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(54) **Title:** SYSTEM AND METHOD FOR ENHANCEMENTS ON BLOCKWISED DMRS

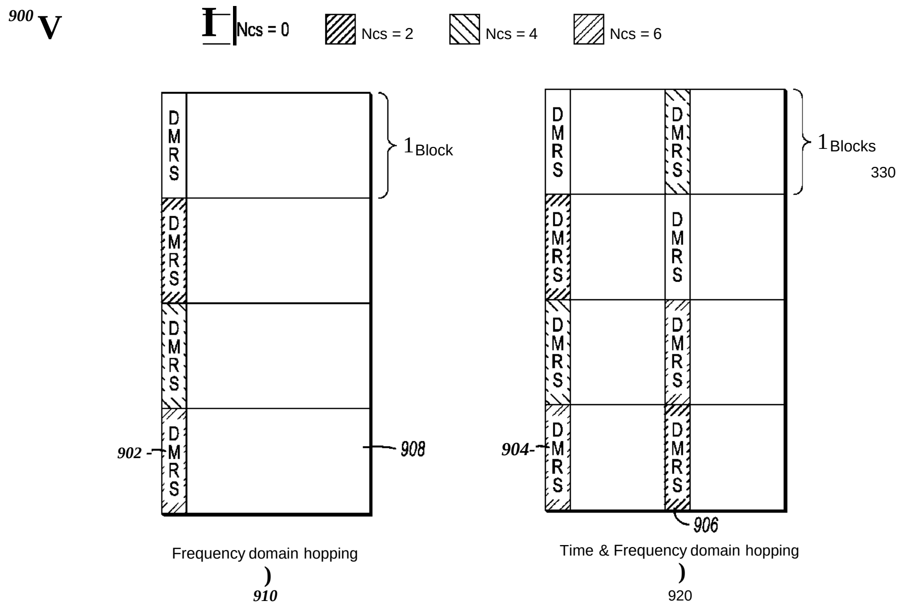

FIG. 9

(57) **Abstract:** Systems and methods of using blockwised DMRSs are generally described. A UE uses wideband or blockwised DMRSs as indicated by higher layer signaling or a DMRS scheme indicator of DCI. When transmitting blockwised DMRSs, the blockwised DMRSs have, for different resource blocks or DMRSs, DMRS cyclic shift hopping, different DMRS sequences, different phase rotation, and/or different scrambling sequences. The manner in which the blockwised DMRSs differ depend on the sequences or hopping are cell-specific or UE-specific, as well as whether the multiple symbols in a subframe are allocated to the UE to transmit the DMRSs.

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SYSTEM AND METHOD FOR ENHANCEMENTS ON BLOCKWISED DMRS

PRIORITY CLAIM

[0001] This application claims the benefit of priority to International Patent Application No. PCT/CN2016/098402, filed September 8, 2016, entitled "ENHANCEMENTS ON BLOCKWISED DMRS," and International Patent Application No. PCT/CN2016/099439, filed September 20, 2016, entitled "ENHANCEMENTS ON BLOCKWISED DMRS," each of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] Embodiments pertain to radio access networks. Some embodiments relate to interference between networks with different numerology including cellular and wireless local area network (WLAN) networks, including Third Generation Partnership Project Long Term Evolution (3GPP LTE) networks and LTE advanced (LTE-A) networks as well as 4^{th} generation (4G) networks and 5^{th} generation (5G) networks.

BACKGROUND

[0003] The use of 3GPP LTE systems (including both LTE and LTE-A systems) has increased due to both an increase in the types of devices user equipment (UEs) using network resources as well as the amount of data and bandwidth being used by various applications, such as video streaming, operating on these UEs. The latest generation (5G - also called new radio or NR) system may continue to use various reference signals to provide feedback between the UEs and the network. Among these reference signals is the Demodulation Reference Signal (DMRS), which may be used to enable coherent demodulation and associated with transmission of uplink control and data signals. However, even using DMRS signals may result in a Peak to Average Power Ratio (PAPR) that is sub-optimal. The PAPR, which is the ratio between the average transmit power of a signal and the maximum instantaneous transmit power, is typically minimized to minimize power consumption and maximize mobile device operating time.

BRIEF DESCRIPTION OF THE FIGURES

[0004] In the figures, which are not necessarily drawn to scale, like numerals may describe similar components in different views. Like numerals having different letter suffixes may represent different instances of similar components. The figures illustrate generally, by way of example, but not by way of limitation, various embodiments discussed in the present document.

[0005] FIG. 1 illustrates an architecture of a system of a network in accordance with some embodiments.

[0006] FIG. 2 illustrates example components of a device in accordance with some embodiments.

[0007] FIG. 3 illustrates example interfaces of baseband circuitry in accordance with some embodiments.

[0008] FIG. 4 is an illustration of a control plane protocol stack in accordance with some embodiments.

[0009] FIG. 5 is an illustration of a user plane protocol stack in accordance with some embodiments.

[0010] FIG. 6 is a block diagram illustrating components, according to some example embodiments, able to read instructions from a machine-readable or computer-readable medium (e.g., a non-transitory machine-readable storage medium) and perform any one or more of the methodologies discussed herein.

[0011] FIG. 7 illustrates a self-contained frame structure in accordance with some embodiments.

[0012] FIG. 8 illustrates DMRS configurations in accordance with some embodiments.

[0013] FIG. 9 illustrates cyclic shift hopping in accordance with some embodiments.

[0014] FIG. 10 illustrates simulation results of PAPR for different DMRS configurations in accordance with some embodiments.

DETAILED DESCRIPTION

[0015] The following description and the drawings sufficiently illustrate specific embodiments to enable those skilled in the art to practice them. Other embodiments may incorporate structural, logical, electrical, process, and other changes. Portions and features of some embodiments may be included in, or substituted for, those of other embodiments. Embodiments set forth in the claims encompass all available equivalents of those claims.

[0016] FIG. 1 illustrates an architecture of a system 100 of a network in accordance with some embodiments. The system 100 is shown to include a user equipment (UE) 101 and a UE 102. The UEs 101 and 102 are illustrated as smartphones (e.g., handheld touchscreen mobile computing devices connectable to one or more cellular networks), but may also comprise any mobile or non-mobile computing device, such as Personal Data Assistants (PDAs), pagers, laptop computers, desktop computers, wireless handsets, or any computing device including a wireless communications interface.

[0017] In some embodiments, any of the UEs 101 and 102 can comprise an Internet of Things (IoT) UE, which can comprise a network access layer designed for low-power IoT applications utilizing short-lived UE connections. An IoT UE can utilize technologies such as machine-to-machine (M2M) or machine-type communications (MTC) for exchanging data with an MTC server or device via a public land mobile network (PLMN), Proximity-Based Service (ProSe) or device-to-device (D2D) communication, sensor networks, or IoT networks. The M2M or MTC exchange of data may be a machine-initiated exchange of data. An IoT network describes interconnecting IoT UEs, which may include uniquely identifiable embedded computing devices (within the Internet infrastructure), with short-lived connections. The IoT UEs may execute background applications (e.g., keep-alive messages, status updates, etc.) to facilitate the connections of the IoT network.

[0018] The UEs 101 and 102 may be configured to connect, e.g., communicatively couple, with a radio access network (RAN) 110 - the RAN 110 may be, for example, an Evolved Universal Mobile Telecommunications System

(UMTS) Terrestrial Radio Access Network (E-UTRAN), aNextGen RAN (NG RAN), or some other type of RAN. The UEs 101 and 102 utilize connections 103 and 104, respectively, each of which comprises a physical communications interface or layer (discussed in further detail below); in this example, the connections 103 and 104 are illustrated as an air interface to enable communicative coupling, and can be consistent with cellular communications protocols, such as a Global System for Mobile Communications (GSM) protocol, a code-division multiple access (CDMA) network protocol, a Push-to-Talk (PTT) protocol, a PTT over Cellular (POC) protocol, a Universal Mobile Telecommunications System (UMTS) protocol, a 3GPP Long Term Evolution (LTE) protocol, a 5G protocol, a New Radio (NR) protocol, and the like.

[0019] In this embodiment, the UEs 101 and 102 may further directly exchange communication data via a ProSe interface 105. The ProSe interface 105 may alternatively be referred to as a sidelink interface comprising one or more logical channels, including but not limited to a Physical Sidelink Control Channel (PSCCH), a Physical Sidelink Shared Channel (PSSCH), a Physical Sidelink Discovery Channel (PSDCH), and a Physical Sidelink Broadcast Channel (PSBCH).

[0020] The UE 102 is shown to be configured to access an access point (AP) 106 via connection 107. The connection 107 can comprise a local wireless connection, such as a connection consistent with any IEEE 802.1 1 protocol, wherein the AP 106 would comprise a wireless fidelity (WiFi®) router. In this example, the AP 106 is shown to be connected to the Internet without connecting to the core network of the wireless system (described in further detail below).

[0021] The RAN 110 can include one or more access nodes that enable the connections 103 and 104. These access nodes (ANs) can be referred to as base stations (BSs), NodeBs, evolved NodeBs (eNBs), next Generation NodeBs (next generation NodeBs - gNBs), RAN nodes, and so forth, and can comprise ground stations (e.g., terrestrial access points) or satellite stations providing coverage within a geographic area (e.g., a cell). The RAN 110 may include one or more RAN nodes for providing macrocells, e.g., macro RAN node 111, and one or more RAN nodes for providing femtocells or picocells (e.g., cells having smaller coverage areas, smaller user capacity, or higher bandwidth compared to macrocells), e.g., low power (LP) RAN node 112.

[0022] Any of the RAN nodes 111 and 112 can terminate the air interface protocol and can be the first point of contact for the UEs 101 and 102. In some embodiments, any of the RAN nodes 111 and 112 can fulfill various logical functions for the RAN 110 including, but not limited to, radio network controller (RNC) functions such as radio bearer management, uplink and downlink dynamic radio resource management and data packet scheduling, and mobility management.

[0023] In accordance with some embodiments, the UEs 101 and 102 can be configured to communicate using Orthogonal Frequency-Division Multiplexing (OFDM) communication signals with each other or with any of the RAN nodes 111 and 112 over a multicarrier communication channel in accordance various communication techniques, such as, but not limited to, an Orthogonal Frequency -Division Multiple Access (OFDMA) communication technique (e.g., for downlink communications) or a Single Carrier Frequency Division Multiple Access (SC-FDMA) communication technique (e.g., for uplink and ProSe or sidelink communications), although the scope of the embodiments is not limited in this respect. The OFDM signals can comprise a plurality of orthogonal subcarriers.

[0024] In some embodiments, a downlink resource grid can be used for downlink transmissions from any of the RAN nodes 111 and 112 to the UEs 101 and 102, while uplink transmissions can utilize similar techniques. The grid can be a time-frequency grid, called a resource grid or time-frequency resource grid, which is the physical resource in the downlink in each slot. Such a time-frequency plane representation is a common practice for OFDM systems, which makes it intuitive for radio resource allocation. Each column and each row of the resource grid corresponds to one OFDM symbol and one OFDM subcarrier, respectively. The duration of the resource grid in the time domain corresponds to one slot in a radio frame. The smallest time-frequency unit in a resource grid is denoted as a resource element. Each resource grid comprises a number of resource blocks, which describe the mapping of certain physical channels to resource elements. Each resource block comprises a collection of resource elements; in the frequency domain, this may represent the smallest quantity of resources that currently can be allocated. There are several different physical downlink channels that are conveyed using such resource blocks.

[0025] The physical downlink shared channel (PDSCH) may carry user data and higher-layer signaling to the UEs 101 and 102. The physical downlink control channel (PDCCH) may carry information about the transport format and resource allocations related to the PDSCH channel, among other things. It may also inform the UEs 101 and 102 about the transport format, resource allocation, and H-ARQ (Hybrid Automatic Repeat Request) information related to the uplink shared channel. Typically, downlink scheduling (assigning control and shared channel resource blocks to the UE 102 within a cell) may be performed at any of the RAN nodes 111 and 112 based on channel quality information fed back from any of the UEs 101 and 102. The downlink resource assignment information may be sent on the PDCCH used for (e.g., assigned to) each of the UEs 101 and 102.

[0026] The PDCCH may use control channel elements (CCEs) to convey the control information. Before being mapped to resource elements, the PDCCH complex- valued symbols may first be organized into quadruplets, which may then be permuted using a sub-block interleaver for rate matching. Each PDCCH may be transmitted using one or more of these CCEs, where each CCE may correspond to nine sets of four physical resource elements known as resource element groups (REGs). Four Quadrature Phase Shift Keying (QPSK) symbols may be mapped to each REG. The PDCCH can be transmitted using one or more CCEs, depending on the size of the downlink control information (DCI) and the channel condition. There can be four or more different PDCCH formats defined in LTE with different numbers of CCEs (e.g., aggregation level, L=l, 2, 4, or 8).

[0027] Some embodiments may use concepts for resource allocation for control channel information that are an extension of the above-described concepts. For example, some embodiments may utilize an enhanced physical downlink control channel (EPDCCH) that uses PDSCH resources for control information transmission. The EPDCCH may be transmitted using one or more enhanced the control channel elements (ECCEs). Similar to above, each ECCE may correspond to nine sets of four physical resource elements known as an enhanced resource element groups (EREGs). An ECCE may have other numbers of EREGs in some situations.

[0028] The RAN 110 is shown to be communicatively coupled to a core network (CN) 120 —via an SI interface 113. In embodiments, the CN 120 may be an evolved packet core (EPC) network, a NextGen Packet Core (NPC) network, or some other type of CN. In this embodiment, the SI interface 113 is split into two parts: the Sl-U interface 114, which carries traffic data between the RAN nodes 111 and 112 and the serving gateway (S-GW) 122, and the Sl-mobility management entity (MME) interface 115, which is a signaling interface between the RAN nodes 111 and 112 and MMEs 121.

[0029] In this embodiment, the CN 120 comprises the MMEs 121, the S-GW 122, the Packet Data Network (PDN) Gateway (P-GW) 123, and a home subscriber server (HSS) 124. The MMEs 121 may be similar in function to the control plane of legacy Serving General Packet Radio Service (GPRS) Support Nodes (SGSN). The MMEs 121 may manage mobility aspects in access such as gateway selection and tracking area list management. The HSS 124 may comprise a database for network users, including subscription-related information to support the network entities' handling of communication sessions. The CN 120 may comprise one or several HSSs 124, depending on the number of mobile subscribers, on the capacity of the equipment, on the organization of the network, etc. For example, the HSS 124 can provide support for routing/roaming, authentication, authorization, naming/addressing resolution, location dependencies, etc.

[0030] The S-GW 122 may terminate the SI interface 113 towards the RAN 110, and routes data packets between the RAN 110 and the CN 120. In addition, the S-GW 122 may be a local mobility anchor point for inter-RAN node handovers and also may provide an anchor for inter-3GPP mobility. Other responsibilities may include lawful intercept, charging, and some policy enforcement.

[0031] The P-GW 123 may terminate an SGi interface toward a PDN. The P-GW 123 may route data packets between the EPC network 123 and external networks such as a network including the application server 130 (alternatively referred to as application function (AF)) via an Internet Protocol (IP) interface 125. Generally, the application server 130 may be an element offering applications that use IP bearer resources with the core network (e.g., UMTS Packet Services (PS) domain, LTE PS data services, etc.). In this embodiment, the P-GW 123 is shown to be communicatively coupled to an application server 130 via an IP communications interface 125. The application server 130 can also be configured to support one or more communication services (e.g., Voice-over-Internet Protocol (VoIP) sessions, PTT sessions, group communication sessions, social networking services, etc.) for the UEs 101 and 102 via the CN 120.

