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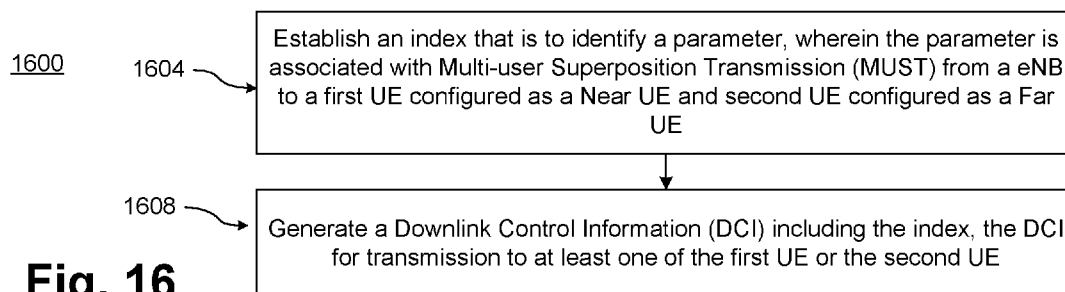
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(57) Abstract: Described is an apparatus of an Evolved Node B (eNB) operable to communicate with a User Equipment (UE) on a wireless network. The apparatus may comprise a first circuitry, and a second circuitry. The first circuitry may be operable to establish an index that is to identify a parameter, wherein the parameter is associated with Multi-user Superposition Transmission (MUST) from the eNB to a first UE configured as a Near UE and a second UE configured as a Far UE. The second circuitry may be operable to generate a Downlink Control Information (DCI) including the index, the DCI for transmission to at least one of the first UE or the second UE.



TRANSMISSION OF MULTIPLE USER SUPERPOSITION TRANSMISSION PARAMETERS TO USER EQUIPMENTS

CLAIM OF PRIORITY

[0001] The present application claims priority under 35 U.S.C. § 119(e) to United States Provisional Patent Application Serial Number 62/378,550, filed August 23, 2016 and entitled “MULTIPLE USER SUPERPOSITION TRANSMISSION UE BEHAVIORS AND NETWORK SIGNALLINGS,” and to United States Provisional Patent Application Serial Number 62/405,029, filed October 6, 2016 and entitled “MULTIPLE USER SUPERPOSITION TRANSMISSION DETECTOR BEHAVIORS AND PARAMETER ESTIMATION,” which are herein incorporated by reference in their entirety.

BACKGROUND

[0002] A variety of wireless cellular communication systems have been implemented, including a 3rd Generation Partnership Project (3GPP) Universal Mobile Telecommunications System, a 3GPP Long-Term Evolution (LTE) system, and a 3GPP LTE-Advanced (LTE-A) system. Next-generation wireless cellular communication systems based upon LTE and LTE-A systems are being developed, such as a fifth generation (5G) wireless system / 5G mobile networks system, New Radio (NR) Access Technology, etc. Next-generation wireless cellular communication systems may provide support for higher bandwidths in part by supporting higher carrier frequencies, such as centimeter-wave and millimeter-wave frequencies.

[0003] Several techniques may be adapted to increase bandwidth of wireless cellular communication systems. For example, Multi-user Superposition Transmission (MUST) scheme for multi-user (MU) communications was introduced for 3GPP LTE systems in Release 14 (e.g., various versions of Release 14) of the 3GPP specification. In some examples, MUST schemes may utilize the concept of superposition coding, e.g., for a multiuser transmission in LTE and LTE-A systems.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] The embodiments of the disclosure will be understood more fully from the detailed description given below and from the accompanying drawings of various embodiments of the disclosure. However, while the drawings are to aid in explanation and

understanding, they are only an aid, and should not be taken to limit the disclosure to the specific embodiments depicted therein.

[0005] **Fig. 1** illustrates a communication system comprising a eNB transmitting to a Near UE and a Far UE, e.g., based on Non-Orthogonal Multiple access (NOMA) power multiplexing, where one or both the Near UE or the Far UE may receive one or more indicators associated with NOMA transmission from the eNB, according to some embodiments.

[0006] **Fig. 2** illustrates various MU communication scenarios, and key parameters associated with the MU communication scenarios, according to some embodiments.

[0007] **Figs. 3A-3C** illustrate graphs depicting impact of NOMA existence detection on an Orthogonal Multiple access (OMA) UE performance, according to some embodiments.

