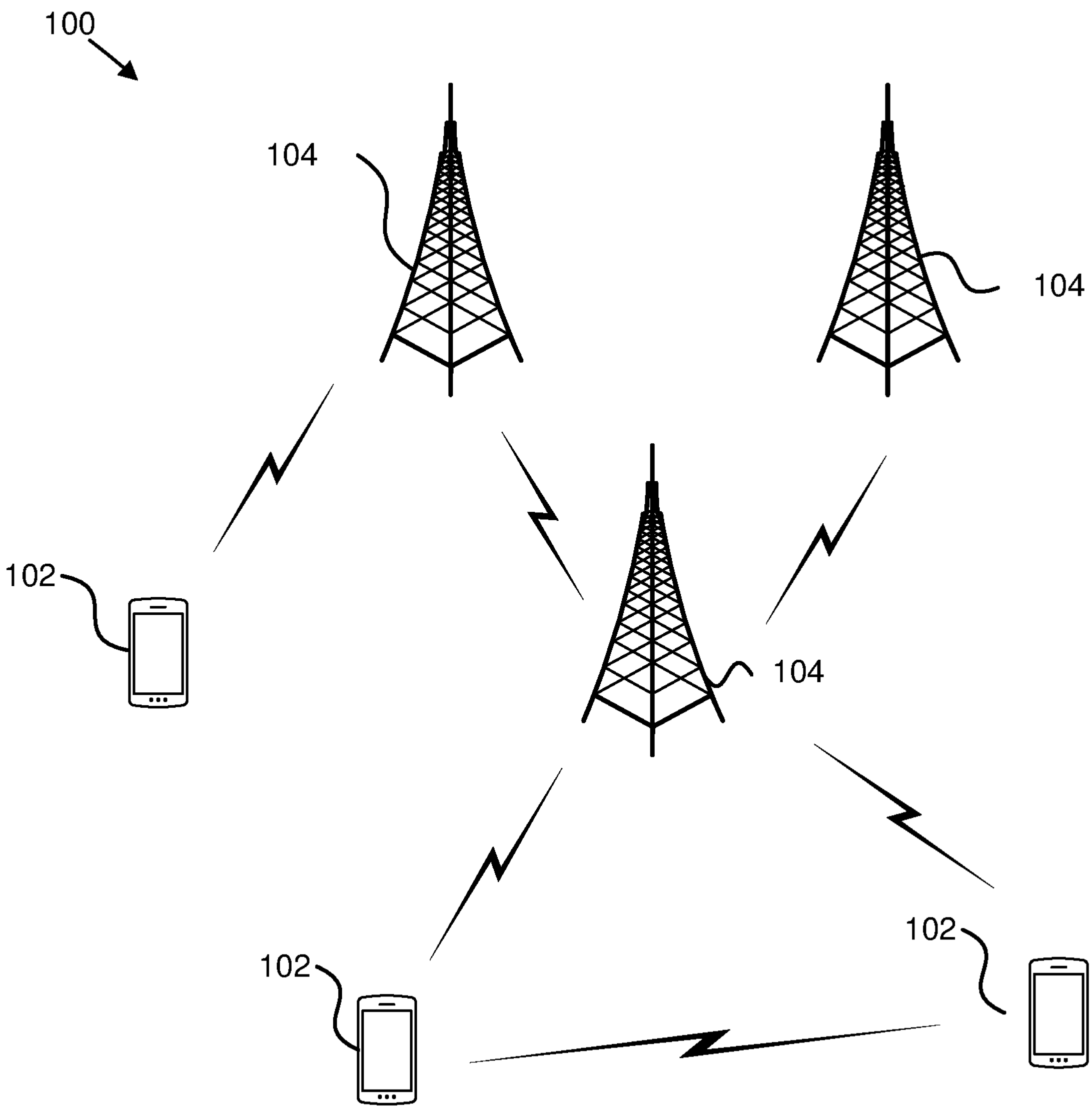
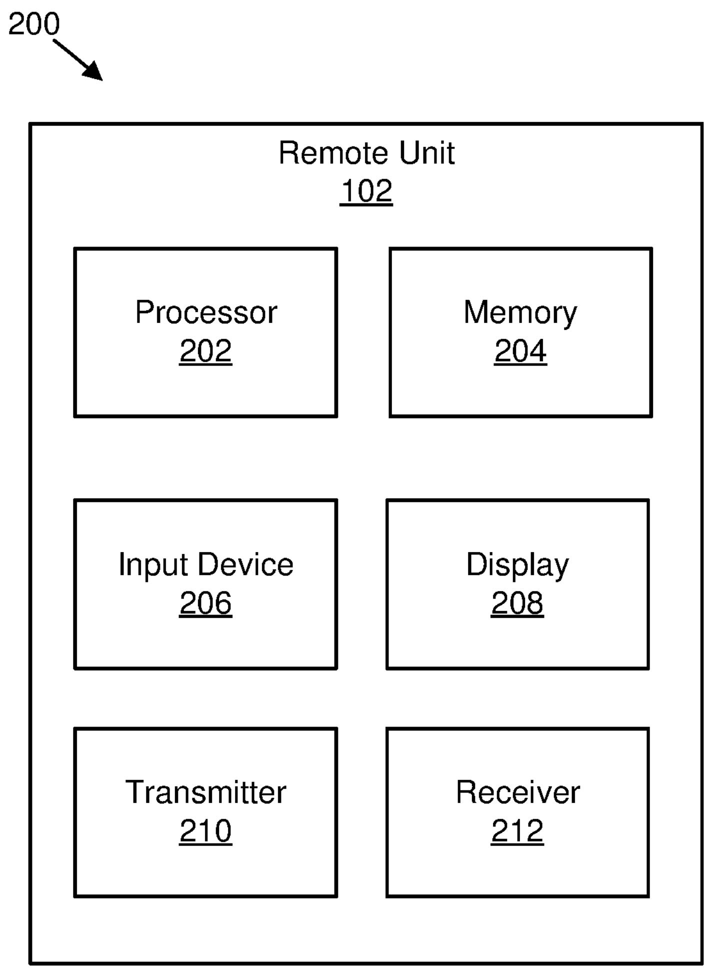