[0032] The P-GW 123 may further be a node for policy enforcement and charging data collection. Policy and Charging Enforcement Function (PCRF) 126 is the policy and charging control element of the CN 120. In a non-roaming scenario, there may be a single PCRF in the Home Public Land Mobile Network (HPLMN) associated with a UE's Internet Protocol Connectivity Access Network (IP-CAN) session. In a roaming scenario with local breakout of traffic, there may be two PCRFs associated with a UE's IP-CAN session: a Home PCRF (H-PCRF) within a HPLMN and a Visited PCRF (V-PCRF) within a Visited Public Land Mobile Network (VPLMN). The PCRF 126 may be communicatively coupled to the application server 130 via the P-GW 123. The application server 130 may signal the PCRF 126 to indicate a new service flow and select the appropriate Quality of Service (QoS) and charging parameters. The PCRF 126 may provision this rule into a Policy and Charging Enforcement Function (PCEF) (not shown) with the appropriate traffic flow template (TFT) and QoS class of identifier (QCI), which commences the QoS and charging as specified by the application server 130.

[0033] FIG. 2 illustrates example components of a device 200 in accordance with some embodiments. In some embodiments, the device 200 may include application circuitry 202, baseband circuitry 204, Radio Frequency (RF) circuitry 206, front-end module (FEM) circuitry 208, one or more antennas 210, and power management circuitry (PMC) 212 coupled together at least as shown. The components of the illustrated device 200 may be included in a UE or a RAN node. In some embodiments, the device 200 may include less elements (e.g., a RAN node may not utilize application circuitry 202, and instead include a processor/controller to process IP data received from an EPC). In some embodiments, the device 200 may include additional elements such as, for example, memory/storage, display, camera, sensor, or input/output (I/O) interface. In other embodiments, the components described below may be included in more than one device (e.g., said circuitries may be separately included in more than one device for Cloud-RAN (C-RAN) implementations).

[0034] The application circuitry 202 may include one or more application processors. For example, the application circuitry 202 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications or operating systems to run on the device 200. In some embodiments, processors of application circuitry 202 may process IP data packets received from an EPC.

[0035] The baseband circuitry 204 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 204 may include one or more baseband processors or control logic to process baseband signals received from a receive signal path of the RF circuitry 206 and to generate baseband signals for a transmit signal path of the RF circuitry 206. Baseband processing circuity 204 may interface with the application circuitry 202 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 206. For example, in some embodiments, the baseband circuitry 204 may include a third generation (3G) baseband processor 204A, a fourth generation (4G) baseband processor 204B, a 5G baseband processor 204C, or other baseband processor(s) 204D for other existing generations, generations in development or to be developed in the future (e.g., second generation (2G), sixth generation (6G), etc.). The baseband circuitry 204 (e.g., one or more of baseband processors 204A-D) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 206. In other embodiments, some or all of the functionality of baseband processors 204A-D may be included in modules stored in the memory 204G and executed via a Central Processing Unit (CPU) 204E. The radio control functions may include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 204 may include Fast-Fourier Transform (FFT), precoding, or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 204 may include convolution, tail-biting convolution, turbo, Viterbi, or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

[0036] In some embodiments, the baseband circuitry 204 may include one or more audio digital signal processor(s) (DSP) 204F. The audio DSP(s) 204F may be include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 204 and the application circuitry 202 may be implemented together such as, for example, on a system on a chip (SOC).

[0037] In some embodiments, the baseband circuitry 204 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 204 may support communication with an evolved universal terrestrial radio access network (EUTRAN) or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN).

Embodiments in which the baseband circuitry 204 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0038] RF circuitry 206 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 206 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 206 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 208 and provide baseband signals to the baseband circuitry 204. RF circuitry 206 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 204 and provide RF output signals to the FEM circuitry 208 for transmission.

[0039] In some embodiments, the receive signal path of the RF circuitry 206 may include mixer circuitry 206A, amplifier circuitry 206B and filter circuitry 206C. In some embodiments, the transmit signal path of the RF circuitry 206 may include filter circuitry 206C and mixer circuitry 206A. RF circuitry 206 may also include synthesizer circuitry 206D for synthesizing a frequency for use by the mixer circuitry 206A of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 206A of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 208 based on the synthesized frequency provided by synthesizer circuitry 206D. The amplifier circuitry 206B may be configured to amplify the down-converted signals and the filter circuitry 206C may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals may be provided to the baseband circuitry 204 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 206A of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0040] In some embodiments, the mixer circuitry 206A of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 206D to generate RF output signals for the FEM circuitry 208. The baseband signals may be provided by the baseband circuitry 204 and may be filtered by filter circuitry 206C.

[0041] In some embodiments, the mixer circuitry 206A of the receive signal path and the mixer circuitry 206A of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and upconversion, respectively. In some embodiments, the mixer circuitry 206A of the receive signal path and the mixer circuitry 206A of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 206A of the receive signal path and the mixer circuitry 206A may be arranged for direct downconversion and direct upconversion, respectively. In some embodiments, the mixer circuitry 206A of the receive signal path and the mixer circuitry 206A of the transmit signal path may be configured for super-heterodyne operation.

[0042] In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 206 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 204 may include a digital baseband interface to communicate with the RF circuitry 206.

[0043] In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[0044] In some embodiments, the synthesizer circuitry 206D may be a fractional-N synthesizer or a fractional N/N+1 synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 206D may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0045] The synthesizer circuitry 206D may be configured to synthesize an output frequency for use by the mixer circuitry 206A of the RF circuitry 206 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 206D may be a fractional N/N+l synthesizer.

[0046] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 204 or the applications processor 202 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 202.

[0047] Synthesizer circuitry 206D of the RF circuitry 206 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or N+1 (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements may be configured to break a VCO period up into Nd equal packets of phase, where Nd is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[0048] In some embodiments, synthesizer circuitry 206D may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency may be a LO frequency (fLO). In some embodiments, the RF circuitry 206 may include an IQ/polar converter.

[0049] FEM circuitry 208 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 210, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 206 for further processing. FEM circuitry 208 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 206 for transmission by one or more of the one or more antennas 2 10. In various embodiments, the amplification through the transmit or receive signal paths may be done solely in the RF circuitry 206, solely in the FEM 208, or in both the RF circuitry 206 and the FEM 208.

[0050] In some embodiments, the FEM circuitry 208 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry may include an LNA to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 206). The transmit signal path of the FEM circuitry 208 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 206), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 2 10).

[0051] In some embodiments, the PMC 212 may manage power provided to the baseband circuitry 204. In particular, the PMC 212 may control power-source selection, voltage scaling, battery charging, or DC-to-DC conversion. The PMC 212 may often be included when the device 200 is capable of being powered by a battery, for example, when the device is included in a UE. The PMC 212 may increase the power conversion efficiency while providing desirable implementation size and heat dissipation characteristics.

[0052] While FIG. 2 shows the PMC 212 coupled only with the baseband circuitry 204. However, in other embodiments, the PMC 2 12 may be additionally or alternatively coupled with, and perform similar power management operations for, other components such as, but not limited to, application circuitry 202, RF circuitry 206, or FEM 208.

[0053] In some embodiments, the PMC 212 may control, or otherwise be part of, various power saving mechanisms of the device 200. For example, if the device 200 is in an RRC_Connected state, where it is still connected to the RAN node as it expects to receive traffic shortly, then it may enter a state known as Discontinuous Reception Mode (DRX) after a period of inactivity. During this state, the device 200 may power down for brief intervals of time and thus save power.

[0054] If there is no data traffic activity for an extended period of time, then the device 200 may transition to an RRC_Idle state. In the RRC_Idle state, the device 200 may disconnect from the network and avoid performing operations such as channel quality feedback, handover, etc. The device 200 may enter a very low power state and perform paging in which the device 200 may periodically wake up to listen to the network and then power down again. To receive data, the device 200 may transition back to the RRC_Connected state.

[0055] An additional power saving mode may allow a device to be unavailable to the network for periods longer than a paging interval (ranging from seconds to a few hours). During this time, the device is totally unreachable to the network and may power down completely. Any data sent during this time incurs a large delay and it is assumed the delay is acceptable.

[0056] Processors of the application circuitry 202 and processors of the baseband circuitry 204 may be used to execute elements of one or more instances of a protocol stack. For example, processors of the baseband circuitry 204, alone or in combination, may be used execute Layer 3, Layer 2, or Layer 1 functionality, while processors of the application circuitry 204 may utilize data (e.g., packet data) received from these layers and further execute Layer 4 functionality (e.g., transmission communication protocol (TCP) and user datagram protocol (UDP) layers). As referred to herein, Layer 3 may comprise a radio resource control (RRC) layer, described in further detail below. As referred to herein, Layer 2 may comprise a medium access control (MAC) layer, a radio link control (RLC) layer, and a packet data convergence protocol (PDCP) layer, described in further detail below. As referred to herein, Layer 1 may comprise a physical (PHY) layer of a UE/RAN node, described in further detail below.

[0057] FIG. 3 illustrates example interfaces of baseband circuitry in accordance with some embodiments. As discussed above, the baseband circuitry 204 of FIG. 2 may comprise processors 204A-XT04E and a memory 204G utilized by said processors. Each of the processors 204A-XT04E may include a memory interface, 304A-XU04E, respectively, to send/receive data to/from the memory 204G.

[0058] The baseband circuitry 204 may further include one or more interfaces to communicatively couple to other circuitries/devices, such as a memory interface 312 (e.g., an interface to send/receive data to/from memory external to the baseband circuitry 204), an application circuitry interface 314 (e.g., an interface to send/receive data to/from the application circuitry 202 of FIG. 2), an RF circuitry interface 316 (e.g., an interface to send/receive data to/from RF circuitry 206 of FIG. 2), a wireless hardware connectivity interface 318 (e.g., an interface to send/receive data to/fromNear Field Communication (NFC) components, Bluetooth® components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components), and a power management interface 320 (e.g., an interface to send/receive power or control signals to/from the PMC 212).

[0059] FIG. 4 is an illustration of a control plane protocol stack in accordance with some embodiments. In this embodiment, a control plane 400 is shown as a communications protocol stack between the UE 101 (or alternatively, the UE 102), the RAN node 111 (or alternatively, the RAN node 112), and the MME 121.

[0060] The PHY layer 401 may transmit or receive information used by the MAC layer 402 over one or more air interfaces. The PHY layer 401 may further perform link adaptation or adaptive modulation and coding (AMC), power control, cell search (e.g., for initial synchronization and handover purposes), and other measurements used by higher layers, such as the RRC layer 405. The PHY layer 401 may still further perform error detection on the transport channels, forward error correction (FEC) coding/decoding of the transport channels, modulation/demodulation of physical channels, interleaving, rate matching, mapping onto physical channels, and Multiple Input Multiple Output (MIMO) antenna processing.

[0061] The MAC layer 402 may perform mapping between logical channels and transport channels, multiplexing of MAC service data units (SDUs) from one or more logical channels onto transport blocks (TB) to be delivered to PHY via transport channels, de-multiplexing MAC SDUs to one or more logical channels from transport blocks (TB) delivered from the PHY via transport channels, multiplexing MAC SDUs onto TBs, scheduling information reporting, error correction through hybrid automatic repeat request (HARQ), and logical channel prioritization.

[0062] The RLC layer 403 may operate in a plurality of modes of operation, including: Transparent Mode (TM), Unacknowledged Mode (UM), and Acknowledged Mode (AM). The RLC layer 403 may execute transfer of upper layer protocol data units (PDUs), error correction through automatic repeat request (ARQ) for AM data transfers, and concatenation, segmentation and reassembly of RLC SDUs for UM and AM data transfers. The RLC layer 403 may also execute re-segmentation of RLC data PDUs for AM data transfers, reorder RLC data PDUs for UM and AM data transfers, detect duplicate data for UM and AM data transfers, discard RLC SDUs for UM and AM data transfers, detect protocol errors for AM data transfers, and perform RLC re-establishment.

[0063] The PDCP layer 404 may execute header compression and decompression of IP data, maintain PDCP Sequence Numbers (SNs), perform in-sequence delivery of upper layer PDUs at re-establishment of lower layers, eliminate duplicates of lower layer SDUs at re-establishment of lower layers for radio bearers mapped on RLC AM, cipher and decipher control plane data, perform integrity protection and integrity verification of control plane data, control timer-based discard of data, and perform security operations (e.g., ciphering, deciphering, integrity protection, integrity verification, etc.).

[0064] The main services and functions of the RRC layer 405 may include broadcast of system information (e.g., included in Master Information

Blocks (MIBs) or System Information Blocks (SIBs) related to the non-access stratum (NAS)), broadcast of system information related to the access stratum (AS), paging, establishment, maintenance and release of an RRC connection between the UE and E-UTRAN (e.g., RRC connection paging, RRC connection establishment, RRC connection modification, and RRC connection release), establishment, configuration, maintenance and release of point to point Radio Bearers, security functions including key management, inter radio access technology (RAT) mobility, and measurement configuration for UE measurement reporting. Said MIBs and SIBs may comprise one or more information elements (IEs), which may each comprise individual data fields or data structures.

[0065] The UE 101 and the RAN node 111 may utilize a Uu interface (e.g., an LTE-Uu interface) to exchange control plane data via a protocol stack comprising the PHY layer 401, the MAC layer 402, the RLC layer 403, the PDCP layer 404, and the RRC layer 405.

[0066] The non-access stratum (NAS) protocols 406 form the highest stratum of the control plane between the UE 101 and the MME 121. The NAS protocols 406 support the mobility of the UE 101 and the session management procedures to establish and maintain IP connectivity between the UE 101 and the P-GW 123.

[0067] The S1 Application Protocol (S1-AP) layer 415 may support the functions of the SI interface and comprise Elementary Procedures (EPs). An EP is a unit of interaction between the RAN node 111 and the CN 120. The Sl-AP layer services may comprise two groups: UE-associated services and non UE-associated services. These services perform functions including, but not limited to: E-UTRAN Radio Access Bearer (E-RAB) management, UE capability indication, mobility, NAS signaling transport, RAN Information Management (RIM), and configuration transfer.

[0068] The Stream Control Transmission Protocol (SCTP) layer (alternatively referred to as the SCTP/IP layer) 414 may ensure reliable delivery of signaling messages between the RAN node 111 and the MME 121 based, in part, on the IP protocol, supported by the IP layer 413. The L2 layer 412 and the

LI layer 411 may refer to communication links (e.g., wired or wireless) used by the RAN node and the MME to exchange information.

[0069] The RAN node 111 and the MME 121 may utilize an S1-MME interface to exchange control plane data via a protocol stack comprising the LI layer 411, the L2 layer 412, the IP layer 413, the SCTP layer 414, and the Sl-AP layer 415.

[0070] FIG. 5 is an illustration of a user plane protocol stack in accordance with some embodiments. In this embodiment, a user plane 500 is shown as a communications protocol stack between the UE 101 (or alternatively, the UE 102), the RAN node 111 (or alternatively, the RAN node 112), the S-GW 122, and the P-GW 123. The user plane 500 may utilize at least some of the same protocol layers as the control plane 400. For example, the UE 101 and the RAN node 111 may utilize a Uu interface (e.g., an LTE-Uu interface) to exchange user plane data via a protocol stack comprising the PHY layer 401, the MAC layer 402, the RLC layer 403, the PDCP layer 404.

