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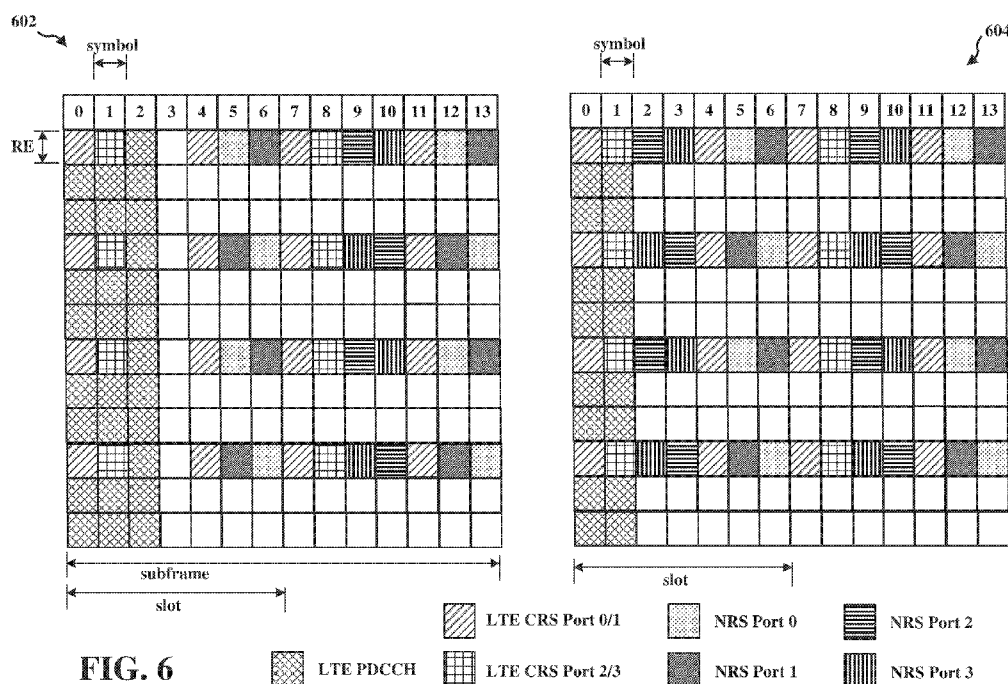


FIG. 6

(57) **Abstract:** In order to address the challenges of using a four-port Narrowband Reference Signal (NRS) configuration at a base station, a base station apparatus may configure four port transmit antenna diversity mode for one user equipment. The base station may select between a two-port NRS configuration and a four-port NRS configuration based on any of a number of factors. The selection may be based on any of a carrier, an NPDSCH, an NPDCCH, a subframe configuration, and an NPRS pattern. The base station then transmits the NRS according to the selection. A UE apparatus may determine whether the base station transmits an NRS comprising a two-port NRS configuration or a four-port NRS configuration based on similar factors. The UE apparatus may then receive the NRS, NPDCCH, and/or NPDSCH according to the determination.

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ENHANCED FOUR PORT NARROWBAND REFERENCE SIGNAL (NRS)**BACKGROUND****Technical Field**

- [0001] The present disclosure relates generally to communication systems, and more particularly, to a Narrowband Internet of Things (NB-IoT) communication using four Narrowband Reference Signal (NRS) ports.

Introduction

- [0002] Wireless communication systems are widely deployed to provide various telecommunication services such as telephony, video, data, messaging, and broadcasts. Typical wireless communication systems may employ multiple-access technologies capable of supporting communication with multiple users by sharing available system resources. Examples of such multiple-access technologies include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, orthogonal frequency division multiple access (OFDMA) systems, single-carrier frequency division multiple access (SC-FDMA) systems, and time division synchronous code division multiple access (TD-SCDMA) systems.
- [0003] These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level. An example telecommunication standard is 5G New Radio (NR). 5G NR is part of a continuous mobile broadband evolution promulgated by Third Generation Partnership Project (3GPP) to meet new requirements associated with latency, reliability, security, scalability (e.g., with Internet of Things (IoT)), and other requirements. Some aspects of 5G NR may be based on the 4G Long Term Evolution (LTE) standard. There exists a need for further improvements in 5G NR technology. These improvements may also be applicable to other multi-access technologies and the telecommunication standards that employ these technologies.

SUMMARY

- [0004] The following presents a simplified summary of one or more aspects in order to provide a basic understanding of such aspects. This summary is not an extensive overview of all contemplated aspects, and is intended to neither identify key or critical elements of all aspects nor delineate the scope of any or all aspects. Its sole purpose is to present some concepts of one or more aspects in a simplified form as a prelude to the more detailed description that is presented later.
- [0005] Two Narrowband Reference Signal (NRS) ports may be supported for Narrowband-Internet of Things (NB-IoT) communication, e.g., NRS Port 0 and NRS Port 1. The two NRS ports may be mapped to the last two symbols of each slot in one subframe, e.g., symbols 5, 6 and 12, 13. The use of four NRS antenna ports with a four antenna diversity for a single UE may lead to collisions at times between a newly added third and fourth NRS port, e.g., NRS Port 2 and NRS Port 3. The present application provides a number of different ways to enable four-port NRS configurations to enable a four port transmit antenna diversity mode for a UE while handling potential collisions with other signals.
- [0006] In an aspect of the disclosure, a method, a computer-readable medium, and an apparatus are provided for wireless communication at a base station. The apparatus configures four port transmit antenna diversity mode for one user equipment (UE). The apparatus then selects between a two-port NRS configuration and a four-port NRS configuration. The selection may be based on at least one of a carrier, a Narrowband Physical Downlink Control Channel (NPDCCH), a Narrowband Physical Downlink Data Channel (NPDSCH), a subframe configuration, a Narrowband Positioning Reference Signal (NPRS) pattern, or an indication from the base station. The apparatus then transmits an NRS according to the selection.
- [0007] In another aspect of the disclosure, a method, a computer-readable medium, and an apparatus are provided for wireless communication at a base station. The apparatus transmitting a broadcast or multicast comprising an NRS based on four NRS antenna ports or two NRS antenna ports. The apparatus also transmits an indication regarding whether the NRS is transmitted based on four NRS antenna ports or two NRS antenna ports.

- [0008] In another aspect of the disclosure, a method, a computer-readable medium, and an apparatus are provided for wireless communication at a base station. The apparatus transmits an NRS according to four-port NRS configuration. The apparatus maps symbols of an NPDSCH to four NRS antenna ports and transmits multiple repetitions of the NPDSCH with the four NRS antenna ports. The mapping of symbols for the NPDSCH may be switched between antenna ports for different repetitions of the NPDSCH.
- [0009] In another aspect of the disclosure, a method, a computer-readable medium, and an apparatus are provided for wireless communication at a UE. The apparatus determines whether a base station transmits an NRS comprising a two-port NRS configuration or a four-port NRS configuration. The determination may be based on at least one of a carrier, an NPDCCH, an NPDSCH, a subframe configuration, an NPRS pattern, or an indication from the base station. The apparatus then receives the NRS according to the determination.
- [0010] To the accomplishment of the foregoing and related ends, the one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative features of the one or more aspects. These features are indicative, however, of but a few of the various ways in which the principles of various aspects may be employed, and this description is intended to include all such aspects and their equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0011] FIG. 1 is a diagram illustrating an example of a wireless communications system and an access network.
- [0012] FIGs. 2A, 2B, 2C, and 2D are diagrams illustrating examples of a DL subframe, DL channels within the DL subframe, an UL subframe, and UL channels within the UL subframe, respectively, for a 5G/NR frame structure.
- [0013] FIG. 3 is a diagram illustrating an example of a base station and user equipment (UE) in an access network.
- [0014] FIG. 4 illustrates example resources for communication involving two NRS ports.
- [0015] FIG. 5 illustrates example resources for a Narrowband Positioning RS (NPRS) part B.

- [0016] FIG. 6 illustrates example resources for communication including up to four NRS ports.
- [0017] FIG. 7 illustrates example resources for a two-port NRS configuration and a four-port NRS configuration.
- [0018] FIG. 8 illustrates examples of changing between a two-port NRS configuration and a four-port NRS configuration.
- [0019] FIG. 9 illustrates example aspects of SFBC precoding for a four-port NRS configuration.
- [0020] FIG. 10 is a flowchart of a method of wireless communication.
- [0021] FIG. 11 is a flowchart of a method of wireless communication.
- [0022] FIG. 12 is a flowchart of a method of wireless communication.
- [0023] FIG. 13 is a conceptual data flow diagram illustrating the data flow between different means/components in an exemplary apparatus.
- [0024] FIG. 14 is a diagram illustrating an example of a hardware implementation for an apparatus employing a processing system.
- [0025] FIG. 15 is a flowchart of a method of wireless communication.
- [0026] FIG. 16 is a conceptual data flow diagram illustrating the data flow between different means/components in an exemplary apparatus.
- [0027] FIG. 17 is a diagram illustrating an example of a hardware implementation for an apparatus employing a processing system.

DETAILED DESCRIPTION

- [0028] The detailed description set forth below in connection with the appended drawings is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. In some instances, well known structures and components are shown in block diagram form in order to avoid obscuring such concepts.
- [0029] Several aspects of telecommunication systems will now be presented with reference to various apparatus and methods. These apparatus and methods will be described in the following detailed description and illustrated in the accompanying drawings by

various blocks, components, circuits, processes, algorithms, etc. (collectively referred to as “elements”). These elements may be implemented using electronic hardware, computer software, or any combination thereof. Whether such elements are implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system.

[0030] By way of example, an element, or any portion of an element, or any combination of elements may be implemented as a “processing system” that includes one or more processors. Examples of processors include microprocessors, microcontrollers, graphics processing units (GPUs), central processing units (CPUs), application processors, digital signal processors (DSPs), reduced instruction set computing (RISC) processors, systems on a chip (SoC), baseband processors, field programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functionality described throughout this disclosure. One or more processors in the processing system may execute software. Software shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software components, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise.

[0031] Accordingly, in one or more example embodiments, the functions described may be implemented in hardware, software, or any combination thereof. If implemented in software, the functions may be stored on or encoded as one or more instructions or code on a computer-readable medium. Computer-readable media includes computer storage media. Storage media may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can comprise a random-access memory (RAM), a read-only memory (ROM), an electrically erasable programmable ROM (EEPROM), optical disk storage, magnetic disk storage, other magnetic storage devices, combinations of the aforementioned types of computer-readable media, or any other medium that can be used to store computer executable code in the form of instructions or data structures that can be accessed by a computer.

- [0032] FIG. 1 is a diagram illustrating an example of a wireless communications system and an access network 100. The wireless communications system (also referred to as a wireless wide area network (WWAN)) includes base stations 102, UEs 104, and an Evolved Packet Core (EPC) 160. The base stations 102 may include macro cells (high power cellular base station) and/or small cells (low power cellular base station). The macro cells include base stations. The small cells include femtocells, picocells, and microcells.
- [0033] The base stations 102 (collectively referred to as Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN)) interface with the EPC 160 through backhaul links 132 (e.g., S1 interface). In addition to other functions, the base stations 102 may perform one or more of the following functions: transfer of user data, radio channel ciphering and deciphering, integrity protection, header compression, mobility control functions (e.g., handover, dual connectivity), inter-cell interference coordination, connection setup and release, load balancing, distribution for non-access stratum (NAS) messages, NAS node selection, synchronization, radio access network (RAN) sharing, multimedia broadcast multicast service (MBMS), subscriber and equipment trace, RAN information management (RIM), paging, positioning, and delivery of warning messages. The base stations 102 may communicate directly or indirectly (e.g., through the EPC 160) with each other over backhaul links 134 (e.g., X2 interface). The backhaul links 134 may be wired or wireless.
- [0034] The base stations 102 may wirelessly communicate with the UEs 104. Each of the base stations 102 may provide communication coverage for a respective geographic coverage area 110. There may be overlapping geographic coverage areas 110. For example, the small cell 102' may have a coverage area 110' that overlaps the coverage area 110 of one or more macro base stations 102. A network that includes both small cell and macro cells may be known as a heterogeneous network. A heterogeneous network may also include Home Evolved Node Bs (eNBs) (HeNBs), which may provide service to a restricted group known as a closed subscriber group (CSG). The communication links 120 between the base stations 102 and the UEs 104 may include uplink (UL) (also referred to as reverse link) transmissions from a UE 104 to a base station 102 and/or downlink (DL) (also referred to as forward link) transmissions from a base station 102 to a UE 104. The communication links 120 may use multiple-input

and multiple-output (MIMO) antenna technology, including spatial multiplexing, beamforming, and/or transmit diversity. The communication links may be through one or more carriers. The base stations 102 / UEs 104 may use spectrum up to Y MHz (e.g., 5, 10, 15, 20, 100 MHz) bandwidth per carrier allocated in a carrier aggregation of up to a total of Yx MHz (x component carriers) used for transmission in each direction. The carriers may or may not be adjacent to each other. Allocation of carriers may be asymmetric with respect to DL and UL (e.g., more or less carriers may be allocated for DL than for UL). The component carriers may include a primary component carrier and one or more secondary component carriers. A primary component carrier may be referred to as a primary cell (PCell) and a secondary component carrier may be referred to as a secondary cell (SCell).

- [0035] Certain UEs 104 may communicate with each other using device-to-device (D2D) communication link 192. The D2D communication link 192 may use the DL/UL WWAN spectrum. The D2D communication link 192 may use one or more sidelink channels, such as a physical sidelink broadcast channel (PSBCH), a physical sidelink discovery channel (PSDCH), a physical sidelink shared channel (PSSCH), and a physical sidelink control channel (PSCCH). D2D communication may be through a variety of wireless D2D communications systems, such as for example, FlashLinQ, WiMedia, Bluetooth, ZigBee, Wi-Fi based on the IEEE 802.11 standard, LTE, or NR.
- [0036] The wireless communications system may further include a Wi-Fi access point (AP) 150 in communication with Wi-Fi stations (STAs) 152 via communication links 154 in a 5 GHz unlicensed frequency spectrum. When communicating in an unlicensed frequency spectrum, the STAs 152 / AP 150 may perform a clear channel assessment (CCA) prior to communicating in order to determine whether the channel is available.
- [0037] The small cell 102' may operate in a licensed and/or an unlicensed frequency spectrum. When operating in an unlicensed frequency spectrum, the small cell 102' may employ NR and use the same 5 GHz unlicensed frequency spectrum as used by the Wi-Fi AP 150. The small cell 102', employing NR in an unlicensed frequency spectrum, may boost coverage to and/or increase capacity of the access network.
- [0038] The gNodeB (gNB) 180 may operate in millimeter wave (mmW) frequencies and/or near mmW frequencies in communication with the UE 104. When the gNB 180 operates in mmW or near mmW frequencies, the gNB 180 may be referred to as an mmW base station. Extremely high frequency (EHF) is part of the RF in the

electromagnetic spectrum. EHF has a range of 30 GHz to 300 GHz and a wavelength between 1 millimeter and 10 millimeters. Radio waves in the band may be referred to as a millimeter wave. Near mmW may extend down to a frequency of 3 GHz with a wavelength of 100 millimeters. The super high frequency (SHF) band extends between 3 GHz and 30 GHz, also referred to as centimeter wave. Communications using the mmW / near mmW radio frequency band has extremely high path loss and a short range. The mmW base station 180 may utilize beamforming 184 with the UE 104 to compensate for the extremely high path loss and short range.

[0039] The EPC 160 may include a Mobility Management Entity (MME) 162, other MMEs 164, a Serving Gateway 166, a Multimedia Broadcast Multicast Service (MBMS) Gateway 168, a Broadcast Multicast Service Center (BM-SC) 170, and a Packet Data Network (PDN) Gateway 172. The MME 162 may be in communication with a Home Subscriber Server (HSS) 174. The MME 162 is the control node that processes the signaling between the UEs 104 and the EPC 160. Generally, the MME 162 provides bearer and connection management. All user Internet protocol (IP) packets are transferred through the Serving Gateway 166, which itself is connected to the PDN Gateway 172. The PDN Gateway 172 provides UE IP address allocation as well as other functions. The PDN Gateway 172 and the BM-SC 170 are connected to the IP Services 176. The IP Services 176 may include the Internet, an intranet, an IP Multimedia Subsystem (IMS), a PS Streaming Service, and/or other IP services. The BM-SC 170 may provide functions for MBMS user service provisioning and delivery. The BM-SC 170 may serve as an entry point for content provider MBMS transmission, may be used to authorize and initiate MBMS Bearer Services within a public land mobile network (PLMN), and may be used to schedule MBMS transmissions. The MBMS Gateway 168 may be used to distribute MBMS traffic to the base stations 102 belonging to a Multicast Broadcast Single Frequency Network (MBSFN) area broadcasting a particular service, and may be responsible for session management (start/stop) and for collecting eMBMS related charging information.

[0040] The base station may also be referred to as a gNB, Node B, evolved Node B (eNB), an access point, a base transceiver station, a radio base station, a radio transceiver, a transceiver function, a basic service set (BSS), an extended service set (ESS), or some other suitable terminology. The base station 102 provides an access point to the EPC 160 for a UE 104. Examples of UEs 104 include a cellular phone, a smart phone, a

session initiation protocol (SIP) phone, a laptop, a personal digital assistant (PDA), a satellite radio, a global positioning system, a multimedia device, a video device, a digital audio player (e.g., MP3 player), a camera, a game console, a tablet, a smart device, a wearable device, a vehicle, an electric meter, a gas pump, a large or small kitchen appliance, a healthcare device, an implant, a display, or any other similar functioning device. Some of the UEs 104 may be referred to as IoT devices (e.g., parking meter, gas pump, toaster, vehicles, heart monitor, etc.). The UE 104 may also be referred to as a station, a mobile station, a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal, a mobile terminal, a wireless terminal, a remote terminal, a handset, a user agent, a mobile client, a client, or some other suitable terminology.

[0041] Referring again to FIG. 1, in certain aspects, the base station 180 may be configured to transmit using a two-port NRS configuration and a four-port NRS configuration (198), e.g., as described in connection with FIGs. 4-17. Similarly, in certain aspects, the UE 104 may be configured to receive using a two-port NRS configuration and a four-port NRS configuration (199), e.g., as described in connection with FIGs. 4-17.

[0042] FIG. 2A is a diagram 200 illustrating an example of a DL subframe within a 5G/NR frame structure. FIG. 2B is a diagram 230 illustrating an example of channels within a DL subframe. FIG. 2C is a diagram 250 illustrating an example of an UL subframe within a 5G/NR frame structure. FIG. 2D is a diagram 280 illustrating an example of channels within an UL subframe. The 5G/NR frame structure may be FDD in which for a particular set of subcarriers (carrier system bandwidth), subframes within the set of subcarriers are dedicated for either DL or UL, or may be TDD in which for a particular set of subcarriers (carrier system bandwidth), subframes within the set of subcarriers are dedicated for both DL and UL. In the examples provided by FIGs. 2A, 2C, the 5G/NR frame structure is assumed to be TDD, with subframe 4 a DL subframe and subframe 7 an UL subframe. While subframe 4 is illustrated as providing just DL and subframe 7 is illustrated as providing just UL, any particular subframe may be split into different subsets that provide both UL and DL. Note that the description *infra* applies also to a 5G/NR frame structure that is FDD.

[0043] Other wireless communication technologies may have a different frame structure and/or different channels. A frame (10 ms) may be divided into 10 equally sized

subframes (1 ms). Each subframe may include one or more time slots. Each slot may include 7 or 14 symbols, depending on the slot configuration. For slot configuration 0, each slot may include 14 symbols, and for slot configuration 1, each slot may include 7 symbols. The number of slots within a subframe is based on the slot configuration and the numerology. For slot configuration 0, different numerologies 0 to 5 allow for 1, 2, 4, 8, 16, and 32 slots, respectively, per subframe. For slot configuration 1, different numerologies 0 to 2 allow for 2, 4, and 8 slots, respectively, per subframe. The subcarrier spacing and symbol length/duration are a function of the numerology. The subcarrier spacing may be equal to $2^{\mu} * 15 \text{ kHz}$, where μ is the numerology 0-5. The symbol length/duration is inversely related to the subcarrier spacing. FIGs. 2A, 2C provide an example of slot configuration 1 with 7 symbols per slot and numerology 0 with 2 slots per subframe. The subcarrier spacing is 15 kHz and symbol duration is approximately 66.7 μs .

