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(54) Title: FIFTH GENERATION (5G) UPLINK CONTROL INFORMATION (xUCI) REPORT

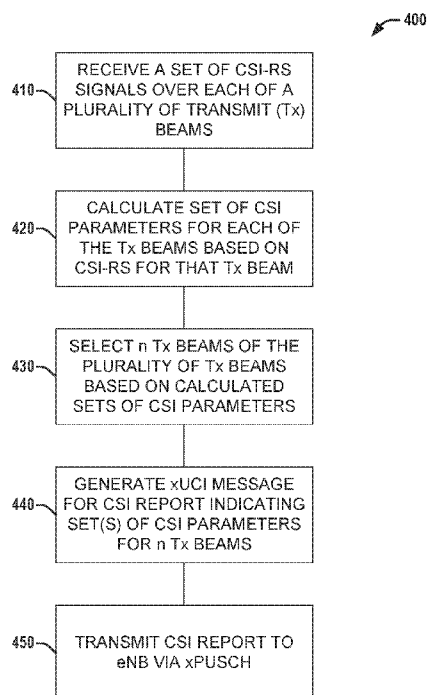


FIG. 4

(57) Abstract: Techniques for generation of fifth generation (5G) Uplink Control Information (xUCI) messages are discussed. One example apparatus comprises a processor configured to process, for each of a plurality of transmit (Tx) beams, a set of channel state information (CSI) reference signal (CSI-RS) signals received over that Tx beam; determine, for each Tx beam, an associated distinct set of CSI parameters that comprises one or more channel quality indicators (CQIs), one or more precoding matrix indicators (PMIs), and a rank indicator (RI) for that Tx beam; generate a CSI report indicating a first set of CSI parameters associated with a first Tx beam and indicating a second set of CSI parameters associated with a second Tx beam; generate a xUCI message comprising the CSI report; and output the xUCI message for transmission to an Evolved NodeB (eNB).



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FIFTH GENERATION (5G) UPLINK CONTROL INFORMATION (xUCI) REPORT**REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims the benefit of U.S. Provisional Application No. 62/297,414 filed February 19, 2016, entitled "UPLINK CONTROL INFORMATION REPORT", the contents of which are herein incorporated by reference in their entirety.

FIELD

[0002] The present disclosure relates to wireless technology, and more specifically to techniques for communicating Uplink Control Information (UCI) in fifth generation (5G) systems.

BACKGROUND

[0003] Uplink Control Information (UCI) transmitted by User Equipments (UEs) in conventional Long Term Evolution (LTE) systems can be transmitted via the Physical Uplink Control Channel (PUCCH) or Physical Uplink Shared Channel (PUSCH) and can carry scheduling requests, Hybrid Automatic Repeat Request (HARQ) Acknowledgment (ACK) feedback, and/or Channel State Information (CSI) feedback.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] **FIG. 1** is a block diagram illustrating an example user equipment (UE) useable in connection with various aspects described herein.

[0005] **FIG. 2** is a block diagram illustrating a system that facilitates generation of a fifth generation (5G) Uplink Control Information (xUCI) report by a user equipment (UE) according to various aspects described herein.

[0006] **FIG. 3** is a block diagram illustrating a system that facilitates reception of a xUCI message comprising a Channel State Information (CSI) report at a base station according to various aspects described herein.

[0007] **FIG. 4** is a flow diagram illustrating an example method that facilitates generation of a CSI report based on CSI Reference Signal (CSI-RS) signals received via a plurality of transmit (Tx) beams at a UE according to various aspects described herein.

[0008] FIG. 5 is a flow diagram illustrating an example method that facilitates reception of a xUCI message comprising a CSI report via a 5G Physical Uplink Shared Channel (xPUSCH) by a base station according to various aspects described herein.

DETAILED DESCRIPTION

[0009] The present disclosure will now be described with reference to the attached drawing figures, wherein like reference numerals are used to refer to like elements throughout, and wherein the illustrated structures and devices are not necessarily drawn to scale. As utilized herein, terms “component,” “system,” “interface,” and the like are intended to refer to a computer-related entity, hardware, software (e.g., in execution), and/or firmware. For example, a component can be a processor (e.g., a microprocessor, a controller, or other processing device), a process running on a processor, a controller, an object, an executable, a program, a storage device, a computer, a tablet PC and/or a user equipment (e.g., mobile phone, etc.) with a processing device. By way of illustration, an application running on a server and the server can also be a component. One or more components can reside within a process, and a component can be localized on one computer and/or distributed between two or more computers. A set of elements or a set of other components can be described herein, in which the term “set” can be interpreted as “one or more.”

[0010] Further, these components can execute from various computer readable storage media having various data structures stored thereon such as with a module, for example. The components can communicate via local and/or remote processes such as in accordance with a signal having one or more data packets (e.g., data from one component interacting with another component in a local system, distributed system, and/or across a network, such as, the Internet, a local area network, a wide area network, or similar network with other systems via the signal).

[0011] As another example, a component can be an apparatus with specific functionality provided by mechanical parts operated by electric or electronic circuitry, in which the electric or electronic circuitry can be operated by a software application or a firmware application executed by one or more processors. The one or more processors can be internal or external to the apparatus and can execute at least a part of the software or firmware application. As yet another example, a component can be an apparatus that provides specific functionality through electronic components without mechanical parts; the electronic components can include one or more processors

therein to execute software and/or firmware that confer(s), at least in part, the functionality of the electronic components.

[0012] Use of the word exemplary is intended to present concepts in a concrete fashion. As used in this application, the term “or” is intended to mean an inclusive “or” rather than an exclusive “or”. That is, unless specified otherwise, or clear from context, “X employs A or B” is intended to mean any of the natural inclusive permutations. That is, if X employs A; X employs B; or X employs both A and B, then “X employs A or B” is satisfied under any of the foregoing instances. In addition, the articles “a” and “an” as used in this application and the appended claims should generally be construed to mean “one or more” unless specified otherwise or clear from context to be directed to a singular form. Furthermore, to the extent that the terms “including”, “includes”, “having”, “has”, “with”, or variants thereof are used in either the detailed description and the claims, such terms are intended to be inclusive in a manner similar to the term “comprising.”

[0013] As used herein, the term “circuitry” may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some embodiments, the circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some embodiments, circuitry may include logic, at least partially operable in hardware.

[0014] Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. **FIG. 1** illustrates, for one embodiment, example components of a User Equipment (UE) device 100. In some embodiments, the UE device 100 may include application circuitry 102, baseband circuitry 104, Radio Frequency (RF) circuitry 106, front-end module (FEM) circuitry 108 and one or more antennas 110, coupled together at least as shown.

[0015] The application circuitry 102 may include one or more application processors. For example, the application circuitry 102 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with and/or may include memory/storage and may be configured to execute instructions stored in

the memory/storage to enable various applications and/or operating systems to run on the system.

[0016] The baseband circuitry 104 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 104 may include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of the RF circuitry 106 and to generate baseband signals for a transmit signal path of the RF circuitry 106. Baseband processing circuitry 104 may interface with the application circuitry 102 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 106. For example, in some embodiments, the baseband circuitry 104 may include a second generation (2G) baseband processor 104a, third generation (3G) baseband processor 104b, fourth generation (4G) baseband processor 104c, and/or other baseband processor(s) 104d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 104 (e.g., one or more of baseband processors 104a-d) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 106. The radio control functions may include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 104 may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 104 may include convolution, tail-biting convolution, turbo, Viterbi, and/or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

[0017] In some embodiments, the baseband circuitry 104 may include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access network (EUTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 104e of the baseband circuitry 104 may be configured to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some embodiments, the baseband circuitry may include one or more audio digital signal

processor(s) (DSP) 104f. The audio DSP(s) 104f may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 104 and the application circuitry 102 may be implemented together such as, for example, on a system on a chip (SOC).

[0018] In some embodiments, the baseband circuitry 104 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 104 may support communication with an evolved universal terrestrial radio access network (EUTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 104 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0019] RF circuitry 106 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 106 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 106 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 108 and provide baseband signals to the baseband circuitry 104. RF circuitry 106 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 104 and provide RF output signals to the FEM circuitry 108 for transmission.