[0071] The General Packet Radio Service (GPRS) Tunneling Protocol for the user plane (GTP-U) layer 504 may be used for carrying user data within the GPRS core network and between the radio access network and the core network. The user data transported can be packets in any of IPv4, IPv6, or PPP formats, for example. The UDP and IP security (UDP/IP) layer 503 may provide checksums for data integrity, port numbers for addressing different functions at the source and destination, and encryption and authentication on the selected data flows. The RAN node 111 and the S-GW 122 may utilize an Sl-U interface to exchange user plane data via a protocol stack comprising the LI layer 411, the L2 layer 412, the UDP/IP layer 503, and the GTP-U layer 504. The S-GW 122 and the P-GW 123 may utilize an S5/S8a interface to exchange user plane data via a protocol stack comprising the LI layer 411, the L2 layer 412, the UDP/IP layer 503, and the GTP-U layer 504. As discussed above with respect to FIG. 4, NAS protocols support the mobility of the UE 101 and the session management procedures to establish and maintain IP connectivity between the UE 101 and the P-GW 123.

[0072] FIG. 6 is a block diagram illustrating components, according to some example embodiments, able to read instructions from a machine-readable or computer-readable medium (e.g., anon-transitory machine-readable storage medium) and perform any one or more of the methodologies discussed herein. Specifically, FIG. 6 shows a diagrammatic representation of hardware resources 600 including one or more processors (or processor cores) 610, one or more memory/storage devices 620, and one or more communication resources 630, each of which may be communicatively coupled via a bus 640. For embodiments where node virtualization (e.g., NFV) is utilized, a hypervisor 602 may be executed to provide an execution environment for one or more network slices/sub-slices to utilize the hardware resources 600

[0073] The processors 610 (e.g., a central processing unit (CPU), a reduced instruction set computing (RISC) processor, a complex instruction set computing (CISC) processor, a graphics processing unit (GPU), a digital signal processor (DSP) such as a baseband processor, an application specific integrated circuit (ASIC), a radio-frequency integrated circuit (RFIC), another processor, or any suitable combination thereof) may include, for example, a processor 612 and a processor 614.

[0074] The memory/storage devices 620 may include main memory, disk storage, or any suitable combination thereof. The memory/storage devices 620 may include, but are not limited to any type of volatile or non-volatile memory such as dynamic random access memory (DRAM), static random-access memory (SRAM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), Flash memory, solid-state storage, etc.

[0075] The communication resources 630 may include interconnection or network interface components or other suitable devices to communicate with one or more peripheral devices 604 or one or more databases 606 via a network 608. For example, the communication resources 630 may include wired communication components (e.g., for coupling via a Universal Serial Bus (USB)), cellular communication components, NFC components, Bluetooth®

components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components.

[0076] Instructions 650 may comprise software, a program, an application, an applet, an app, or other executable code for causing at least any of the processors 610 to perform any one or more of the methodologies discussed herein. The instructions 650 may reside, completely or partially, within at least one of the processors 610 (e.g., within the processor's cache memory), the memory/storage devices 620, or any suitable combination thereof. In some embodiments, the instructions 650 may reside on a tangible, non-volatile communication device readable medium, which may include a single medium or multiple media. Furthermore, any portion of the instructions 650 may be transferred to the hardware resources 600 from any combination of the peripheral devices 604 or the databases 606. Accordingly, the memory of processors 610, the memory/storage devices 620, the peripheral devices 604, and the databases 606 are examples of computer-readable and machine-readable media.

[0077] As described above, 5G (NR) systems are currently in development. To meet the needs of disparate UEs, NR networks may use a number of different technologies, including Multiple Input and Multiple Output (MIMO) to increase the communication speed or amount of data provided. The use of massive Multi-User MIMO (MU-MIMO) communications may further be a possibility due to the increased antenna dimensions and number of ports. To use MU-MIMO the eNB or gNB (gNB hereinafter is used for convenience) may allocate the same or different Resource Blocks (RBs) to different UEs. If different RBs are granted, the RBs may partially overlap or may be exclusive. The DMRS may be generated based on Zadoff-Chu sequences and different UEs may be configured with different cyclic shifts. The root sequences for DMRSs with partially overlapping RBs may not be the same, and the use of the non-orthogonal DMRSs may impact the decoding performance at the gNB.

[0078] Turning from the DMRS from different UEs to the DMRS from a single UE, the relative location of the DMRS of one of the UEs in different subframes is described below, independent of the particular RB in which the

DMRS is disposed. **FIG.** 7 illustrates **a** self-contained frame structure **in** accordance **with** some **embodiments.** The self-contained 5G TDD frame structure 700 includes a downlink (DL) transmission 710 and an uplink **(UL)** transmission 720, each of which may contain control information (e.g., Physical **Downlink Control Channel (PDCCH)** 702 or **Physical Uplink Control Channel (PUCCH)** 712) and data (e.g., Physical Downlink Shared Channel (PDSCH) 706 **or Physical Uplink** Shared **Channel (PUSCH)** 714) as well as feedback (e.g., **DMRS** 704) multiplexed **in** the same subframe. A gap period 708 may be used between the downlink and uplink transmissions to permit the transceiver to switch from the transmitter chain to the receiver chain. Note that in 5G systems, unlike LTE systems, the DMRS may be constrained to be located in only the first slot of a subframe.

[0079] The DMRS 704 can be mapped, as shown, to the symbol before the Physical Data Channel **(PDCH).** The **PDCH** may be the PDSCH 706 or PUSCH 714, depending on whether the TDD subframe is a **UL** subframe, **a** DL subframe or, as shown, a special subframe that contains both **UL** and DL transmissions. The UE initially may estimate the channel by using the DMRS 704. After the estimation, the UE may use the channel, possibly with phase compensation, to equalize the received **subcarriers** for the PDCH. in some embodiments, the UE may use phase compensation such as through the use of a Tracking Reference Signals **(TRS).**

[0080] The DMRS 704 may be generated differently, dependent on the embodiment desired. The DMRS 704 may be generated by a baseband processor or a sequence generator separate from the baseband processor. A **"blockwised"** DMRS may be used in which the UE may use multiple RBs for DMRS transmission with each set of RBs may have an independent DMRS sequence. Each set of RBs may include a single RB or an RB Group (RBG) (group **of multiple** RBs). In this case, different UEs that use the same RB **or** RBG can be distinguished by different cyclic shifts. This permits the blockwised DMRS to achieve **orthogonality** among UEs when the UEs are allocated by the gNB with partial overlapping bandwidth (not shown). Even though the use of blockwised DMRS may result in a substantive decrease in the

PAPR compared with wideband DMRS usage, further PAPR decreases are desirable.

[0081] **FIG.** 8 **illustrates** DMRS configurations in accordance **with** some embodiments. The use of different DMRS configurations 800 may reduce **the** PAPR achieved for blockwised DMRS. Further, **in** various embodiments, each set of **resource** blocks (a RB or a RBG) of the blockwised DMRS configuration may have different characteristics, which may include one or more of: DMRS cyclic shift hopping, a different DMRS sequence, a different phase rotation, or a different scrambling sequence for blockwised DMRS. The DMRS characteristics may change if multiple DMRSs at the same frequency are used **by** the **UE** in a subframe; e.g., if a DMRS is used in each slot, the DMRS characteristics (indicated above) may change between slots. Here, as throughout this description, the DMRS in each RB may be generated and encoded by the UE before being transmitted via a UE interface, and received at the gNB via a gNB interface and decoded by the gNB.

[0082] **As shown, a** DMRS configuration 800 **may be either a** blockwised DMRS 810, in which the UE may use the different DMRSs over the allocated bandwidth, or **a** wideband DMRS 820, **in** which the UE may use the same DMRS over the allocated bandwidth. Whether the blockwised DMRS 810 or wideband DMRS 820 is used, the subframe may contain a DMRS region 802, 804 followed by a data region 806 (the **PDCH - PDSCH** or PUSCH, as indicated above). The DMRS 802, 804, whether in the blockwised DMRS 810 configuration or wideband DMRS 820 configuration, may thus be disposed in the same relative location of the subframe. The blockwised DMRS 810 may, as described above, use multiple DMRSs 802 over the system bandwidth, each of which is associated with a different RB or RBG. The wideband DMRS 820 may use the same DMRS 804 over the system bandwidth. The size of the block in the blockwised DMRS 810 may be **preconfigured** or indicated via RRC signaling or through a **DCI.**

[0083] **In some embodiments, the** DMRS configurations 800 **may** switch **between a** blockwised DMRS 810 scheme and a wideband DMRS 820 scheme between subframes or sets of **subframes** (2 or more **subframes).** The switching of the DMRS configuration may reduce the PAPR compared with the use of blockwised DMRS alone. DMRS hopping may be enabled in different blocks to reduce the PAPR. Alternatively, or in addition, a new DMRS base sequence may be used in different blocks. The blockwised DMRS can be used to create an orthogonal DMRS for UEs with a partially overlapping bandwidth allocation. If the UEs are allocated without overlapping or with fully overlapping bandwidth, however it may be desirable to use a single DMRS block to reduce the PAPR. Thus, switching or fallback methods from a blockwised DMRS to a wideband DMRS can also be applied.

[0084] In some embodiments, multiple DMRS generation schemes including the blockwised DMRS and wideband DMRS can be predefined (i.e., set by the 3GPP standard). As above, a single DMRS sequence may be used in the allocated bandwidth for the wideband DMRS scheme. The DMRS scheme selection may be configured via higher layer signaling via aNR master information block (xMIB), a NR system information block (xSIB) or RRC signaling. Alternatively, the DMRS scheme selection may be indicated by a DCI. In the latter case, which is shown in FIG. 8, the DCI may include a 1-bit DMRS scheme indicator (DSI), in which a DSI value of 0 may indicate that a wideband DMRS is utilized and a DSI value of 1 may indicate that the blockwised DMRS is used, although these values may be reversed in other embodiments.

[0085] If the blockwised DMRS configuration is used, turning to the first variation, DMRS cyclic shift hopping may be used in different blocks in a blockwised DMRS scheme. In the TS 36.211, section 5.5 of the 3GPP specification, a cyclic shift for DMRS generation is determined by three values: 1) a 3-bit cell specific broadcast cyclic time shift offset parameter $n_{DMRS}^{(1)}$; 2) 3-bit cyclic time shift offset indicated in the DCI for each uplink scheduling grant $n_{DMRS,\lambda}^{(1)}$ and 3) a pseudo-random cyclic shift offset obtained from the output of the length-31 Gold sequence generator $n_{PN}(n_s)$. In particular, the cyclic shift value can be determined by:

$$n_{CS,\lambda} = (n_{DMRS}^{(1)} + n_{DMRS,\lambda}^{(1)} + n_{PN}(n_s)) mod 12 \qquad (1)$$

where n_s is the slot index and λ is the layer index.

[0086] When the biockwised DMRS is used, in some embodiments the same base sequence can be applied generate each biockwised DMRS to reduce the PAPR, while the DMRS **orthogonality** is maintained between multiple UEs by the use of different cyclic shift values. Different DMRS cyclic shift hopping mechanisms may be used **for** the biockwised DMRS. In cyclic shift hopping, different cyclic shifts can be used in different DMRS blocks. **Whether** cyclic shift hopping is enabled or disabled can be predefined, configured via higher layer signaling or configured dynamically as indicated in the DCI, in the same manner as above. When cyclic shift hopping is disabled, the same cyclic shift can be applied for each block for data transmission.

[0087] As above, cyclic shift can be determined by three values: $n_{DMRS}^{(1)}$; $n_{DMRSA}^{(1)}$; and $nm(n_s)$. The cyclic shift hopping pattern may be derived from the cyclic shift value indicated in the DCl. Defining the cyclic shift value indicated in the DCI as $n_{DMRS,\lambda,start}^{(2)}$, the cyclic shift hopping pattern for each block can be defined as a function of at least one of the following parameters: the virtual ceil ID associated with the gNB, the physical cell ID associated **with** the gNB, the DMRS block index, **the subframe/symbol/slot** index or **the** cyclic **shift** value indicated in the DCI or the UE ID including Cell Radio Network Temporary Identifier (C-RNTI).

[0088] The cyclic shift value can be either cell-specific or UE-specific. In one example, cyclic shift hopping pattern can be generated as:

$$n_{DMRS,\lambda}^{(2)}(l_{block}) = f(n_{ID}, l_{block}, n_{DMRS,\lambda,start}^{(2)}) \bmod N_{CS}^{max} \quad (2)$$

[0089] where n_{ID} denotes the cell ID or virtual cell ID; N_{CS}^{max} refers **to** the maximum cyclic shifts predefined or configured via higher layer signaling, e.g., N_{CS}^{max} = **12;** ¾ ¾$_{RS,\lambda,start}$ **can** be **indicated** by the DCI and may be optional; and I_{biock} i**s the** block index within the allocated bandwidth or within the whole bandwidth. If l_{block} is calculated based on the block index within the allocated bandwidth, the hopping pattern can be **UE-specific** as the hopping pattern may depend on the starting RB index; otherwise the hopping pattern can be cell-specific. The manner in which l_{block} is calculated can be pre-defined or configured via higher layer signaling.

[0090] In one example, the cyclic shift value on each block can be given by:

$$n_{DMRS,\lambda}^{(2)}(l_{block}) = (n_{DMRS,\lambda,start}^{(2)} + \Delta_{CS} \cdot l_{block}) \bmod N_{CS}^{max} \quad (3)$$

[0091] where Δ_{CS} is the cyclic shift offset between two DMRS blocks. **The** cyclic shift value used for the blockwised DMRS generation can be determined by three factors: 1) cell specific cyclic shift offset; 2) a pseudo-random cyclic shift offset obtained from the output of the length-31 Gold sequence generator; and 3) a cyclic shift value according to the cyclic shift hopping pattern, which is given by:

$$n_{CS,\lambda}(l_{block}) = \left(n_{DMRS}^{(1)} + n_{DMRS,\lambda}^{(2)}(l_{block}) + n_{PN}(n_s)\right) \bmod 12 \quad (4)$$

[0092] The values described **in** the equations may be determined by the processing circuitry in the gNB or UE.

[0093] The DMRS in a single subframe may use a single symbol **or** multiple symbols, depending on the embodiment used. For embodiments **in** which high speed communications are desired, two or more symbols can be allocated for DMRS transmission. In this case, cyclic shift hopping across different symbols can be specified. In particular, for one antenna port, the DMRS in different symbols **in** the same block can use different cyclic shifts. **Whether** this is enabled or disabled may be pre-defined or configured via **higher** layer signaling.

[0094] **FIG.** 9 illustrates cyclic shift hopping in accordance **with** some embodiments. **The** DMRS configurations 900 may include a frequency domain hopping DMRS scheme 910 and a time and frequency domain hopping DMRS scheme DMRS 920. Similar **to the** above, both the frequency domain hopping DMRS scheme 910 and time and frequency domain hopping DMRS scheme 920 contain DMRS 902, 904 **in the** first symbol of the subframe of each RB and a PDCH 908 after the DMRS 902, 904. Although the first symbol of a slot is shown as containing the DMRS, in some embodiments, a different symbol of the slot may be used to transmit the DMRS.

[0095] Frequency domain hopping only (rather than time and frequency domain hopping DMRS) may be applied if only one symbol in a subframe is allocated for DMRS. The DMRS 902 may be allocated to the first symbol in the first slot of the block 930. In the frequency domain hopping DMRS scheme 910, DMRS 902 having the same Ncs may frequency hop between one **or** more blocks 930 in adjacent subframes. On the other hand, if multiple symbols in a subframe are used for DMRS, frequency domain and time domain hopping can be enabled such that DMRS 904, 906 having the same N_{cs} may frequency hop between different blocks 930 within a single subframe.