FIG. 1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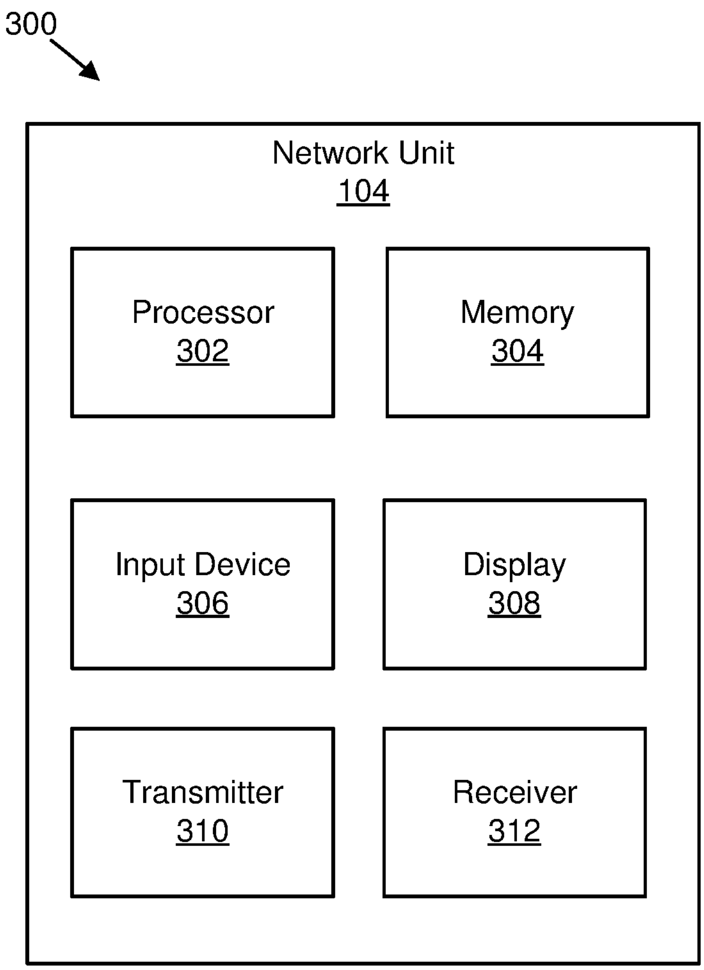
102
Processor
202
Memory
204
Input Device
206
Display
208
Transmitter
210
Receiver
212

FIG. 2


300
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104
Processor
302
Memory
304
Input Device
306
Display
308
Transmitter
310
Receiver
312