[0020] In some embodiments, the RF circuitry 106 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 106 may include mixer circuitry 106a, amplifier circuitry 106b and filter circuitry 106c. The transmit signal path of the RF circuitry 106 may include filter circuitry 106c and mixer circuitry 106a. RF circuitry 106 may also include synthesizer circuitry 106d for synthesizing a frequency for use by the mixer circuitry 106a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 106a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 108 based on the synthesized frequency provided by synthesizer circuitry 106d. The amplifier circuitry 106b may be configured to amplify the down-converted signals and the filter circuitry

106c may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals may be provided to the baseband circuitry 104 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 106a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0021] In some embodiments, the mixer circuitry 106a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 106d to generate RF output signals for the FEM circuitry 108. The baseband signals may be provided by the baseband circuitry 104 and may be filtered by filter circuitry 106c. The filter circuitry 106c may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

[0022] In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and/or upconversion respectively. In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a of the transmit signal path may be configured for super-heterodyne operation.

[0023] In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 106 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 104 may include a digital baseband interface to communicate with the RF circuitry 106.

[0024] In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[0025] In some embodiments, the synthesizer circuitry 106d may be a fractional-N synthesizer or a fractional $N/N+1$ synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 106d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0026] The synthesizer circuitry 106d may be configured to synthesize an output frequency for use by the mixer circuitry 106a of the RF circuitry 106 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 106d may be a fractional $N/N+1$ synthesizer.

[0027] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 104 or the applications processor 102 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 102.

[0028] Synthesizer circuitry 106d of the RF circuitry 106 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or $N+1$ (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements may be configured to break a VCO period up into N_d equal packets of phase, where N_d is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[0029] In some embodiments, synthesizer circuitry 106d may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency may be a LO frequency (fLO). In some embodiments, the RF circuitry 106 may include an IQ/polar converter.

[0030] FEM circuitry 108 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 110, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 106 for further processing. FEM circuitry 108 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 106 for transmission by one or more of the one or more antennas 110.

[0031] In some embodiments, the FEM circuitry 108 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry may include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 106). The transmit signal path of the FEM circuitry 108 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 106), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 110).

[0032] In some embodiments, the UE device 100 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface.

[0033] Additionally, although the above example discussion of device 100 is in the context of a UE device, in various aspects, a similar device can be employed in connection with a base station (BS) such as an Evolved NodeB (eNB).

[0034] Massive Multiple Input and Multiple Output (MIMO) techniques can be employed in 5G systems to enhance coverage and improve spectrum efficiency. In a massive MIMO system, the eNB can maintain a number of Transmitting (Tx) and Receiving (Rx) beams. A UE can report the Channel State Information (CSI) as well as the beam information. The beam information can contain the Tx beam index and the Beam Reference Signal Receiving Power (BRS-RP).

[0035] The 5G Uplink Control Information (xUCI) can be reported via the 5G Physical Uplink Shared Channel (xPUSCH) if the uplink grant is received. In various embodiments, techniques can be employed to facilitate reporting the xUCI via the xPUSCH. Aspects described herein can facilitate xUCI reporting and various aspects such as xUCI report context, mechanism(s) for beam information reporting, etc.

[0036] Referring to **FIG. 2**, illustrated is a block diagram of a system 200 that facilitates generation of a fifth generation (5G) Uplink Control Information (xUCI) report by a user equipment (UE) according to various aspects described herein. System 200 can include a processor 210 (e.g., a baseband processor such as one of the baseband processors discussed in connection with FIG. 1), receiver circuitry 220, transmitter circuitry 230, and a memory 240 (which can comprise any of a variety of storage mediums and can store instructions and/or data associated with one or more of processor 210, receiver circuitry 220, or transmitter circuitry 230). In various aspects, system 200 can be included within a user equipment (UE). As described in greater detail below, system 200 can facilitate reception of Channel State Information (CSI) Reference Signal (CSI-RS) signals via one or more transmit (Tx) beams and generation of a xUCI message based on the received CSI-RS signals.

[0037] Processor 210 can process CSI-RS signals received by receiver circuitry 220. CSI-RS signals received by receiver circuitry can comprise a distinct set of CSI-RS signals for each of a plurality of Tx beams. Based on the CSI-RS signals received over each Tx beam of the plurality of Tx beams, processor 210 can determine a set of CSI parameters associated with that beam. Each set of CSI parameters determined for a Tx beam by processor 210 can comprise one or more of: at least one Channel Quality Indicator (CQI) associated with that Tx beam (e.g., a wideband CQI and/or one or more subband differential CQIs, etc.), at least one Precoding Matrix Indicator (PMI) associated with that Tx beam (e.g., a wideband PMI and/or one or more subband differential PMIs, etc.), or a Rank Indicator (RI) for that beam.

[0038] Based on the distinct set(s) of CSI parameters for n (e.g., $n=2$) Tx beams (e.g., the n best Tx beams based on the measured sets of CSI parameters), processor 210 can generate a CSI report (e.g., as a set of CSI bits) that indicates the n distinct set(s) of CSI parameters for each of the n Tx beams. Depending on the specific CSI report, what those distinct sets of CSI parameters comprise may vary. Examples of CSI reports discussed herein include example wideband CQI reports and subband CQI reports configured via higher layer signaling, such as higher layer configured subband CQI reports and higher layer configured subband CQI and subband PMI reports.

[0039] Additionally, in some aspects, processor 210 can process a distinct set of beam reference signals (BRS) received by receiver circuitry 220 over each Tx beam of at least a subset of the Tx beams. Based on the set of BRS signals received over a given Tx beam, processor 210 can determine a BRS Received Power (BRS-RP)

associated with that Tx beam. Depending on the type of received signal or message, processing (e.g., by processor 210, processor 310, etc.) can comprise one or more of: identifying physical resources associated with the signal/message, detecting the signal/message, resource element group deinterleaving, demodulation, descrambling, and/or decoding.

[0040] Processor 210 can generate a xUCI message that can comprise the CSI report (e.g., that indicates the n distinct set(s) of CSI parameters for the n Tx beams). In some aspects (e.g., when the xUCI message is to be transmitted without data, etc.), the xUCI message can also comprise a BRS-RP report indicating BRS-RPs for x beams (e.g., with x predefined or configured via higher layer signaling). In other aspects, processor 210 can output the BRS-RP report for transmission as MAC (medium access control) Control Elements. Processor 210 can output the xUCI message for transmission by transmitter circuitry 230 to a serving eNB via xPUSCH. Depending on the type of signal or message generated, generation (e.g., by processor 210, processor 310, etc.) can comprise one or more of: generating a set of associated bits (e.g., xUCI bits) that indicate the data of the signal or message (e.g., for the xUCI message, this can comprise the CSI report and/or BRS-RP report), coding (e.g., which can include adding a cyclic redundancy check (CRC) and/or coding via one or more of turbo code, low density parity-check (LDPC) code, tailbiting convolution code (TBCC), etc.), scrambling (e.g., based on a scrambling seed), modulating (e.g., via one of binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), or some form of quadrature amplitude modulation (QAM), etc.), and/or resource mapping (e.g., to a set of time and frequency resources granted for uplink transmission of the xUCI report).

[0041] An example wideband CQI report can comprise, for each of n (e.g., $n=2$) beams: a beam indicator (BI) (e.g., indicated via 3 bits), a wideband CQI (e.g., indicated via 4 bits), a PMI (e.g., indicated via $2N$ bits for rank 1 or N bits for rank 2, where N can be predetermined or configured via higher layer signaling and/or based on system bandwidth, etc.), and an RI (e.g., indicated via 1 bit). In some aspects, the wideband CQI report can comprise, in order: the BI, wideband CQI, PMI, and RI for a first Tx beam of the n Tx beams; the BI, wideband CQI, PMI, and RI for a second Tx beam of the n Tx beams; etc.; through to the BI, wideband CQI, PMI, and RI for a n th Tx beam of the n Tx beams. In aspects, the wideband CQI report can comprise a bit sequence in an order indicated herein, for example, beginning with the first bit of the BI of the first Tx beam, and ending with the last bit of the RI of the n th Tx beam. In some such aspects,

the PMI can be in increasing order of subband index (or an alternate order, e.g., decreasing order of subband index), and multiple bit fields can be in order of most significant bit (MSB) to least significant bit (LSB) (or, alternatively, LSB to MSB).