[0096] As shown in FIG. 9, the time and frequency domain hopping DMRS scheme 920 may contain, **in** addition to the DMRS 904 in the first symbol of the first slot in the block 930, an additional DMRS 906 in each block that separates the PDCH 908 **in** the block 930. **In** particular, the additional DMRS 906 may be provided **in** the first symbol of the second slot of the block 930. The DRMS 904, 906 in a single block 930 of the time and frequency domain hopping DMRS scheme 920 may be different; that is, frequency domain hopping may occur in the same block 930 in a subframe of the time and frequency domain hopping DMRS scheme 920. The amount of frequency hopping (i.e., the number of blocks between the first DMRS 604 and the second DMRS 606 having the same Ncs within a subframe) in different embodiments may be the same or may be different among the blocks 930. For example, as **shown in** FIG. 9, the DMRSs 904, 906 may frequency hop one or more blocks 930 in a subframe. This is not exclusive however - the DMRSs 904, 906 may frequency hop more than two blocks 930, or not at ail, dependent on the above equations.

[0097] **Whether** the frequency domain hopping DMRS scheme 910 **or** time and frequency domain hopping DMRS scheme 920 is used, in some embodiments different sequences can be applied to different DMRS blocks instead **of or** in addition to the use of different cyclical shifts. The sequence used for each DMRS can be predefined or configured via higher layer signaling. **In** one example, different sequence groups can be used in different DMRSs in different blocks or different slots within a subframe (if multiple DMRSs are present in a single subframe). In this case, a group index **for** the DMRS in a particular block and subframe can be determined by the block index as well as the slot index.

[0098] Alternatively, the group index can be determined by the block index as well as group index offset, and may be configured via higher layer signaling or DCI. For example, the group index offset may use 1 bit and be provided as an additional value to the DCI. In this case, an additional DCI value of 0 may indicate that the group index offset is equal to 0 while an additional DCI value 1 may indicate that the group index offset is equal to 1. The DMRS for co-scheduled UEs with overlapping bandwidth allocation may thus be distinguished via a different group index offset.

[0099] In other embodiments, the different DMRS may be differentiated using a sequence index that is determined based on the block index. A sequence index offset can be added to the DCI or may be provided to the UE via higher layer signaling. The sequence index offset, like the group index offset, may in some embodiments be indicated via a single bit. The root sequence for DMRS in DMRS block can be generated by:

$$e^{ian} f_{u,v}(n) \qquad (5)$$

[00100] where u and/or v can be determined by the block index as well as group **and/or** sequence index offset, **a** may be determined by the cyclic shift configuration and $f_{u,v}(n)$ can be the Zadoff-Chu sequence defined in section 5.5. 1 in 3GPP TS 36.21 1.

[00101] In some embodiments, different phase rotations may be used for biockwised DMRS instead of or in addition to the use of different sequences. This is to say that the PAPR may be reduced by applying different phase offsets/rotations on different blocks for DMRS transmission. To allow the gNB to properly decode the uplink data channel, the same phase offset on the DMRS transmission may be applied for the data channel in the same block.

[00102] **When** different phase rotations are used, the base sequence can be generated via $e^{j\beta}e^{j_{a}n}f_{u,v}(n)$, where β indicates the phase rotation and can be determined by the DMRS block index. in embodiments in which the DMRS is mapped to multiple symbols, the phase rotation can also be determined by the symbol index or slot index as well as DMRS block index. In this case, the gNB may assume the same precoder is utilized on each block, but different precoders used on different blocks, so that channel estimation may not be combined across different blocks.

[00103] **In** some embodiments, different scrambling sequences can be applied on a **blockwised** DMRS sequence to reduce the PAPR or cubic **metric** (CM). The scrambling code used to generate the scrambling sequence can be defined in a **UE-specific** or cell-specific manner.

[00104] **In** some embodiments, **the** scrambling code can be generated as a function of at least one of the following parameters: physical ceil ID, virtual cell ID, or subframe/slot/symbol index. As a cell-specific scrambling code can be used for all UEs on the blockwised DMRS sequence, for one UE only the scrambling code within **the** allocated resource for data transmission may be used to scramble the DMRS sequence. For instance, assuming a 20MHz system bandwidth **with** 100 physical resource blocks (PRB), a cell-specific scrambling code may span 0 to 99 PRBs. A first UE (UE #1) assigned **with** resource PRB#4-7 for data transmission may use a scrambling code from PRB#4-7 to scramble the blockwised DMRS sequence. Similarly, a second UE (UE #2) assigned **with** resource PRB#48-87 for data transmission may use a scrambling code from PRB#48-87 to scramble the blockwised DMRS sequence.

[00105] In one example, the scrambling seed can **be** given by:

$$c_{init} = f(N_{cell}^{ID}, (n_S)) \qquad (6)$$

[00106] where n_s is the slot index and N_{cell}^{ID} is the physical ceil ID. For instance:

$$c_{init} = \left(\left\lfloor \frac{n_S}{2} \right\rfloor + 1\right) \cdot (2N_{cell}^{ID} + 1) \cdot 2^{16} \qquad (7)$$

[00107] The scrambling code can be generated as a function of at least one of the following parameters: physical ceil ID, virtual ceil ID, UE ID (e.g. Cell-Radio Network Temporary' Identifier **(C-RNTI)),** subframe/slot/symbol index, or UE-specific parameter. The UE-specific parameter may be dynamically indicated in the DC! format or configured by higher layers via **UE-specific** dedicated RRC signaling.

[00108] The scrambling sequence may be defined **in** a UE-specific manner. More specifically, the scrambling sequence length may be based on the number of the subcarriers within the allocated resource. In one example, the scrambling seed can be given **by:**

$$c_{init} = \left(\left\lfloor \frac{n_s}{2} \right\rfloor + 1 \right) \cdot (2N_{cell}^{ID} + 1) \cdot 2^{16} + n_{RNTI} \qquad (8)$$

[00109] where n_s is the slot index, N_{cell}^{ID} is the physical ceil ID and n_{RNTI} is the **C-RNTI.**

[00110] In another example, the scrambling sequence can be initialized as a function of virtual cell ID **or** a **cluster/sub-cluster** ID. In this case:

$$c_{init} = \left(\left\lfloor \frac{n_s}{2} \right\rfloor + 1 \right) \cdot (2N_{DMRS} + 1) \cdot 2^{16} + n_{ID} \qquad (9)$$

[00111] where N_{DMRS} is the virtual cell ID, which can be configured by higher layers **via aNR** master information block (xMIB), **aNR** system information block (xSIB) or UE-specific dedicated RRC signaling, and n_{ID} is a UE-specific parameter, which can be indicated in the **DCI** format.

[00112] **FIG.** 10 illustrates simulation results **of PAPR for** different DMRS configurations in accordance **with** some embodiments. From the simulation results, it can be observed that the CS hopping, group hopping and the phase hopping can help **to** reduce the PAPR of DMRS, with the CS hopping appearing to provide the maximum PAPR reduction compared with the biockwised DMRS without hopping. in the simulation, the DMRS block size was assumed to be 4 PRB and the **full** bandwidth 100 RB. The simulation was based on 1000 trials of random PRB allocation and base sequence of DMRS.

[00113] Note that although DMRS are referred to herein, similar techniques may be used for other reference signals. This is to say that reference signals such as sounding reference signals (SRS) or Channel State Information Reference Signals (CSI-RS) may be split into blockwised sets and then one or more of cyclic shift hopping, different sequences, different phase rotations and/or different scrambling sequences in different blocks be used in much the same manner as described.

[00114] Examples

[00115] Example 1 is an apparatus of a user equipment (UE), the apparatus comprising: an interface to communicate with a next generation NodeB (gNB); and processing circuitry in communication with the interface and arranged to: determine, based on information from the gNB, whether blockwised demodulation reference signals (DMRSs) or a wideband DMRS is to be transmitted; encode, in response to a determination that the blockwised DMRSs are to be transmitted, blockwised DMRSs having different DMRS characteristics in sets of resource blocks; and cause the blockwised DMRSs to be transmitted to the gNB via the interface.

[00116] In Example 2, the subject matter of Example 1 includes, wherein the processing circuitry is further configured to: decode a DMRS scheme indicator (DSI) of Downlink Control Information (DCI) from the gNB to determine whether blockwised DMRSs or the wideband DMRS is to be transmitted.

[00117] In Example 3, the subject matter of Examples 1-2 includes, wherein: the different DMRS characteristics comprise at least one of: DMRS cyclic shift hopping, DMRS sequence, phase rotation, or scrambling sequence such that each set of resource blocks has at least one of a different cyclic shift, DMRS sequence, phase rotation, or scrambling sequence.

[00118] In Example 4, the subject matter of Example 3 includes, wherein: the blockwised DMRSs comprise DMRS cyclic shift hopping in which different cyclic shifts are used in different sets of resource blocks.

[00119] In Example 5, the subject matter of Example 4 includes, wherein: a same base sequence is applied to form the blockwised DMRSs.

[00120] In Example 6, the subject matter of Examples 4-5 includes, wherein the processing circuitry is further configured to: determine whether the DMRS cyclic shift hopping is enabled via one of higher layer signaling or indicated in Downlink Control Signaling (DCI).

[00121] In Example 7, the subject matter of Example 6 includes, wherein the processing circuitry is further configured to: determine whether the DMRS cyclic shift hopping is cell-specific or UE-specific via the higher layer signaling.

[00122] In Example 8, the subject matter of Examples 4-7 includes, wherein: a DMRS cyclic shift hopping pattern is dependent on at least one of: virtual cell identification (ID), physical cell ID, a DMRS block index, at least one of a subframe, symbol, or slot index or a cyclic shift value indicated in Downlink Control Signaling (DCI), or a UE ID including a Cell Radio Network Temporary Identifier (C-RNTI) of the UE.

[00123] In Example 9, the subject matter of Examples 3-8 includes, wherein: the blockwised DMRSs comprise different DMRS sequences used in different sets of resource blocks, the DMRS sequence of a particular resource block is determined by a group index that is dependent on a block and slot index of the particular resource block.

[00124] In Example 10, the subject matter of Examples 3-9 includes, wherein: the blockwised DMRSs comprise different DMRS sequences used in different sets of resource blocks, the DMRS sequence of a particular resource block is determined by a group index that is dependent on a block index and a group index offset of the particular resource block, the group index offset indicated in Downlink Control Signaling (DCI).

[00125] In Example 11, the subject matter of Examples 3-10 includes, wherein: the blockwised DMRSs comprise different DMRS sequences used in different sets of resource blocks, the DMRS sequence of a particular resource block is determined by a sequence index that is dependent on a sequence index offset of the particular resource block, the sequence index and sequence index offset indicated in one of higher layer signaling or Downlink Control Signaling (DCI).

[00126] In Example 12, the subject matter of Examples 3-1 1 includes, wherein: the blockwised DMRSs comprise different phase rotations used in different sets of resource blocks, a phase rotation of a particular resource block is determined by a block index of the particular resource block, the phase rotation of the particular resource block used to generate a base sequence of the DMRS.

[00127] In Example 13, the subject matter of Example 12 includes, wherein: when the blockwised DMRS of the particular resource block is mapped to multiple symbols in a subframe, a phase rotation of a particular DMRS in the particular resource block is further determined by at least one of a symbol or slot index of the particular DMRS.

[00128] In Example 14, the subject matter of Examples 3-13 includes, wherein: the blockwised DMRSs comprise different scrambling sequences used in different sets of resource blocks, a scrambling sequence of a particular DMRS is dependent on at least one of virtual cell identification (ID), physical cell ID, UE ID or at least one of a subframe, symbol, slot index of the particular DMRS or a UE-specific parameter.

[00129] In Example 15, the subject matter of Examples 3-14 includes, wherein: the blockwised DMRSs comprise different scrambling sequences used in different sets of DMRSs, a scrambling sequence of a particular DMRS is determined by a scrambling code that is dependent on at least one of: virtual cell identification (ID), physical cell ID, UE ID, at least one of a subframe, symbol, slot index of the particular DMRS, or a UE-specific parameter, the UE-specific parameter is indicated in one of higher layer signaling or Downlink Control Signaling (DCI).

[00130] In Example 16, the subject matter of Example 15 includes, wherein: a length of the scrambling sequence for the particular DMRS is based on a number of subcarriers in a resource allocated for the particular DMRS.

[00131] In Example 17, the subject matter of Examples 1-16 includes, wherein: each set of resource blocks is a single resource block.

[00132] In Example 18, the subject matter of Examples 1-17 includes, wherein: each set of resource blocks comprises multiple resource blocks.

[00133] In Example 19, the subject matter of Examples 1-18 includes, wherein: the processing circuitry comprises a baseband processor configured to generate the blockwised DMRSs.

[00134] Example 20 is an apparatus of a next generation NodeB (gNB), the apparatus comprising: an interface to communicate with a user equipment (UE); and processing circuitry in communication with the interface and arranged to: communicate, via one of a DMRS scheme indicator (DSI) of Downlink Control Signaling (DCI) or higher layer signaling, whether the UE is to transmit blockwised demodulation reference signals (DMRSs) or a wideband DMRS; and decode, from the UE via the interface, the blockwised DMRSs in response to an indication to transmit the blockwised DMRSs, the blockwised DMRSs having, for different resource blocks or DMRSs, at least one of: DMRS cyclic shift hopping, different DMRS sequences, different phase rotation, or different scrambling sequences.

[00135] In Example 21, the subject matter of Example 20 includes, wherein: when the blockwised DMRSs comprise DMRS cyclic shift hopping, a same base sequence forms the blockwised DMRSs.

[00136] In Example 22, the subject matter of Examples 20-21 includes, wherein the processing circuitry is further configured to: indicate to the UE via the higher layer signaling whether the DMRS cyclic shift hopping is cell-specific or UE-specific.

[00137] In Example 23, the subject matter of Examples 20-22 includes, wherein: a DMRS cyclic shift hopping pattern is dependent on at least one of: virtual cell identification (ID), physical cell ID, a DMRS block index, at least one of a subframe, symbol, or slot index or a cyclic shift value indicated in Downlink Control Signaling (DCI), or a UE ID including a Cell Radio Network Temporary Identifier (C-RNTI) of the UE.

[00138] In Example 24, the subject matter of Examples 20-23 includes, wherein: the blockwised DMRSs comprise different DMRS sequences used in different resource blocks, the DMRS sequence of a particular resource block is determined by one of: a group index that is dependent on one of: a block and slot index of the particular resource block, or the block index and a group index offset of the particular resource block, the group index offset indicated in Downlink Control Signaling (DCI), or a sequence index that is dependent on a sequence index offset of the particular resource block, the sequence index and sequence index offset indicated in one of higher layer signaling or the DCI.

[00139] In Example 25, the subject matter of Examples 20-24 includes, wherein: the blockwised DMRSs comprise different phase rotations used in different resource blocks, or in different DMRSs when the blockwised DMRS of the particular resource block is mapped to multiple symbols in a subframe, a phase rotation of a particular resource block or particular DMRS is determined by a block index of the particular resource block, and further by at least one of a symbol or slot index of the particular DMRS when the blockwised DMRS of the particular resource block is mapped to multiple symbols in the subframe.

[00140] In Example 26, the subject matter of Examples 20-25 includes, wherein: the blockwised DMRSs comprise different scrambling sequences used in different DMRSs, and a scrambling sequence of a particular DMRS is determined by a scrambling code that is dependent on at least one of: virtual cell identification (ID), physical cell ID, UE ID or at least one of a subframe, symbol, slot index of the particular DMRS or a UE-specific parameter.