- [0044] A resource grid may be used to represent the frame structure. Each time slot includes a resource block (RB) (also referred to as physical RBs (PRBs)) that extends 12 consecutive subcarriers. The resource grid is divided into multiple resource elements (REs). The number of bits carried by each RE depends on the modulation scheme.
- [0045] As illustrated in FIG. 2A, some of the REs carry reference (pilot) signals (RS) for the UE (indicated as R). The RS may include demodulation RS (DM-RS) and channel state information reference signals (CSI-RS) for channel estimation at the UE. The RS may also include beam measurement RS (BRS), beam refinement RS (BRRS), and phase tracking RS (PT-RS).
- [0046] FIG. 2B illustrates an example of various channels within a DL subframe of a frame. The physical control format indicator channel (PCFICH) is within symbol 0 of slot 0, and carries a control format indicator (CFI) that indicates whether the physical downlink control channel (PDCCH) occupies 1, 2, or 3 symbols (FIG. 2B illustrates a PDCCH that occupies 3 symbols). The PDCCH carries downlink control information (DCI) within one or more control channel elements (CCEs), each CCE including nine RE groups (REGs), each REG including four consecutive REs in an OFDM symbol. A UE may be configured with a UE-specific enhanced PDCCH (ePDCCH) that also carries DCI. The ePDCCH may have 2, 4, or 8 RB pairs (FIG. 2B shows two RB pairs, each subset including one RB pair). The physical hybrid automatic repeat request (ARQ) (HARQ) indicator channel (PHICH) is also within

symbol 0 of slot 0 and carries the HARQ indicator (HI) that indicates HARQ acknowledgement (ACK) / negative ACK (NACK) feedback based on the physical uplink shared channel (PUSCH). The primary synchronization channel (PSCH) may be within symbol 6 of slot 0 within subframes 0 and 5 of a frame. The PSCH carries a primary synchronization signal (PSS) that is used by a UE 104 to determine subframe/symbol timing and a physical layer identity. The secondary synchronization channel (SSCH) may be within symbol 5 of slot 0 within subframes 0 and 5 of a frame. The SSCH carries a secondary synchronization signal (SSS) that is used by a UE to determine a physical layer cell identity group number and radio frame timing. Based on the physical layer identity and the physical layer cell identity group number, the UE can determine a physical cell identifier (PCI). Based on the PCI, the UE can determine the locations of the aforementioned DL-RS. The physical broadcast channel (PBCH), which carries a master information block (MIB), may be logically grouped with the PSCH and SSCH to form a synchronization signal (SS)/PBCH block. The MIB provides a number of RBs in the DL system bandwidth, a PHICH configuration, and a system frame number (SFN). The physical downlink shared channel (PDSCH) carries user data, broadcast system information not transmitted through the PBCH such as system information blocks (SIBs), and paging messages.

[0047] As illustrated in FIG. 2C, some of the REs carry demodulation reference signals (DM-RS) for channel estimation at the base station. The UE may additionally transmit sounding reference signals (SRS) in the last symbol of a subframe. The SRS may have a comb structure, and a UE may transmit SRS on one of the combs. The SRS may be used by a base station for channel quality estimation to enable frequency-dependent scheduling on the UL.

[0048] FIG. 2D illustrates an example of various channels within an UL subframe of a frame. A physical random access channel (PRACH) may be within one or more subframes within a frame based on the PRACH configuration. The PRACH may include six consecutive RB pairs within a subframe. The PRACH allows the UE to perform initial system access and achieve UL synchronization. A physical uplink control channel (PUCCH) may be located on edges of the UL system bandwidth. The PUCCH carries uplink control information (UCI), such as scheduling requests, a channel quality indicator (CQI), a precoding matrix indicator (PMI), a rank indicator (RI), and HARQ ACK/NACK feedback. The PUSCH carries data, and may

additionally be used to carry a buffer status report (BSR), a power headroom report (PHR), and/or UCI.

[0049] FIG. 3 is a block diagram of a base station 310 in communication with a UE 350 in an access network. In the DL, IP packets from the EPC 160 may be provided to a controller/processor 375. The controller/processor 375 implements layer 3 and layer 2 functionality. Layer 3 includes a radio resource control (RRC) layer, and layer 2 includes a packet data convergence protocol (PDCP) layer, a radio link control (RLC) layer, and a medium access control (MAC) layer. The controller/processor 375 provides RRC layer functionality associated with broadcasting of system information (e.g., MIB, SIBs), RRC connection control (e.g., RRC connection paging, RRC connection establishment, RRC connection modification, and RRC connection release), inter radio access technology (RAT) mobility, and measurement configuration for UE measurement reporting; PDCP layer functionality associated with header compression / decompression, security (ciphering, deciphering, integrity protection, integrity verification), and handover support functions; RLC layer functionality associated with the transfer of upper layer packet data units (PDUs), error correction through ARQ, concatenation, segmentation, and reassembly of RLC service data units (SDUs), re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto transport blocks (TBs), demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through HARQ, priority handling, and logical channel prioritization.

[0050] The transmit (TX) processor 316 and the receive (RX) processor 370 implement layer 1 functionality associated with various signal processing functions. Layer 1, which includes a physical (PHY) layer, may include error detection on the transport channels, forward error correction (FEC) coding/decoding of the transport channels, interleaving, rate matching, mapping onto physical channels, modulation/demodulation of physical channels, and MIMO antenna processing. The TX processor 316 handles mapping to signal constellations based on various modulation schemes (e.g., binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), M-phase-shift keying (M-PSK), M-quadrature amplitude modulation (M-QAM)). The coded and modulated symbols may then be split into parallel streams. Each stream may then be mapped to an OFDM subcarrier, multiplexed with

a reference signal (e.g., pilot) in the time and/or frequency domain, and then combined together using an Inverse Fast Fourier Transform (IFFT) to produce a physical channel carrying a time domain OFDM symbol stream. The OFDM stream is spatially precoded to produce multiple spatial streams. Channel estimates from a channel estimator 374 may be used to determine the coding and modulation scheme, as well as for spatial processing. The channel estimate may be derived from a reference signal and/or channel condition feedback transmitted by the UE 350. Each spatial stream may then be provided to a different antenna 320 via a separate transmitter 318TX. Each transmitter 318TX may modulate an RF carrier with a respective spatial stream for transmission.

[0051] At the UE 350, each receiver 354RX receives a signal through its respective antenna 352. Each receiver 354RX recovers information modulated onto an RF carrier and provides the information to the receive (RX) processor 356. The TX processor 368 and the RX processor 356 implement layer 1 functionality associated with various signal processing functions. The RX processor 356 may perform spatial processing on the information to recover any spatial streams destined for the UE 350. If multiple spatial streams are destined for the UE 350, they may be combined by the RX processor 356 into a single OFDM symbol stream. The RX processor 356 then converts the OFDM symbol stream from the time-domain to the frequency domain using a Fast Fourier Transform (FFT). The frequency domain signal comprises a separate OFDM symbol stream for each subcarrier of the OFDM signal. The symbols on each subcarrier, and the reference signal, are recovered and demodulated by determining the most likely signal constellation points transmitted by the base station 310. These soft decisions may be based on channel estimates computed by the channel estimator 358. The soft decisions are then decoded and deinterleaved to recover the data and control signals that were originally transmitted by the base station 310 on the physical channel. The data and control signals are then provided to the controller/processor 359, which implements layer 3 and layer 2 functionality.

[0052] The controller/processor 359 can be associated with a memory 360 that stores program codes and data. The memory 360 may be referred to as a computer-readable medium. In the UL, the controller/processor 359 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, and control signal processing to recover IP packets from the EPC 160.

The controller/processor 359 is also responsible for error detection using an ACK and/or NACK protocol to support HARQ operations.

[0053] Similar to the functionality described in connection with the DL transmission by the base station 310, the controller/processor 359 provides RRC layer functionality associated with system information (e.g., MIB, SIBs) acquisition, RRC connections, and measurement reporting; PDCP layer functionality associated with header compression / decompression, and security (ciphering, deciphering, integrity protection, integrity verification); RLC layer functionality associated with the transfer of upper layer PDUs, error correction through ARQ, concatenation, segmentation, and reassembly of RLC SDUs, re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto TBs, demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through HARQ, priority handling, and logical channel prioritization.

[0054] Channel estimates derived by a channel estimator 358 from a reference signal or feedback transmitted by the base station 310 may be used by the TX processor 368 to select the appropriate coding and modulation schemes, and to facilitate spatial processing. The spatial streams generated by the TX processor 368 may be provided to different antenna 352 via separate transmitters 354TX. Each transmitter 354TX may modulate an RF carrier with a respective spatial stream for transmission.

[0055] The UL transmission is processed at the base station 310 in a manner similar to that described in connection with the receiver function at the UE 350. Each receiver 318RX receives a signal through its respective antenna 320. Each receiver 318RX recovers information modulated onto an RF carrier and provides the information to a RX processor 370.

[0056] The controller/processor 375 can be associated with a memory 376 that stores program codes and data. The memory 376 may be referred to as a computer-readable medium. In the UL, the controller/processor 375 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, control signal processing to recover IP packets from the UE 350. IP packets from the controller/processor 375 may be provided to the EPC 160. The controller/processor 375 is also responsible for error detection using an ACK and/or NACK protocol to support HARQ operations.

- [0057] A focus of the traditional LTE design relates to the improvement of spectral efficiency, ubiquitous coverage, and enhanced quality of service (QoS) support, etc. Current LTE system down link (DL) and uplink (UL) link budgets may be designed for coverage of high end devices, such as state-of-the-art smartphones and tablets. However, it may be desirable to support low cost low rate devices as well. Such communication may involve a reduction in a maximum bandwidth, e.g., a narrowband bandwidth, use of a single receive radio frequency (RF) chain, a reduction in peak rate, a reduction in transmit power, the performance of half duplex operation, etc. One example of such narrowband wireless communication is Narrowband-Internet of Things (NB-IoT), which may be limited to a single RB of system bandwidth, e.g., 180 kHz.
- [0058] FIG. 4 illustrates an example resource mapping 400 for in which a maximum of two NRS ports are able to be supported, e.g., for NB-IOT communication. In this example, the two NRS ports (NRS Port 0, NRS Port 1) are mapped to the last two symbols of each slot, e.g., symbols 5, 6 and 12, 13. The frequency location for the two NRS ports may be determined, e.g., based on a cell specific frequency shift. The cell specific frequency shift may be derived, e.g., based on an NB-IoT Physical Cell Identity (PCID), e.g., $PCID \bmod 6$.
- [0059] Aspects presented herein may include the use of four NRS antenna ports with a four antenna diversity for a single UE, e.g., to provide coverage enhancement. However, in order to avoid a collision between a newly added third and fourth NRS port, e.g., NRS Port 2, NRS Port 3, transmission may be limited to certain symbols. For example, NRS Port 2 and NRS Port 3 transmissions may be limited to symbols 2, 3, 9, or 10. This may help to avoid the use of OFDM symbols that are used for LTE CRS and for NRS Port 0 or NRS Port 1 transmissions.
- [0060] An additional challenge for the use of four NRS antenna ports is the use of certain symbols for PDCCH transmissions. For example, if the first three symbols are used for LTE PDCCH transmission, as illustrated in 400, then the third and fourth NRS ports (NRS Port 2, NRS Port 3) cannot transmit on symbol 2. By being unable to transmit on symbol 2, the Reference Signal (RS) density on NRS Port 2 and NRS Port 3 will be lower than the RS density of NRS Port 0 and NRS Port 1.

- [0061] Furthermore, in Time Division Duplex (TDD) special subframes, symbols 2, 3, 9, and 10 may be used for transmissions from NRS Port 0 and NRS Port 1. In this situation, there are no symbols available for transmissions from NRS Port 2 and NRS Port 3.
- [0062] FIG. 5 illustrates a resource mapping 500 for a Narrowband Positioning RS (NPRS) configured with a part B pattern. The NPRS part B configuration may be the configuration used for standalone and guardband communication, for example. The NPRS Part B configuration may comprise a periodicity, offset, number of subframes, etc. to give contiguous bursts of NPRS subframes. This configuration of NPRS may improve active positioning at a UE, including power management and performance. As illustrated in FIG. 5, the NPRS may be transmitted in symbols 2, 3, 9, and 10. Thus, a mapping of NRS port 2 or NRS Port 3 on symbol 2, 3, 9 or 10 may collide with the NPRS having an NPRS part B configuration.
- [0063] The present application provides a number of different ways to enable four-port NRS configurations while avoiding potential collisions with other signals.
- [0064] Carrier Based Pattern
- [0065] In a first example, a particular four-port NRS pattern may be based on a carrier used to transmit the NRS pattern. Thus, a base station may apply different, carrier specific four-port NRS patterns. In one example, the four-port NRS pattern may be semi-statically configured based on a number of OFDM symbols used for LTE PDCCH in a particular carrier leading to different four-port NRS patterns for each NB-IoT carrier. FIG. 6 illustrates two example NRS patterns 602, 604 for different carriers. For example, pattern 602 may correspond to an inband NB-IoT carrier having the first three OFDM symbols configured for LTE PDCCH. For this carrier, NRS Port 2 and NRS Port 3 may be mapped to only symbol 9 and symbol 10. The first pattern 602 includes 8 REs per subframe. The second pattern 604 may be applied for other carriers, e.g., an inband carrier having fewer than the first three symbols reserved for PDCCH and/or a guard band or standalone carrier. In the second pattern, NRS Port 2 and NRS Port 3 may be mapped to symbol 2 and symbol 3 in addition to symbol 9 and symbol 10. This leads to 16 REs per subframe, similar to the number of REs for NRS Port 0 and NRS Port 1. The second pattern 604 may be applied for standalone or guard band carriers, e.g., because such carriers will not have LTE PDCCH transmissions. Thus, an NRS pattern may be selected based on a type of the carrier,

e.g., whether the carrier is an inband carrier, a standalone carrier, or a guard band carrier.

[0066] In the another example for an inband carrier, LTE CRS ports may be used in a complementary manner to the two-port NRS in order to achieve four transmission antenna diversity transmission from the base station. For example, CRS Port 2 and CRS Port 3 may be used in a complementary manner with NRS Port 0 and NRS Port 1 to achieve four transmission antenna diversity.

[0067] Mixed Two-Port and Four-Port Pattern

[0068] In a second example a mixed two-port NRS configuration and four-port NRS configuration may be applied for NPDCCH transmission using one NCCE. FIG. 7 illustrates an example mapping in which a base station may apply a two-port NRS configuration and a four-port NRS configuration within a same subframe. For example, for NCCE0, a two-port NRS configuration is applied. For NCCE1, a four-port NRS configuration is applied. In other examples, a four-port NRS configuration may be applied for NCCE0, and a two-port NRS configuration may be applied for NCCE1. The base station may transmit NB-IoT communication on NCCE0 to a first UE, and transmit NB-IoT communication on NCCE1 to a second UE. For example, NCCE0 may be transmitted with two port NRS for legacy UEs, while NCCE1 may be transmitted with a four-port NRS configuration for UEs having such added capability. FIG. 7 illustrates NRS Port 2 and NRS Port 3 only present in a half Physical Resource Block (PRB) of the corresponding NCCE. Thus, a UE may not be able to assume that NRS Port 2 and NRS Port 3 are available across an entire PRB.

[0069] Fallback to Two-Port NRS Configuration

[0070] As four NRS ports might not be supported at times, a fallback procedure may be provided to fallback to a two NRS port configuration, e.g., in downlink subframes that do not support the four-port NRS configuration. In a first example, a base station may return to a two-port NRS configuration for TDD special subframes. In a second example, the base station may return to a two-port NRS configuration for subframes having an NPRS part B configuration. An NPRS part A configuration may have a different pattern that does not involve a potential collision between the NPRS and transmissions based on a four-port NRS configuration. In a third example, a base station may return to a two-port NRS configuration when a downlink subframe is configured as an invalid subframe for four-port NRS. An indication that the subframe

is invalid for four-port NRS configuration may be received, e.g., via higher layer signaling.

[0071] Thus, a base station may use a four-port NRS configuration, and may change to a two-port NRS configuration for certain subframes. This change from four-port NRS configuration to a two-port NRS configuration may be referred to as a fallback to the two-port NRS configuration. If a fallback is supported for the base station, a mixed two-port and four-port transmission diversity may be used for NPDSCH and/or NPDCCH transmissions. Thus, the PDSCH power ratio may change from one subframe to another subframe. A receiving UE may apply a power boost based, e.g., on a power ratio between NPDSCH Energy Per Resource Element (EPRE) to NRS EPRE. As the power ratio may change from one subframe to another, the UE may assume or determine a different power ratio between NPDSCH EPRE and NRS EPRE for NPDSCH REs for a two-port NRS transmission and NPDSCH REs for a four-port NRS transmission. For example, the UE may scale the power boosting based on -3dB for two NRS antenna ports and based on 0 dB for 4 NRS antenna ports. The specific value of scaling may vary. This is merely one example to illustrate that the UE may apply different power boosting depending on whether two NRS antenna ports or four NRS antenna ports are configured.

[0072] NPDCCH and/or NPDSCH transmissions may be transmitted with repetition. If a base station changes from a four-port NRS configuration to a two-port NRS configuration, the change may overlap NPDCCH/NPDSCH repetitions. For NPDCCH/NPDSCH transmission with repetition, if 2-ports are used in one subframe due to fallback (e.g., colliding with NPRS subframe or TDD special subframe) then

[0073] In a first option, all subframes comprising a repetition of NPDCCH or NPDSCH may use the same NRS port configuration, e.g., either a four-port NRS configuration or a two-port NRS configuration. Thus, if a fallback to two NRS ports needs to be applied in a subframe comprising a repetition of NPDCCH or NPDSCH, a two-port NRS configuration may be applied in each subframe comprising the repetitions.

[0074] In a second option, the fallback to a two-port NRS configuration may be applied on a per repetition basis. Thus, the same NRS ports may be used for each NPDCCH or NPDSCH transmission within a repetition. However, but different repetition transmission may use different numbers of NRS ports. FIG. 8 illustrates an example 802 showing a per repetition change between 2 NRS ports and 4 NRS ports for the

transmission of repetitions of NPDSCH. While the example is illustrated for NPDSCH, the same concept is equally applicable to repetitions of NPDCCH.

[0075] In a third option, the fallback to a two-port NRS configuration may be applied for a block of subframes, e.g., based on the cyclic repetition pattern. In each cycle, the same NRS ports may be used for NPDCCH or NPDSCH transmission. For cyclic repetition, each NB-IoT subframe may be repeated consecutively for Z times where $Z = \min(4, \text{repetition})$ for the example showing a block of 4 subframes. FIG. 8 illustrates an example 804 showing a change between 2 NRS ports and 4 NRS ports for a block of 4 subframes within a single repetition of NPDSCH. While the example is illustrated for NPDSCH, the same concept is equally applicable to repetitions of NPDCCH.

[0076] Broadcast/Multicast

[0077] In addition to the use of four-port NRS configurations for UE specific NPDCCH and/or NPDSCH transmissions in a connected mode, a four-port NRS configuration may be applied for broadcasts or multicasts from the base station. For example, a four-port NRS configuration may be used for NPDCCH and/or NPDSCH configured by a Cell Radio Network Temporary Identifier (C-RNTI) during a random access procedure. For example, the four-port NRS configuration may be applied for a msg2 or msg4 used for early data transmission. In another example, a four-port NRS configuration, as described herein, may be applied for a Single Cell-Point to Multi-Point (SC-PTM) groupcast transmission.

[0078] The base station may signal whether a two-port NRS configuration or a four-port NRS configuration is used for the multicast/broadcast. For example, the base station may send an indication in system information such as a System Information Block (SIB) that indicates to a UE whether the based station is using two NRS ports or four NRS ports for the multicast/broadcast.

[0079] NRS Port Switching for SFBC precoding

[0080] Four transmit antenna diversity is similar to a combination of two 2x2 Space Frequency Block Coding (SFBC) schemes mapped to independent subcarriers. A symbol is only mapped to two out of the four NRS ports for a transmission. Therefore, a downlink transmission using a four-port NRS configuration may switch a mapping of symbols to different NRS antenna ports for different repetitions of a transmission.

This switch between the mapping of symbols to different NRS antenna ports may provide a diversity gain. FIG. 9 illustrates an example in which SFBC precoding is used to generate a set of modulated symbols x0-x7 for transmission of an NPDSCH or NPDCCH. In a first repetition of the NPDSCH/NPDCCH, modulated symbols x0, x1, x4, and x5 are mapped to NRS Port 0 and NRS Port 1. Modulated symbols x2, x3, x6, and x7 are mapped to NRS Port 2 and NRS Port 3.