[0042] An example higher layer configured subband CQI report can comprise, for each of n (e.g., $n=2$) beams: a BI (e.g., indicated via 3 bits), a wideband CQI (e.g., indicated via 4 bits), one or more subband differential CQIs (e.g., indicated via $2N$ bits, with N as described herein), a PMI (e.g., indicated via 2 bits for rank 1 or 1 bit for rank 2), and an RI (e.g., indicated via 1 bit). In some aspects, the higher layer configured subband CQI report can comprise, in order: the BI, wideband CQI, one or more subband differential CQIs, PMI, and RI for a first Tx beam of the n Tx beams; the BI, wideband CQI, one or more subband differential CQIs, PMI, and RI for a second Tx beam of the n Tx beams; etc.; through to the BI, wideband CQI, one or more subband differential CQIs, PMI, and RI for a n th Tx beam of the n Tx beams. In aspects, the higher layer configured subband CQI report can comprise a bit sequence in an order indicated herein, for example, beginning with the first bit of the BI of the first Tx beam, and ending with the last bit of the RI of the n th Tx beam. In some such aspects, the subband differential CQI(s) can be in increasing order of subband index (or an alternate order, e.g., decreasing order of subband index), and multiple bit fields can be in order of MSB to LSB (or, alternatively, LSB to MSB).

[0043] An example higher layer configured subband CQI and subband PMI report can comprise, for each of n (e.g., $n=2$) beams: a BI (e.g., indicated via 3 bits), a wideband CQI (e.g., indicated via 4 bits), subband differential CQI(s) (e.g., indicated via $2N$ bits, with N as described herein), subband PMI(s) (e.g., indicated via $2N$ bits for rank 1 or N bit for rank 2), and an RI (e.g., indicated via 1 bit). In some aspects, the higher layer configured subband CQI and subband PMI report can comprise, in order: the BI, wideband CQI, subband differential CQI(s), subband PMI(s), and RI for a first Tx beam of the n Tx beams; the BI, wideband CQI, subband differential CQI(s), subband PMI(s), and RI for a second Tx beam of the n Tx beams; etc.; through to the BI, wideband CQI, subband differential CQI(s), subband PMI(s), and RI for a n th Tx beam of the n Tx beams. In aspects, the higher layer configured subband CQI and subband PMI report can comprise a bit sequence in an order indicated herein, for example, beginning with the first bit of the BI of the first Tx beam, and ending with the last bit of the RI of the n th Tx beam. In some such aspects, the subband differential CQI(s) and/or subband PMI(s) can be in increasing order of subband index (or an alternate order, e.g., decreasing

order of subband index), and multiple bit fields can be in order of MSB to LSB (or, alternatively, LSB to MSB).

[0044] Referring to **FIG. 3**, illustrated is a block diagram of a system 300 that facilitates reception of a xUCI message comprising a CSI report at a base station according to various aspects described herein. System 300 can include a processor 310 (e.g., a baseband processor such as one of the baseband processors discussed in connection with FIG. 1), transmitter circuitry 320, receiver circuitry 330, and memory 340 (which can comprise any of a variety of storage mediums and can store instructions and/or data associated with one or more of processor 310, transmitter circuitry 320, or receiver circuitry 330). In various aspects, system 300 can be included within an Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Node B (Evolved Node B, eNodeB, or eNB) or other base station in a wireless communications network. In some aspects, the processor 310, the transmitter circuitry 320, the receiver circuitry 330, and the memory 340 can be included in a single device, while in other aspects, they can be included in different devices, such as part of a distributed architecture. As described in greater detail below, system 300 can facilitate processing of a xUCI message received from a UE that indicates CSI associated with one or more Tx beams.

[0045] Processor 310 can generate a distinct set of CSI-RS signals for each of one or more Tx beams, and can output the distinct sets of CSI-RS signals to transmitter circuitry 320 for transmission to a UE via the associated Tx beam.

[0046] Processor 310 can process a xUCI message received by receiver circuitry 330 from the UE. The xUCI message can comprise a CSI report (and optionally a BRS-RP report) that indicates a distinct set of CSI parameters for each of n Tx beams (e.g., $n=2$, etc.). In aspects, the n Tx beams can comprise at least one of the one or more Tx beams transmitted by transmitter circuitry 320, or can comprise none of the one or more Tx beams. Depending on the type of CSI report, the distinct set of CSI parameters for each of the n Tx beams can vary. As examples, for a wideband CQI report, each distinct set of CSI parameters can comprise a BI, wideband CQI, PMI, and RI for the Tx beam associated with that set of CSI parameters; for a higher layer configured (e.g., by higher layer signaling generated by processor 310, etc.) subband CQI report, each distinct set of CSI parameters can comprise a BI, wideband CQI, one or more subband differential CQIs, PMI, and RI for the Tx beam associated with that set of CSI parameters; for a higher layer configured (e.g., by higher layer signaling generated by processor 310, etc.) subband CQI and PMI report, each distinct set of CSI parameters can comprise a

BI, wideband CQI, one or more subband differential CQIs, one or more subband differential PMIs, and RI for the Tx beam associated with that set of CSI parameters; etc.

[0047] In some aspects, processor 310 can determine transmit parameters for some or all of the n Tx beams, which can be determined based at least in part on the distinct set of CSI parameters associated with that Tx beam.

[0048] The following discussion provides specific examples of CSI reports that can be generated at a UE or processed at an eNB in connection with various aspects described herein.

[0049] In various aspects, for wideband CQI reports, a UE can report the CSI for the two best beams measured from CSI-RS received by the eNB. The UE can report the following information in the wideband CQI report: BI for beam 1; wideband CQI, PMI, and RI for beam 1; BI for beam 2; and wideband CQI, PMI, and RI for beam 2. Table 1, below, shows fields and example corresponding bit widths for the CQI feedback for wideband reports for xPDSCH (5G Physical Downlink Shared Channel) transmissions. N in Table 1 below can be configured by higher layer signaling and/or determined by system bandwidth.

Table 1: Fields for channel quality information feedback for wideband CQI reports

Field	Bit Width	
	Rank = 1	Rank = 2
Beam Index first beam	3	3
Wideband CQI first beam	4	4
Precoding matrix indicator first beam	$2N$	N
Beam Index second beam	3	3
Wideband CQI second beam	4	4
Precoding matrix indicator second beam	$2N$	N

[0050] Table 2, below, shows the fields and example corresponding bit widths for the rank indication feedback for wideband CQI reports for xPDSCH transmissions.

Table 2: Fields for rank indication feedback for wideband CQI reports

Field	Bit width
Rank Indication first beam	1

Rank Indication second beam	1
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[0051] The channel quality bits in Tables 1 and 2 can form the bit sequence $o_0, o_1, o_2, \dots, o_{O-1}$ with o_0 corresponding to the first bit of the first field in each of the tables, o_1 corresponding to the second bit of the first field in each of the tables, and o_{O-1} corresponding to the last bit in the last field in each of the tables. The field of PMI can be in an increasing order of subband index. The first bit of each field can correspond to the MSB for that field, and the last bit can correspond to the LSB for that field.

[0052] In various aspects, for higher layer configured CQI reports, the UE can report the CSI for the two best beams measured from the CSI-RS. The UE can report the following information: BI for beam 1, subband CQI and PMI for beam 1, RI for beam 1, BI for beam 2, subband CQI and PMI for beam 2, and RI for beam 2. Table 3, below, shows the fields and example corresponding bit widths for the channel quality information feedback for higher layer configured reports for xPD SCH transmissions.

Table 3: Fields for channel quality information feedback for higher layer configured subband CQI reports

Field	Bit Width	
	Rank = 1	Rank = 2
Beam Index first beam	3	3
Wideband CQI first beam	4	4
Subband differential CQI first beam	$2N$	$2N$
Precoding matrix indicator first beam	2	1
Beam Index second beam	3	3
Wideband CQI second beam	4	4
Subband differential CQI second beam	$2N$	$2N$
Precoding matrix indicator second beam	2	1

[0053] Table 4, below, shows the fields and example corresponding bit widths for the channel quality information feedback for higher layer configured reports for xPD SCH transmissions configured with subband PMI/RI reporting.

Table 4: Fields for channel quality information feedback for higher layer configured subband CQI and subband PMI reports

Field	Bit Width	
	Rank = 1	Rank = 2
Beam Index first beam	3	3
Wideband CQI first beam	4	4
Subband differential CQI first beam	$2N$	$2N$
Subband precoding matrix indicator first beam	$2N$	N
Beam Index second beam	3	3
Wideband CQI second beam	4	4
Subband differential CQI second beam	$2N$	$2N$
Subband precoding matrix indicator second beam	$2N$	N

[0054] Table 5, below, shows the fields and example corresponding bit widths for the rank indication feedback for higher layer configured subband CQI reports or higher layer configured subband CQI and subband PMI reports for xPDSCH transmissions.