FIG. 3

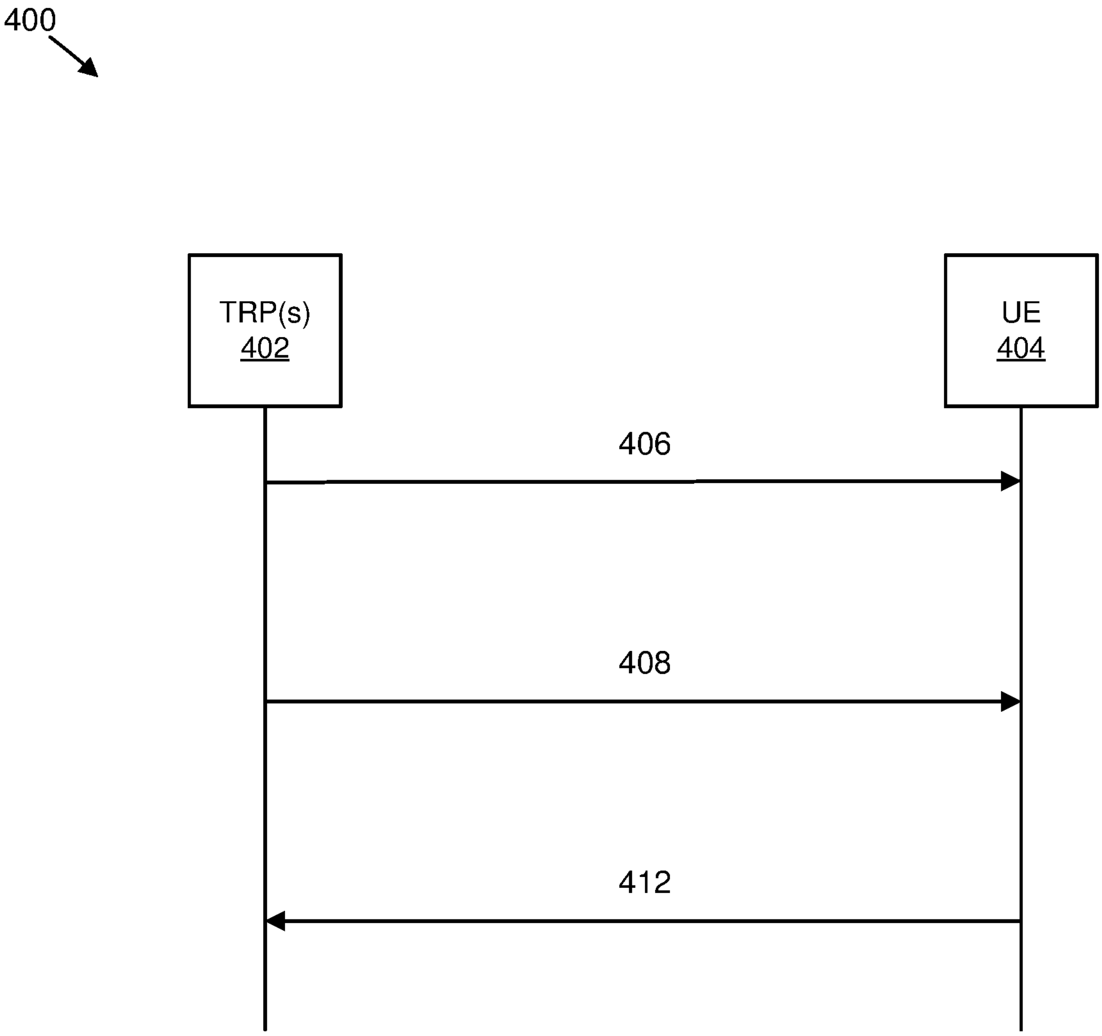

FIG. 4

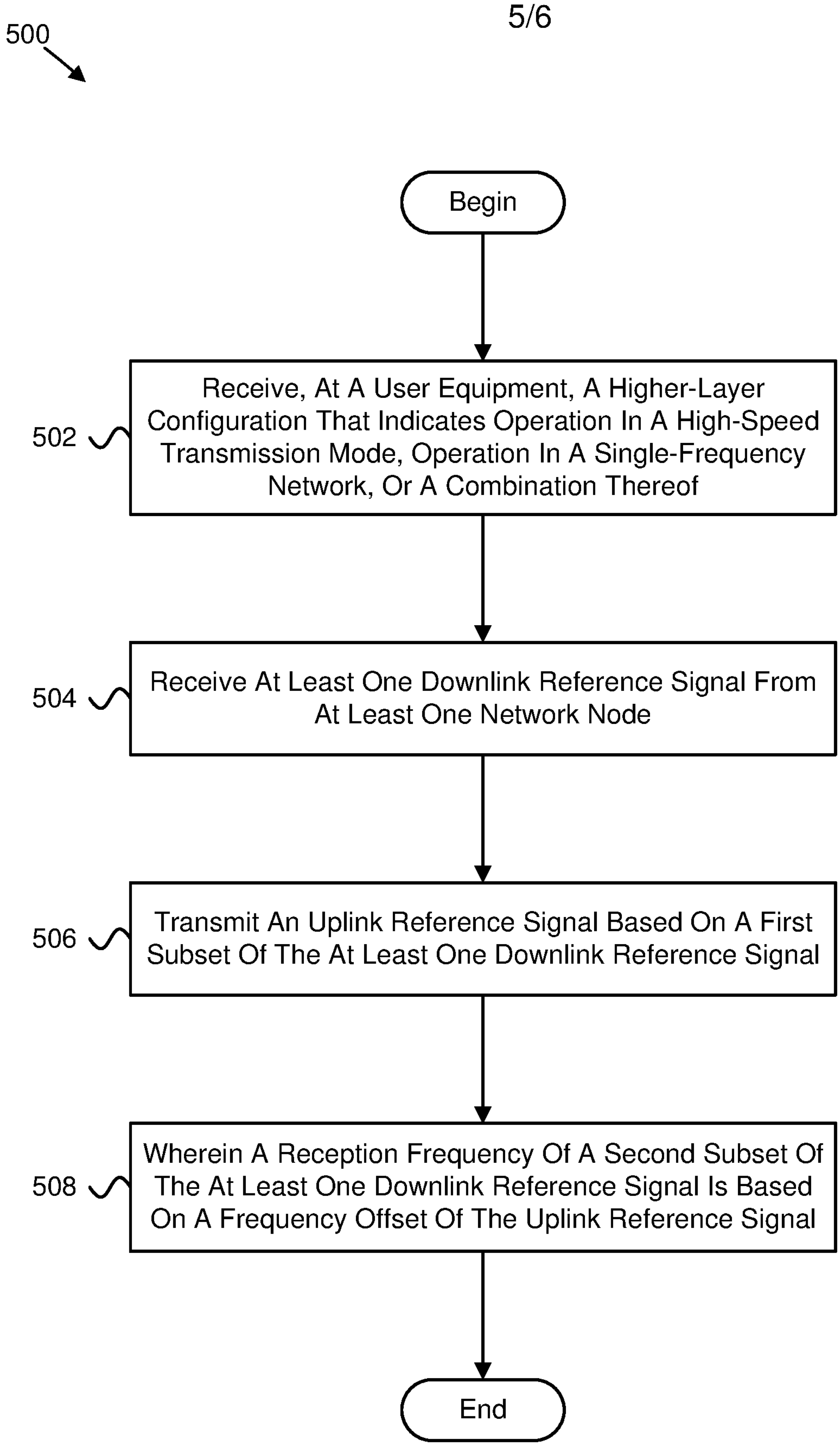
500
Begin
502
Receive, At A User Equipment, A Higher-Layer Configuration That Indicates Operation In A High-Speed Transmission Mode, Operation In A Single-Frequency Network, Or A Combination Thereof
504
Receive At Least One Downlink Reference Signal From At Least One Network Node
506
Transmit An Uplink Reference Signal Based On A First Subset Of The At Least One Downlink Reference Signal
508
Wherein A Reception Frequency Of A Second Subset Of The At Least One Downlink Reference Signal Is Based On A Frequency Offset Of The Uplink Reference Signal
End