[0008] **Figs. 4A-4C** illustrate graphs depicting impact of NOMA existence detection on a NOMA Near UE performance, according to some embodiments.

[0009] **Fig. 5** illustrates a graph depicting impact of NOMA existence detection on a NOMA Far UE performance, according to some embodiments.

[0010] **Figs. 6A-6C** illustrate graphs depicting power BD (blind detection) impact on NOMA Near UE performance, e.g., under a three hypotheses assumption, according to some embodiments.

[0011] **Figs. 7A-7C** illustrate graphs depicting power BD impact on NOMA Near UE performance, e.g., under an eight hypotheses assumption, according to some embodiments.

[0012] **Fig. 8** illustrates a Downlink Control Information (DCI) comprising a NOMA Near UE indication field, wherein the NOMA Near UE indication field may indicate a NOMA Near UE on a transmitted Physical Downlink Shared Channel (PDSCH), according to some embodiments.

[0013] **Fig. 9** illustrates a DCI comprising a NOMA Physical Resource Block (PRB) identification field, wherein the NOMA PRB identification field may identify, to a Near UE, one or more PRBs and/or PRB groups for which NOMA transmission is used, according to some embodiments.

[0014] **Fig. 10** illustrates a DCI comprising a NOMA index, wherein the NOMA index may identify a NOMA transmission set of a plurality of NOMA transmission sets, and wherein parameters of the identified NOMA transmission set may be used for transmission from an eNB to one or more UEs, according to some embodiments.

[0015] **Fig. 11A** illustrates a DCI comprising a co-scheduled UE information, wherein the DCI may be transmitted to a first UE, to inform the first UE about information

associated with a second UE that is co-scheduled with the first UE for NOMA spatial multiplexing transmission, according to some embodiments.

[0016] **Fig. 11B** illustrates a DCI comprising a MUST modulation order field, wherein the DCI may be transmitted to a first UE, to inform the first UE about modulation order of a second UE that is co-scheduled with the first UE for NOMA spatial multiplexing transmission, according to some embodiments.

[0017] **Fig. 12A** generally illustrates various MU communication scenarios and specifically illustrates non-orthogonal spatial multiplexing (SM) scenarios, and key parameters associated with the non-orthogonal spatial multiplexing (SM) scenarios, according to some embodiments.

[0018] **Figs. 12B-12G** illustrate link level results for scenarios with CRS-based and DMRS-based TMs, respectively, according to some embodiments.

[0019] **Fig. 13** illustrates an eNB and a UE, accordance to some embodiments.

[0020] **Fig. 14** illustrates hardware processing circuitries for an eNB for establishing and transmitting parameters associated with MUST transmissions to one or more UEs, according to some embodiments.

[0021] **Fig. 15** illustrates hardware processing circuitries for a UE for receiving an indicator via a DCI from an eNB, and mapping the indicator to a parameter associated with MUST transmission, according to some embodiments.

[0022] **Figs. 16-17A** illustrate methods for an eNB to transmit indicators identifying MUST parameters to one or more UEs, according to some embodiments.

[0023] **Fig. 17B** illustrate a method for an eNB to transmit MU parameters to an UE, according to some embodiments.

[0024] **Fig. 18** illustrates a method for a UE to receive an index that identifies a parameter associated with MUST transmission, according to some embodiments.

[0025] **Fig. 19A** illustrates a method for a UE to receive an indicator that identifies a modulator order of a co-scheduled UE, according to some embodiments.

[0026] **Fig. 19B** illustrates a method for a UE to receive ME parameters, according to some embodiments.

[0027] **Fig. 20** illustrates an architecture of a system of a network, in accordance with some embodiments.

[0028] **Fig. 21** illustrates example components of a device, in accordance with some embodiments.

[0029] **Fig. 22** illustrates example interfaces of baseband circuitry, in accordance with some embodiments.

DETAILED DESCRIPTION

[0030] MUST scheme for multi-user communications was introduced for 3GPP LTE systems in Release 14 (e.g., various versions of Release 14) of the 3GPP specification. In some examples, MUST schemes may utilize the concept of superposition coding, e.g., for a multiuser transmission in LTE and LTE-A systems. In some examples, multi-user transmission parameter estimation at the UE side may be a key issue to achieve high performance. In some embodiments, the eNB may transmit an indicator to a UE, where the UE may map the indicator to a parameter. In some embodiments, the eNB may use the parameter for MUST transmission to the UE and one or more other UEs. The UE may use the parameter to demodulate Downlink (DL) signals from the eNB.