Table 5: Fields for rank indication feedback for higher layer configured subband CQI reports or higher layer configured subband CQI and subband PMI reports

Field	Bit width
Rank Indication first beam	1
Rank Indication second beam	1

[0055] The channel quality bits in Tables 3, 4, and 5 can form the bit sequence $o_0, o_1, o_2, \dots, o_{O-1}$ with o_0 corresponding to the first bit of the first field in each of the tables, o_1 corresponding to the second bit of the first field in each of the tables, and o_{O-1} corresponding to the last bit in the last field in each of the tables. The fields of the PMI and subband differential CQI can be in an increasing order of subband index. The first bit of each field can correspond to the MSB for that field, and the last bit can correspond to the LSB for that field.

[0056] In various aspects, the BRS-RP for x beams can be reported by a UE to an eNB by xPUSCH when triggered, where x can be provided by higher layer signaling or predefined in the specification. The BRS-RPs can be reported as MAC Control Elements. Alternatively, the BRS-RPs can be reported as a component of xUCI, for example, when the xUCI is transmitted without data.

[0057] Referring to **FIG. 4**, illustrated is a flow diagram of a method 400 that facilitates generation of a CSI report based on CSI-RS signals received via a plurality of Tx beams at a UE according to various aspects described herein. In some aspects, method 400 can be performed at a UE. In other aspects, a machine readable medium can store instructions associated with method 400 that, when executed, can cause a UE to perform the acts of method 400.

[0058] At 410, a distinct set of CSI-RS signals can be received over each of a plurality of Tx beams.

[0059] At 420, a distinct set of CSI parameters can be calculated for each of the plurality of Tx beams based on the CSI-RS received via that Tx beam. Depending on the embodiment, the distinct set of CSI parameters for each Tx beam can comprise one or more of a wideband CQI, one or more subband differential CQIs, a PMI, one or more subband PMIs, or a RI.

[0060] At 430, n Tx beams (e.g., $n=2$, etc.) can be selected from among the plurality of Tx beams for reporting of CSI parameters to an eNB. The n Tx beams can be selected based on the distinct set(s) of CSI parameters associated with the n Tx beams (e.g., the n beams having the best channel quality, etc.).

[0061] At 440, a xUCI message can be generated that can comprise a CSI report indicating the n sets of CSI parameters associated with the n Tx beams. In some aspects (e.g., if the xUCI is to be transmitted without data), the xUCI message can also comprise a BRS-RP report generated as described herein.

[0062] At 450, the CSI report can be transmitted to an eNB (e.g., via xPUSCH).

[0063] Referring to **FIG. 5**, illustrated is a flow diagram of a method 500 that facilitates reception of a xUCI message comprising a CSI report via xPUSCH by a base station according to various aspects described herein. In some aspects, method 500 can be performed at an eNB. In other aspects, a machine readable medium can store instructions associated with method 500 that, when executed, can cause an eNB to perform the acts of method 500.

[0064] At 510, a distinct set of CSI-RS signals can be generated for each of one or more Tx beams.

[0065] At 520, the distinct set(s) of CSI-RS signals can be transmitted via the associated Tx beams to a UE.

[0066] At 530, a xUCI message can be received from the UE, wherein the xUCI report can comprise a CSI report that indicates n sets of CSI parameters each

associated with a distinct Tx beam. In various aspects, depending on the type of CSI report, the set(s) of CSI parameters can comprise one or more of the following: a wideband CQI, one or more subband differential CQIs, a PMI, one or more subband PMIs, or a RI. In some aspects, the xUCI message can also comprise a BRS-RP report.

[0067] Optionally, based on the received set(s) of CSI parameters, transmit characteristics or parameters associated with one or more of the n Tx beams can be determined.

[0068] Examples herein can include subject matter such as a method, means for performing acts or blocks of the method, at least one machine-readable medium including executable instructions that, when performed by a machine (e.g., a processor with memory, an application-specific integrated circuit (ASIC), a field programmable gate array (FPGA), or the like) cause the machine to perform acts of the method or of an apparatus or system for concurrent communication using multiple communication technologies according to embodiments and examples described.

[0069] Example 1 is an apparatus configured to be employed within a User Equipment (UE), comprising a processor configured to: process, for each of a plurality of transmit (Tx) beams, a set of channel state information (CSI) reference signal (CSI-RS) signals received over that Tx beam; determine, for each of the plurality of Tx beams, a distinct set of CSI parameters associated with that Tx beam, wherein each set of CSI parameters comprises one or more channel quality indicators (CQIs), one or more precoding matrix indicators (PMIs), and a rank indicator (RI) associated with that Tx beam; generate a CSI report indicating a first set of CSI parameters associated with a first Tx beam of the plurality of Tx beams and indicating a second set of CSI parameters associated with a second Tx beam of the plurality of Tx beams; generate a fifth generation (5G) uplink control information (xUCI) message comprising the CSI report; and output the xUCI message for transmission to an Evolved NodeB (eNB).

[0070] Example 2 comprises the subject matter of any variation of example 1, wherein the first set of CSI parameters comprises a first wideband CQI associated with the first Tx beam and the second set of CSI parameters comprises a second wideband CQI associated with the second Tx beam.

[0071] Example 3 comprises the subject matter of any variation of example 2, wherein the CSI report indicates the first wideband CQI and the second wideband CQI via four bits each.

[0072] Example 4 comprises the subject matter of any variation of any of examples 1-3, wherein the CSI report is a wideband CSI report.

[0073] Example 5 comprises the subject matter of any variation of example 4, wherein the CSI report indicates a first BI, a first wideband CQI, a first PMI and a first RI associated with the first Tx beam, and indicates a second BI, a second wideband CQI, a second PMI and a second RI associated with the second Tx beam.

[0074] Example 6 comprises the subject matter of any variation of example 5, wherein the CSI report indicates the first PMI and the second PMI via $2N$ bits each when a rank 1 transmission is received via the associated Tx beam, and indicates the first PMI and the second PMI via N bits each when a rank 2 transmission is received via the associated Tx beam.

[0075] Example 7 comprises the subject matter of any variation of example 6, wherein N is configured via higher layer signaling.

[0076] Example 8 comprises the subject matter of any variation of example 6, wherein N is determined based on system bandwidth.

[0077] Example 9 comprises the subject matter of any variation of any of examples 1-3, wherein the CSI report is a subband CSI report configured via higher layer signaling.

[0078] Example 10 comprises the subject matter of any variation of example 9, wherein the CSI report indicates a first set of subband differential CQIs associated with the first Tx beam and a second set of subband differential CQIs associated with the second Tx beam.

[0079] Example 11 comprises the subject matter of any variation of example 1, wherein the CSI report is a wideband CSI report.

[0080] Example 12 comprises the subject matter of any variation of example 1, wherein the CSI report is a subband CSI report configured via higher layer signaling.

[0081] Example 13 is a machine readable medium comprising instructions that, when executed, cause a User Equipment (UE) to: receive a distinct set of channel state information (CSI) reference signal (CSI-RS) signals over each of a plurality of transmit (Tx) beams; calculate a set of CSI parameters for each Tx beam of the plurality of Tx beams, wherein each set of CSI parameters is calculated based on the distinct set of CSI-RS signals received over that Tx beam, wherein each set of CSI parameters comprises one or more channel quality indicators (CQIs), one or more precoding matrix indicators (PMIs), and a rank indicator (RI) associated with that Tx beam; select a first

Tx beam and a second Tx beam of the plurality of Tx beams, wherein the first Tx beam is selected based at least in part on a first set of CSI parameters based on the distinct set of CSI-RS signals received over the first Tx beam, and the second Tx beam is selected based at least in part on a second set of CSI parameters based on the distinct set of CSI-RS signals received over the second Tx beam; generate a fifth generation (5G) uplink control information (xUCI) message comprising a CSI report that indicates the first set of CSI parameters and the second set of CSI parameters; and transmit the CSI report to an Evolved NodeB (eNB).

[0082] Example 14 comprises the subject matter of any variation of example 13, wherein the first set of CSI parameters comprises a first BI, a first wideband CQI, and a first RI associated with the first Tx beam, and wherein the second set of CSI parameters comprises a second BI, a second wideband CQI, and a second RI associated with the second Tx beam.

[0083] Example 15 comprises the subject matter of any variation of example 13, wherein the CSI report comprises a plurality of bits that indicate, in order, a first BI, one or more first CQIs, one or more first PMIs, and a first RI associated with the first Tx beam, and a second BI, one or more second CQIs, one or more second PMIs, and a second RI associated with the second Tx beam.