[0081] In the second repetition of the NPDSCH/NPDCCH, modulated symbols x0, x1, x4, and x5, which were mapped to NRS Port 0 and NRS Port 1 in the first repetition, are instead mapped to NRS Port 2 and NRS Port 3. Similarly, modulated symbols x2, x3, x6, and x7, which were mapped to NRS Port 2 and NRS Port 3 in the first repetition, are instead mapped to NRS Port 0 and NRS Port 1 in the second repetition. Thus, in different repetitions, the same modulated symbols are switched to the opposite NRS ports.

[0082] FIG. 10 is a flowchart 1000 of a method of wireless communication. The method may be performed by a base station (e.g., base station 102, 180, 310, 1302, 1302', 1650). At 1002, the base station configures four port transmit antenna diversity mode for one UE.

[0083] At 1004, the base station selects between a two-port NRS configuration and a four-port NRS configuration based on at least one of a carrier, an NPDCCH, an NPDSCH, a subframe configuration, and an NPRS pattern. Then, at 1006, the base station transmits an NRS according to the selection. The base station may also transmit NPDSCH/NPDCCH according to the selection.

[0084] The selection at 1004 may be based on a carrier, e.g., a carrier type. used to transmit the NRS, as described in connection with FIG. 6. For example, the four-port NRS configuration may be selected at 1004 when the carrier is a guardband carrier or a standalone carrier. The four-port NRS configuration may be selected at 1004, when the carrier is an inband carrier, wherein the four-port NRS port configuration comprises an NRS port pattern based on a number of symbols used for a control channel.

[0085] Different four-port NRS port patterns may be configured for different in band carriers, a standalone carrier or a guardband carrier, e.g., as described in connection with FIGs. 6 and 7.

- [0086] The two-port NRS configuration may be selected at 1004 when downlink subframes that do not support the four-port NRS configuration, e.g., in TDD special subframes. In this example, the base station may use two NRS ports to achieve two transmit antenna diversity at 1008.
- [0087] The NRS may be transmitted at 1006 in a subframe associated with the NPDCCH, and the NPDCCH may be transmitted using one NCCE. The base station may transmit NRS at 1008 according to the two-port NRS configuration for a first NCCE and may transmit NRS according to the four-port NRS configuration for a second NCCE, e.g., as described in connection with FIG. 7
- [0088] The base station may transmit the NRS at 1006 according to the four-port NRS configuration in at least a first subframe and may also transmit the NRS according to the two-port NRS configuration in at least a second subframe, e.g., as described in connection with FIG. 8.
- [0089] The second subframe in which the NRS is transmitted according to the two-port NRS configuration may comprise at least one of a TDD special subframe, a subframe having an NPRS configured with a Part B pattern, or an invalid subframe configured as invalid for four-port NRS transmission.
- [0090] A first power ratio for transmissions of the NRS and a data channel may be used by the base station in the first subframe and a second power ratio may be used by the base station for transmission of the NRS and the data channel is used in the second subframe. Thus, when the two-port NRS configuration is selected at 1004, the base station may transmit data, at 1010 using two transmit antenna diversity.
- [0091] The selection between the two-port NRS configuration and the four-port NRS configuration at 1004 may be performed uniformly for each subframe comprising a repetition of the NPDSCH or the NPDCCH. For example, when the two-port NRS configuration is selected for at least one subframe comprising a repetition of the NPDSCH or the NPDCCH, all subframes comprising repetitions of the NPDSCH or the NPDCCH transmission are transmitted with the two-port NRS configuration.
- [0092] The selection between the two-port NRS configuration and the four-port NRS configuration at 1004 may be performed separately for each subframe comprising a repetition of the NPDSCH or the NPDCCH, e.g., as described in connection with FIG. 8. For example, a first repetition of the NPDSCH or the NPDCCH may be transmitted

with the two-port NRS configuration and a second repetition of the NPDSCH or the NPDCCH may be transmitted with the four-port NRS configuration.

- [0093] The selection between the two-port NRS configuration and the four-port NRS configuration may be performed in common for each a block of subframes comprising at least a portion of repetitions of the NPDSCH or the NPDCCH, e.g., as described in connection with FIG. 8. The block of subframes may be based on a cyclic repetition pattern.
- [0094] The NRS transmitted at 1008 may comprise a broadcast and/or a multicast. The broadcast or multicast may comprise at least one of an NPDSCH channel configured by a C-RNTI during a random access procedure, an NPDCCH channel configured by the C-RNTI during the random access procedure, or an SC-PTM groupcast transmission. In this example, the base station may transmit, at 1012, an indication regarding whether the NRS is transmitted according to the two-port NRS configuration or the four-port NRS configuration. The indication may comprise system information, e.g., a SIB, transmitted by the base station.
- [0095] When the NRS is transmitted at 1006 according to the four-port NRS configuration, the base station may map, at 1016, data symbols to different antenna ports for different subframes that comprise repetitions of the NPDSCH or the NPDCCH.
- [0096] The base station may use an SFBC precoding to generate a first set of modulated symbols and a second set of modulated symbols at 1014. Then, at 1016, the base station may map the first set of modulated symbols and the second set of modulated symbols to different NRS ports in different repetitions, such as described in connection with FIG. 9. For example, in a first repetition transmission, the first set of modulated symbols may be mapped to a first NRS port and a second NRS port and the second set of modulated symbols may be mapped to a third NRS port and a fourth NRS port. In a second repetition transmission, the first set of modulated symbols may be mapped to the third NRS port and the fourth NRS port and the second set of modulated symbols may be mapped to the first NRS port and the second NRS port.
- [0097] FIG. 11 is a flowchart 1100 of a method of wireless communication. The method may be performed by a base station (e.g., base station 102, 180, 310, 1302, 1302', 1650). At 1102, the base station transmits a broadcast or multicast comprising an NRS based on four NRS antenna ports or two NRS antenna ports. At 1104, the base station transmits an indication regarding whether the NRS is transmitted based on four

NRS antenna ports or two NRS antenna ports. The broadcast or multicast comprises at least one of a data channel configured by a C-RNTI during a random access procedure, a control channel configured by the C-RNTI during the random access procedure, or an SC-PTM groupcast transmission. The indication may comprise system information, e.g., a SIB, transmitted by the base station.

[0098] FIG. 12 is a flowchart 1200 of a method of wireless communication. The method may be performed by a base station (e.g., base station 102, 180, 310, 1302, 1302', 1650). At 1202, the base station transmits an NRS according to four-port NRS configuration. At 1206, the base station maps symbols of an NPDSCH to four NRS antenna ports. At 1210, the base station transmits multiple repetitions of the NPDSCH with the four NRS antenna ports, wherein a mapping of symbols for the NPDSCH is switched between antenna ports for different repetitions of the NPDSCH, e.g., as described in connection with FIG. 9.

[0099] For example, at 1204, the base station may use SFBC precoding to generate a first set of modulated symbols and a second set of modulated symbols for the NPDSCH. Then, at 1208, the base station may switch the mapping of symbols to different NRS ports for different repetitions. For example, in a first repetition transmission, the first set of modulated symbols may be mapped to a first NRS port and a second NRS port and the second set of modulated symbols may be mapped to a third NRS port and a fourth NRS port. In a second repetition transmission, the first set of modulated symbols may be mapped to the third NRS port and the fourth NRS port and the second set of modulated symbols may be mapped to the first NRS port and the second NRS port.

[00100] FIG. 13 is a conceptual data flow diagram 1300 illustrating the data flow between different means/components in an exemplary apparatus 1302. The apparatus may be a base station (e.g., base station 102, 180, 310) communicating with at least one UE 1350. The communication may comprise NB-IoT communication. The apparatus includes a reception component 1304 that receives uplink communication from at least one UE 1350, a transmission component 1306 that transmits downlink communication to the UE(s) 1350. The apparatus may include a configuration component 1308 configured to configure a four-port transmit antenna diversity for one UE. The apparatus may include a selection component 1310 configured to select between a two-port NRS configuration and a four-port NRS configuration, as

described in connection with 1004 in FIG. 10. The transmission component 1306 may transmit the NRS according to the selection. The apparatus may include a CRS component 1312 configured to use two CRS ports with two NRS ports for four transmit antenna diversity. The apparatus may include a data component 1314, wherein the transmission component 1306 is configured to transmit data transmissions from the data component 1314 based on the selection by the selection component 1310. The apparatus may include an indication component 1316 configured to transmit an indication regarding whether the NRS is transmitted according to the two-port NRS configuration or the four-port NRS configuration. The apparatus may further include a precoding component 1318 configured to use SFBC to precode modulated symbols and a mapping component 1320 configured to map the modulated symbols/data to NRS ports, e.g., as described in connection with any of FIGs. 9, 10, and 12.

- [00101]** The apparatus may include additional components that perform each of the blocks of the algorithm in the aforementioned flowcharts of FIGs. 10-12. As such, each block in the aforementioned flowcharts of FIGs. 10-12 may be performed by a component and the apparatus may include one or more of those components. The components may be one or more hardware components specifically configured to carry out the stated processes/algorithm, implemented by a processor configured to perform the stated processes/algorithm, stored within a computer-readable medium for implementation by a processor, or some combination thereof.
- [00102]** FIG. 14 is a diagram 1400 illustrating an example of a hardware implementation for an apparatus 1302' employing a processing system 1414. The processing system 1414 may be implemented with a bus architecture, represented generally by the bus 1424. The bus 1424 may include any number of interconnecting buses and bridges depending on the specific application of the processing system 1414 and the overall design constraints. The bus 1424 links together various circuits including one or more processors and/or hardware components, represented by the processor 1404, the components 1304, 1306, 1308, 1310, 1312, 1314, 1316, 1318, 1320, and the computer-readable medium / memory 1406. The bus 1424 may also link various other circuits such as timing sources, peripherals, voltage regulators, and power management circuits, which are well known in the art, and therefore, will not be described any further.

[00103] The processing system 1414 may be coupled to a transceiver 1410. The transceiver 1410 is coupled to one or more antennas 1420. The transceiver 1410 provides a means for communicating with various other apparatus over a transmission medium. The transceiver 1410 receives a signal from the one or more antennas 1420, extracts information from the received signal, and provides the extracted information to the processing system 1414, specifically the reception component 1304. In addition, the transceiver 1410 receives information from the processing system 1414, specifically the transmission component 1308, and based on the received information, generates a signal to be applied to the one or more antennas 1420. The processing system 1414 includes a processor 1404 coupled to a computer-readable medium / memory 1406. The processor 1404 is responsible for general processing, including the execution of software stored on the computer-readable medium / memory 1406. The software, when executed by the processor 1404, causes the processing system 1414 to perform the various functions described *supra* for any particular apparatus. The computer-readable medium / memory 1406 may also be used for storing data that is manipulated by the processor 1404 when executing software. The processing system 1414 further includes at least one of the components 1304, 1306, 1308, 1310, 1312, 1314, 1316, 1318, 1320. The components may be software components running in the processor 1404, resident/stored in the computer readable medium / memory 1406, one or more hardware components coupled to the processor 1404, or some combination thereof. The processing system 1414 may be a component of the base station 310 and may include the memory 376 and/or at least one of the TX processor 316, the RX processor 370, and the controller/processor 375.

[00104] In one configuration, the apparatus 1302/1302' for wireless communication includes means for configuring four port transmit antenna diversity mode for one user equipment (e.g., configuration component 1308), means for selecting between a two-port NRS configuration and a four-port NRS configuration (e.g., selection component 1310), means for transmitting an NRS according to the selection (e.g., transmission component 1306), means for using two CRS ports with two NRS ports for four transmit antenna diversity (e.g., CRS component 1312), means for transmitting data using two transmit antenna diversity (e.g., data component 1314, transmission component 1306), means for transmitting an indication regarding whether the NRS is transmitted according to the two-port NRS configuration or the four-port NRS

configuration (e.g., indication component 1316), means for using an SFBC precoding to generate a first set of modulated symbols and a second set of modulated symbols (e.g., precoding component 1318), and means for mapping the symbols/data to NRS ports (e.g., map component 1320). The aforementioned means may be one or more of the aforementioned components of the apparatus 1302 and/or the processing system 1414 of the apparatus 1302' configured to perform the functions recited by the aforementioned means. As described *supra*, the processing system 1414 may include the TX Processor 316, the RX Processor 370, and the controller/processor 375. As such, in one configuration, the aforementioned means may be the TX Processor 316, the RX Processor 370, and the controller/processor 375 configured to perform the functions recited by the aforementioned means.

[00105] FIG. 15 is a flowchart 1500 of a method of wireless communication. The method may be performed by a UE (e.g., UE 104, 350, 1350, the apparatus 1602, 1602') At 1502, the UE determines whether a base station transmits an NRS comprising a two-port NRS configuration or a four-port NRS configuration based on at least one of a carrier, an NPDCCH, an NPDSCH, a subframe configuration, an NPRS pattern, or an indication from the base station. At 1504, the UE receives the NRS according to the determination at 1502.

[00106] The determination at 1502 may be based on a carrier, e.g., a carrier type. used to transmit the NRS, as described in connection with FIG. 6. For example, the four-port NRS configuration may be determined at 1502 when the carrier is a guardband carrier or a standalone carrier. The four-port NRS configuration may be determined at 1502, when the carrier is an inband carrier, wherein the four-port NRS port configuration comprises an NRS port pattern based on a number of symbols used for a control channel, e.g., LTE PDCCH.

[00107] Different four-port NRS port patterns may be determined for different in band carriers, e.g., as described in connection with FIGs. 6 and 7.

[00108] The two-port NRS configuration may be determined at 1502 when the carrier is an inband carrier. In this example, the UE may use two CRS ports with two NRS ports to achieve four transmit antenna diversity at 1506.

[00109] The NRS may be received at 1504 according to the four-port NRS configuration in at least a first subframe and may also receive the NRS according to the two-port NRS

configuration in at least a second subframe, e.g., as described in connection with FIG. 8.

- [00110] The second subframe in which the NRS is received according to the two-port NRS configuration may comprise at least one of a TDD special subframe, a subframe having an NPRS configured with a Part B pattern, or an invalid subframe configured as invalid for four-port NRS transmission.
- [00111] A first power ratio for transmissions of the NRS and a data channel used by the base station in the first subframe may be different than a second power ratio used by the base station for transmission of the NRS and the data channel is used in the second subframe. Thus, when the two-port NRS configuration is selected at 1502, the UE may receive data, at 1508, using two transmit antenna diversity. The UE may also use a first power ratio to receive the NRS and a data channel in the first subframe and a second power ratio to receive the NRS and the data channel in the second subframe.
- [00112] The determination between the two-port NRS configuration and the four-port NRS configuration at 1502 may be performed uniformly, or in common, for each subframe comprising a repetition of the NPDSCH or the NPDCCH. For example, when the two-port NRS configuration is determined for at least one subframe comprising a repetition of the NPDSCH or the NPDCCH, all subframes comprising repetitions of the NPDSCH or the NPDCCH transmission may be determined to be transmitted by the base station with the two-port NRS configuration.
- [00113] The determination between the two-port NRS configuration and the four-port NRS configuration at 1502 may be performed separately for each subframe comprising a repetition of the NPDSCH or the NPDCCH, e.g., as described in connection with FIG. 8. For example, a first repetition of the NPDSCH or the NPDCCH may be received with the two-port NRS configuration and a second repetition of the NPDSCH or the NPDCCH may be received with the four-port NRS configuration.
- [00114] The determination between the two-port NRS configuration and the four-port NRS configuration may be performed together for each a block of subframes comprising at least a portion of repetitions of the NPDSCH or the NPDCCH, e.g., as described in connection with FIG. 8. The block of subframes may be based on a cyclic repetition pattern.

- [00115] The NRS received at 1504 may comprise a broadcast and/or a multicast. The broadcast or multicast may comprise at least one of an NPDSCH channel configured by a C-RNTI during a random access procedure, an NPDCCH channel configured by the C-RNTI during the random access procedure, or an SC-PTM groupcast transmission. In this example, the UE may receive, at 11510, an indication regarding whether the NRS is transmitted according to the two-port NRS configuration or the four-port NRS configuration. The indication may comprise system information, e.g., a SIB, received from the base station.
- [00116] When the NRS is received at 1504 or data is received at 1512 according to the four-port NRS configuration, data symbols may be mapped to different antenna ports for different subframes that comprise repetitions of the NPDSCH or the NPDCCH.
- [00117] The UE may receive a first set of modulated symbols and a second set of modulated symbols mapped to different NRS ports in different repetitions, such as described in connection with FIG. 9. For example, in a first repetition transmission, the first set of modulated symbols may be mapped to a first NRS port and a second NRS port and the second set of modulated symbols may be mapped to a third NRS port and a fourth NRS port. In a second repetition transmission, the first set of modulated symbols may be mapped to the third NRS port and the fourth NRS port and the second set of modulated symbols may be mapped to the first NRS port and the second NRS port.
- [00118] FIG. 16 is a conceptual data flow diagram 1600 illustrating the data flow between different means/components in an exemplary apparatus 1602. The apparatus may be a UE (e.g., UE 104, 350, 1350) communicating with base station 1650. The communication may comprise NB-IoT communication.
- [00119] The apparatus includes a reception component 1604 that receives downlink communication from base station 1650, a transmission component 1606 that transmits uplink communication to the base station. The apparatus may include a determination component 1608 configured to determine whether a base station transmits an NRS comprising a two-port NRS configuration or a four-port NRS configuration, as described in connection with 1502 in FIG. 15. The reception component 1604 may receive the NRS according to the selection. The apparatus may include a CRS component 1610 configured to use two CRS ports with two NRS ports for four transmit antenna diversity. The apparatus may include a data component 1612,

wherein the reception component 1604 is configured to receive data transmissions from the data component 1612 based on the determination by the determination component 1608. The apparatus may include an indication component 1614 configured to receive an indication regarding whether the NRS is transmitted by the base station according to the two-port NRS configuration or the four-port NRS configuration.

[00120] The apparatus may include additional components that perform each of the blocks of the algorithm in the aforementioned flowchart of FIG. 15. As such, each block in the aforementioned flowchart of FIG. 15 may be performed by a component and the apparatus may include one or more of those components. The components may be one or more hardware components specifically configured to carry out the stated processes/algorithm, implemented by a processor configured to perform the stated processes/algorithm, stored within a computer-readable medium for implementation by a processor, or some combination thereof.

[00121] FIG. 17 is a diagram 1700 illustrating an example of a hardware implementation for an apparatus 1602' employing a processing system 1714. The processing system 1714 may be implemented with a bus architecture, represented generally by the bus 1724. The bus 1724 may include any number of interconnecting buses and bridges depending on the specific application of the processing system 1714 and the overall design constraints. The bus 1724 links together various circuits including one or more processors and/or hardware components, represented by the processor 1704, the components 1604, 1606, 1608, 1610, 1612, 1614, and the computer-readable medium / memory 1706. The bus 1724 may also link various other circuits such as timing sources, peripherals, voltage regulators, and power management circuits, which are well known in the art, and therefore, will not be described any further.

[00122] The processing system 1714 may be coupled to a transceiver 1710. The transceiver 1710 is coupled to one or more antennas 1720. The transceiver 1710 provides a means for communicating with various other apparatus over a transmission medium. The transceiver 1710 receives a signal from the one or more antennas 1720, extracts information from the received signal, and provides the extracted information to the processing system 1714, specifically the reception component 1604. In addition, the transceiver 1710 receives information from the processing system 1714, specifically the transmission component 1606, and based on the received information, generates

a signal to be applied to the one or more antennas 1720. The processing system 1714 includes a processor 1704 coupled to a computer-readable medium / memory 1706. The processor 1704 is responsible for general processing, including the execution of software stored on the computer-readable medium / memory 1706. The software, when executed by the processor 1704, causes the processing system 1714 to perform the various functions described *supra* for any particular apparatus. The computer-readable medium / memory 1706 may also be used for storing data that is manipulated by the processor 1704 when executing software. The processing system 1714 further includes at least one of the components 1604, 1606, 1608, 1610, 1612, 1614. The components may be software components running in the processor 1704, resident/stored in the computer readable medium / memory 1706, one or more hardware components coupled to the processor 1704, or some combination thereof. The processing system 1714 may be a component of the UE 350 and may include the memory 360 and/or at least one of the TX processor 368, the RX processor 356, and the controller/processor 359.