[0031] In the following description, numerous details are discussed to provide a more thorough explanation of embodiments of the present disclosure. It will be apparent to one skilled in the art, however, that embodiments of the present disclosure may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form, rather than in detail, in order to avoid obscuring embodiments of the present disclosure.

[0032] Note that in the corresponding drawings of the embodiments, signals are represented with lines. Some lines may be thicker, to indicate a greater number of constituent signal paths, and/or have arrows at one or more ends, to indicate a direction of information flow. Such indications are not intended to be limiting. Rather, the lines are used in connection with one or more exemplary embodiments to facilitate easier understanding of a circuit or a logical unit. Any represented signal, as dictated by design needs or preferences, may actually comprise one or more signals that may travel in either direction and may be implemented with any suitable type of signal scheme.

[0033] Throughout the specification, and in the claims, the term "connected" means a direct electrical, mechanical, or magnetic connection between the things that are connected, without any intermediary devices. The term "coupled" means either a direct electrical, mechanical, or magnetic connection between the things that are connected or an indirect connection through one or more passive or active intermediary devices. The term "circuit" or "module" may refer to one or more passive and/or active components that are arranged to cooperate with one another to provide a desired function. The term "signal" may refer to at

least one current signal, voltage signal, magnetic signal, or data/clock signal. The meaning of "a," "an," and "the" include plural references. The meaning of "in" includes "in" and "on."

[0034] The terms "substantially," "close," "approximately," "near," and "about" generally refer to being within +/- 10% of a target value. Unless otherwise specified the use of the ordinal adjectives "first," "second," and "third," etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

[0035] It is to be understood that the terms so used are interchangeable under appropriate circumstances such that the embodiments of the invention described herein are, for example, capable of operation in other orientations than those illustrated or otherwise described herein.

[0036] The terms "left," "right," "front," "back," "top," "bottom," "over," "under," and the like in the description and in the claims, if any, are used for descriptive purposes and not necessarily for describing permanent relative positions.

[0037] For the purposes of the present disclosure, the phrases "A and/or B" and "A or B" mean (A), (B), or (A and B). For the purposes of the present disclosure, the phrase "A, B, and/or C" means (A), (B), (C), (A and B), (A and C), (B and C), or (A, B and C).

[0038] In addition, the various elements of combinatorial logic and sequential logic discussed in the present disclosure may pertain both to physical structures (such as AND gates, OR gates, or XOR gates), or to synthesized or otherwise optimized collections of devices implementing the logical structures that are Boolean equivalents of the logic under discussion.

[0039] In addition, for purposes of the present disclosure, the term "eNB" may refer to a legacy eNB, a next-generation or NR gNB, a 5G eNB, an Access Point (AP), a Base Station or an eNB communicating on the unlicensed spectrum, and/or another base station for a wireless communication system. For purposes of the present disclosure, the term "UE" may refer to a legacy UE, a next-generation or NR UE, a 5G UE, an STA, and/or another mobile equipment for a wireless communication system.

[0040] Various embodiments of eNBs and/or UEs discussed below may process one or more transmissions of various types. Some processing of a transmission may comprise receiving, conducting, and/or otherwise handling a transmission that has been received. In some embodiments, an eNB or UE processing a transmission may determine or recognize the transmission's type and/or a condition associated with the transmission. For some

embodiments, an eNB or UE processing a transmission may act in accordance with the transmission's type, and/or may act conditionally based upon the transmission's type. An eNB or UE processing a transmission may also recognize one or more values or fields of data carried by the transmission. Processing a transmission may comprise moving the transmission through one or more layers of a protocol stack (which may be implemented in, e.g., hardware and/or software-configured elements), such as by moving a transmission that has been received by an eNB or a UE through one or more layers of a protocol stack.

[0041] Various embodiments of eNBs and/or UEs discussed below may also generate one or more transmissions of various types. Some generating of a transmission may comprise receiving, conducting, and/or otherwise handling a transmission that is to be transmitted. In some embodiments, an eNB or UE generating a transmission may establish the transmission's type and/or a condition associated with the transmission. For some embodiments, an eNB or UE generating a transmission may act in accordance with the transmission's type, and/or may act conditionally based upon the transmission's type. An eNB or UE generating a transmission may also determine one or more values or fields of data carried by the transmission. Generating a transmission may comprise moving the transmission through one or more layers of a protocol stack (which may be implemented in, e.g., hardware and/or software-configured elements), such as by moving a transmission to be sent by an eNB or a UE through one or more layers of a protocol stack.