[0084] Example 16 comprises the subject matter of any variation of any of examples 13-15, wherein the CSI report is a subband CSI report configured via higher layer signaling.

[0085] Example 17 comprises the subject matter of any variation of example 16, wherein the CSI report indicates one or more first subband differential CQIs associated with distinct subbands of the first Tx beam and one or more second subband differential CQIs associated with distinct subbands of the second Tx beam.

[0086] Example 18 comprises the subject matter of any variation of example 16, wherein the CSI report indicates the one or more first subband differential CQIs and the one or more second subband differential CQIs in order of increasing subband indices.

[0087] Example 19 comprises the subject matter of any variation of example 16, wherein the CSI report indicates one or more first subband PMIs associated with distinct subbands of the first Tx beam and one or more second subband PMIs associated with distinct subbands of the second Tx beam.

[0088] Example 20 comprises the subject matter of any variation of any of examples 13-15, wherein the CSI report is a wideband CSI report.

[0089] Example 21 comprises the subject matter of any variation of any of examples 13-15, wherein the xUCI message comprises a beam reference signal (BRS) received power (BRS-RP) report that indicates an associated BRS-RP for each of one or more Tx beams, wherein each of the associated BRS-RPs is calculated based on a set of BRSs received via the associated Tx beam.

[0090] Example 22 comprises the subject matter of any variation of example 21, wherein the number of BRS-RPs indicated in the BRS-RP report is configured via higher layer signaling.

[0091] Example 23 comprises the subject matter of any variation of example 21, wherein the number of BRS-RPs indicated in the BRS-RP report is predefined.

[0092] Example 24 comprises the subject matter of any variation of example 13, wherein the CSI report is a subband CSI report configured via higher layer signaling.

[0093] Example 25 comprises the subject matter of any variation of example 13, wherein the CSI report is a wideband CSI report.

[0094] Example 26 comprises the subject matter of any variation of example 13, wherein the xUCI message comprises a beam reference signal (BRS) received power (BRS-RP) report that indicates an associated BRS-RP for each of one or more Tx beams, wherein each of the associated BRS-RPs is calculated based on a set of BRSs received via the associated Tx beam.

[0095] Example 27 is an apparatus configured to be employed within an Evolved NodeB (eNB), comprising a processor configured to: generate, for each of one or more transmit (Tx) beams, a distinct set of channel state information (CSI) reference signal (CSI-RS) signals associated with that Tx beam; output each distinct set of CSI-RS signals for transmission to a user equipment (UE) via the Tx beam associated with that distinct set of CSI-RS signals; process a CSI report received from the UE via a fifth generation uplink control information (xUCI) message, wherein the CSI report indicates a first beam index (BI), one or more first channel quality indicators (CQIs), one or more first precoding matrix indicators (PMIs), and a first rank indicator (RI) associated with a first Tx beam, and wherein the CSI report indicates a second BI, one or more second CQIs, one or more second PMIs, and a second RI associated with a distinct second Tx beam.

[0096] Example 28 comprises the subject matter of any variation of example 27, wherein the CSI report is a wideband CSI report.

[0097] Example 29 comprises the subject matter of any variation of example 27, wherein the CSI report is a subband CSI report generated based at least in part on configuration via higher layer signaling.

[0098] Example 30 comprises the subject matter of any variation of example 29, wherein the one or more first CQIs comprise a first wideband CQI and one or more first subband differential CQIs, and wherein the one or more second CQIs comprise a second wideband CQI and one or more second subband differential CQIs.

[0099] Example 31 comprises the subject matter of any variation of any of examples 29-30, wherein the one or more first PMIs comprise one or more first subband PMIs, and wherein the one or more second PMIs comprise one or more second subband PMIs.

[00100] Example 32 comprises the subject matter of any variation of example 29, wherein the one or more first PMIs comprise one or more first subband PMIs, and wherein the one or more second PMIs comprise one or more second subband PMIs.

[00101] Example 33 is an apparatus configured to be employed within a User Equipment (UE), comprising: means for receiving configured to receive a distinct set of channel state information (CSI) reference signal (CSI-RS) signals over each of a plurality of transmit (Tx) beams; means for processing configured to: calculate a set of CSI parameters for each Tx beam of the plurality of Tx beams, wherein each set of CSI parameters is calculated based on the distinct set of CSI-RS signals received over that Tx beam, wherein each set of CSI parameters comprises one or more channel quality indicators (CQIs), one or more precoding matrix indicators (PMIs), and a rank indicator (RI) associated with that Tx beam; select a first Tx beam and a second Tx beam of the plurality of Tx beams, wherein the first Tx beam is selected based at least in part on a first set of CSI parameters based on the distinct set of CSI-RS signals received over the first Tx beam, and the second Tx beam is selected based at least in part on a second set of CSI parameters based on the distinct set of CSI-RS signals received over the second Tx beam; and generate a fifth generation (5G) uplink control information (xUCI) message comprising a CSI report that indicates the first set of CSI parameters and the second set of CSI parameters; and means for transmitting configured to transmit the CSI report to an Evolved NodeB (eNB).

[00102] Example 34 comprises the subject matter of any variation of example 33, wherein the first set of CSI parameters comprises a first BI, a first wideband CQI, and a first RI associated with the first Tx beam, and wherein the second set of CSI parameters

comprises a second BI, a second wideband CQI, and a second RI associated with the second Tx beam.

[00103] Example 35 comprises the subject matter of any variation of example 33, wherein the CSI report comprises a plurality of bits that indicate, in order, a first BI, one or more first CQIs, one or more first PMIs, and a first RI associated with the first Tx beam, and a second BI, one or more second CQIs, one or more second PMIs, and a second RI associated with the second Tx beam.

[00104] Example 36 comprises the subject matter of any variation of any of examples 33-35, wherein the CSI report is a subband CSI report configured via higher layer signaling.

[00105] Example 37 comprises the subject matter of any variation of example 36, wherein the CSI report indicates one or more first subband differential CQIs associated with distinct subbands of the first Tx beam and one or more second subband differential CQIs associated with distinct subbands of the second Tx beam.

[00106] Example 38 comprises the subject matter of any variation of example 36, wherein the CSI report indicates the one or more first subband differential CQIs and the one or more second subband differential CQIs in order of increasing subband indices.

[00107] Example 39 comprises the subject matter of any variation of example 36, wherein the CSI report indicates one or more first subband PMIs associated with distinct subbands of the first Tx beam and one or more second subband PMIs associated with distinct subbands of the second Tx beam.

[00108] Example 40 comprises the subject matter of any variation of any of examples 33-35, wherein the CSI report is a wideband CSI report.

[00109] Example 41 comprises the subject matter of any variation of any of examples 33-35, wherein the xUCI message comprises a beam reference signal (BRS) received power (BRS-RP) report that indicates an associated BRS-RP for each of one or more Tx beams, wherein each of the associated BRS-RPs is calculated based on a set of BRSs received via the associated Tx beam.

[00110] Example 42 comprises the subject matter of any variation of example 41, wherein the number of BRS-RPs indicated in the BRS-RP report is configured via higher layer signaling.

[00111] Example 43 comprises the subject matter of any variation of example 41, wherein the number of BRS-RPs indicated in the BRS-RP report is predefined.

[00112] Example 44 comprises the subject matter of any variation of any of examples 1-12, wherein the processor being configured to generate the xUCI message comprises the processor being configured to: generate a set of xUCI bits that indicate the CSI report; code the set of xUCI bits; scramble the set of xUCI bits; modulate the set of xUCI bits; and determine a set of physical resources to map the set of xUCI bits to.

[00113] The above description of illustrated embodiments of the subject disclosure, including what is described in the Abstract, is not intended to be exhaustive or to limit the disclosed embodiments to the precise forms disclosed. While specific embodiments and examples are described herein for illustrative purposes, various modifications are possible that are considered within the scope of such embodiments and examples, as those skilled in the relevant art can recognize.

[00114] In this regard, while the disclosed subject matter has been described in connection with various embodiments and corresponding Figures, where applicable, it is to be understood that other similar embodiments can be used or modifications and additions can be made to the described embodiments for performing the same, similar, alternative, or substitute function of the disclosed subject matter without deviating therefrom. Therefore, the disclosed subject matter should not be limited to any single embodiment described herein, but rather should be construed in breadth and scope in accordance with the appended claims below.