FIG. 5

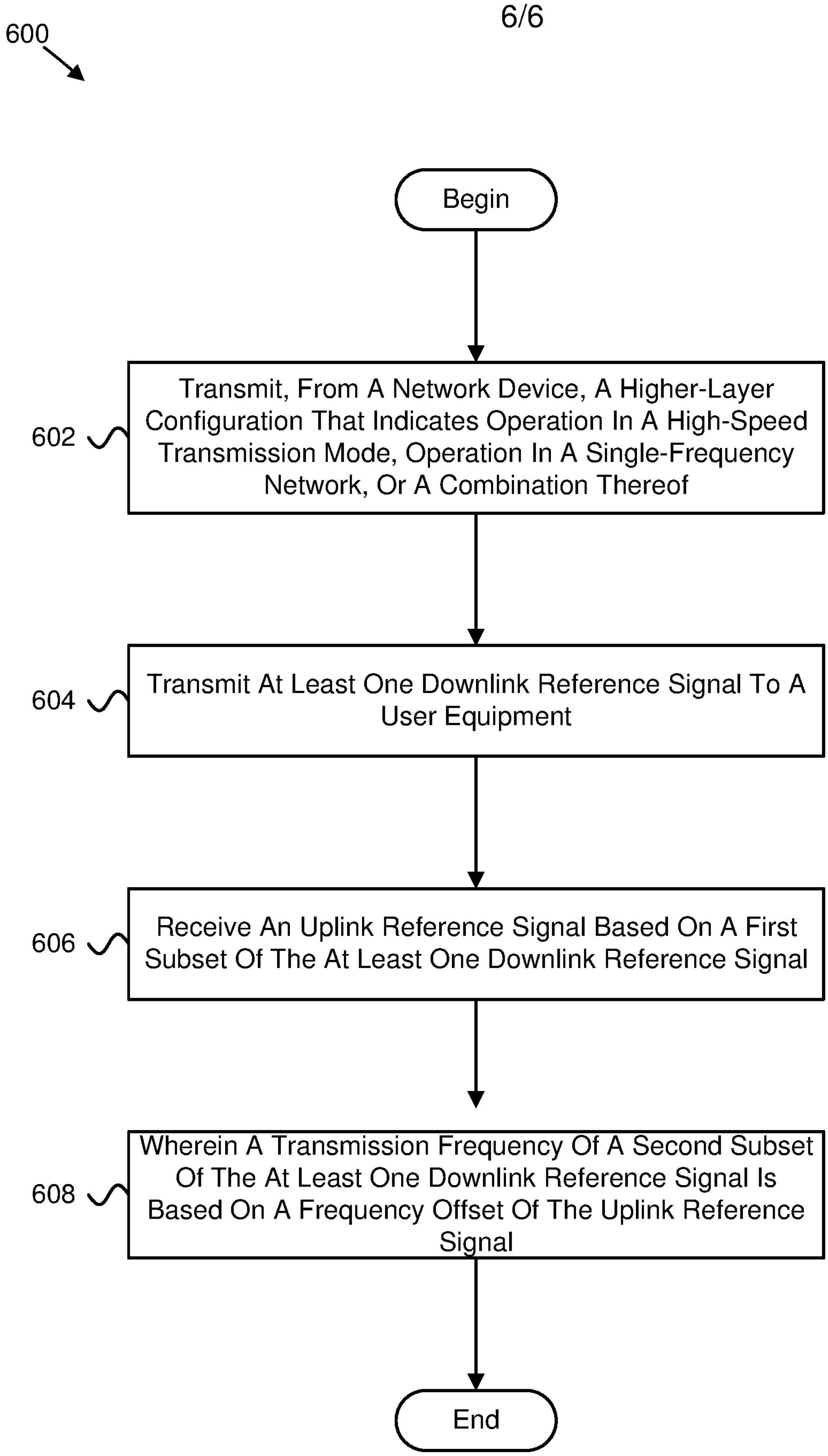
600
Begin
602
Transmit, From A Network Device, A Higher-Layer Configuration That Indicates Operation In A High-Speed Transmission Mode, Operation In A Single-Frequency Network, Or A Combination Thereof
604
Transmit At Least One Downlink Reference Signal To A User Equipment
606
Receive An Uplink Reference Signal Based On A First Subset Of The At Least One Downlink Reference Signal
608
Wherein A Transmission Frequency Of A Second Subset Of The At Least One Downlink Reference Signal Is Based On A Frequency Offset Of The Uplink Reference Signal
End

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2021/057234

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L5/00 H04B7/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L H04B

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	EP 2 797 243 A1 (LG ELECTRONICS INC [KR]) 29 October 2014 (2014-10-29) paragraph [0008] - paragraph [0032] paragraph [0055] - paragraph [0126] -----	1-8, 12-15 9-11
A	EP 2 892 169 A2 (LG ELECTRONICS INC [KR]) 8 July 2015 (2015-07-08) paragraph [0067] - paragraph [0125] -----	1-15

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

☒ See patent family annex.

* Special categories of cited documents :

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

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

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

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"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
4 November 2021	12/11/2021

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

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2021/057234

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