[0042] Several techniques may be adapted to increase bandwidth of wireless cellular communication systems. For example, MUST scheme for multi-user communications was introduced for 3GPP LTE systems in Release 14 (e.g., various versions of Release 14) of the 3GPP specification. In some examples, MUST schemes may utilize the concept of superposition coding, e.g., for a multiuser transmission in LTE and LTE-A systems. In some examples, multi-user transmission parameter estimation at the UE side may be a key issue to achieve high performance, e.g., as discussed herein in this disclosure.

[0043] In general, different multi-users (MU) transmission schemes with different multiplexing approaches may be possible. For example, the users may be multiplexed in frequency domain resources, time domain resources, and/or spatial domain resources. In general, multiplexing in frequency and time domain resources may be regarded as Orthogonal Multiple Access (OMA). Spatial domain multiplexing may be OMA or Non-Orthogonal Multiple access (NOMA), e.g., based on beamforming precoder design.

[0044] In some examples, in addition to or instead of the above discussed multiplexing schemes (e.g., multiplexing in frequency domain resources, time domain

resources, and/or spatial domain resources), NOMA power multiplexing may be applied using superposition transmissions. For example, if NOMA with power ratio multiplexing is used, the scheduled MU UEs may be divided (e.g., by eNB's transmission intention) into two UE behaviors of a "Near UE" and a "Far UE". The Near UE may be located relatively near a serving eNB, e.g., compared to the Far UE. The eNB may transmit to the Near UE information with relatively small transmitting power on a QAM constellation multiplexed with the Far UE. The Near UE may detect the co-scheduled NOMA UE (e.g., the Far UE) together for its own demodulation process. In an example, multiplexed Near UE information may be shown as additional noise to the Far UE. For example, **Fig. 1** illustrates a communication system 100 comprising a eNB 102 transmitting to a Near UE 104a and a Far UE 104b, e.g., based on NOMA power multiplexing, where one or both the Near UE 104a or the Far UE 104b may receive one or more indicators associated with NOMA transmission from the eNB 102, in accordance with some embodiments. For example, the Near UE 104a may be located relatively near the serving eNB 102, e.g., compared to the Far UE 104b, within a cell boundary 106 of the eNB 102. Various example parameters associated with the NOMA transmission, which may be received by the UE 104a and/or the UE 104b from the eNB 102, have been discussed herein later in further details.

[0045] **Fig. 2** illustrates various example MU scenarios and example parameters associated with the MU scenarios, according to some embodiments. For example, MU communication may be broadly classified as either OMA 204 or as NOMA 206. In an example, OMA 204 may be based on, for example, frequency multiplexing, time multiplexing and/or orthogonal spatial multiplexing.

[0046] In an example, NOMA 206 may be classified either as non-orthogonal spatial multiplexing 208 or power multiplexing 210. In an example, MU parameters of interest for the non-orthogonal spatial multiplexing 208 may be number of UEs, a precoder, a modulation scheme used, etc. In an example, the power multiplexing 210 may comprise a Near UE and a Far UE, e.g., as discussed with respect to **Fig. 1**. In some embodiments, MU parameters of interest for a Near UE 104a may be, for example, power ratio, modulation used for transmission to the Near UE and/or the Far UE, etc.

[0047] In some embodiments, in a MU scenario, a UE may have better performance (e.g., better decoding of DL (Downlink) signals) if the UE is aware of various key parameters associated with the MU transmission. Examples of such key parameters are illustrated as A, B, C, D, and E (e.g., each of these letters within a corresponding circle) in **Fig. 2**. In some embodiments, a UE may benefit from knowing whether OMA or NOMA is being used for

MU transmission, illustrated by “A” within a circle. In some embodiments, a UE may benefit from knowing whether non-orthogonal spatial multiplexing 208 or NOMA power multiplexing 210 is being used (e.g., if NOMA is used for MU transmission), illustrated by “B” within a circle. In some embodiments, a UE may benefit from knowing one or more MU parameters associated with the non-orthogonal spatial multiplexing 208, e.g., if non-orthogonal spatial multiplexing 208 is used (illustrated by “C” within a circle). In some embodiments, for power multiplexing NOMA, a UE may benefit from knowing whether the UE is a Near UE or a Far UE, illustrated by “D” within a circle. In some embodiments, if the UE is a Near UE in a power multiplexing NOMA, the UE may benefit from knowing one or more MU parameters, such as power ratio, modulation, etc., illustrated by “E” within a circle in **Fig. 2**.