[00115] In particular regard to the various functions performed by the above described components or structures (assemblies, devices, circuits, systems, etc.), the terms (including a reference to a "means") used to describe such components are intended to correspond, unless otherwise indicated, to any component or structure which performs the specified function of the described component (e.g., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary implementations. In addition, while a particular feature may have been disclosed with respect to only one of several implementations, such feature may be combined with one or more other features of the other implementations as may be desired and advantageous for any given or particular application.

CLAIMS

What is claimed is:

1. An apparatus configured to be employed within a User Equipment (UE), comprising:
 - a processor configured to:
 - process, for each of a plurality of transmit (Tx) beams, a set of channel state information (CSI) reference signal (CSI-RS) signals received over that Tx beam;
 - determine, for each of the plurality of Tx beams, a distinct set of CSI parameters associated with that Tx beam, wherein each set of CSI parameters comprises one or more channel quality indicators (CQIs), one or more precoding matrix indicators (PMIs), and a rank indicator (RI) associated with that Tx beam;
 - generate a CSI report indicating a first set of CSI parameters associated with a first Tx beam of the plurality of Tx beams and indicating a second set of CSI parameters associated with a second Tx beam of the plurality of Tx beams;
 - generate a fifth generation (5G) uplink control information (xUCI) message comprising the CSI report; and
 - output the xUCI message for transmission to an Evolved NodeB (eNB).
2. The apparatus of claim 1, wherein the first set of CSI parameters comprises a first wideband CQI associated with the first Tx beam and the second set of CSI parameters comprises a second wideband CQI associated with the second Tx beam.
3. The apparatus of claim 2, wherein the CSI report indicates the first wideband CQI and the second wideband CQI via four bits each.
4. The apparatus of any of claims 1-3, wherein the CSI report is a wideband CSI report.
5. The apparatus of claim 4, wherein the CSI report indicates a first BI, a first wideband CQI, a first PMI and a first RI associated with the first Tx beam, and indicates a second BI, a second wideband CQI, a second PMI and a second RI associated with the second Tx beam.

6. The apparatus of claim 5, wherein the CSI report indicates the first PMI and the second PMI via $2N$ bits each when a rank 1 transmission is received via the associated Tx beam, and indicates the first PMI and the second PMI via N bits each when a rank 2 transmission is received via the associated Tx beam.
7. The apparatus of claim 6, wherein N is configured via higher layer signaling.
8. The apparatus of claim 6, wherein N is determined based on system bandwidth.
9. The apparatus of any of claims 1-3, wherein the CSI report is a subband CSI report configured via higher layer signaling.
10. The apparatus of claim 9, wherein the CSI report indicates a first set of subband differential CQIs associated with the first Tx beam and a second set of subband differential CQIs associated with the second Tx beam.
11. A machine readable medium comprising instructions that, when executed, cause a User Equipment (UE) to:
 - receive a distinct set of channel state information (CSI) reference signal (CSI-RS) signals over each of a plurality of transmit (Tx) beams;
 - calculate a set of CSI parameters for each Tx beam of the plurality of Tx beams, wherein each set of CSI parameters is calculated based on the distinct set of CSI-RS signals received over that Tx beam, wherein each set of CSI parameters comprises one or more channel quality indicators (CQIs), one or more precoding matrix indicators (PMIs), and a rank indicator (RI) associated with that Tx beam;
 - select a first Tx beam and a second Tx beam of the plurality of Tx beams, wherein the first Tx beam is selected based at least in part on a first set of CSI parameters based on the distinct set of CSI-RS signals received over the first Tx beam, and the second Tx beam is selected based at least in part on a second set of CSI parameters based on the distinct set of CSI-RS signals received over the second Tx beam;

generate a fifth generation (5G) uplink control information (xUCI) message comprising a CSI report that indicates the first set of CSI parameters and the second set of CSI parameters; and

transmit the CSI report to an Evolved NodeB (eNB).

12. The machine readable medium of claim 11, wherein the first set of CSI parameters comprises a first BI, a first wideband CQI, and a first RI associated with the first Tx beam, and wherein the second set of CSI parameters comprises a second BI, a second wideband CQI, and a second RI associated with the second Tx beam.

13. The machine readable medium of claim 11, wherein the CSI report comprises a plurality of bits that indicate, in order, a first BI, one or more first CQIs, one or more first PMIs, and a first RI associated with the first Tx beam, and a second BI, one or more second CQIs, one or more second PMIs, and a second RI associated with the second Tx beam.

14. The machine readable medium of any of claims 11-13, wherein the CSI report is a subband CSI report configured via higher layer signaling.

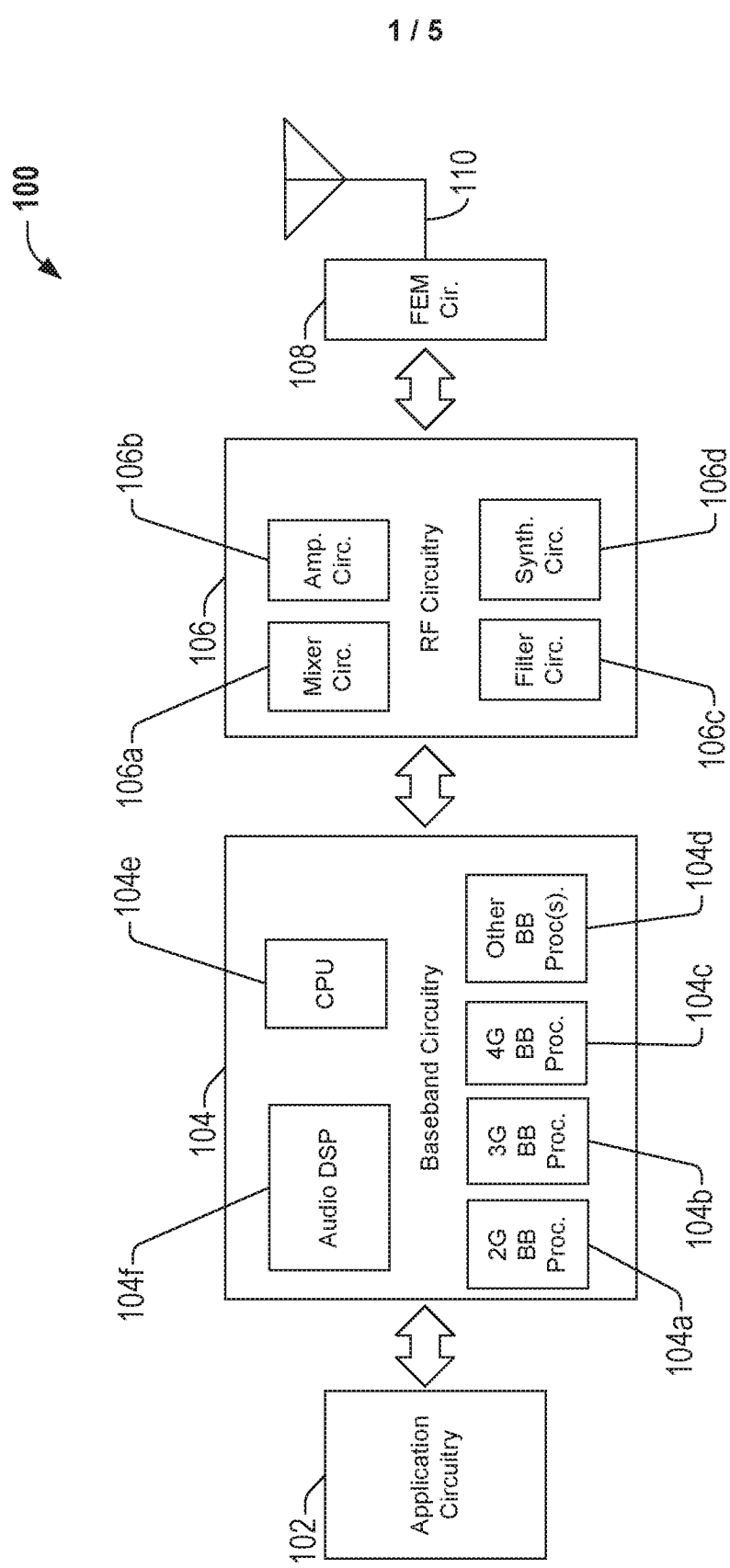
15. The machine readable medium of claim 14, wherein the CSI report indicates one or more first subband differential CQIs associated with distinct subbands of the first Tx beam and one or more second subband differential CQIs associated with distinct subbands of the second Tx beam.