[00141] Example 27 is a computer-readable storage medium that stores instructions for execution by one or more processors of a user equipment (UE), the one or more processors to configure the UE to: receive, via one of a DMRS scheme indicator (DSI) of Downlink Control Signaling (DCI) or higher layer signaling, whether the UE is to transmit blockwised demodulation reference signals (DMRSs) or a wideband DMRS; and transmit the blockwised DMRSs in response to an indication to transmit the blockwised DMRSs, the blockwised DMRSs having, for different resource blocks or DMRSs, at least one of: DMRS cyclic shift hopping, different DMRS sequences, different phase rotation, or different scrambling sequences.

[00142] In Example 28, the subject matter of Example 27 includes, wherein: the blockwised DMRSs comprise different DMRS sequences used in

different resource blocks, the DMRS sequence of a particular resource block is determined by one of: a group index that is dependent on one of: a block and slot index of the particular resource block, or the block index and a group index offset of the particular resource block, the group index offset indicated in Downlink Control Signaling (DCI), or a sequence index that is dependent on a sequence index offset of the particular resource block, the sequence index and sequence index offset indicated in one of higher layer signaling or the DCI.

[00143] In Example 29, the subject matter of Examples 27-28 includes, wherein: the blockwised DMRSs comprise different phase rotations used in different resource blocks, or in different DMRSs when the blockwised DMRS of the particular resource block is mapped to multiple symbols in a subframe, a phase rotation of a particular resource block or particular DMRS is determined by a block index of the particular resource block, and further by at least one of a symbol or slot index of the particular DMRS when the blockwised DMRS of the particular resource block is mapped to multiple symbols in the subframe.

[00144] In Example 30, the subject matter of Examples 27-29 includes, wherein: the blockwised DMRSs comprise different scrambling sequences used in different DMRSs, and a scrambling sequence of a particular DMRS is determined by a scrambling code that is dependent on at least one of: virtual cell identification (ID), physical cell ID, UE ID or at least one of a subframe, symbol, slot index of the particular DMRS or a UE-specific parameter.

[00145] Example 31 is an apparatus of a user equipment (UE), the apparatus comprising: means for receiving, via one of a DMRS scheme indicator (DSI) of Downlink Control Signaling (DCI) or higher layer signaling, whether the UE is to transmit blockwised demodulation reference signals (DMRSs) or a wideband DMRS; and means for transmitting the blockwised DMRSs in response to an indication to transmit the blockwised DMRSs, the blockwised DMRSs having, for different resource blocks or DMRSs, at least one of: DMRS cyclic shift hopping, different DMRS sequences, different phase rotation, or different scrambling sequences.

[00146] In Example 32, the subject matter of Example 31 includes, wherein: the blockwised DMRSs comprise different DMRS sequences used in

different resource blocks, the DMRS sequence of a particular resource block is determined by one of: a group index that is dependent on one of: a block and slot index of the particular resource block, or the block index and a group index offset of the particular resource block, the group index offset indicated in Downlink Control Signaling (DCI), or a sequence index that is dependent on a sequence index offset of the particular resource block, the sequence index and sequence index offset indicated in one of higher layer signaling or the DCI.

[00147] In Example 33, the subject matter of Examples 31-32 includes, wherein: the blockwised DMRSs comprise different phase rotations used in different resource blocks, or in different DMRSs when the blockwised DMRS of the particular resource block is mapped to multiple symbols in a subframe, a phase rotation of a particular resource block or particular DMRS is determined by a block index of the particular resource block, and further by at least one of a symbol or slot index of the particular DMRS when the blockwised DMRS of the particular resource block is mapped to multiple symbols in the subframe.

[00148] In Example 34, the subject matter of Examples 31-33 includes, wherein: the blockwised DMRSs comprise different scrambling sequences used in different DMRSs, and a scrambling sequence of a particular DMRS is determined by a scrambling code that is dependent on at least one of: virtual cell identification (ID), physical cell ID, UE ID or at least one of a subframe, symbol, slot index of the particular DMRS or a UE-specific parameter.

[00149] Example 35 is a method of enhancing blockwised reference signals in a user equipment (UE), the method comprising: receiving, via one of a DMRS scheme indicator (DSI) of Downlink Control Signaling (DCI) or higher layer signaling, whether the UE is to transmit blockwised demodulation reference signals (DMRSs) or a wideband DMRS; and transmitting the blockwised DMRSs in response to an indication to transmit the blockwised DMRSs, the blockwised DMRSs having, for different resource blocks or DMRSs, at least one of: DMRS cyclic shift hopping, different DMRS sequences, different phase rotation, or different scrambling sequences.

[00150] In Example 36, the subject matter of Example 35 includes, wherein: the blockwised DMRSs comprise different DMRS sequences used in

different resource blocks, the DMRS sequence of a particular resource block is determined by one of: a group index that is dependent on one of: a block and slot index of the particular resource block, or the block index and a group index offset of the particular resource block, the group index offset indicated in Downlink Control Signaling (DCI), or a sequence index that is dependent on a sequence index offset of the particular resource block, the sequence index and sequence index offset indicated in one of higher layer signaling or the DCI.

[00151] In Example 37, the subject matter of Examples 35-36 includes, wherein: the blockwised DMRSs comprise different phase rotations used in different resource blocks, or in different DMRSs when the blockwised DMRS of the particular resource block is mapped to multiple symbols in a subframe, a phase rotation of a particular resource block or particular DMRS is determined by a block index of the particular resource block, and further by at least one of a symbol or slot index of the particular DMRS when the blockwised DMRS of the particular resource block is mapped to multiple symbols in the subframe.

[00152] In Example 38, the subject matter of Examples 35-37 includes, wherein: the blockwised DMRSs comprise different scrambling sequences used in different DMRSs, and a scrambling sequence of a particular DMRS is determined by a scrambling code that is dependent on at least one of: virtual cell identification (ID), physical cell ID, UE ID or at least one of a subframe, symbol, slot index of the particular DMRS or a UE-specific parameter.

[00153] Example 39 is at least one machine-readable medium including instructions that, when executed by processing circuitry, cause the processing circuitry to perform operations to implement of any of Examples 1-38.

[00154] Example 40 is an apparatus comprising means to implement of any of Examples 1-38.

[00155] Example 41 is a system to implement of any of Examples 1-38.

[00156] Example 42 is a method to implement of any of Examples 1-38.

[00157] Example 43 is at least one machine-readable medium including instructions that, when executed by processing circuitry, cause the processing circuitry to perform operations to implement of any of Examples 1-38 to a reference signal other than a DMRS.

[00158] Example 44 is an apparatus comprising means to implement of any of Examples 1-38 to a reference signal other than a DMRS.

[00159] Example 45 is a system to implement of any of Examples 1-38 to a reference signal other than a DMRS.

[00160] Example 46 is a method to implement of any of Examples 1-38 to a reference signal other than a DMRS.

[00161] Although an embodiment has been described with reference to specific example embodiments, it will be evident that various modifications and changes may be made to these embodiments without departing from the broader scope of the present disclosure. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense. The accompanying drawings that form a part hereof show, by way of illustration, and not of limitation, specific embodiments in which the subject matter may be practiced. The embodiments illustrated are described in sufficient detail to enable those skilled in the art to practice the teachings disclosed herein. Other embodiments may be utilized and derived therefrom, such that structural and logical substitutions and changes may be made without departing from the scope of this disclosure. This Detailed Description, therefore, is not to be taken in a limiting sense, and the scope of various embodiments is defined only by the appended claims, along with the full range of equivalents to which such claims are entitled.

[00162] The subject matter may be referred to herein, individually and/or collectively, by the term "embodiment" merely for convenience and without intending to voluntarily limit the scope of this application to any single inventive concept if more than one is in fact disclosed. Thus, although specific embodiments have been illustrated and described herein, it should be appreciated that any arrangement calculated to achieve the same purpose may be substituted for the specific embodiments shown. This disclosure is intended to cover any and all adaptations or variations of various embodiments. Combinations of the above embodiments, and other embodiments not specifically described herein, will be apparent to those of skill in the art upon reviewing the above description.

[00163] In this document, the terms "a" or "an" are used, as is common in patent documents, to include one or more than one, independent of any other instances or usages of "at least one" or "one or more." In this document, the term "or" is used to refer to a nonexclusive or, such that "A or B" includes "A but not B," "B but not A," and "A and B," unless otherwise indicated. In this document, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Also, in the following claims, the terms "including" and "comprising" are open-ended, that is, a system, UE, article, composition, formulation, or process that includes elements in addition to those listed after such a term in a claim are still deemed to fall within the scope of that claim. Moreover, in the following claims, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects.

[00164] The Abstract of the Disclosure is provided to comply with 37 C.F.R. §1.72(b), requiring an abstract that will allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description, it can be seen that various features are grouped together in a single embodiment for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed embodiments require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter lies in less than all features of a single disclosed embodiment. Thus the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separate embodiment.

CLAIMS

What is claimed is:

1. An apparatus of a user equipment (UE), the apparatus comprising:

an interface to communicate with a next generation NodeB (gNB); and

processing circuitry in communication with the interface and arranged to:

determine, based on information from the gNB, whether blockwised demodulation reference signals (DMRSs) or a wideband DMRS is to be transmitted;

encode, in response to a determination that the blockwised DMRSs are to be transmitted, blockwised DMRSs having different DMRS characteristics in sets of resource blocks; and

cause the blockwised DMRSs to be transmitted to the gNB via the interface.

2. The apparatus of claim 1, wherein the processing circuitry is further configured to:

decode a DMRS scheme indicator (DS1) of Downlink Control Information (DCI) from the gNB to determine whether blockwised DMRSs or the wideband DMRS is to be transmitted.

3. The apparatus of claim 1 or 2, wherein:

the different DMRS characteristics comprise at least one of: DMRS cyclic shift hopping, DMRS sequence, phase rotation, or scrambling sequence such that each set of resource blocks has at least one of a different cyclic shift, DMRS sequence, phase rotation, or scrambling sequence.

4. The apparatus of claim 3, wherein:

the blockwised DMRSs comprise DMRS cyclic shift hopping in which different cyclic shifts are used in different sets of resource blocks.

5. The apparatus of claim 4, wherein:

a same base sequence is applied to form the blockwised DMRSs.

6. The apparatus of claim 4, wherein the processing circuitry is further configured to:

determine whether the DMRS cyclic shift hopping is enabled via one of higher layer signaling or indicated in Downlink Control Signaling (DCI).

7. The apparatus of claim 6, wherein the processing circuitry is further configured to:

determine whether the DMRS cyclic shift hopping is cell-specific or UE-specific via the higher layer signaling.

8. The apparatus of claim 4, wherein:

a DMRS cyclic shift hopping pattern is dependent on at least one of: virtual cell identification (ID), physical cell ID, a DMRS block index, at least one of a subframe, symbol, or slot index or a cyclic shift value indicated in Downlink Control Signaling (DCI), or a UE ID including a Cell Radio Network Temporary Identifier (C-RNTI) of the UE.

9. The apparatus of claim 3, wherein:

the blockwised DMRSs comprise different DMRS sequences used in different sets of resource blocks, the DMRS sequence of a particular resource block is determined by a group index that is dependent on a block and slot index of the particular resource block.

10. The apparatus of claim 3, wherein:

the blockwised DMRSs comprise different DMRS sequences used in different sets of resource blocks, the DMRS sequence of a particular resource block is determined by a group index that is dependent on a block index and a group index offset of the particular resource block, the group index offset indicated in Downlink Control Signaling (DCI).

11. The apparatus of claim 3, wherein:

the blockwised DMRSs comprise different DMRS sequences used in different sets of resource blocks, the DMRS sequence of a particular resource block is determined by a sequence index that is dependent on a sequence index offset of the particular resource block, the sequence index and sequence index offset indicated in one of higher layer signaling or Downlink Control Signaling (DC!).

12. The apparatus of claim 3, wherein:

the blockwised DMRSs comprise different phase rotations used in different sets of resource blocks, a phase rotation of a particular resource block is determined by a block index of the particular resource block, the phase rotation of the particular resource block used to generate a base sequence of the DMRS.

13. The apparatus of claim 12, wherein:

when the blockwised DMRS of the particular resource block is mapped to multiple symbols in a subframe, a phase rotation of a particular DMRS in the particular resource block is further determined by at least one of a symbol or slot index of the particular DMRS.

14. The apparatus of claim 3, wherein:

the blockwised DMRSs comprise different scrambling sequences used in different sets of resource blocks, a scrambling sequence of a particular DMRS is dependent on at least one of virtual ceil identification (ID), physical cell ID, UE ID or at least one of a subframe, symbol, slot index of the particular DMRS or a UE-specific parameter.

15. The apparatus of claim 3, wherein:

the blockwised DMRSs comprise different scrambling sequences used in different sets of DMRSs, a scrambling sequence of a particular DMRS is determined by a scrambling code that is dependent on at least one of: virtual cell identification (ID), physical cell ID, UE ID, at least one of a subframe, symbol, slot index of the particular DMRS, or a UE-specific parameter, the UE-specific parameter is indicated in one of higher layer signaling or Downlink Control Signaling (DCI).

16. The apparatus of claim 15, wherein:

a length of the scrambling sequence for the paiticular DMRS is based on a number of subcarriers in a resouixe allocated for the pat iculai DMRS.

17. The apparatus of claim 1 or 2, wherein:

each set of resource blocks is a single resource block.

18. The apparatus of claim 1 or 2, wherein:

each set of resource blocks comprises multiple resource blocks.

19. The apparatus of claim 1 or 2, wherein:

the processing circuitry comprises a baseband processor configured to generate the blockwised DMRSs.

20. An apparatus of a next generation NodeB (gNB), the apparatus comprising:

an interface to communicate with a user equipment (UE); and

processing circuitry in communication with the interface and arranged to:

communicate, via one of a DMRS scheme indicator (DSI) of Downlink Control Signaling (DCI) or higher layer signaling, whether the UE is to transmit blockwised demodulation reference signals (DMRSs) or a wideband DMRS; and

decode, from the UE via the interface, the blockwised DMRSs in response to an indication to transmit the blockwised DMRSs, the blockwised DMRSs having, for different resource blocks or DMRSs, at least one of: DMRS cyclic shift hopping, different DMRS sequences, different phase rotation, or different scrambling sequences.

21. The apparatus of claim 20, wherein:

when the biockwised DMRSs comprise DMRS cyclic shift hopping, a same base sequence forms the biockwised DMRSs.

22. The apparatus of claim 20 or 21, wherein the processing circuitry is further configured to:

indicate to the UE via the higher layer signaling whether the DMRS cyclic shift hopping is cell-specific or UE-specific.

23. The apparatus of claim 20 or 21, wherein:

a DMRS cyclic shift hopping pattern is dependent on at least one of: virtual cell identification (ID), physical cell ID, a DMRS block index, at least one of a subframe, symbol, or slot index or a cyclic shift value indicated in Downlink Control Signaling (DCI), or a UE ID including a Cell Radio Network Temporary Identifier (C-RNTI) of the UE.

24. The apparatus of claim 20 or 21, wherein:

the biockwised DMRSs comprise different DMRS sequences used in different resource blocks, the DMRS sequence of a particular resource block is determined by one of:

a group index that is dependent on one of:

a block and slot index of the particular resource block, or

the block index and a group index offset of the particular resource block, the group index offset indicated in Downlink Control Signaling (DCI), or

a sequence index that is dependent on a sequence index offset of the particular resource block, the sequence index and sequence index offset indicated in one of higher layer signaling or the DCI.