[0048] In some embodiments, an eNB may provide network signaling to MU UEs (e.g., UEs involved in MU transmission), where such network signaling may provide one or more indicators or parameters providing details about the specific MU transmission schemes used. However, in an example, too much network signaling may result in relatively high signaling overload. Thus, in an example, parameters associated with MU transmission schemes, which may be transmitted to MU UEs, may have to be limited. Various embodiments of this disclosure propose signaling methods and UE blind parameter estimation methods for MUST scheme. For example, some of the embodiments propose one or more parameters associated with the MUST scheme used, which may be provided to MU UEs.

[0049] In this disclosure, various graphs have been provided and discussed herein later. For example, graphs illustrated in **Figs. 3A-5**, in essence, analyze aspects of OMA versus NOMA detection (e.g., a UE has to detect if the transmission from the eNB is OMA transmission or NOMA transmission). For example, blind detection impacts on the OMA and NOMA performance are analyzed in graphs of **Figs. 3A-5**. For example, NOMA capable UEs have to be able to detect, e.g., if a PDSCH transmission is OMA-based or NOMA-based.

[0050] In the example graphs of **Figs. 3A-5**, the impact of NOMA existence detection on the OMA and NOMA UE performance are analyzed. It is assumed that the eNB transmitter only uses a single power ratio combination with combined constellation being one of the LTE legacy constellations: (QPSK+QPSK), uniform 16QAM, (16QAM+QPSK), uniform 64QAM, (64QAM+QPSK), or uniform 256QAM.

[0051] In the graphs illustrated in **Figs. 3A-3C**, the impact of NOMA existence detection on a OMA UE performance is analyzed, according to some embodiments. In the

graphs illustrated in **Figs. 3A-3C**, various MCS (modulation and coding scheme) may be used. For example, **Figs. 3A-3C** are plots of SNR (Signal to Noise Ratio) versus existence detection error rate for a OMA UE performance (e.g., the UE is a OMA UE) and for various MCSs (e.g., MCS 0, MCS 10, and MCS 17, respectively), according to some embodiments. For each of **Figs. 3A-3C**, two lines respectively corresponding to two detection cases are illustrated: (i) “Blind Sum-Exp” (e.g., blind sum exponential is adapted for detection at the UE end), and (ii) “Blind Max Log” (e.g., blind maximum logarithmic process is adapted for detection at the UE end). In **Figs. 3A-3C**, it is assumed that the UE receives OMA transmission, but applies blind detection and may possibly erroneously detect NOMA signal. In case UE detects NOMA presence, the UE may apply NOMA Near UE reception processing. In case UE does not detect NOMA presence, the UE may apply regular OMA minimum mean square error (MMSE)-interference rejection combining (IRC) (MMSE-IRC) processing.

[0052] From **Figs. 3A-3C**, it may be observed that OMA scenarios may be detected with relative accuracy (e.g., without substantial error) by the Max-Log blind detection method. It is also observed that Sum-Exp method may cause OMA UE performance degradation reaching up to 7dB.

[0053] In the graphs illustrated in **Figs. 4A-4C**, impact of NOMA existence detection on a NOMA Near UE performance is analyzed, according to some embodiments. In the graphs illustrated in **Figs. 4A-4C**, various MCS may be used. For example, **Figs. 4A-4C** are plots of SNR versus existence detection error rate for a NOMA Near UE performance (e.g., the UE is a NOMA Near UE) and for various MCSs (e.g., MCS 0, MCS 10, and MCS 17, respectively), according to some embodiments. For each of **Figs. 4A-4C**, two lines respectively corresponding to two detection cases are illustrated: (i) “Blind Sum-Exp” (e.g., blind sum exponential is adapted for detection at the UE end), and (ii) “Blind Max Log” (e.g., blind maximum logarithmic process is adapted for detection at the UE end). In **Figs. 4A-4C**, it is assumed that the UE receives NOMA Near UE transmission, but applies blind detection and may possibly erroneously detect OMA signal. If OMA is detected, the UE may apply OMA UE RX processing. Otherwise, the UE may apply correct NOMA Near UE processing.