[00123] In one configuration, the apparatus 1602/1602' for wireless communication includes means for determining whether a base station transmits an NRS comprising a two-port NRS configuration or a four-port NRS configuration (e.g., determination component 1608), means for receiving the NRS according to the determination (e.g., reception component 1604), means for using two CRS ports with two NRS ports for four transmit antenna diversity (e.g., CRS component 1610), means for receiving an indication regarding whether the NRS is transmitted according to the two-port NRS configuration or the four-port NRS configuration (e.g., indication component 1614), and means for receiving data based on the determination (e.g., data component 1612). The aforementioned means may be one or more of the aforementioned components of the apparatus 1602 and/or the processing system 1714 of the apparatus 1602' configured to perform the functions recited by the aforementioned means. As described *supra*, the processing system 1714 may include the TX Processor 368, the RX Processor 356, and the controller/processor 359. As such, in one configuration, the aforementioned means may be the TX Processor 368, the RX Processor 356, and the controller/processor 359 configured to perform the functions recited by the aforementioned means.

[00124] Further disclosure is included in the Appendix.

[00125] It is understood that the specific order or hierarchy of blocks in the processes / flowcharts disclosed is an illustration of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of blocks in the processes / flowcharts may be rearranged. Further, some blocks may be combined or omitted. The accompanying method claims present elements of the various blocks in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

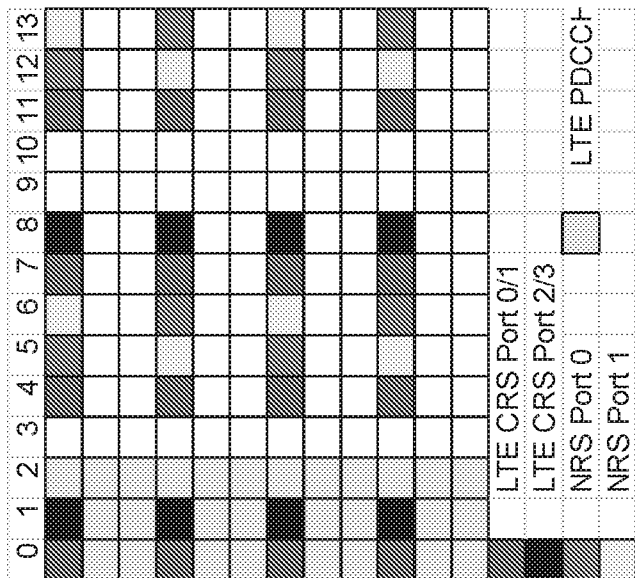
[00126] The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language claims, wherein reference to an element in the singular is not intended to mean “one and only one” unless specifically so stated, but rather “one or more.” The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any aspect described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other aspects. Unless specifically stated otherwise, the term “some” refers to one or more. Combinations such as “at least one of A, B, or C,” “one or more of A, B, or C,” “at least one of A, B, and C,” “one or more of A, B, and C,” and “A, B, C, or any combination thereof” include any combination of A, B, and/or C, and may include multiples of A, multiples of B, or multiples of C. Specifically, combinations such as “at least one of A, B, or C,” “one or more of A, B, or C,” “at least one of A, B, and C,” “one or more of A, B, and C,” and “A, B, C, or any combination thereof” may be A only, B only, C only, A and B, A and C, B and C, or A and B and C, where any such combinations may contain one or more member or members of A, B, or C. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. The words “module,” “mechanism,” “element,” “device,” and the like may not be a substitute for the word

“means.” As such, no claim element is to be construed as a means plus function unless the element is expressly recited using the phrase “means for.”

Enhanced 4 NRS ports for NB-IoT

Background

- Maximum two NRS ports can be supported in the current NB-IoT. The two NRS ports were mapped to the last two symbols of each slot and the frequency location is determined by cell specific frequency shift derived as $\text{NB-IoT PCID} \bmod 6$
- Recently it was proposed to support 4 NRS antenna ports with 4-Tx antenna diversity for coverage enhancement
- To avoid the collision the newly added NRS port 2/3 can only be transmitted on symbol 2, 3, 9 or 10 of the subframe, e.g., not using OFDM symbols used by LTE CRS and NRS port 0/1



Background

- If the first 3 symbols are used for LTE PDCCH, then NRS ports 2/3 cannot be transmitted on symbol #2 resulting in the RS density on NRS ports 2/3 is lower than that of the NRS ports 0/1
- For TDD special subframe, symbol 2, 3, 9 or 10 may be used for NRS ports 0/1 and then it seems no other symbols available for NRS ports 2/3
- For NPRS (narrowband positioning RS) part B only config for standalone and guardband scenario (i.e., PRS config with periodicity, offset, #subframes etc to give contiguous bursts of PRS subframe which is better from active positioning UE's power and performance), the mapping of NRS ports 2/3 on symbol 2, 3, 9 or 10 may collide with NPRS
 - Puncture NPRS on NRS ports 2/3 symbol may not work for legacy NB-IoT UE

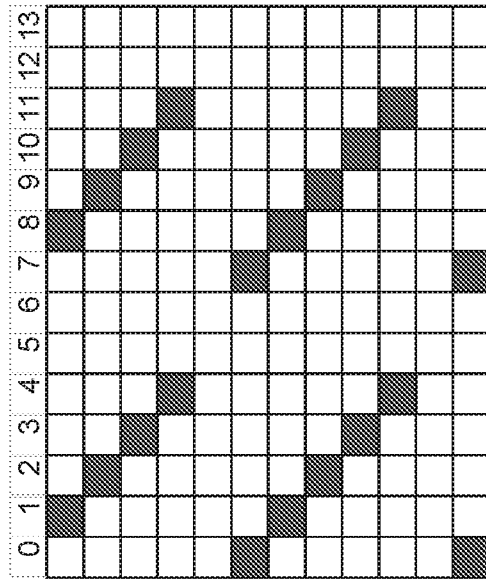
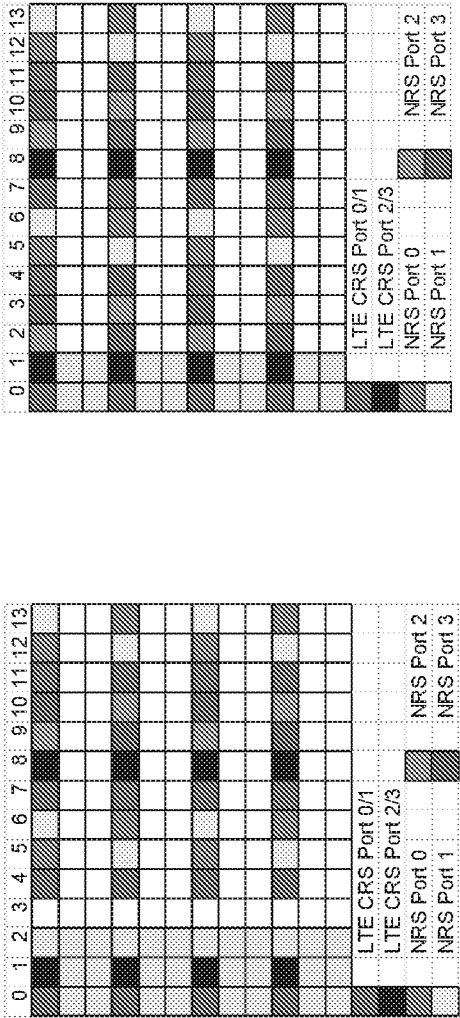


Figure: NPRS pattern with Part B only config for guardband/standalone scenario

Proposals

Carrier specific 4-ports NRS pattern

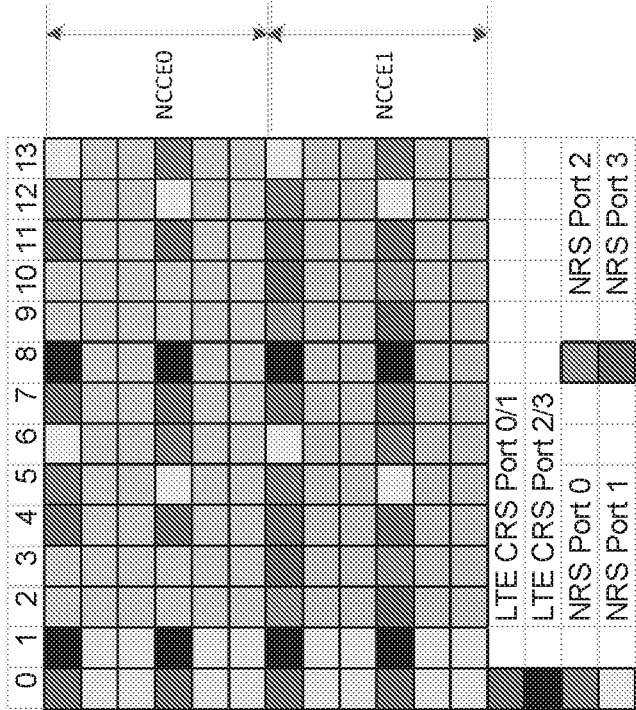
- The 4-ports NRS patterns can be semi-statically configured based on the number of OFDM symbols used for LTE PDCCH and can be different for each NB-IoT carrier
 - E.g., for inband NB-IoT carrier, if 3 OFDM symbols are configured for LTE PDCCH then NRS ports 2/3 are mapped only on symbol 9&10 with total 8 REs per subframe. Otherwise NRS ports 2/3 can be transmitted on both symbol 2&3 and 9&10 with total 16 REs similar to NRS ports 0/1
 - For guardband/standalone carrier, there is no LTE control and NRS ports 2/3 can be on both symbols 2&3 and 9&10
- For inband carrier, may also consider to use LTE CRS ports complementary to 2-ports NRS to achieve 4-TX antenna diversity transmission
 - E.g., use CRS port 2&3 and NRS port 0/1 for 4-TX antenna diversity



Proposals

Mixed 2-ports and 4-ports in one subframe

- Mixed 2-ports and 4-ports NRS can be considered for NPDDCH with one CCE.
- For example, NCCE0 is transmitted with 2-ports NRS for legacy UE and NCCE1 is transmitted with 4-ports for new UE. Note that NRS ports 2/3 are only presented in a half PRB of the corresponding NCCE
- Alternatively, NCCE0 is used with 4-ports and NCCE1 is used with 2-ports.
- For NRS ports 2/3 channel estimation, UE cannot assume that NRS ports 2/3 are available in the whole PRB, i.e., on one RE per symbol



Proposals

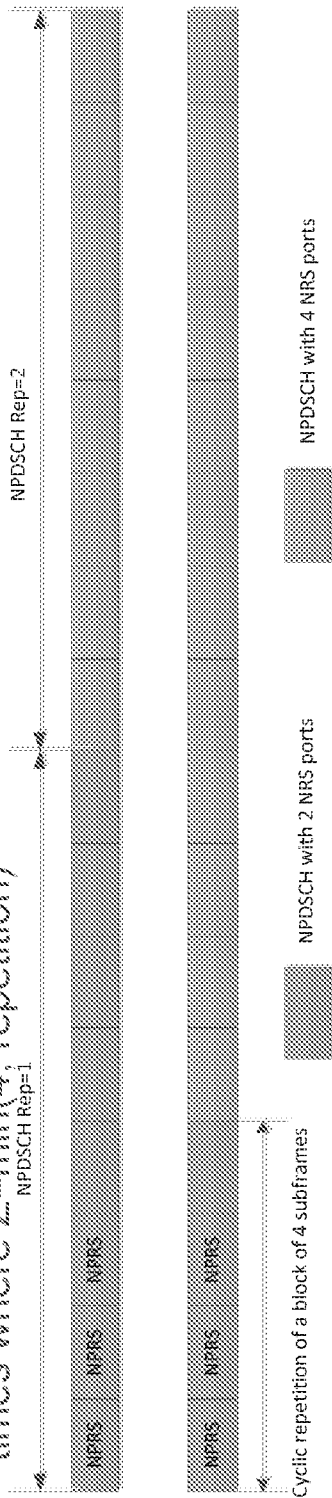
Fallback to 2 NRS ports

- Since 4 NRS ports cannot be supported in all the DL subframe, the fallback to legacy 2 NRS ports shall be supported.
- At least the fallback to 2 NRS ports shall be considered TDD special subframes and NPRS subframe configured with PartB only (or any DL subframe configured as invalid subframe for 4-ports NRS by high layer signaling
- If fallback is supported it could imply that a mixed 2-ports and 4-ports TX diversity transmission is used for NPDSCH/NPDCCH and the PDSCH power ratio may change from one subframe to another.
- UE shall assume different power ratio of NPDSCH EPRE to NRS EPRE among NPDSCH REs for the 2-ports and 4-ports NRS transmission, i.e., -3dB with 2 NRS antenna ports and 0 dB for 4 NRS ports

Proposals

Fallback to 2 NRS ports

- For NPDCCH/NPDSCH transmission with repetition, if 2-ports are used in one subframe due to fallback (e.g., colliding with NPRS subframe or TDD special subframe) then
 - Option 1: all the subframes will be used with 2-ports NRS
 - Option 2: The fallback is on the repetition basis. The same NRS ports are used for each transmission, but different repetition transmission may use different number of NRS ports
 - Option 3: the fallback is on a block of subframes based on the cyclic repetition pattern. In each cycle, the same NRS ports are used
- Note: For cyclic repetition, each NB-IoT subframes is repeated consecutively for Z times where $Z = \min(4, \text{repetition})$



Proposals

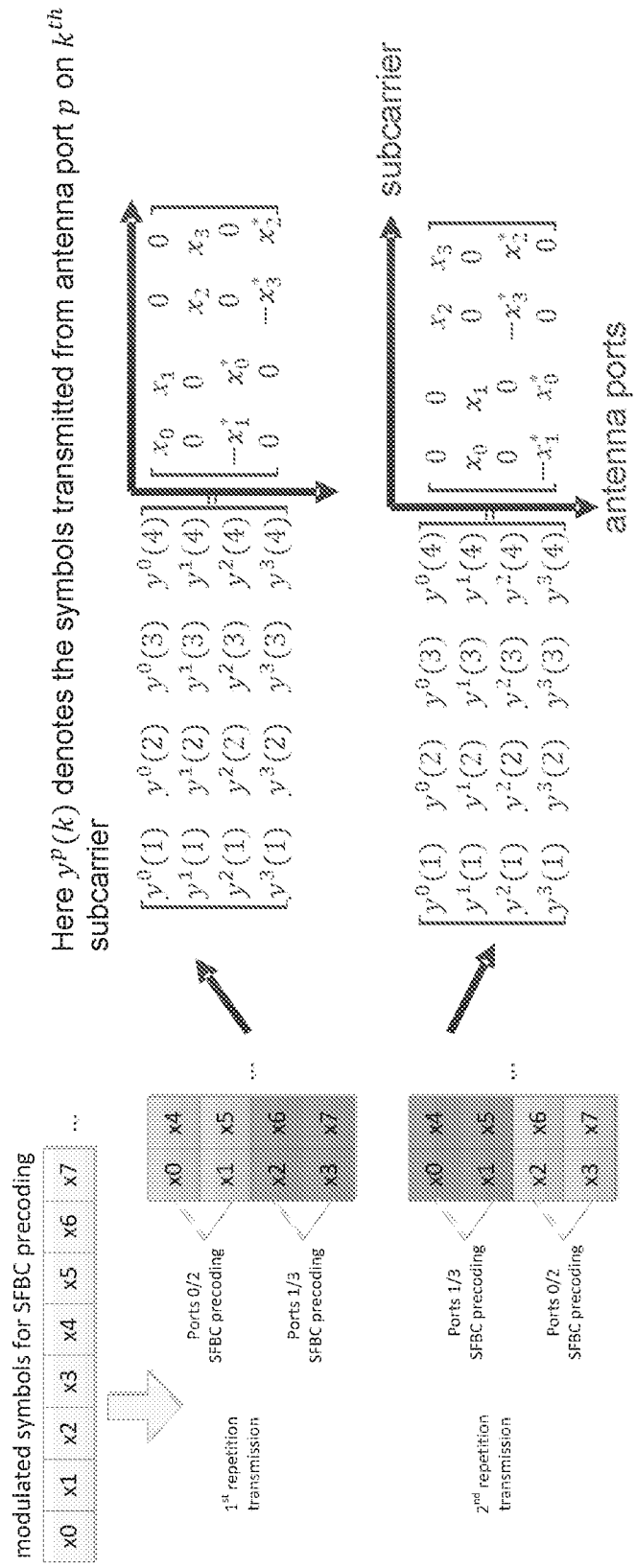
Applicable to broadcast/multicast transmission

- It is expected that the usage of 4-ports NRS is mainly for UE specific NPDCCH/NPDSCH transmission in connected mode, however, it can also be considered for broadcast/multicast
 - E.g., for NPDCCH and NPDSCH configured by C-RNTI during random access procedure (e.g., msg2/msg4 used for early data transmission)
 - Or SC-PTM (Single Cell-Point to Multi-point) groupcast transmission
- In such case, the eNB should signal in SIB whether it is using 2 ports or 4 ports for NRS

Proposals

Swap of NRS ports for SFBC precoding

- Since 4-Tx diversity transmission is in fact a combination of two 2 x2 SFBC schemes mapped to independent subcarriers, the symbol is only mapped to two out of the four ports for the transmission. So for DL transmission using 4-ports NRS, it is also possible to swap the mapping of the symbols to antenna ports for different repetition transmission, resulting in a slight diversity gain



CLAIMS

WHAT IS CLAIMED IS:

1. A method of wireless communication at a base station, comprising:
configuring four port transmit antenna diversity mode for one user equipment (UE);
selecting between a two-port Narrowband Reference Signal (NRS) configuration and a four-port NRS configuration based on at least one of a carrier, a Narrowband Physical Downlink Control Channel (NPDCCH), a Narrowband Physical Downlink Data Channel (NPDSCH), a subframe configuration, and a Narrowband Positioning Reference Signal (NPRS) pattern; and
transmitting an NRS according to the selection.
2. The method of claim 1, wherein the selection is based on the carrier used to transmit the NRS.
3. The method of claim 2, wherein the four-port NRS configuration is selected when the carrier is a guardband carrier or a standalone carrier.
4. The method of claim 2, wherein the four-port NRS configuration is selected when the carrier is an inband carrier, wherein the four-port NRS configuration comprises an NRS port pattern based on a number of symbols used for a control channel.
5. The method of claim 2, wherein different four-port NRS port patterns are configured for different carriers.
6. The method of claim 2, wherein the two-port NRS configuration is selected when the carrier is an inband carrier, the method further comprising:
using two Cell Specific Reference Signal (CRS) ports with two NRS ports for four transmit antenna diversity.

7. The method of claim 1, wherein the NRS is transmitted in a subframe associated with the NPDCCH, wherein the NPDCCH is transmitted using one Narrowband Control Channel Element (NCCE).

8. The method of claim 7, wherein transmitting the NRS comprises transmitting the NRS according to the two-port NRS configuration for a first Narrowband Control Channel Element (NCCE) and transmitting the NRS according to the four-port NRS configuration for a second NCCE.

9. The method of claim 1, wherein transmitting the NRS comprises transmitting the NRS according to the four-port NRS configuration in at least a first subframe and transmitting the NRS according to the two-port NRS configuration in at least a second subframe.

10. The method of claim 9, wherein the second subframe in which the NRS is transmitted according to the two-port NRS configuration comprises at least one of a Time Division Duplex (TDD) special subframe, a subframe having a Narrowband Positioning Reference Signal (NPRS) configured with a Part B pattern, or an invalid subframe configured as invalid for four-port NRS transmission.

11. The method of claim 9, wherein a first power ratio for transmissions of the NRS and a data channel is used in the first subframe and a second power ratio for transmission of the NRS and the data channel is used in the second subframe.

12. The method of claim 9, wherein when the two-port NRS configuration is selected, the method further comprising:

transmitting data using two transmit antenna diversity.

13. The method of claim 1, wherein the selection between the two-port NRS configuration and the four-port NRS configuration is performed uniformly for each subframe comprising a repetition of the NPDSCH or the NPDCCH,

wherein when the two-port NRS configuration is selected for at least one subframe comprising the repetition of the NPDSCH or the NPDCCH, all subframes comprising

repetitions of the NPDSCH or the NPDCCH are transmitted with the two-port NRS configuration.

14. The method of claim 1, wherein the selection between the two-port NRS configuration and the four-port NRS configuration is performed separately for each subframe comprising a repetition of the NPDSCH or the NPDCCH.

15. The method of claim 14, wherein a first repetition of the NPDSCH or the NPDCCH is transmitted with the two-port NRS configuration and a second repetition of the NPDSCH or the NPDCCH is transmitted with the four-port NRS configuration.