25. The apparatus of claim 20 or 21, wherein:

the biockwised DMRSs comprise different phase rotations used in different resouice blocks, or in different DMRSs when the biockwised DMRS of the particular resource block is mapped to multiple symbols in a subframe, a phase rotation of a particular resource block or particular DMRS is determined by a block index of the particular resource block, and further by at least one of a symbol or slot index of the particular DMRS when the blockwised DMRS of the particular resource block is mapped to multiple symbols in the subframe.

26. The apparatus of claim 20 or 21, wherein:

the blockwised DMRSs comprise different scrambling sequences used in different DMRSs, and

a scrambling sequence of a particular DMRS is determined by a scrambling code that is dependent on at least one of: virtual cell identification (ID), physical ceil ID, UE ID or at least one of a subframe, symbol, slot index of the particular DMRS or a UE-specific parameter.

27. A computer-readable storage medium that stores instructions for execution by one or more processors of a user equipment (UE), the one or more processors to configure the UE to:

receive, via one of a DMRS scheme indicator (DSI) of Downlink Control Signaling (DCI) or higher layer signaling, whether the UE is to transmit blockwised demodulation reference signals (DMRSs) or a wideband DMRS; and

transmit the blockwised DMRSs in response to an indication to transmit the blockwised DMRSs, the blockwised DMRSs having, for different resource blocks or DMRSs, at least one of: DMRS cyclic shift hopping, different DMRS sequences, different phase rotation, or different scrambling sequences.

28. The medium of claim 27, wherein:

the blockwised DMRSs comprise different DMRS sequences used in different resource blocks, the DMRS sequence of a particular resource block is determined by one of:

a group index that is dependent on one of:

a block and slot index of the particular resource block, or the block index and a group index offset of the particular resource block, the group index offset indicated in Downlink Control Signaling (DCI), or

a sequence index that is dependent on a sequence index offset of the particular resource block, the sequence index and sequence index offset indicated in one of higher layer signaling or the DCI.

29. The medium of claim 27, wherein:

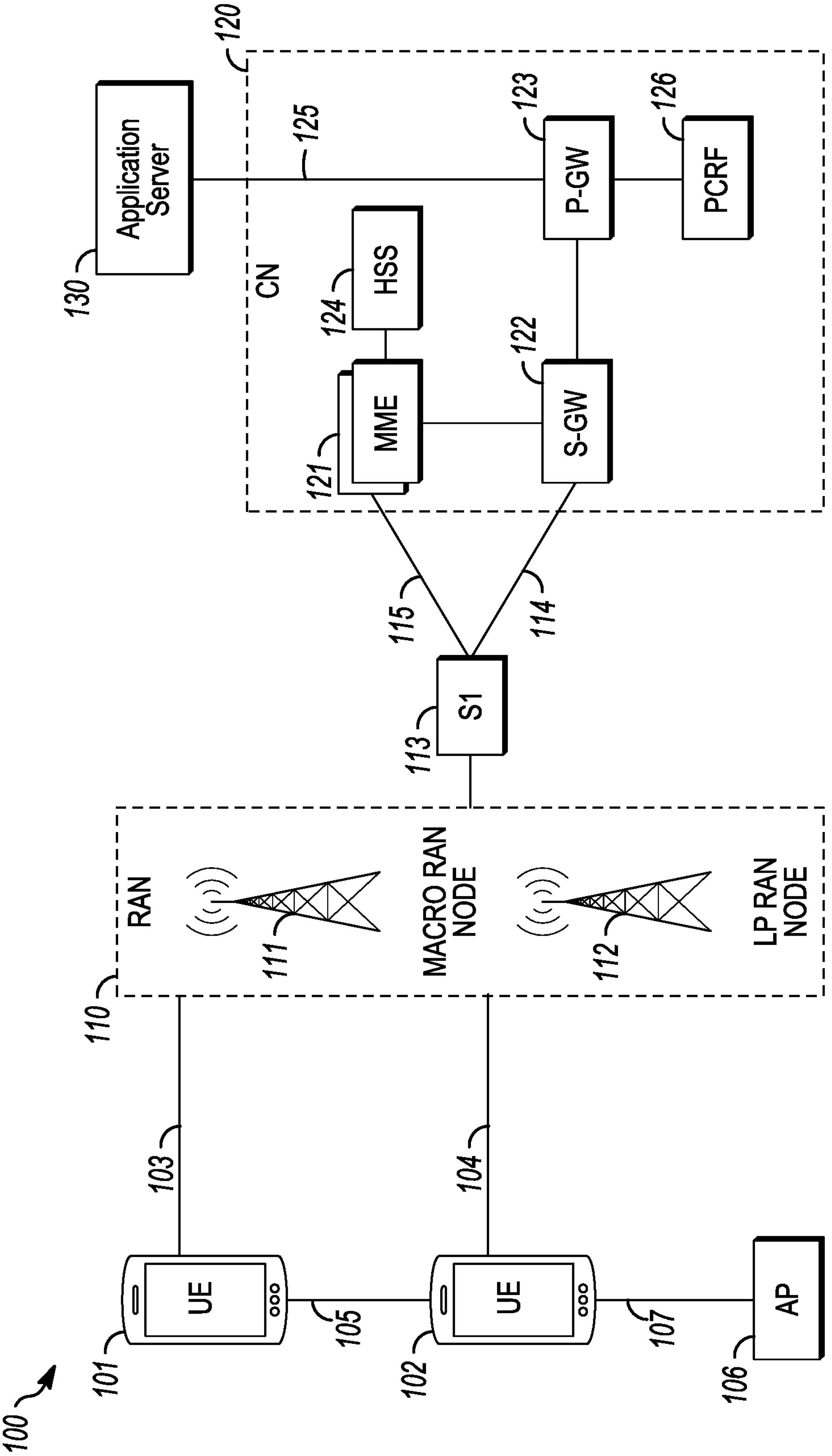
the biockwised DMRSs comprise different phase rotations used in different resource blocks, or in different DMRSs when the biockwised DMRS of the particular resource block is mapped to multiple symbols in a subframe,

a phase rotation of a particular resource block or particular DMRS is determined by a block index of the particular resource block, and further by at least one of a symbol or slot index of the particular DMRS when the biockwised DMRS of the particular resource block is mapped to multiple symbols in the subframe.

30. The medium of claim 27, wherein:

the biockwised DMRSs comprise different scrambling sequences used in different DMRSs, and

a scrambling sequence of a particular DMRS is determined by a scrambling code that is dependent on at least one of: virtual cell identification (ID), physical cell ID, UE ID or at least one of a subframe, symbol, slot index of the particular DMRS or a UE-specific parameter.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P-GW
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HSS
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PCRF
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Application Server

FIG. 1

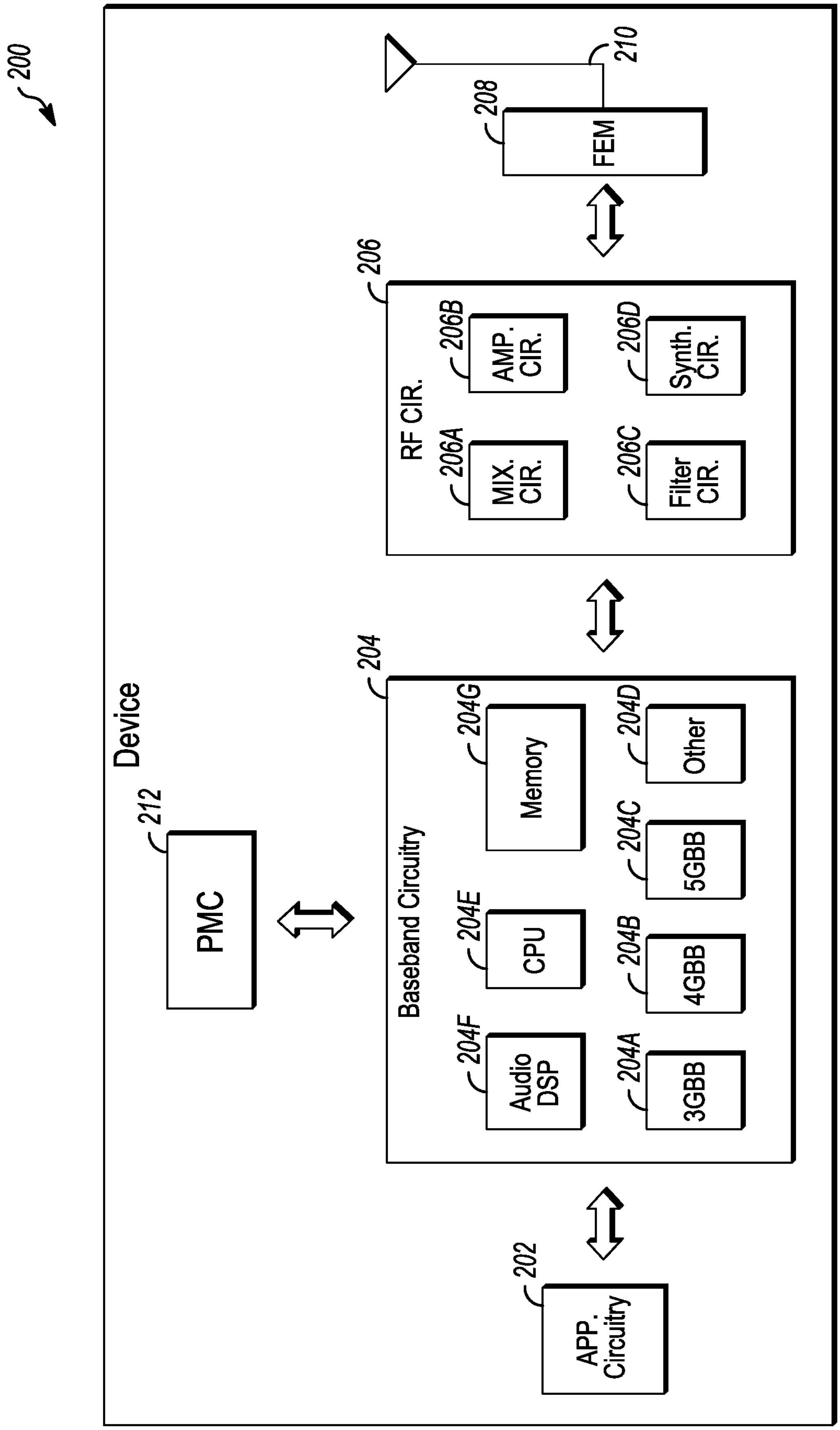
200
Device
PMC
212
APP. Circuitry
202
Baseband Circuitry
204
Audio DSP
204F
CPU
204E
Memory
204G
3GBB
204A
4GBB
204B
5GBB
204C
Other
204D
RF CIR.
206
MIX. CIR.
206A
AMP. CIR.
206B
Filter CIR.
206C
Synth. CIR.
206D
FEM
208
210

FIG. 2

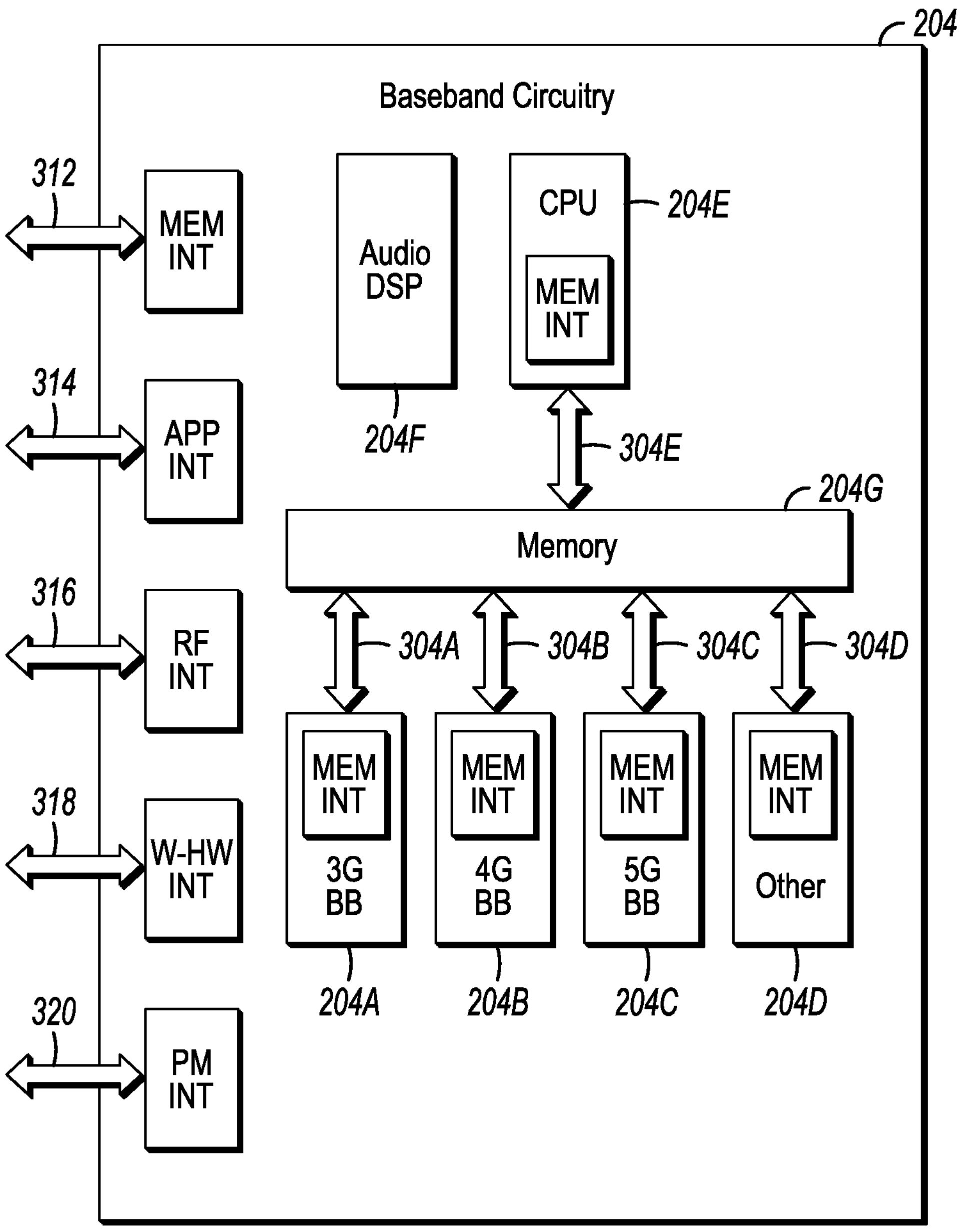
204
Baseband Circuitry
312
MEM INT
314
APP INT
316
RF INT
318
W-HW INT
320
PM INT
Audio DSP
204F
CPU
MEM INT
204E
304E
204G
Memory
304A
304B
304C
304D
MEM INT
3G BB
MEM INT
4G BB
MEM INT
5G BB
MEM INT
Other
204A
204B
204C
204D