[0054] From **Figs. 4A-4C**, it may be observed that for the NOMA scenarios, Sum-rate method have relatively better detection performance, e.g., compared to the max-log method. Thus, the observation of **Figs. 4A-4C** are opposite of that in **Figs. 3A-3C** (e.g., in **Figs. 3A-3C**, the Max-Log blind detection method had better performance than the Sum-Exp blind detection method).

[0055] In the graph illustrated in **Fig. 5**, the impact of NOMA existence detection on a NOMA Far UE performance is analyzed, according to some embodiments. For example, **Fig. 5** is plots of SNR versus existence detection error rate for a NOMA Far UE performance (e.g., the UE is a NOMA Far UE) and for an example MCS, according to some embodiments. In **Fig. 5**, two lines respectively corresponding to two detection cases are illustrated: (i) “Blind Sum-Exp” (e.g., blind sum exponential is adapted for detection at the UE end), and (ii) “Blind Max Log” (e.g., blind maximum logarithmic process is adapted for detection at the UE end). In **Fig. 5**, it is assumed that the UE receives NOMA Far UE transmission, but applies blind detection and may possibly erroneously detect OMA signal. For example, it is assumed that a UE performs blind detection of NOMA existence (e.g., compares QPSK and 16QAM hypothesis). If a Far UE detects NOMA existence, then the UE may not have information on whether the UE is a Near UE or Far UE, and it is assumed that the UE may attempt to apply a NOMA Near UE processing (e.g., which is incorrect, and may lead to performance loss).

[0056] The graph of **Fig. 5** may illustrate that a Far UE can detect a NOMA constellation in good SNR conditions, but the UE may not know if the UE is a Near UE or a Far UE. In such a case, further detection process becomes relatively less useful, and may result in performance degradation.

[0057] Referring to **Figs. 3A-5**, it may be observed that for NOMA scenarios, a Far UE may not apply OMA/NOMA blind detection. Otherwise, the Far UE may mislead to wrong UE behavior (e.g., assuming, as discussed with respect to **Fig. 5**, that the Far UE may mistakenly detect itself as a Near UE). In some embodiments, based on the analysis associated with **Figs. 3A-5**, the following observations may be drawn:

[0058] 1. OMA UE may not apply blind detection of NOMA existence, or may use Max-Log method for OMA/NOMA blind detection, e.g., to exclude or reduce performance degradation in non-MUST scenarios.

[0059] 2. NOMA Far UE may not apply blind detection of NOMA existence, e.g., to avoid or reduce performance limitation.

[0060] 3. NOMA Near UE may not use Exp-Sum method due to unsuitability of this method for OMA UE. Therefore, NOMA Near UE may use Max Log based blind detection method, e.g., at the cost of substantial performance loss.

[0061] Thus, the above observations may conclude that, for improving performance of the UEs, the network may have to provide signaling to the UE, e.g., to inform the UE whether the UE is a MUST Near UE.

[0062] In some embodiments and as discussed with respect to **Figs. 6A-7C**, link level analysis of power offset blind detection algorithm impact on the NOMA Near UE performance (e.g., in case the UE knows about existence of co-scheduled UE) may be provided. For example, for **Figs. 6A-7C**, it may be assumed that the eNB uses power offsets, which may allow generating legacy constellation after superposition of two UEs. Different sets of hypotheses for power blind detection may be considered, and Table 1 below lists such example hypotheses.

[0063] Table 1. List of hypotheses for Power Blind Detection

Modulation	Correct Far UE power offset	Set of Far UE power offset for Blind detection	
		3 hypothesis	8 hypothesis
QPSK + QPSK	0.8	[0.7 0.8 0.9]	[0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95]
16QAM + QPSK	0.762	[0.7 0.762 0.9]	[0.7 0.72 0.762 0.8, 0.85, 0.875, 0.9, 0.9]
64QAM + QPSK	0.7529	[0.7529 0.8 0.9]	[0.74 0.7529, 0.762 0.8, 0.85, 0.875, 0.9, 0.95]

[0064] The list of hypotheses for power Blind Detection may be generated under the assumption that different constellation points from combined constellations are not collided (e.g., for QPSK+QPSK case the power offset may be larger than 0.5, for 16QAM+QPSK case the power offset may be larger than 0.6429, for 62QAM+QPSK case the power offset may be larger than 0.7).