16. The method of claim 1, wherein the selection between the two-port NRS configuration and the four-port NRS configuration is performed in common for each a block of subframes comprising at least a portion of repetitions of the NPDSCH or the NPDCCH, wherein the block of subframes is based on a cyclic repetition pattern.

17. The method of claim 1, wherein the transmitted NRS comprises at least one of a broadcast or a multicast.

18. The method of claim 17, wherein the broadcast or the multicast comprises at least one of an NPDSCH channel configured by a Cell Radio Network Temporary Identifier (C-RNTI) during a random access procedure, an NPDCCH channel configured by the C-RNTI during the random access procedure, or a Single Cell-Point to Multi-Point (SC-PTM) groupcast transmission.

19. The method of claim 17, further comprising:
transmitting an indication regarding whether the NRS is transmitted according to the two-port NRS configuration or the four-port NRS configuration.

20. The method of claim 19, wherein the indication comprises system information transmitted by the base station.

21. The method of claim 1, wherein the NRS is transmitted according to the four-port NRS configuration, and

wherein a mapping of data symbols to antenna ports differs for different subframes that comprise repetitions of the NPDSCH or the NPDCCH.

22. The method of claim 21, further comprising:

using a Space Frequency Block Coding (SFBC) precoding to generate a first set of modulated symbols and a second set of modulated symbols,

wherein, in a first repetition transmission, the first set of modulated symbols are mapped to a first NRS port and a second NRS port and the second set of modulated symbols are mapped to a third NRS port and a fourth NRS port, and

wherein, in a second repetition transmission, the first set of modulated symbols are mapped to the third NRS port and the fourth NRS port and the second set of modulated symbols are mapped to the first NRS port and the second NRS port.

23. A method of wireless communication at a base station, comprising:

transmitting a broadcast or a multicast comprising an Narrowband Reference Signal (NRS) based on four NRS antenna ports or two NRS antenna ports; and

transmitting an indication regarding whether the NRS is transmitted based on the four NRS antenna ports or the two NRS antenna ports.

24. The method of claim 23, wherein the broadcast or the multicast comprises at least one of a data channel configured by a Cell Radio Network Temporary Identifier (C-RNTI) during a random access procedure, a control channel configured by the C-RNTI during the random access procedure, or a Single Cell-Point to Multi-Point (SC-PTM) groupcast transmission.

25. The method of claim 23, wherein the indication comprises system information transmitted by the base station.

26. A method of wireless communication at a base station, comprising:

transmitting a Narrowband Reference Signal (NRS) according to four-port NRS configuration, and

mapping symbols of a Narrowband Physical Downlink Data Channel (NPDSCH) to four NRS antenna ports; and

transmitting multiple repetitions of the NPDSCH with the four NRS antenna ports, wherein a mapping of symbols for the NPDSCH is switched between antenna ports for different repetitions of the NPDSCH.

27. The method of claim 26, further comprising:

using a Space Frequency Block Coding (SFBC) precoding to generate a first set of modulated symbols and a second set of modulated symbols for the NPDSCH,

wherein, in a first repetition transmission, the first set of modulated symbols are mapped to a first NRS port and a second NRS port and the second set of modulated symbols are mapped to a third NRS port and a fourth NRS port, and

wherein, in a second repetition transmission, the first set of modulated symbols are mapped to the third NRS port and the fourth NRS port and the second set of modulated symbols are mapped to the first NRS port and the second NRS port.

28. An apparatus for wireless communication at a base station, comprising:

means for configuring four port transmit antenna diversity mode for one user equipment (UE);

means for selecting between a two-port Narrowband Reference Signal (NRS) configuration and a four-port NRS configuration based on at least one of a carrier, a Narrowband Physical Downlink Control Channel (NPDCCH), a Narrowband Physical Downlink Data Channel (NPDSCH), a subframe configuration, and a Narrowband Positioning Reference Signal (NPRS) pattern; and

means for transmitting an NRS according to the selection.

29. An apparatus for wireless communication at a base station, comprising:

a memory; and

at least one processor coupled to the memory and configured to:

configure four port transmit antenna diversity mode for one user equipment (UE);

select between a two-port Narrowband Reference Signal (NRS) configuration and a four-port NRS configuration based on at least one of a carrier, a Narrowband

Physical Downlink Control Channel (NPDCCH), a Narrowband Physical Downlink Data Channel (NPDSCH), a subframe configuration, and a Narrowband Positioning Reference Signal (NPRS) pattern; and

transmit an NRS according to the selection.

30. A computer-readable medium storing computer executable code for wireless communication at a base station, comprising code to:

configure four port transmit antenna diversity mode for one user equipment (UE);

select between a two-port Narrowband Reference Signal (NRS) configuration and a four-port NRS configuration based on at least one of a carrier, a Narrowband Physical Downlink Control Channel (NPDCCH), a Narrowband Physical Downlink Data Channel (NPDSCH), a subframe configuration, and a Narrowband Positioning Reference Signal (NPRS) pattern; and

transmit an NRS according to the selection.

31. An apparatus for wireless communication at a base station, comprising:

means for transmitting a broadcast or a multicast comprising an Narrowband Reference Signal (NRS) based on four NRS antenna ports or two NRS antenna ports; and

means for transmitting an indication regarding whether the NRS is transmitted based on the four NRS antenna ports or the two NRS antenna ports.

32. An apparatus for wireless communication at a base station, comprising:

a memory; and

at least one processor coupled to the memory and configured to:

transmit a broadcast or a multicast comprising an Narrowband Reference Signal (NRS) based on four NRS antenna ports or two NRS antenna ports; and

transmit an indication regarding whether the NRS is transmitted based on the four NRS antenna ports or the two NRS antenna ports.

33. A computer-readable medium storing computer executable code for wireless communication at a base station, comprising code to:

transmit a broadcast or a multicast comprising an Narrowband Reference Signal (NRS) based on four NRS antenna ports or two NRS antenna ports; and

transmit an indication regarding whether the NRS is transmitted based on the four NRS antenna ports or the two NRS antenna ports.

34. An apparatus for wireless communication at a base station, comprising:
means for transmitting a Narrowband Reference Signal (NRS) according to four-port NRS configuration, and
means for mapping symbols of a Narrowband Physical Downlink Data Channel (NPDSCH) to four NRS antenna ports; and
means for transmitting multiple repetitions of the NPDSCH with the four NRS antenna ports, wherein a mapping of symbols for the NPDSCH is switched between antenna ports for different repetitions of the NPDSCH.

35. An apparatus for wireless communication at a base station, comprising:
a memory; and
at least one processor coupled to the memory and configured to:
transmit a Narrowband Reference Signal (NRS) according to four-port NRS configuration, and
map symbols of a Narrowband Physical Downlink Data Channel (NPDSCH) to four NRS antenna ports; and
transmit multiple repetitions of the NPDSCH with the four NRS antenna ports, wherein a mapping of symbols for the NPDSCH is switched between antenna ports for different repetitions of the NPDSCH.

36. A computer-readable medium storing computer executable code for wireless communication at a base station, comprising code to:
transmit a Narrowband Reference Signal (NRS) according to four-port NRS configuration, and
map symbols of a Narrowband Physical Downlink Data Channel (NPDSCH) to four NRS antenna ports; and

transmit multiple repetitions of the NPDSCH with the four NRS antenna ports, wherein a mapping of symbols for the NPDSCH is switched between antenna ports for different repetitions of the NPDSCH.

37. A method of wireless communication at a user equipment (UE), comprising:
determining whether a base station transmits a Narrowband Reference Signal (NRS) comprising a two-port NRS configuration or a four-port NRS configuration based on at least one of a carrier, a Narrowband Physical Downlink Control Channel (NPDCCH), a Narrowband Physical Downlink Data Channel (NPDSCH), a subframe configuration, a Narrowband Positioning Reference Signal (NPRS) pattern, or an indication from the base station; and
receiving the NRS according to the determination.

38. The method of claim 37, wherein the determination is based on the carrier used to transmit the NRS.

39. The method of claim 38, wherein the UE determines that the four-port NRS configuration will be used to transmit the NRS when the carrier is a guardband carrier or a standalone carrier.

40. The method of claim 38, wherein the UE determines that the four-port NRS configuration will be used when the carrier is an inband carrier, wherein the four-port NRS configuration comprises an NRS port pattern based on a number of symbols used for a control channel.

41. The method of claim 38, wherein the UE determines that the two-port NRS configuration will be used when the carrier is an inband carrier, the method further comprising:

using two Cell Specific Reference Signal (CRS) ports with two NRS ports for four transmit antenna diversity.

42. The method of claim 37, wherein receiving the NRS comprises receiving the NRS according to the four-port NRS configuration in at least a first subframe and receiving the NRS according to the two-port NRS configuration in at least a second subframe.

43. The method of claim 42, wherein the second subframe in which the NRS is received according to the two-port NRS configuration comprises at least one of a Time Division Duplex (TDD) special subframe, a subframe having a Narrowband Positioning Reference Signal (NPRS) configured with a Part B pattern, or an invalid subframe configured as invalid for four-port NRS transmission.

44. The method of claim 42, wherein the UE uses a first power ratio to receive the NRS and a data channel in the first subframe and a second power ratio to receive the NRS and the data channel in the second subframe.

45. The method of claim 37, wherein the determination between the two-port NRS configuration and the four-port NRS configuration is performed in common for each subframe comprising a repetition of the data,

wherein when the two-port NRS configuration is determined for at least one subframe comprising the repetition of the data, all subframes comprising repetitions of the data are received based on the two-port NRS configuration.

46. The method of claim 37, wherein the determination between the two-port NRS configuration and the four-port NRS configuration is performed separately for each repetition of the data.

47. The method of claim 46, wherein a first repetition of the data is received with the two-port NRS configuration and a second repetition of the data is received with the four-port NRS configuration.

48. The method of claim 37, wherein the determination between the two-port NRS configuration and the four-port NRS configuration is performed in uniformly for each block of subframes comprising at least a portion of repetitions of the data, wherein the block of subframes corresponds to a cyclic repetition pattern.

49. The method of claim 37, wherein the received NRS comprises at least one of a broadcast or a multicast.

50. The method of claim 49, further comprising:
receiving the indication regarding whether the NRS is transmitted according to the two-port NRS configuration or the four-port NRS configuration, wherein the determination is based on the indication.

51. The method of claim 50, wherein the indication comprises system information received from the base station.

52. The method of claim 37, wherein the NRS is received according to the four-port NRS configuration, and wherein a mapping of data symbols and antenna ports differs for different subframes in a subframe repetition.

53. The method of claim 52, wherein, in a first repetition transmission, a first set of modulated symbols are mapped to a first NRS port and a second NRS port and a second set of modulated symbols are mapped to a third NRS port and a fourth NRS port, and
wherein, in a second repetition transmission, the first set of modulated symbols are mapped to the third NRS port and the fourth NRS port and the second set of modulated symbols are mapped to the first NRS port and the second NRS port.

54. An apparatus for wireless communication at a user equipment, comprising:
means for determining whether a base station transmits a Narrowband Reference Signal (NRS) comprising a two-port NRS configuration or a four-port NRS configuration based on at least one of a carrier, a Narrowband Physical Downlink Control Channel (NPDCCH), a Narrowband Physical Downlink Data Channel (NPDSCH), a subframe configuration, a Narrowband Positioning Reference Signal (NPRS) pattern, or an indication from the base station; and
means for receiving the NRS according to the determination.

55. An apparatus for wireless communication at a user equipment, comprising:

a memory; and

at least one processor coupled to the memory and configured to:

determine whether a base station transmits a Narrowband Reference Signal (NRS) comprising a two-port NRS configuration or a four-port NRS configuration based on at least one of a carrier, a Narrowband Physical Downlink Control Channel (NPDCCH), a Narrowband Physical Downlink Data Channel (NPDSCH), a subframe configuration, a Narrowband Positioning Reference Signal (NPRS) pattern, or an indication from the base station; and

receive the NRS according to the determination.

56. A computer-readable medium storing computer executable code for wireless communication at a user equipment, comprising code to:

determine whether a base station transmits a Narrowband Reference Signal (NRS) comprising a two-port NRS configuration or a four-port NRS configuration based on at least one of a carrier, a Narrowband Physical Downlink Control Channel (NPDCCH), a Narrowband Physical Downlink Data Channel (NPDSCH), a subframe configuration, a Narrowband Positioning Reference Signal (NPRS) pattern, or an indication from the base station; and

receive the NRS according to the determination.

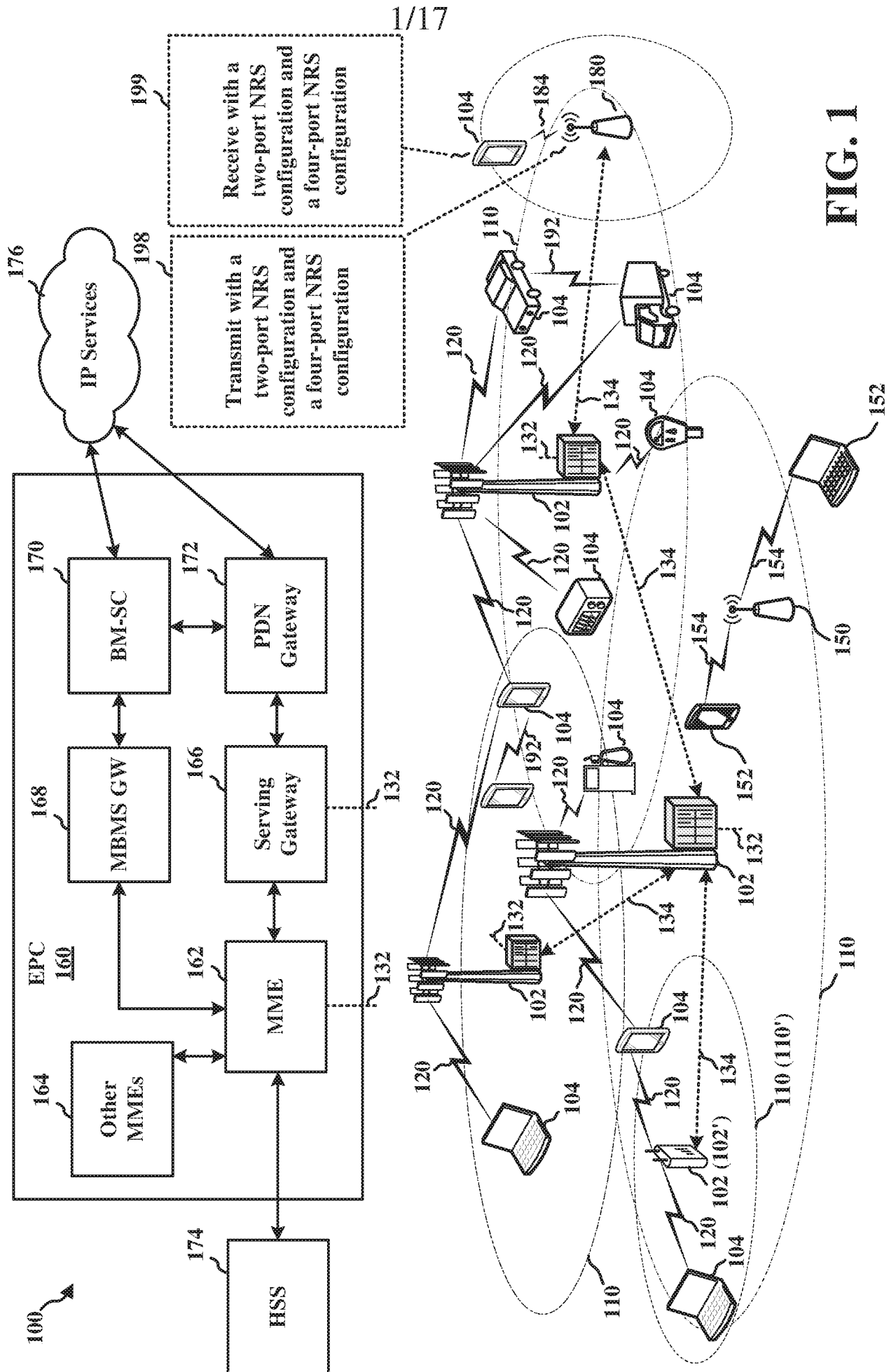
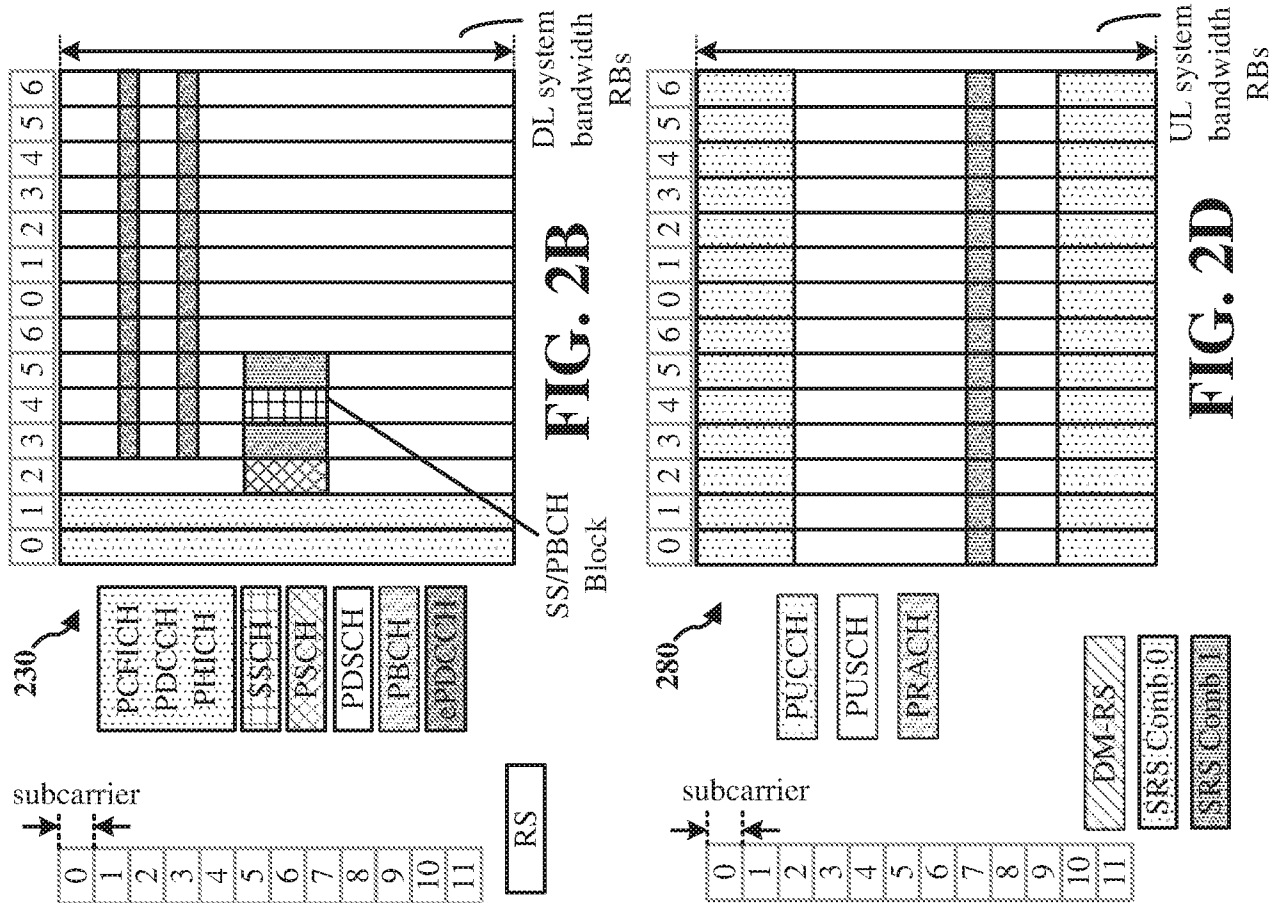
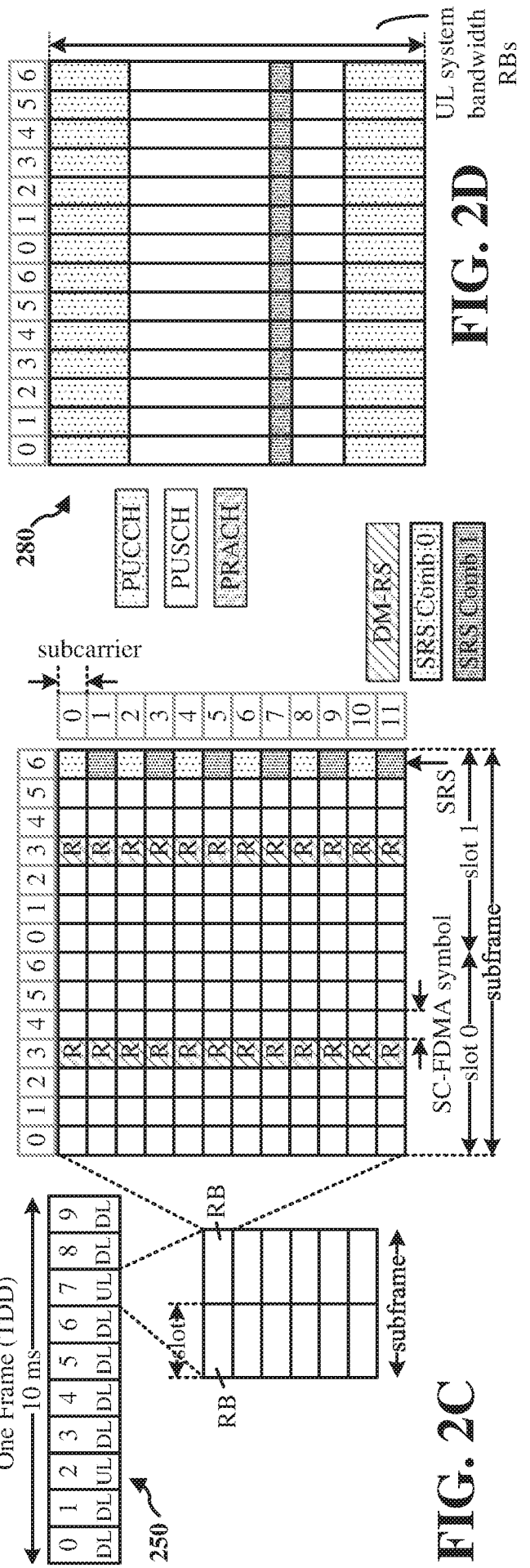
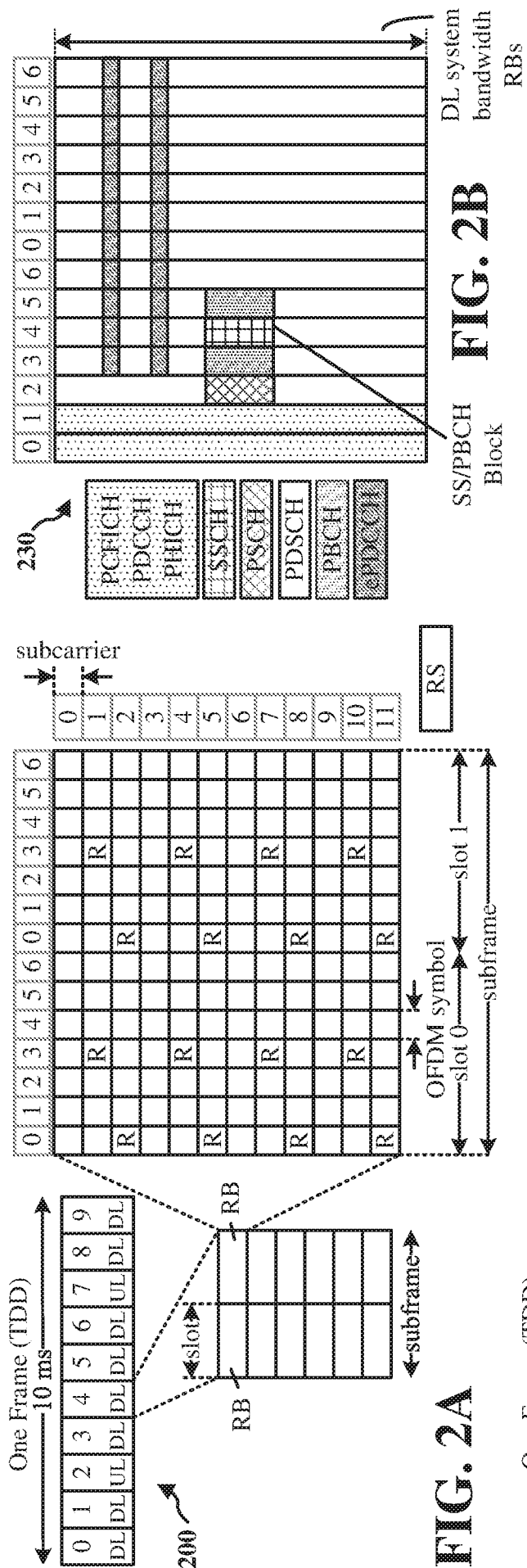