FIG. 3

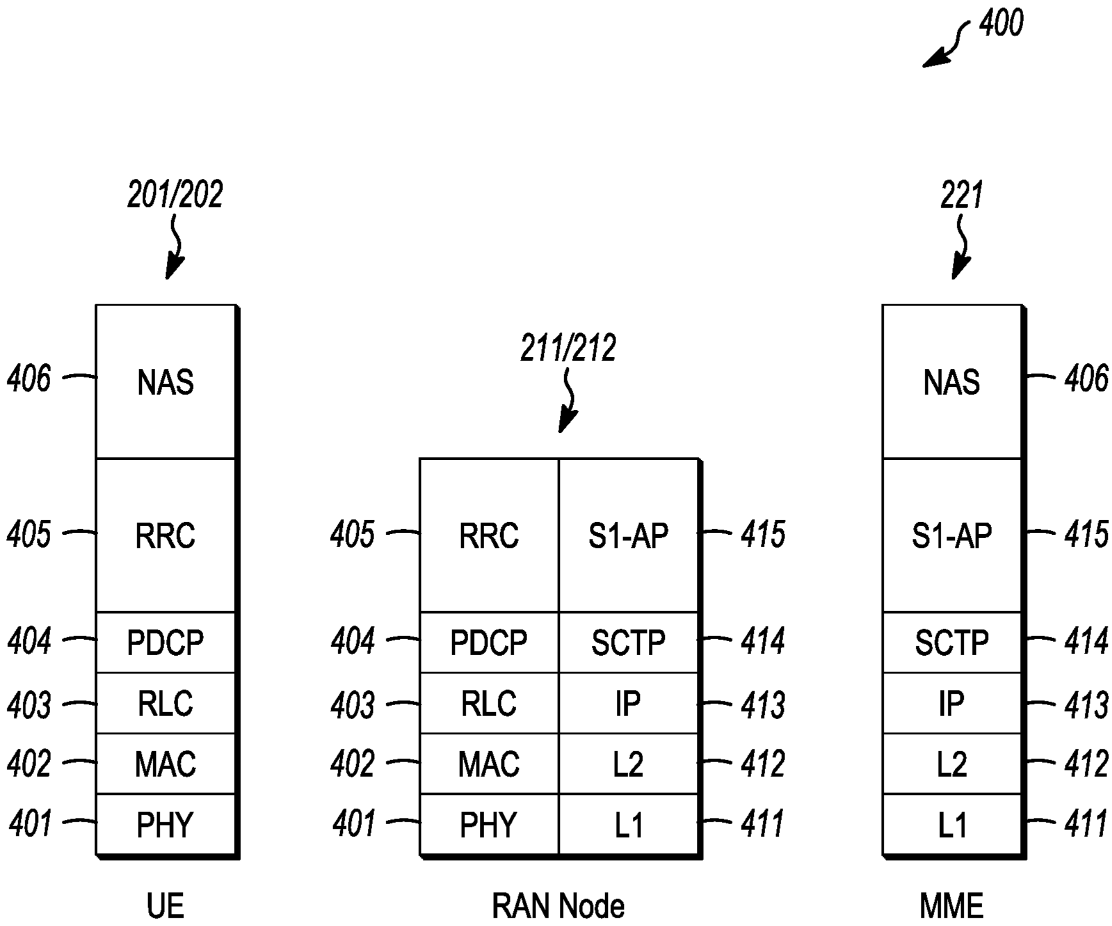
400
201/202
211/212
221
406
NAS
405
RRC
404
PDCP
403
RLC
402
MAC
401
PHY
UE
RRC
S1-AP
415
PDCP
SCTP
414
RLC
IP
413
MAC
L2
412
PHY
L1
411
RAN Node
NAS
406
S1-AP
SCTP
IP
L2
L1
MME

FIG. 4

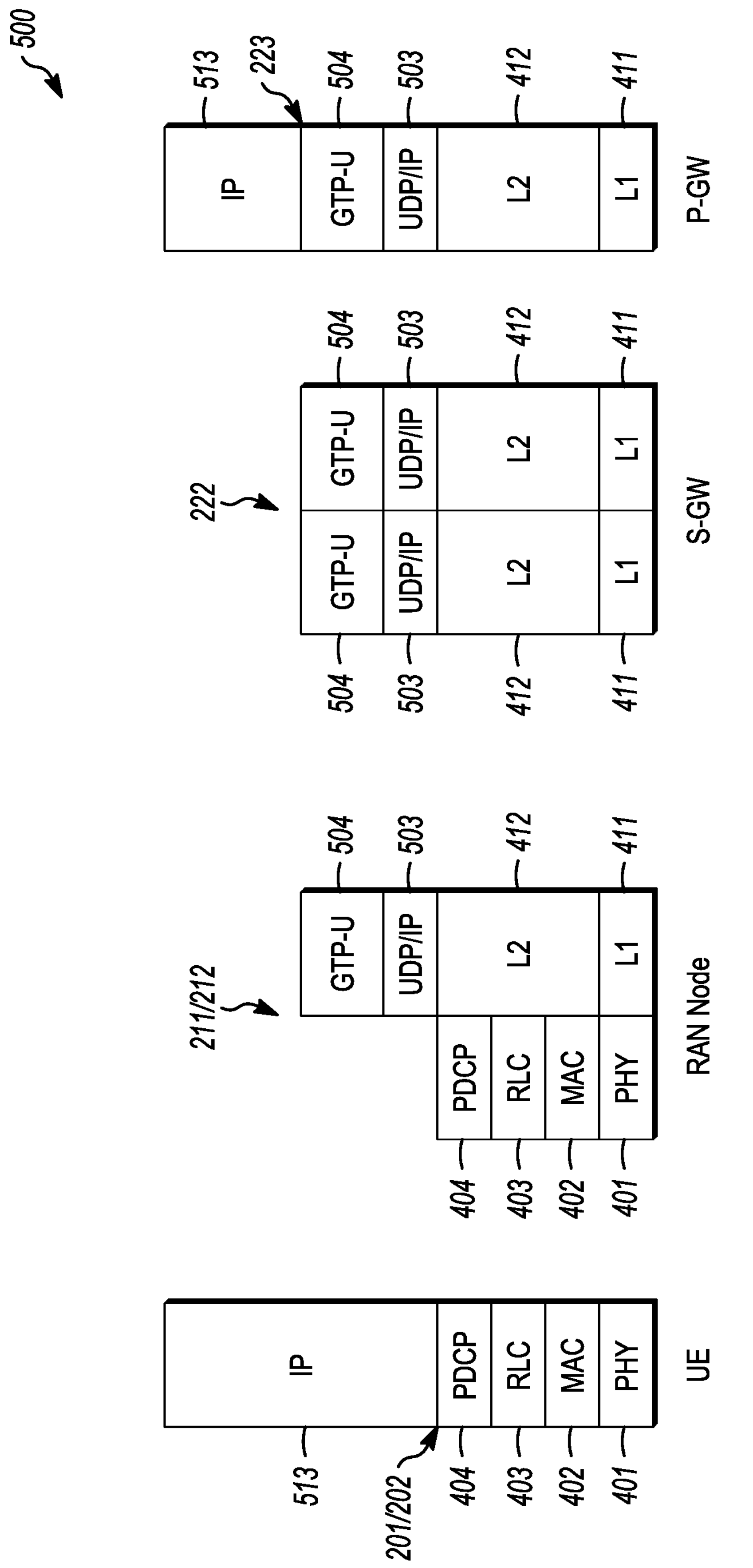
500
IP
GTP-U
UDP/IP
L2
L1
P-GW
513
223
504
503
412
411
S-GW
222
RAN Node
211/212
PDCP
RLC
MAC
PHY
404
403
402
401
UE
201/202

FIG. 5

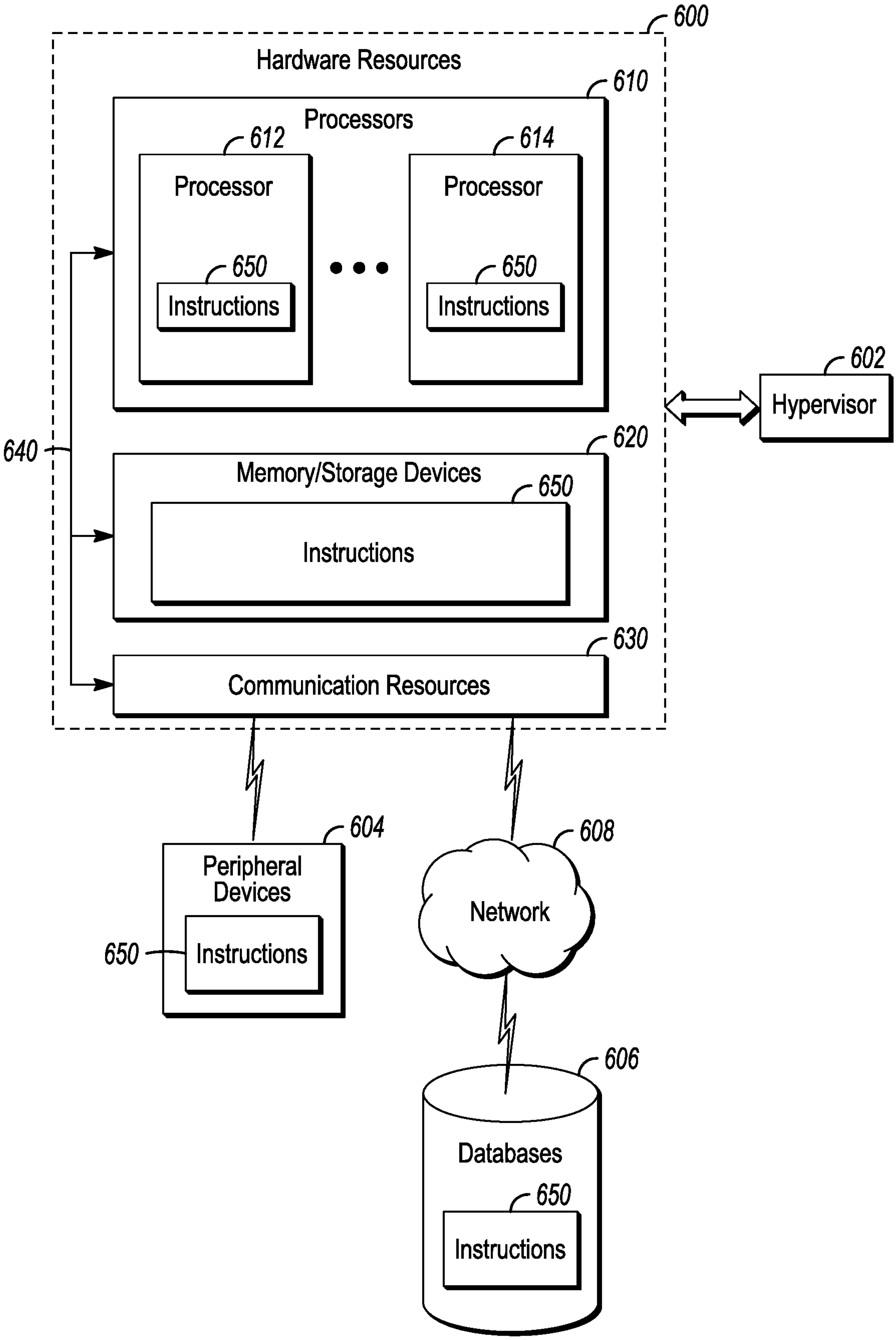
600
Hardware Resources
610
Processors
612
Processor
650
Instructions
614
Processor
650
Instructions
602
Hypervisor
640
620
Memory/Storage Devices
650
Instructions
630
Communication Resources
604
Peripheral Devices
650
Instructions
608
Network
606
Databases
650
Instructions

FIG. 6

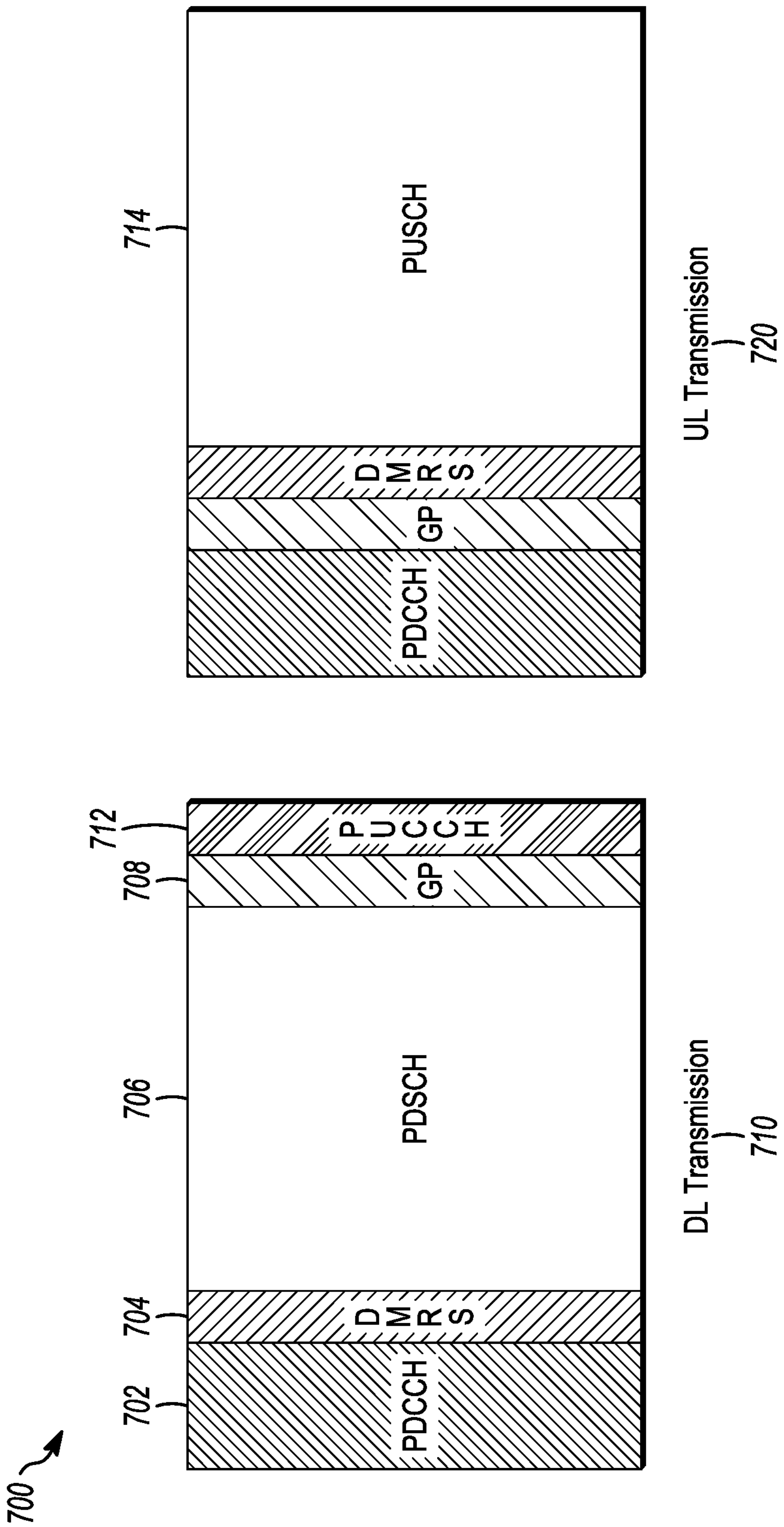
700
702
704
706
708
712
714
PDCCH
DMRS
PDSCH
GP
PUCCH
PUSCH
DL Transmission
710
UL Transmission
720