16. The machine readable medium of claim 14, wherein the CSI report indicates the one or more first subband differential CQIs and the one or more second subband differential CQIs in order of increasing subband indices.

17. The machine readable medium of claim 14, wherein the CSI report indicates one or more first subband PMIs associated with distinct subbands of the first Tx beam and one or more second subband PMIs associated with distinct subbands of the second Tx beam.

18. The machine readable medium of any of claims 11-13, wherein the CSI report is a wideband CSI report.
19. The machine readable medium of any of claims 11-13, wherein the xUCI message comprises a beam reference signal (BRS) received power (BRS-RP) report that indicates an associated BRS-RP for each of one or more Tx beams, wherein each of the associated BRS-RPs is calculated based on a set of BRSs received via the associated Tx beam.
20. The machine readable medium of claim 19, wherein the number of BRS-RPs indicated in the BRS-RP report is configured via higher layer signaling.
21. The machine readable medium of claim 19, wherein the number of BRS-RPs indicated in the BRS-RP report is predefined.
22. An apparatus configured to be employed within an Evolved NodeB (eNB), comprising:
a processor configured to:
generate, for each of one or more transmit (Tx) beams, a distinct set of channel state information (CSI) reference signal (CSI-RS) signals associated with that Tx beam;
output each distinct set of CSI-RS signals for transmission to a user equipment (UE) via the Tx beam associated with that distinct set of CSI-RS signals;
process a CSI report received from the UE via a fifth generation uplink control information (xUCI) message, wherein the CSI report indicates a first beam index (BI), one or more first channel quality indicators (CQIs), one or more first precoding matrix indicators (PMIs), and a first rank indicator (RI) associated with a first Tx beam, and wherein the CSI report indicates a second BI, one or more second CQIs, one or more second PMIs, and a second RI associated with a distinct second Tx beam.
23. The apparatus of claim 22, wherein the CSI report is a wideband CSI report.

24. The apparatus of claim 22, wherein the CSI report is a subband CSI report generated based at least in part on configuration via higher layer signaling.
25. The apparatus of claim 24, wherein the one or more first CQIs comprise a first wideband CQI and one or more first subband differential CQIs, and wherein the one or more second CQIs comprise a second wideband CQI and one or more second subband differential CQIs.
26. The apparatus of any of claims 24-25, wherein the one or more first PMIs comprise one or more first subband PMIs, and wherein the one or more second PMIs comprise one or more second subband PMIs.