FIG. 1



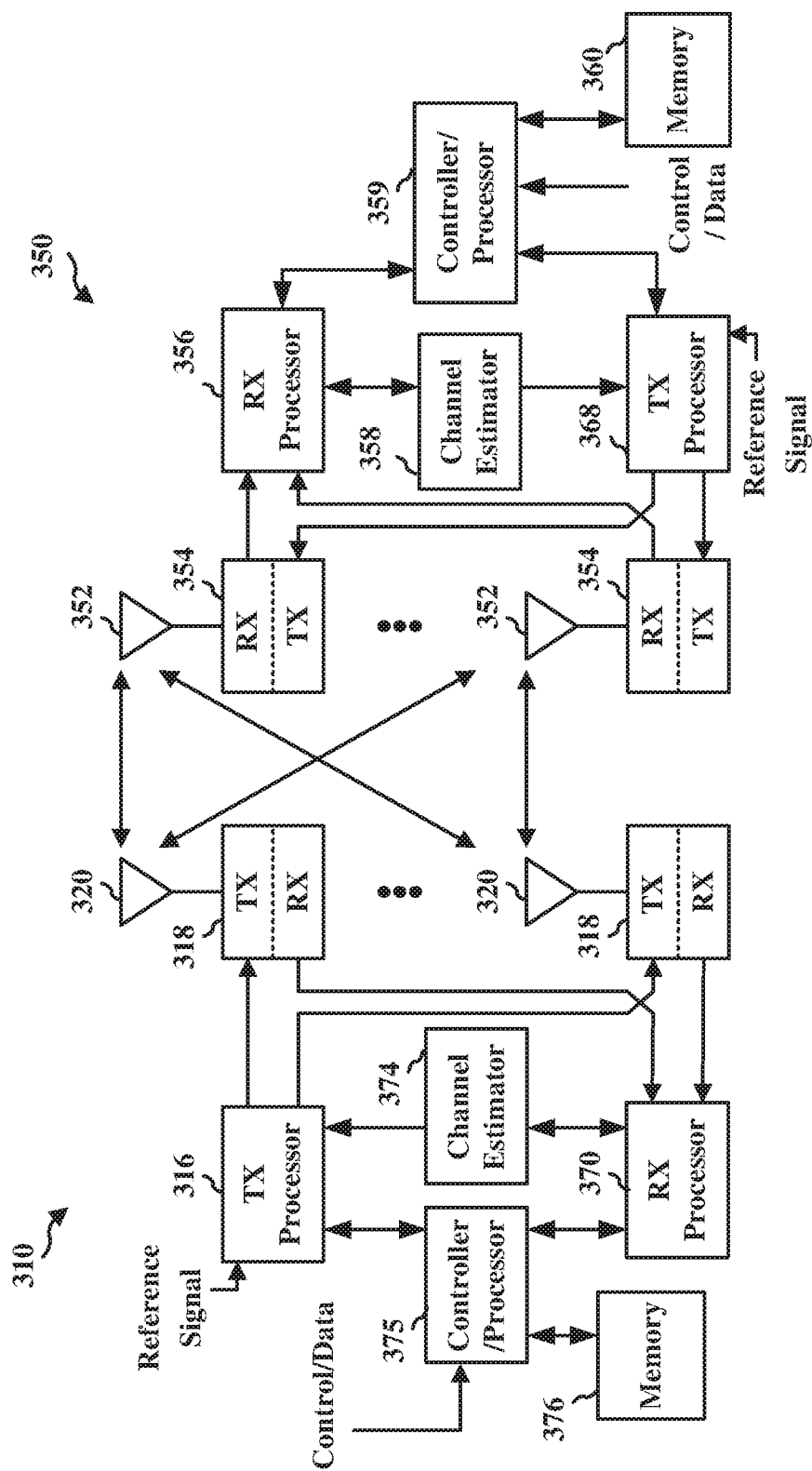


FIG. 3

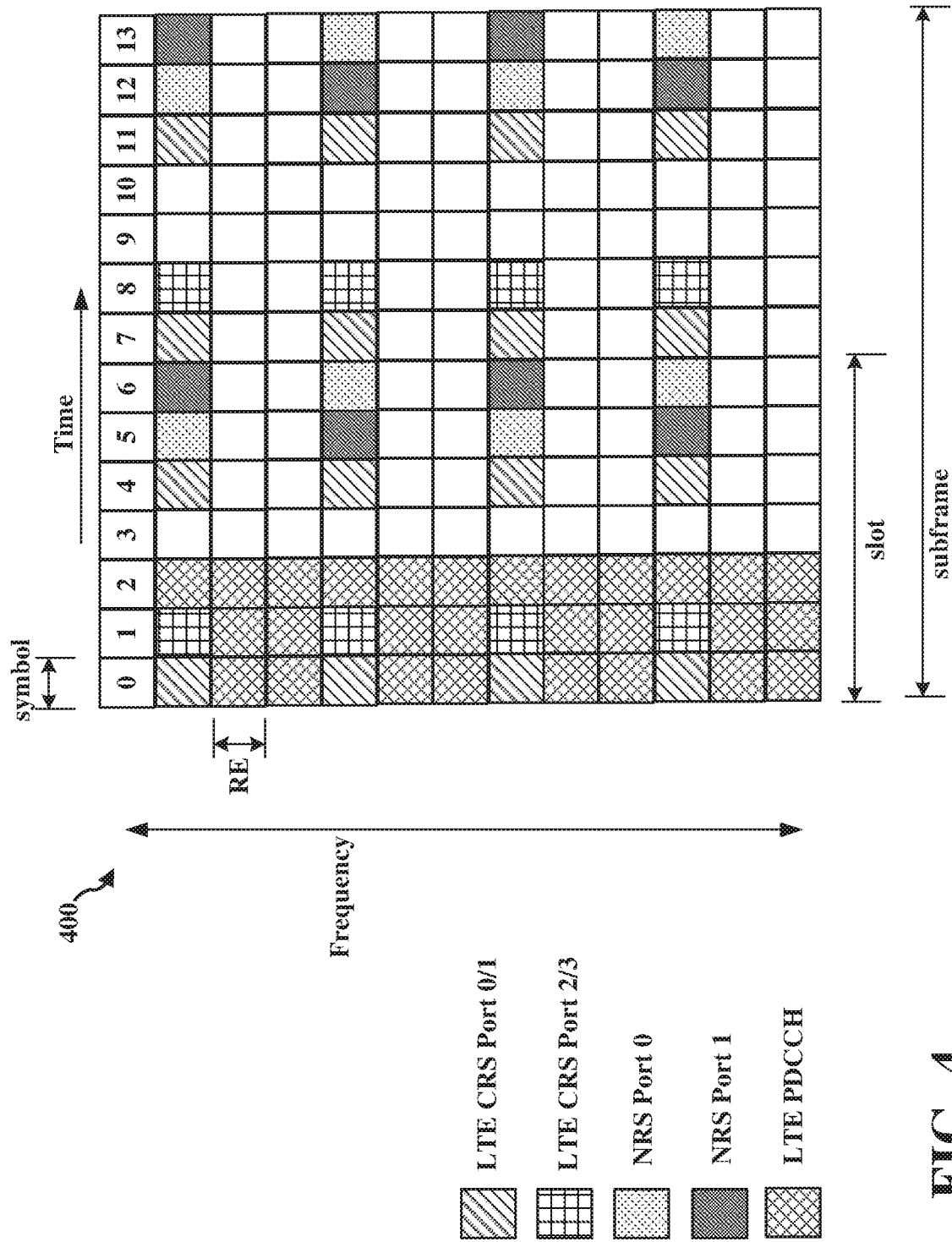


FIG. 4

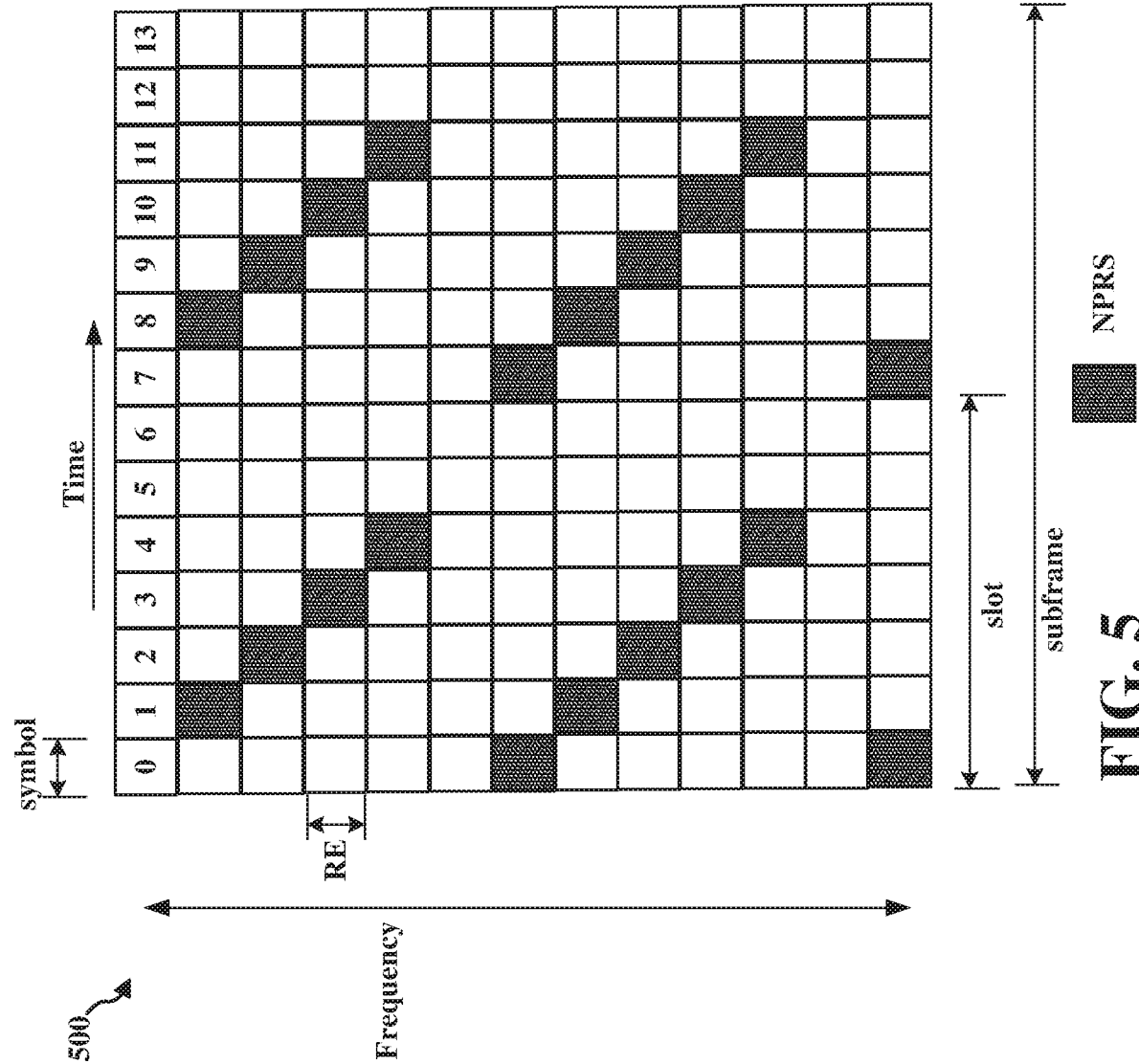


FIG. 5

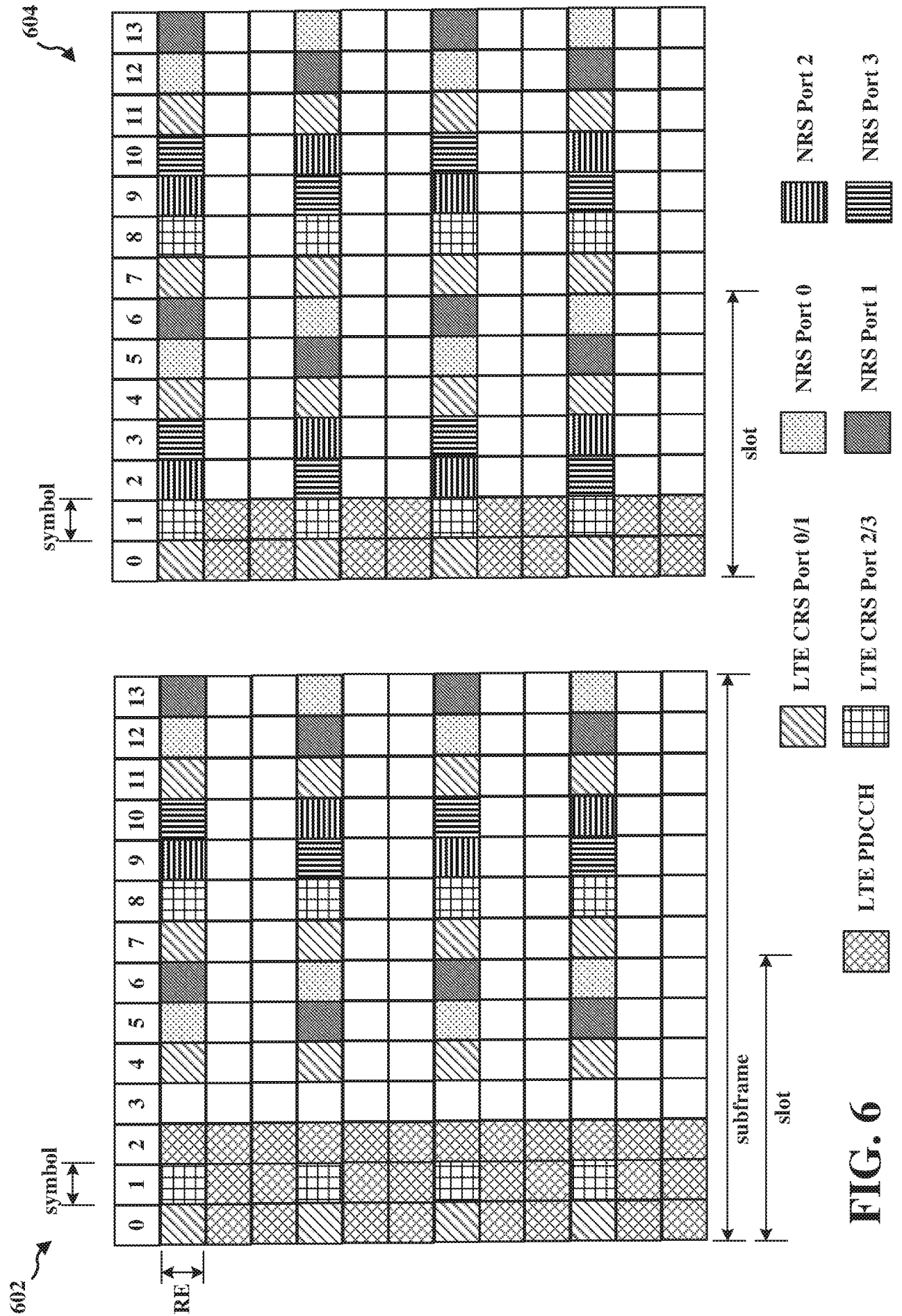


FIG. 6

700

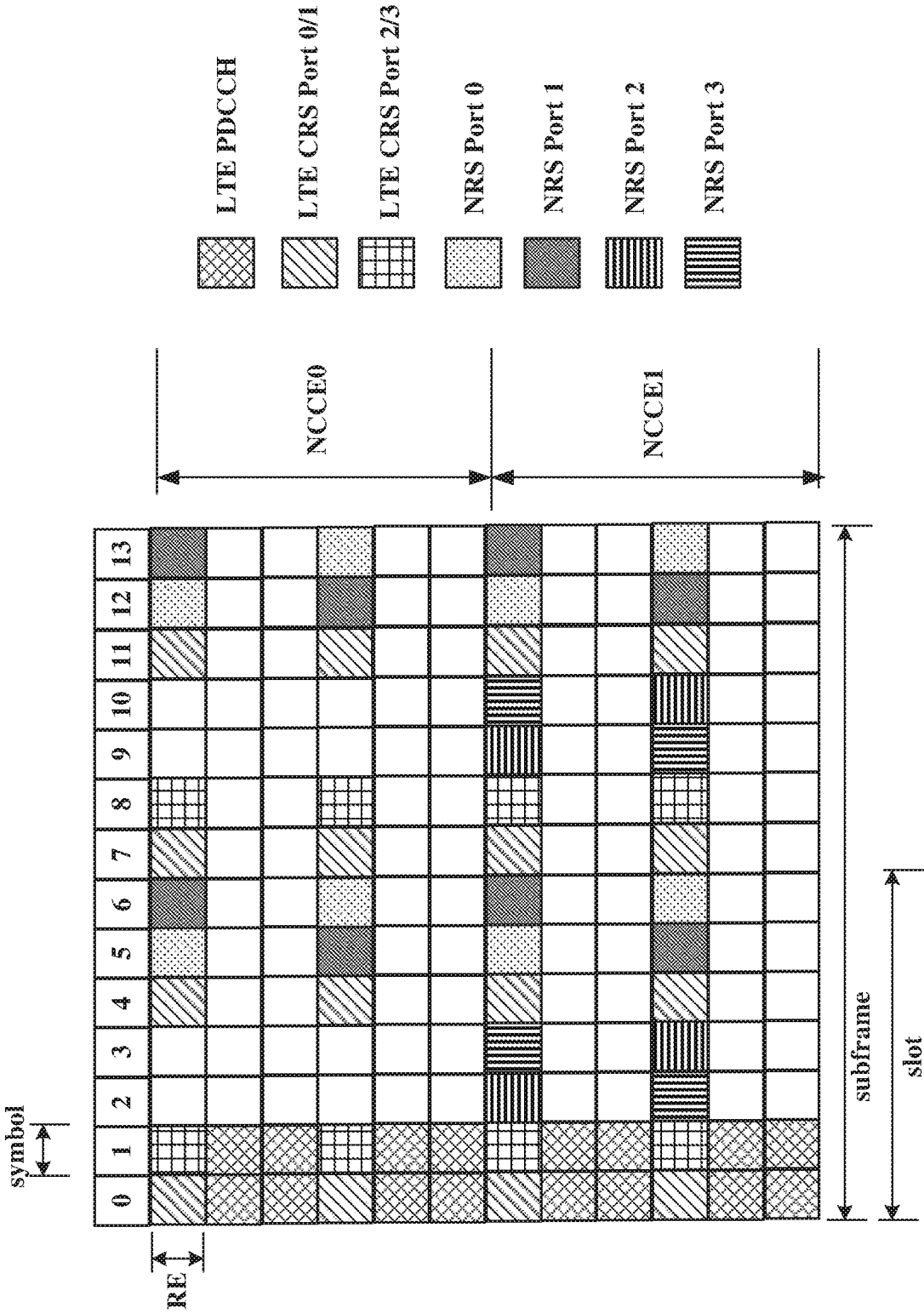


FIG. 7

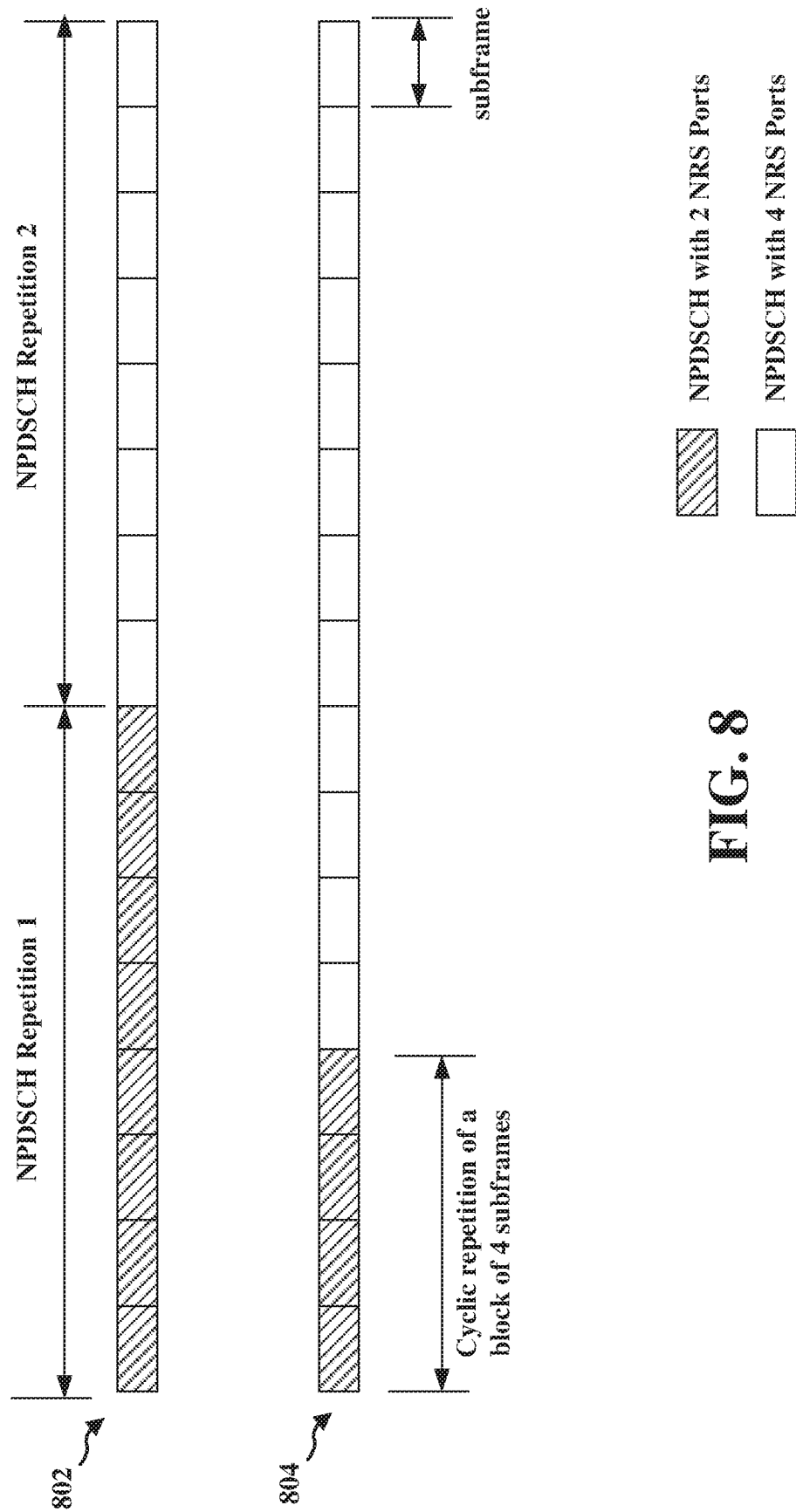


FIG. 8

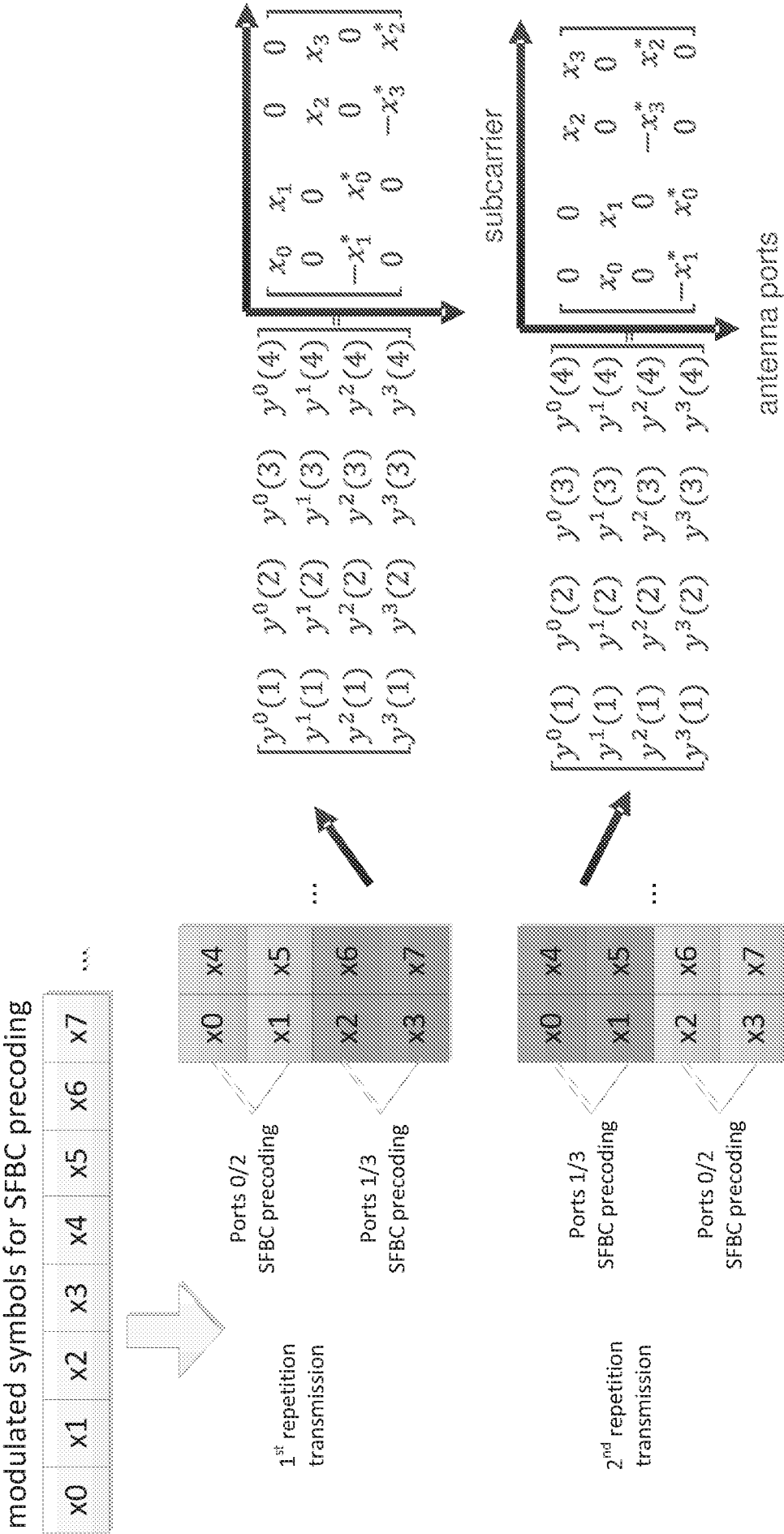


FIG. 9

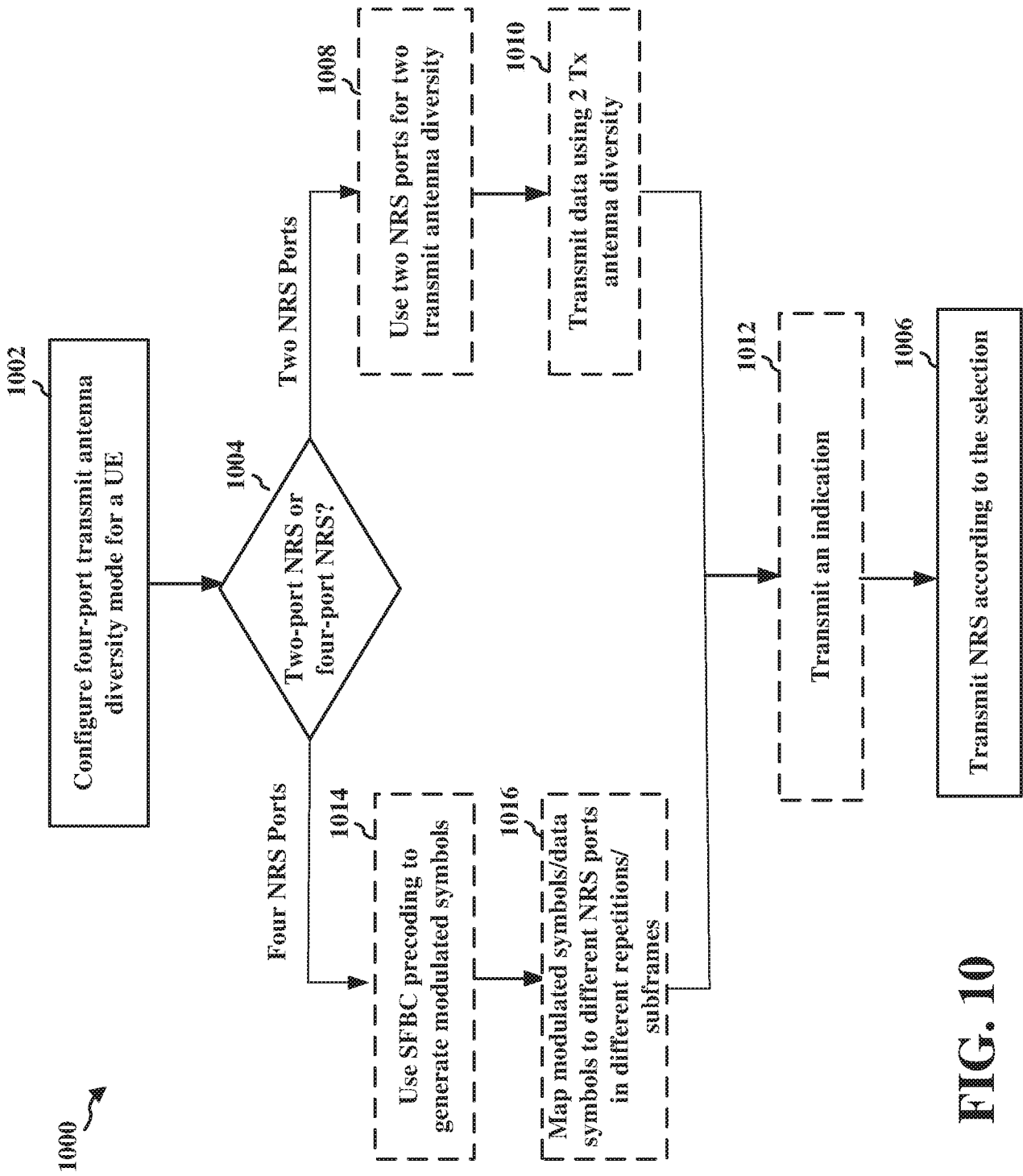


FIG. 10

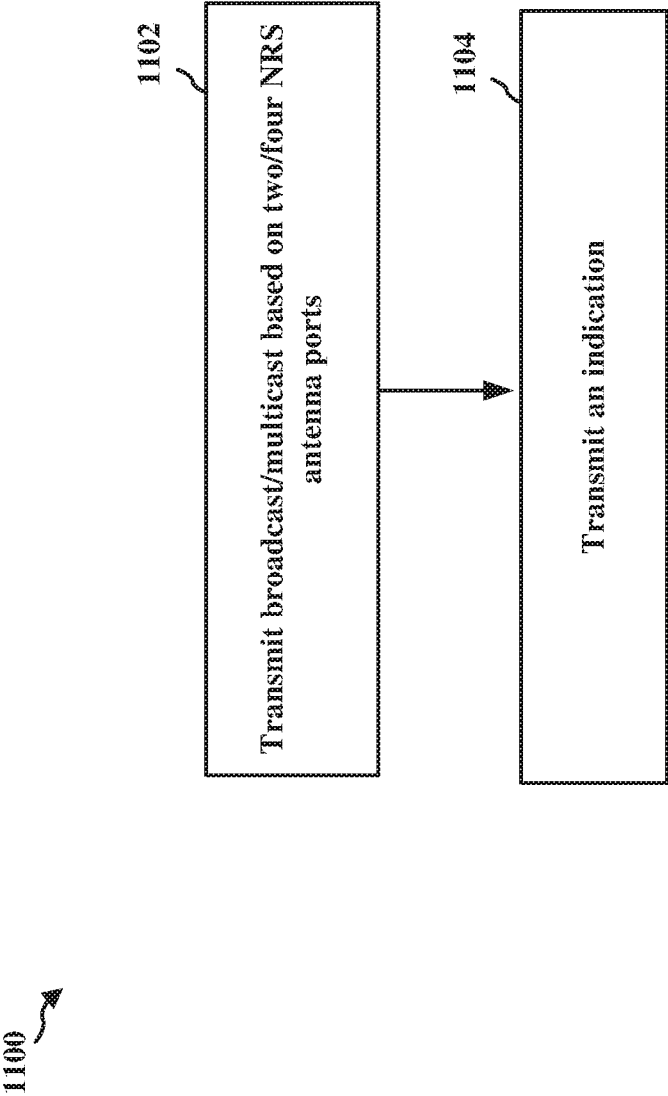


FIG. 11

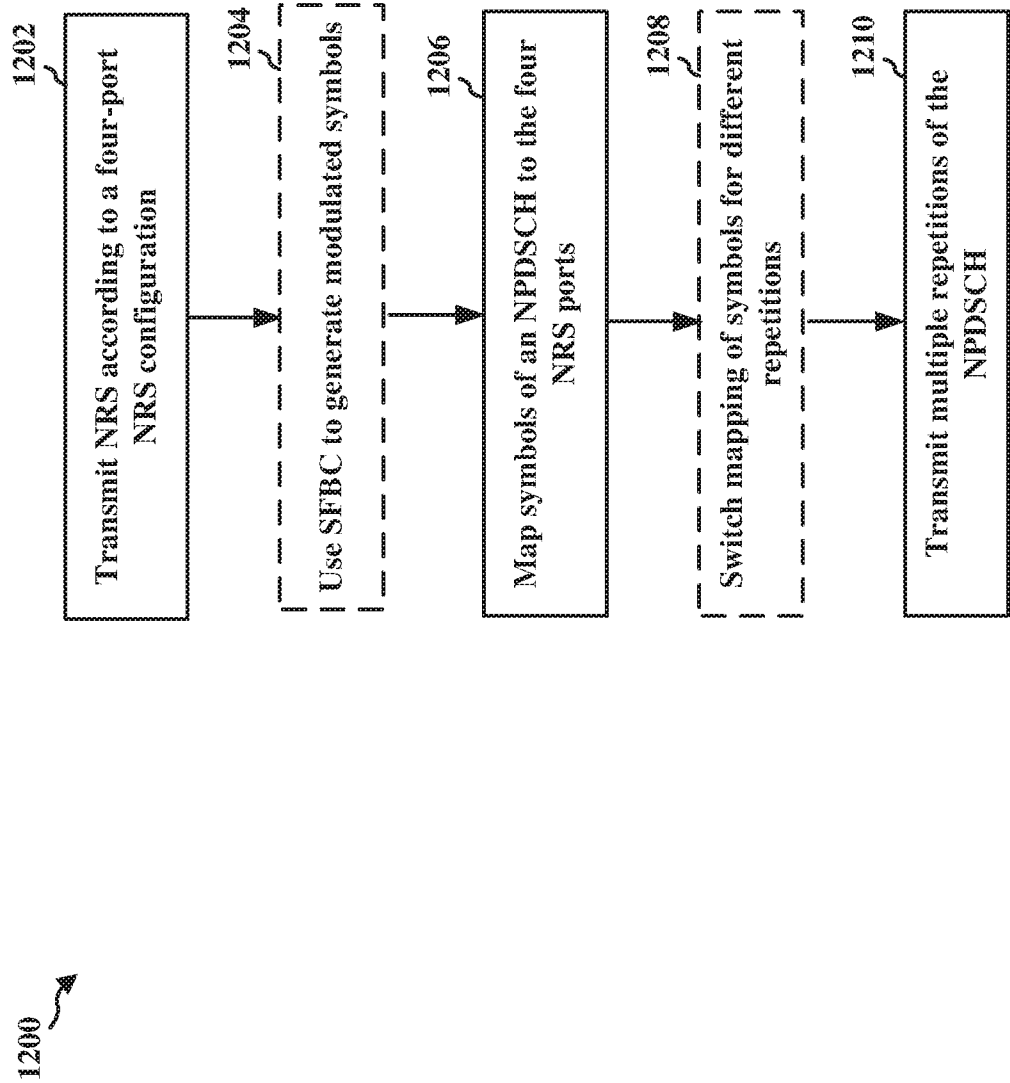


FIG. 12

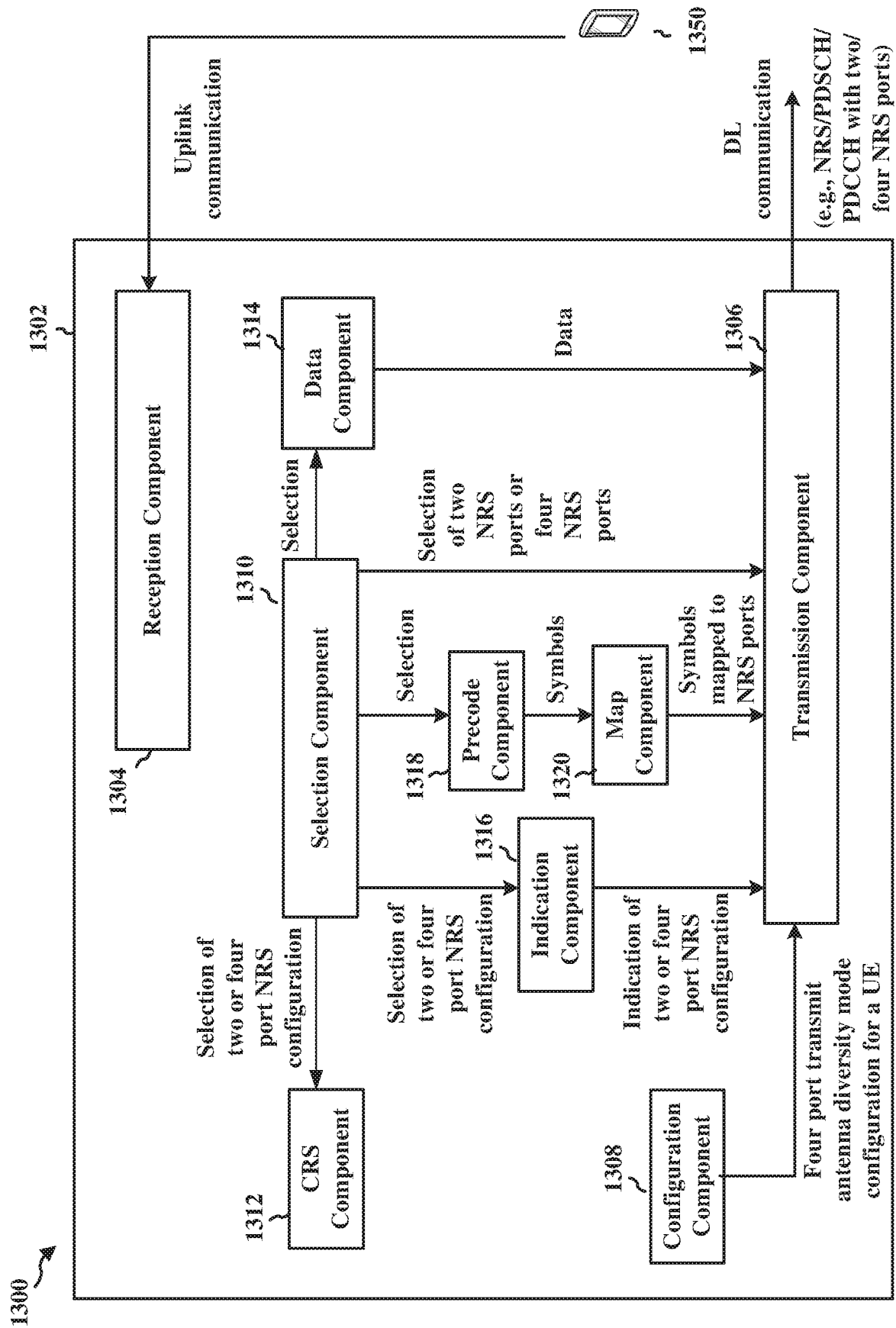


FIG. 13

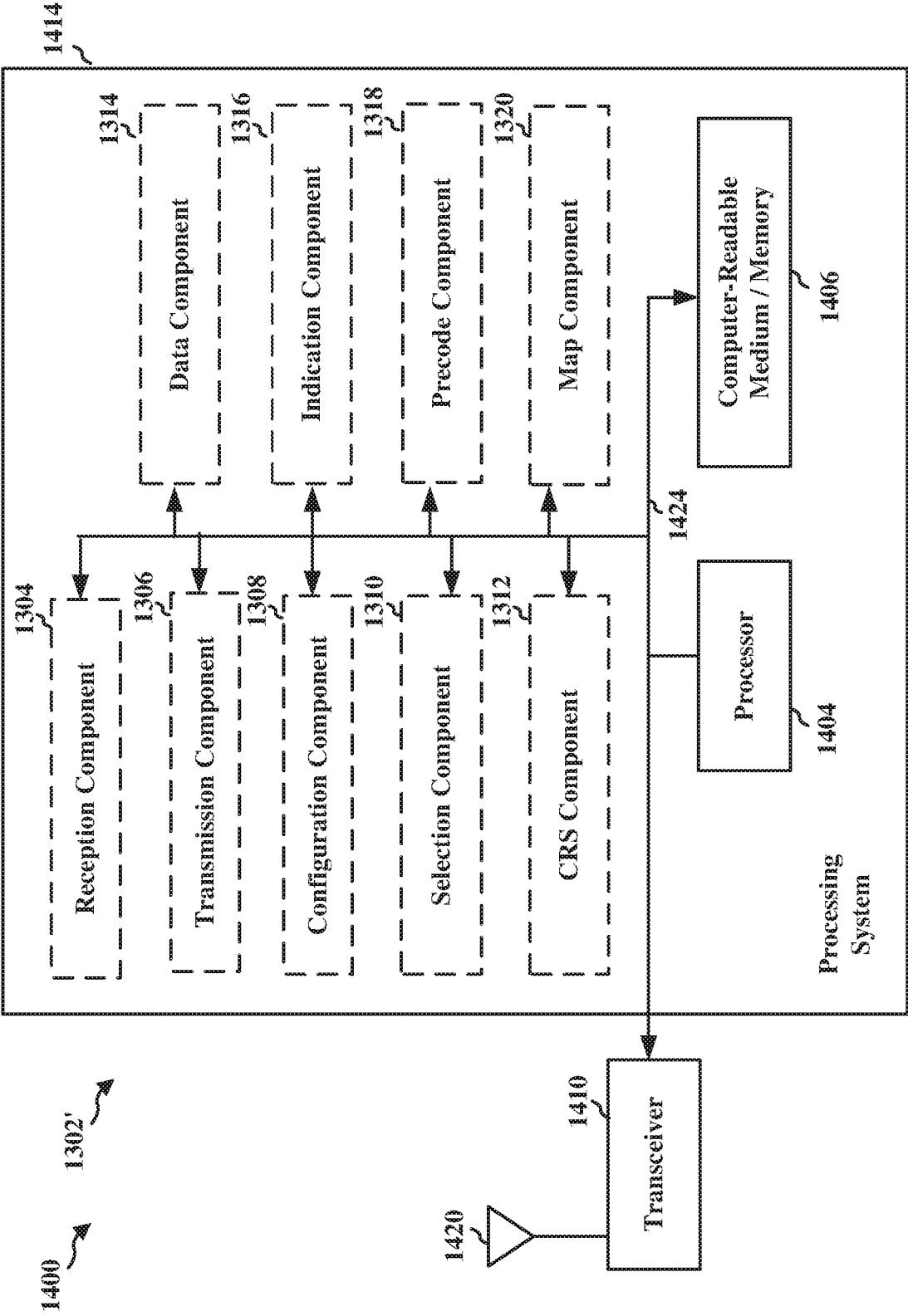


FIG. 14

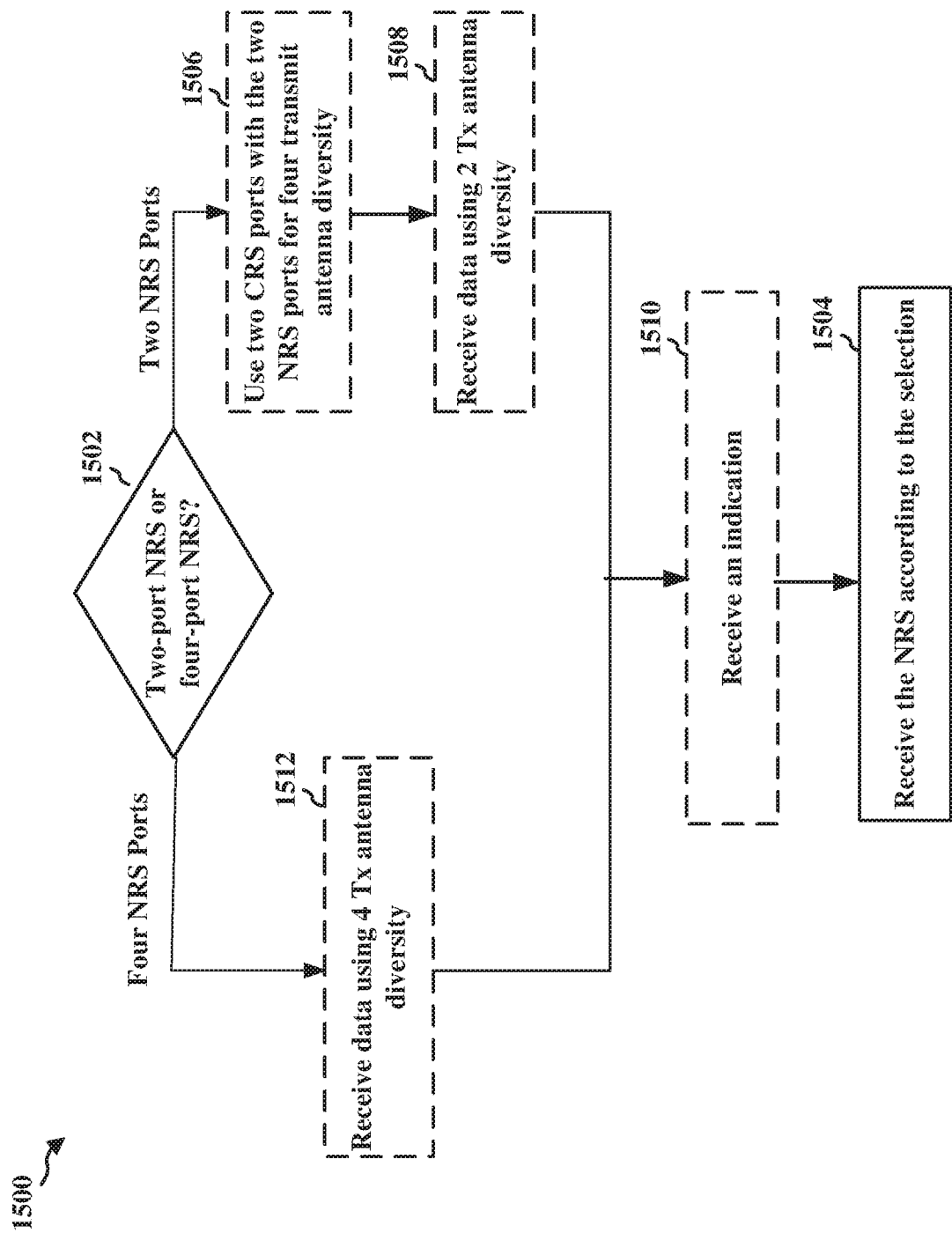


FIG. 15

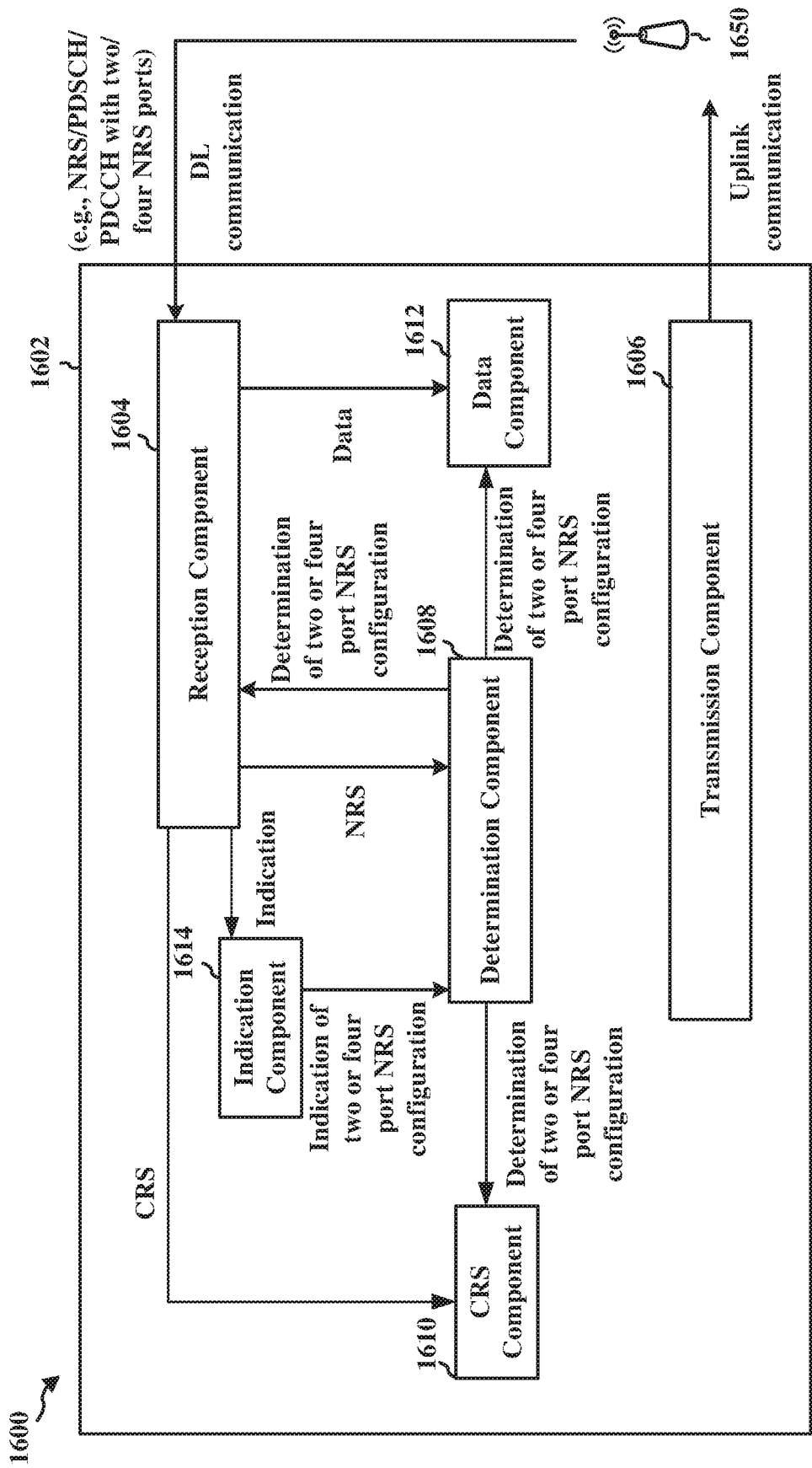


FIG. 16

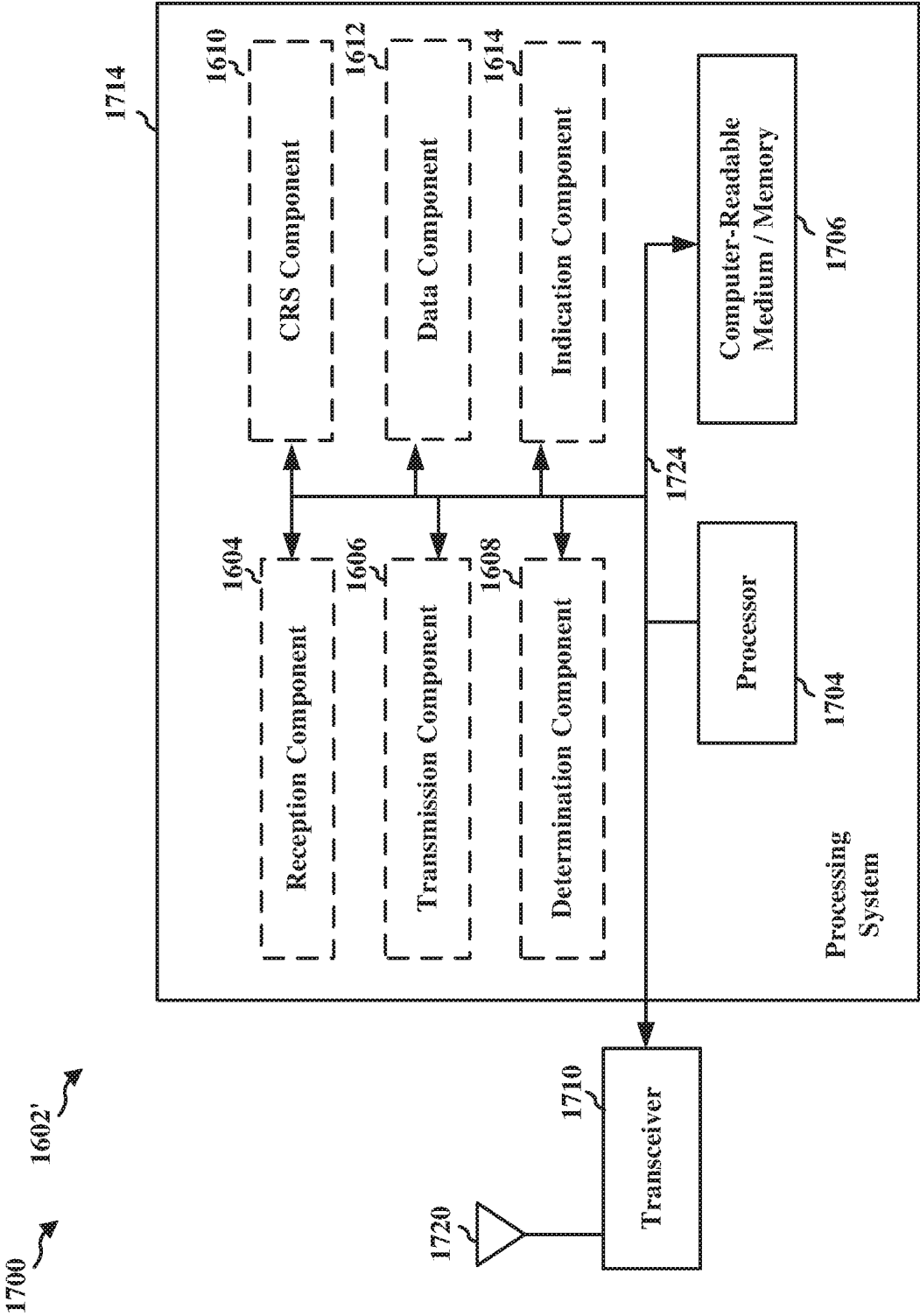


FIG. 17

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2018/074986

A. CLASSIFICATION OF SUBJECT MATTER

H04L 27/26(2006.01)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; H04W