FIG. 7

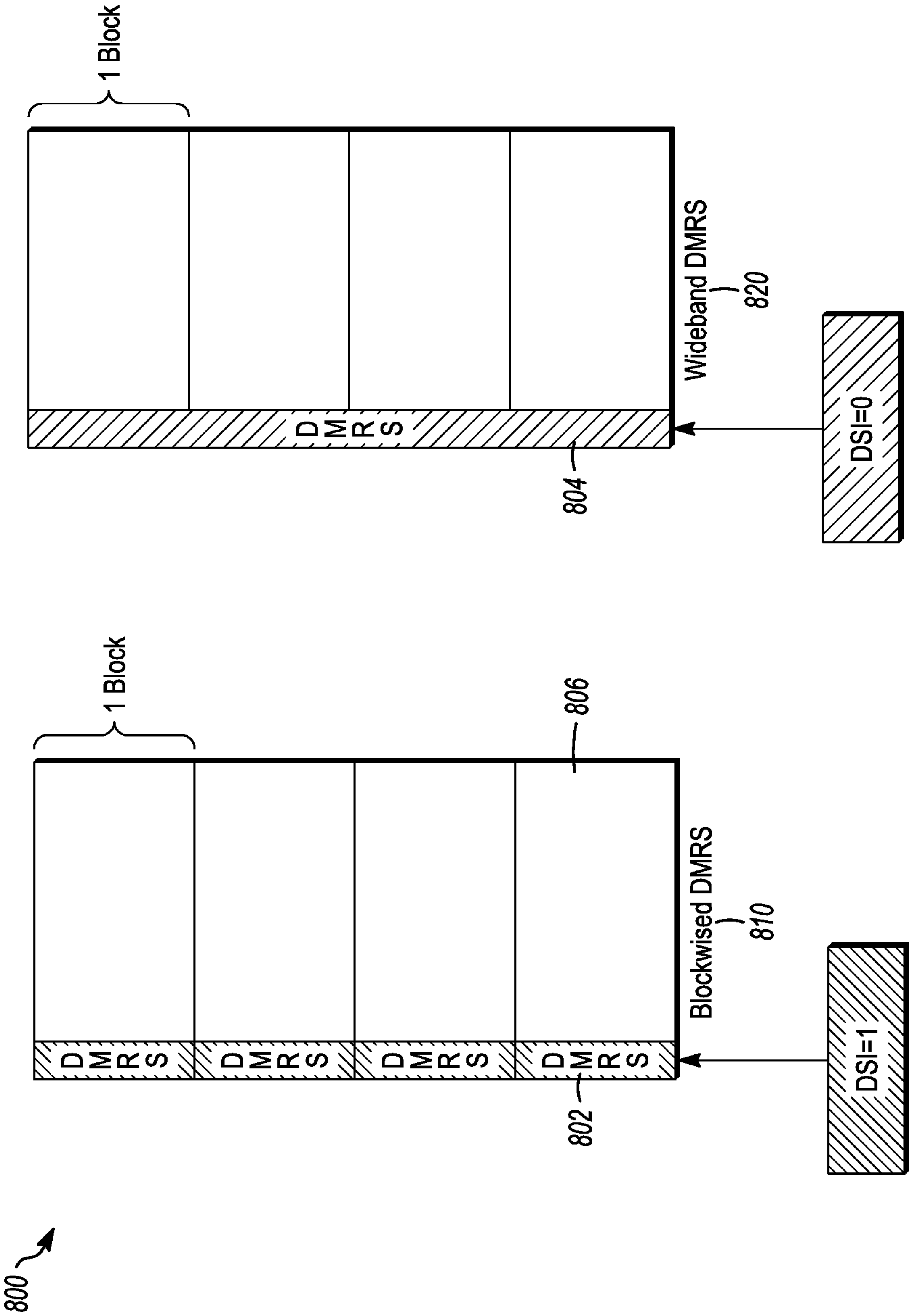
800
1 Block
806
Blockwised DMRS
810
DMRS
DMRS
DMRS
DMRS
802
DSI=1
1 Block
Wideband DMRS
820
DMRS
804
DSI=0

FIG. 8

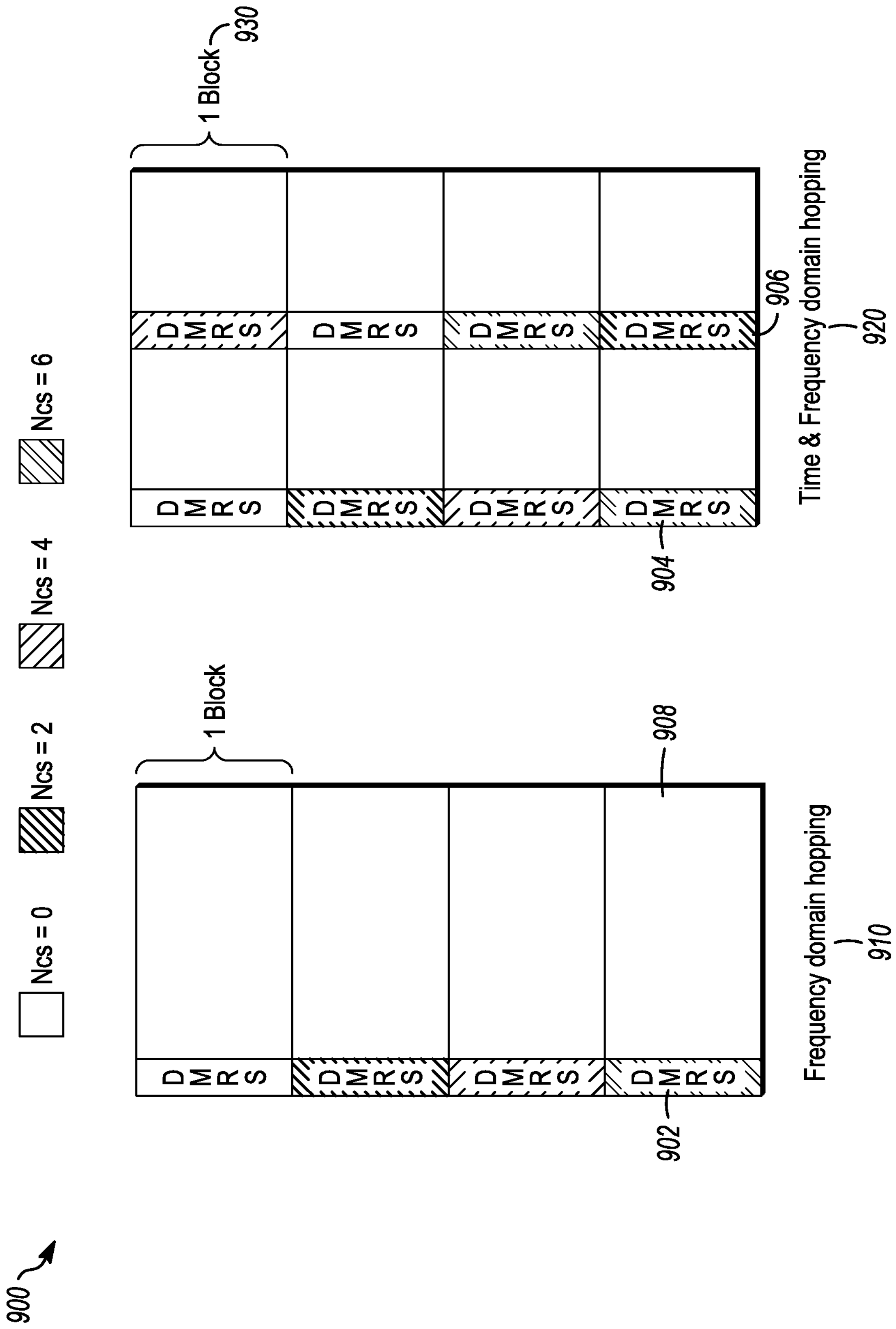
900
Ncs = 0
Ncs = 2
Ncs = 4
Ncs = 6
1 Block
1 Block
930
DMRS
902
904
906
908
Frequency domain hopping
910
Time & Frequency domain hopping
920

FIG. 9

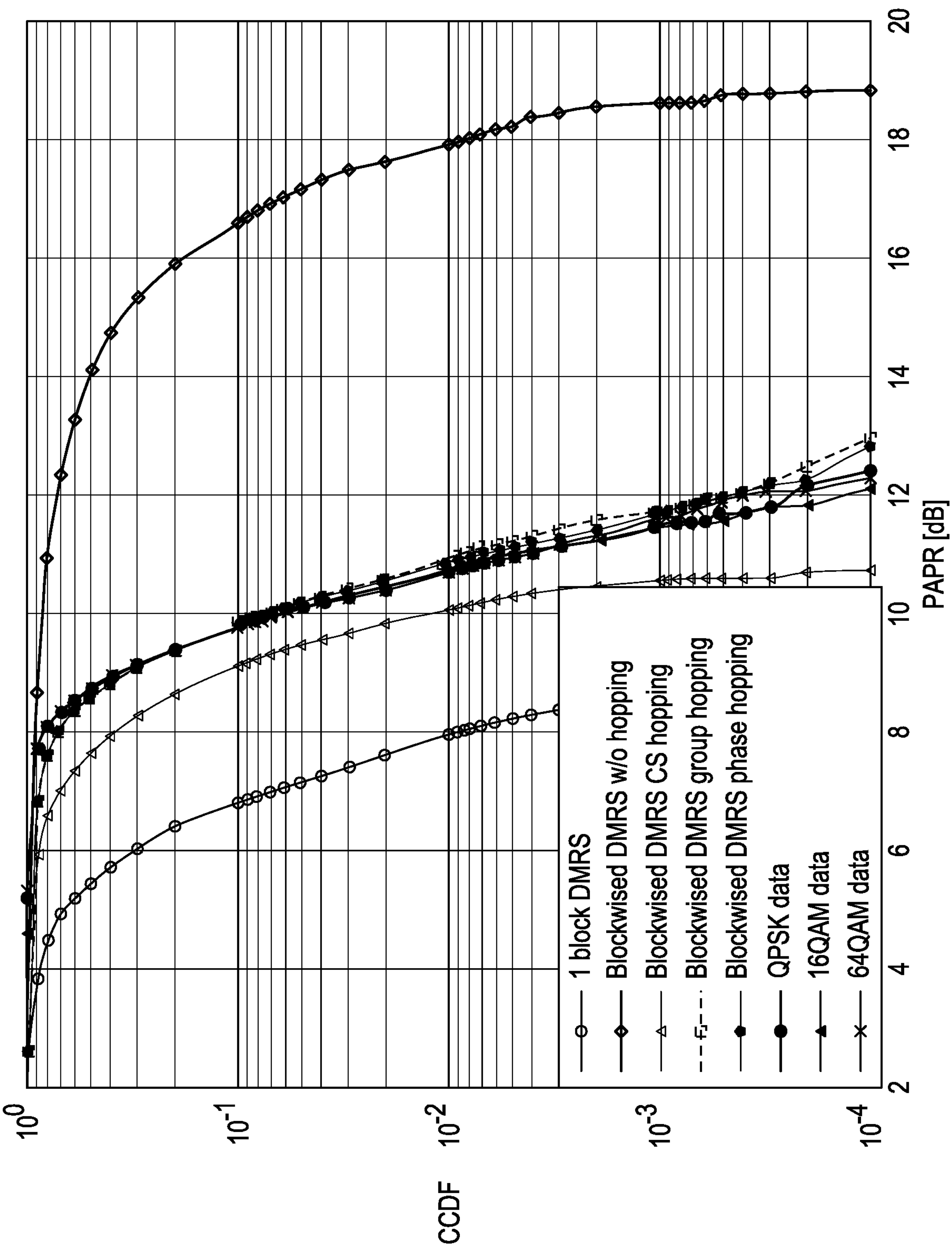
CCDF
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
2
4
6
8
10
12
14
16
18
20
PAPR [dB]
1 block DMRS
Blockwised DMRS w/o hopping
Blockwised DMRS CS hopping
Blockwised DMRS group hopping
Blockwised DMRS phase hopping
QPSK data
16QAM data
64QAM data

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/050488

A. CLASSIFICATION OF SUBJECT MATTER

H04L 5/00(2006.01)i, H04W 72/04(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)
H04L 5/00; H04W 74/08; H04W 72/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: blockwised demodulation reference signal, wideband, cyclic shift hopping, scrambling sequence, encode, resource block

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2011-0317596 Al (GEORGE JONGREN et al.) 29 December 2011 See paragraphs [0033H0035], [0043H0045]; and figures 3-8.	1-30
Y	US 2013-0294366 Al (SAMSUNG ELECTRONICS CO., LTD.) 07 November 2013 See paragraphs [0071], [0086]; and figures 9, 12.	1-30
Y	US 2014-0293881 Al (SHARP LABORATORIES OF AMERICA, INC.) 02 October 2014 See paragraphs [0119], [0130]-[0133], [0141]-[0142]; and figures 1, 4-5, 8.	7,9-10,14-16,19,22,24,26,28,30
Y	US 2014-0247799 Al (SHARP KABUSHIKI KAISHA) 04 September 2014 See paragraphs [0064]-[0065]; and figure 1.	12-13,25,29
A	US 2012-0250655 Al (MIN SEOK NOH et al.) 04 October 2012 See paragraphs [0058]-[0063], [0154]-[0155]; and figures 7-9, 13.	1-30

☐ 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
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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
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
05 January 2018 (05.01.2018)	**05 January 2018 (05.01.2018)**

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International Application Division
Korean Intellectual Property Office
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Facsimile No. +82-42-481-8578

Authorized officer
LEE, Jong Kyung
Telephone No. +82-42-481-3360

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		EP 2586167 Al	01/05/2013
		EP 2586167 Bl	07/01/2015
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		US 2015-0207605 Al	23/07/2015
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		us 9584280 B2	28/02/2017
		wo 2012-001631 Al	05/01/2012
US 2013-0294366 Al	07/11/2013	EP 2847902 Al	18/03/2015
		EP 2847902 A4	02/03/2016
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		US 2017-0171847 Al	15/06/2017
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		wo 2013-165216 Al	07/11/2013
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		JP 6193392 B2	06/09/2017
		us 9197385 B2	24/11/2015
		wo 2014-155899 Al	02/10/2014
US 2014-0247799 Al	04/09/2014	AU 2012-319790 Al	24/04/2014
		AU 2012-319790 B2	20/04/2017
		CN 103858503 A	11/06/2014
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		JP 5162699 Bl	13/03/2013
		WO 2013-051413 Al	11/04/2013
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		AU 2010-296221 B8	16/01/2014
		AU 2010-296222 Al	12/04/2012
		AU 2010-296222 B2	06/02/2014
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		CA 2774414 C	28/02/2017
		CA 2774419 Al	24/03/2011
		CA 2774419 C	12/05/2015
		CN 102577296 A	11/07/2012
		CN 102577296 B	12/11/2014
		CN 102598530 A	18/07/2012

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		EP 2479901 A4	02/10/2013
		EP 2479901 B1	17/05/2017
		EP 2479948 A2	25/07/2012
		EP 2479948 A4	02/10/2013
		EP 2479948 B1	29/06/2016
		ES 2590329 T3	21/11/2016
		HU E029583 T2	28/03/2017
		JP 2013-505621 A	14/02/2013
		JP 2013-505622 A	14/02/2013
		JP 5518198 B2	11/06/2014
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		US 2015-0139165 A1	21/05/2015
		US 2016-0100386 A1	07/04/2016
		US 2016-0135151 A1	12/05/2016
		US 2017-0134132 A1	11/05/2017
		US 8902849 B2	02/12/2014
		US 8982834 B2	17/03/2015
		US 9236988 B2	12/01/2016
		US 9264200 B2	16/02/2016
		US 9578637 B2	21/02/2017
		WO 2011-034357 A2	24/03/2011
		WO 2011-034357 A3	01/09/2011
		WO 2011-034358 A2	24/03/2011
		WO 2011-034358 A3	14/07/2011