[0065] In the graphs illustrated in **Figs. 6A-6C**, the power BD (blind detection) impact on NOMA Near UE performance is analyzed under the 3 hypotheses assumption of Table 1, according to some embodiments. In the graphs illustrated in **Figs. 7A-7C**, the power BD (blind detection) impact on NOMA Near UE performance is analyzed under the 8 hypotheses assumption of Table 1, according to some embodiments.

[0066] In the graphs illustrated in **Figs. 6A-7C**, various MCS may be used. For example, **Figs. 6A-6C** are plots of SNR versus average power estimation error for various MCSs, e.g., MCS 0, MCS 10, and MCS 17, respectively, according to some embodiments; and **Figs. 7A-7C** are plots of SNR versus average power estimation error for various MCSs, e.g., MCS 0, MCS 10, and MCS 17 respectively, according to some embodiments. For each of **Figs. 6A-7C**, two lines respectively corresponding to two detection cases are illustrated: (i) “Blind Sum-Exp” (e.g., blind sum exponential is adapted for detection at the UE end), and

(ii) “Blind Max Log” (e.g., blind maximum logarithmic process is adapted for detection at the UE end).

[0067] From **Figs. 6A-7C**, it may be observed that power blind detection may lead to relatively small detection error, e.g., in case a Far UE power blind detection is used under a given RAN4 study scenario with a single layer. These graphs indicate that UE blind detection on power ratio may be feasible under some limited cases. A reasonably acceptable or good detection performance may be achieved when NOMA transmission structure gets simple, e.g., such that a Far UE constellation restriction to QPSK and the number of layer or the number of UEs restriction. Thus, it may be concluded that UE blind detection on power ratio may be feasible under some limited cases.

[0068] In some embodiments, it may be desirable for a Near UE to detect a power ratio and/or a constellation order of a Far UE, e.g., in a NOMA scenario. In some embodiments, a UE has to be able to detect one of the following two hypotheses:

[0069] $y = H.x_{SU} + n$, Hypothesis 1

[0070] $y = \sqrt{(1 - \alpha)}.H.x_{MU-near} + \sqrt{\alpha}.H.x_{MU-far} + n$. Hypothesis 2

[0071] In hypotheses 1 and 2, y is the received signal, H is the channel, x is the transmitted symbol, and n is the complex AWGN. For example, x_{SU} is the transmitted symbol for a single user scenario in hypothesis 1. In an example, in hypothesis 2, $x_{MU-near}$ is the transmitted symbol for the Near UE in a MU scenario, and x_{MU-far} is the transmitted symbol for the Far UE in the MU scenario. Thus, hypothesis 1 is for the single user case, and hypothesis 2 is for the MU case. The term α is a power ratio discussed herein later.

[0072] In an example, when NOMA is applied, a constellation associated with the transmission may be determined, e.g., along with the power ratio. For example, Table 2 below illustrates example NOMA transmission sets, where each NOMA transmission set comprises corresponding NOMA parameters such as corresponding constellation symbols, corresponding example power ratios, etc.

[0073] Table 2: Example NOMA transmission sets

NOMA TX Index	Modulation order pair (Far+Near)	Number of QAM symbols	Underlying uniform constellation	Subset selection	Power ratio α
1	QPSK+QPSK	16QAM	16QAM	$\{\pm 1, \pm 3\}$	0.8 (uniform case)
2	QPSK+QPSK	16	64QAM	$\{\pm 1, \pm 5\}$	0.692
3	QPSK+QPSK	16	64QAM	$\{\pm 3, \pm 7\}$	0.862
4	QPSK+QPSK	16	64QAM	$\{\pm 3, \pm 5\}$	0.941

5	QPSK+QPSK	16	64QAM	$\{\pm 5, \pm 7\}$	0.973
6	QPSK+16QAM	64QAM	64QAM	$\{\pm 1, \pm 3, \pm 5, \pm 7\}$	0.762 (uniform case)
7	QPSK+16QAM	64	256QAM	$\{\pm 1, \pm 5, \pm 9, \pm 13\}$	0.71
8	QPSK+16QAM	64	256QAM	$\{\pm 3, \pm 7, \pm 11, \pm 15\}$	0.802
9	QPSK+16QAM	64	256QAM	$\{\pm 3, \pm 5, \pm 7, \pm 9\}$	0.878
10	QPSK+16QAM	64	256QAM	$\{\pm 5, \pm 7, \pm 9, \pm 11\}$	0.928
11	QPSK+16QAM	64	256QAM	$\{\pm 7, \pm 9, \pm 11, \pm 13\}$	0.952
12	QPSK+16QAM	64	256QAM	$\{\pm 9, \pm 11, \pm 13, \pm 15\}$	0.966
13	QPSK+64QAM	256QAM	256QAM	$\{\pm 1, \pm 3, \pm 5, \pm 7, \pm 9, \pm 11, \pm 13, \pm 15\}$	0.7529 (uniform case)