Example UE

FIG. 1

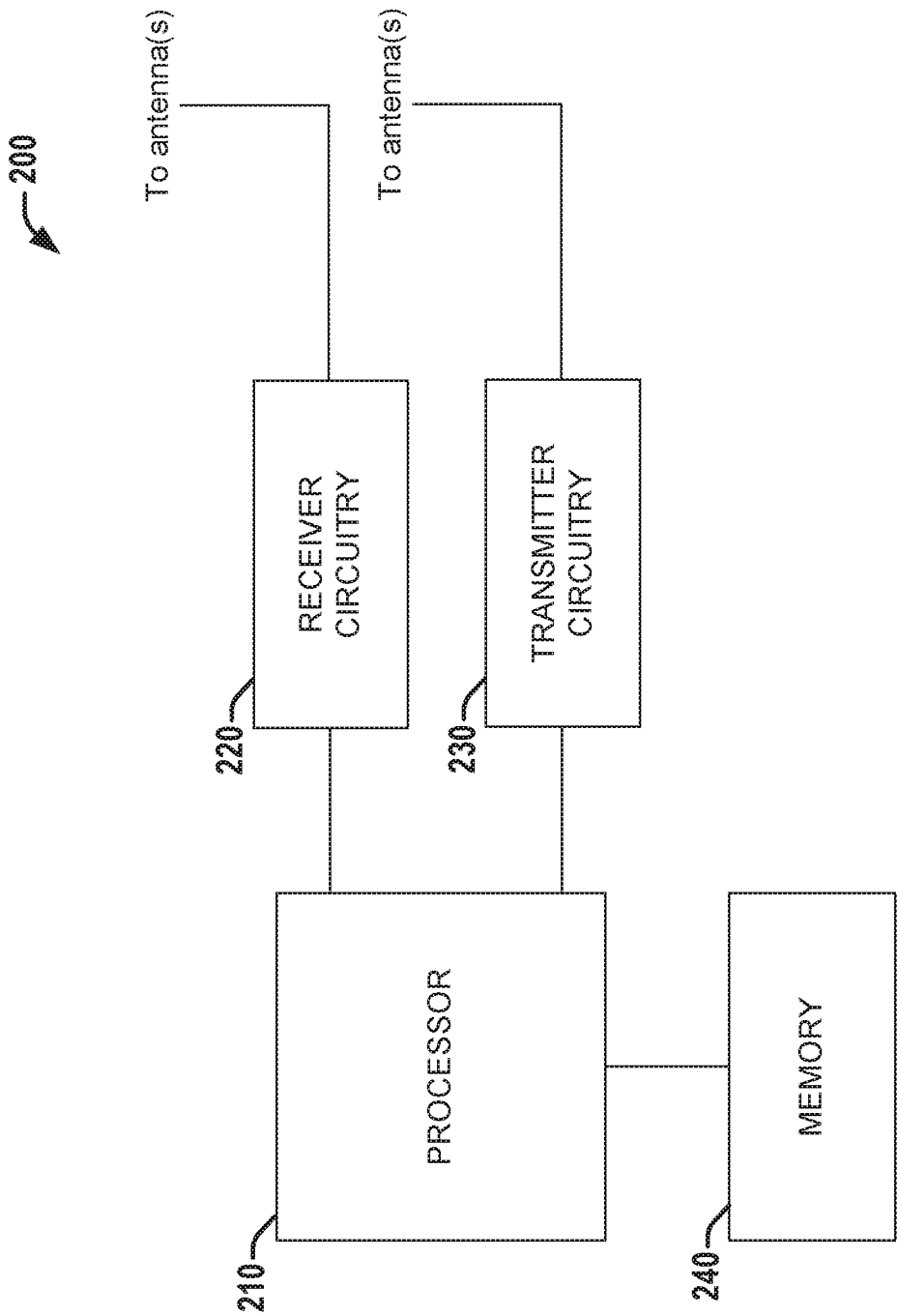


FIG. 2

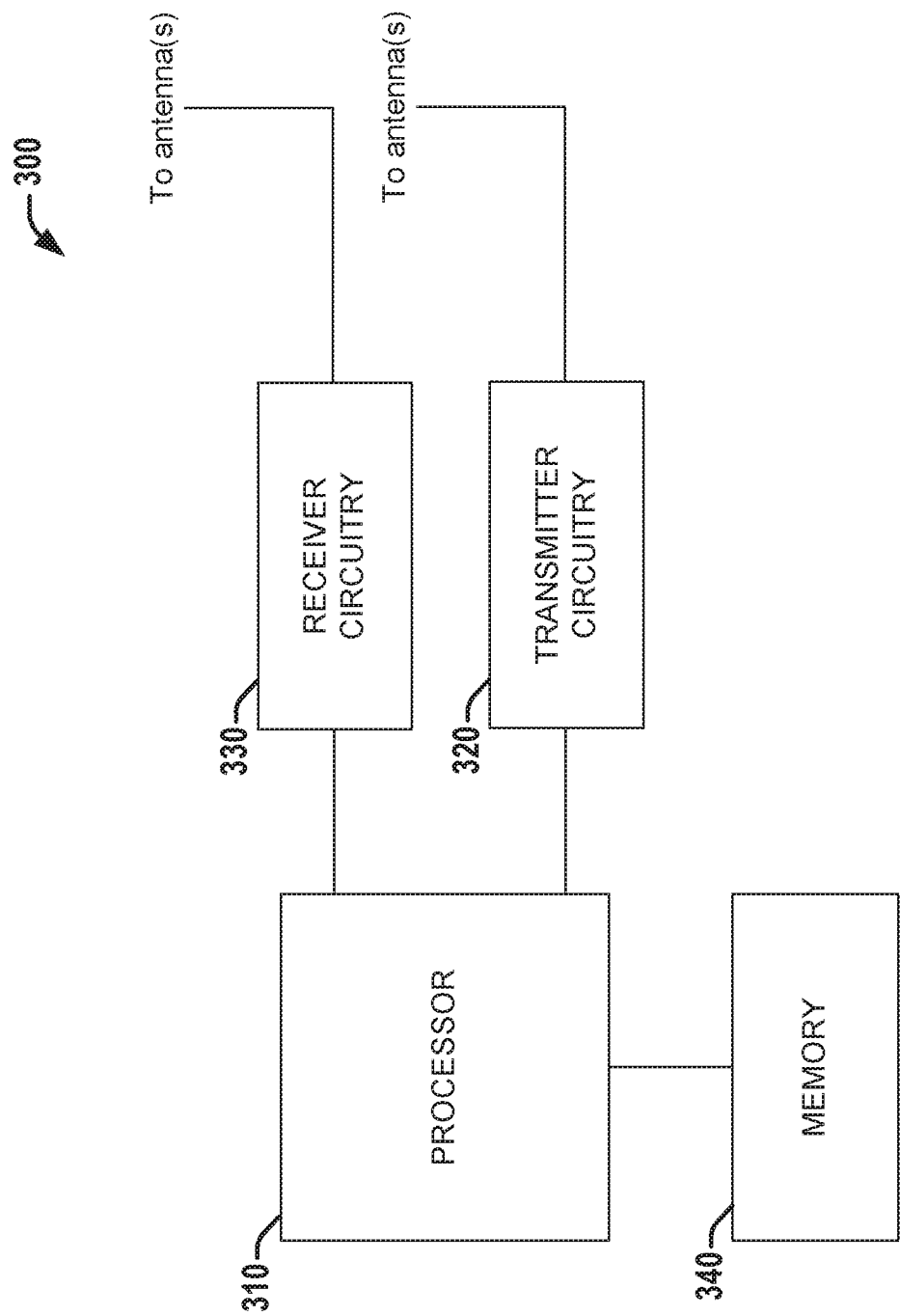


FIG. 3

4 / 5

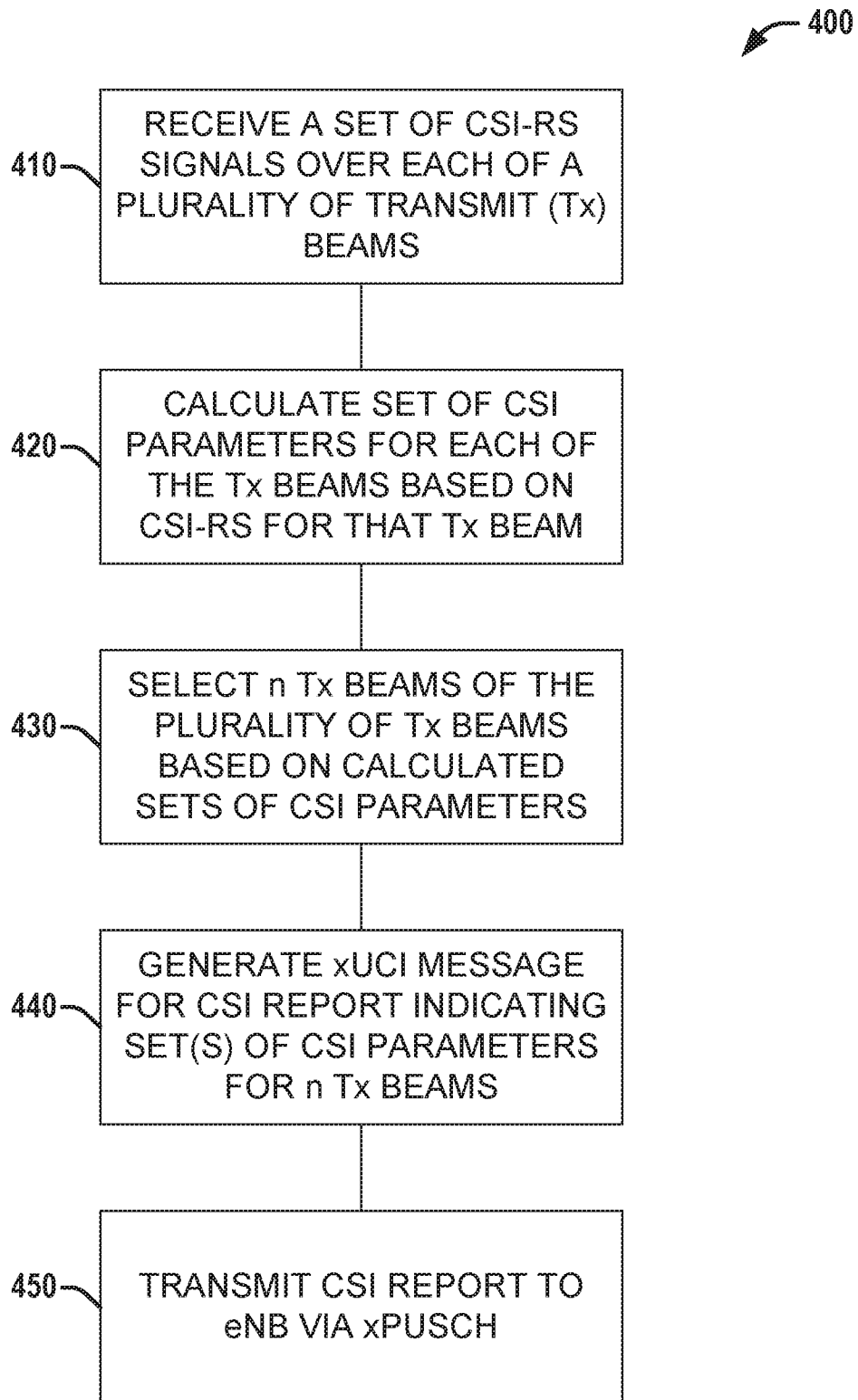


FIG. 4

5 / 5

500

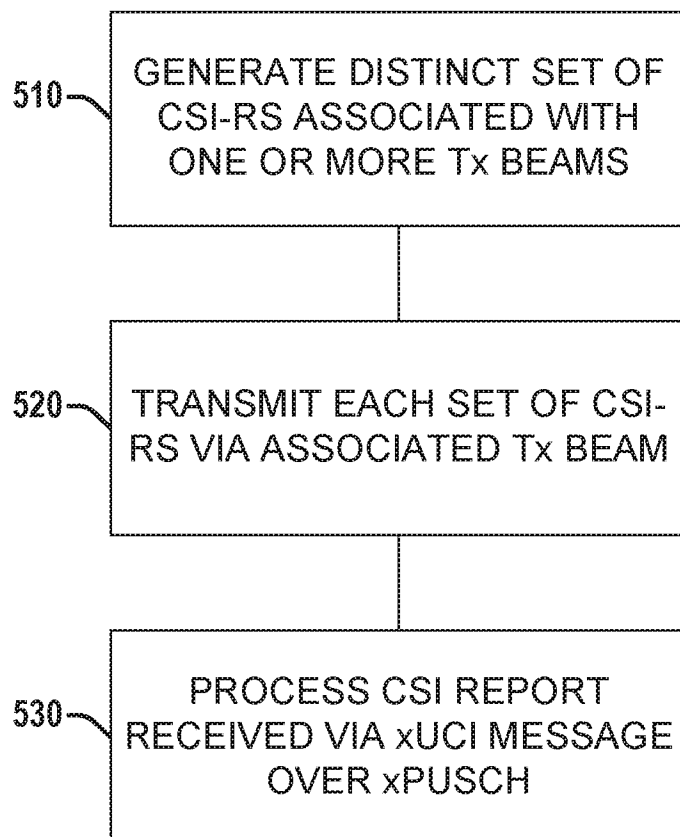


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/033069

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04L1/00 H04B7/04 H04B7/06
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04L H04B

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/235742 A1 (JOSIAM KAUSHIK MORAPAKKAM [US] ET AL) 12 September 2013 (2013-09-12) page 4, left-hand column, paragraph 44 - page 7, left-hand column, paragraph 66; figures 4-6	1-26
A	US 2013/163457 A1 (KIM KIIL [KR] ET AL) 27 June 2013 (2013-06-27) page 2, left-hand column, paragraph 22 - page 3, right-hand column, paragraph 47; figure 1	1-26
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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

7 November 2016

Date of mailing of the international search report

22/11/2016

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Courville, Nicolas

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/033069

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	NTT DOCOMO: "General Views on Precoding Schemes for Elevation BF and FD-MIMO", 3GPP DRAFT; R1-153153 PRECODING SCHEMES, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Fukuoka, Japan; 20150525 - 20150529 16 May 2015 (2015-05-16), XP050972621, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_81/Docs/ [retrieved on 2015-05-16] section 2.1, pages 2-4 -----	1-26

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2016/033069

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