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

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

CPRSABS;CNTXT;USTXT;EPTXT;WOTXT;VEN;3GPP:base station, Narrowband Reference Signal, NRS, two-port, four-port NRS, carrier, Narrowband Physical Downlink Control Channel, NPDCCH, Narrowband Physical Downlink Data Channel, NPDSCH, subframe, Narrowband Positioning Reference Signal, NPRS, pattern, indication

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2017273026 A1 (QUALCOMM INC.) 21 September 2017 (2017-09-21) the whole document	1-56
A	WO 2017069470 A1 (LG ELECTRONICS INC.) 27 April 2017 (2017-04-27) the whole document	1-56
A	SG 98435 A1 (NANYANG POLYTECHNIC) 19 September 2003 (2003-09-19) the whole document	1-56
A	KR 20120062546 A (KOREA ELECTRONICS TELECOMM) 14 June 2012 (2012-06-14) the whole document	1-56
A	JP 2015084466 A (SONY CORP.) 30 April 2015 (2015-04-30) the whole document	1-56

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

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

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

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

“&” document member of the same patent family

Date of the actual completion of the international search

10 October 2018

Date of mailing of the international search report

24 October 2018

Name and mailing address of the ISA/CN

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2018/074986

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
US	2017273026	A1	21 September 2017	WO	2017160513	A1	21 September 2017
WO	2017069470	A1	27 April 2017	EP	3367602	A1	29 August 2018
				CN	108352953	A	31 July 2018
				KR	20180057631	A	30 May 2018
				WO	2017069474	A1	27 April 2017
				CN	108141341	A	08 June 2018
				KR	20180057635	A	30 May 2018
				EP	3367601	A1	29 August 2018
SG	98435	A1	19 September 2003	None			
KR	20120062546	A	14 June 2012	None			
JP	2015084466	A	30 April 2015	US	2015117656	A1	30 April 2015
				US	9595998	B2	14 March 2017