[0074] For example, the first column of Table 2 may be an NOMA transmission index, which may be used to identify various entries of the table. The second column of Table 2 may identify the modulation orders used for the Near UE and the Far UE, the third column may identify the number of QAM (Quadrature amplitude modulation) symbols to be used for the MU transmission, the fourth column may identify an underlying uniform constellation used for the MU transmission, the fifth column may identify a subset selection (e.g., selection of I/Q component), and the sixth column may identify the power ratio α (e.g., as discussed in hypotheses 1 and 2).

[0075] For example, if the eNB is to transmit a NOMA transmit index of 6, this may refer to the sixth row of the table (e.g., a sixth NOMA transmission set) corresponding to (QPSK+16 QAM) modulation pair, 64 QAM number of symbols, 64 QAM underlying uniform constellation, and so on.

[0076] Table 2 is merely an example of various possible NOMA transmission sets comprising example constellations, power ratios, etc. Table 2 may be expanded or shortened, e.g., depending on the system design.

[0077] In some embodiments, in a MUST communication setup, the network may provide signaling to a UE, e.g., to inform the UE whether the UE is a MUST Near UE. For example, as discussed with respect to the graphs of **Figs. 3A-7C**, such information may help the UE to more effectively communicate with the eNB. Put differently, in a NOMA power

multiplexing setup, the eNB may inform a UE if the UE is a Near UE. In some embodiments, the MUST transmission may be allocated differently per transmission and frequency resources. In an example, such signaling may be considered per PRB, per PRB group, and/or per transmission. For example, the eNB may periodically (or aperiodically) inform the UE that the UE is a Near UE, and in some examples, such information may be transmitted at every PRB, at every PRB group, at every transmission, and/or at another appropriate interval.

[0078] In some embodiments, the network (e.g., an eNB) may indicate a NOMA Near UE on a per transmission basis. For example, the network may indicate to a UE that the UE is a Near UE in a NOMA setup, e.g., if the UE is a Near UE.

[0079] Table 3 below illustrates a list of example DCI formats of PDSCH (Physical Downlink Shared Channel) scheduling through PDSCH transmission modes. For example, for transmission mode 1, DCI format 1 may be utilized; for transmission mode 2, DCI format 1 may be utilized, and so on. Information included in Table 3 has been adopted in 3GPP Technical Specification TS36.213, chapter 7.1 (Table 7.1-5). Content of each DCI format has been adopted in 3GPP Technical Specification TS36.212, chapter 5.3.3.1.

[0080] Table 3: Example DCI format of transmission modes

Transmission mode	DCI format
Transmission Mode 1	DCI format 1
Transmission Mode 2	DCI format 1
Transmission Mode 3	DCI format 2A
Transmission Mode 4	DCI format 2
Transmission Mode 5	DCI format 1D
Transmission Mode 6	DCI format 1B
Transmission Mode 7	DCI format 1
Transmission Mode 8	DCI format 2B
Transmission Mode 9	DCI format 2C
Transmission Mode 10	DCI format 2D

[0081] In some embodiments, a field comprising one or more bits (e.g., an information element) may be added to a DCI (e.g., any one of the DCI formats of Table 3). The newly added field may be referred to as a “NOMA Near UE indication field” (although such a name of the field is merely an example, and any other appropriate name of the field may be used). In some embodiments, the NOMA Near UE indication field may indicate a

NOMA Near UE on a transmitted PDSCH (e.g., may indicate to a UE whether the UE is associated with a MUST transmission and whether the UE is a NOMA Near UE). For example, **Fig. 8** illustrates a DCI 800 comprising a NOMA Near UE indication field 802, where the NOMA Near UE indication field 802 may indicate a NOMA Near UE on a transmitted PDSCH (e.g., may indicate to a UE whether the UE is associated with a MUST transmission and whether the UE is a NOMA Near UE), according to some embodiments.

[0082] Merely as an example, the NOMA Near UE indication field may be a single bit field. A value of “1” may indicate to a UE that the UE is associated with a MUST transmission and the UE is a NOMA Near UE. A value of “0” may indicate to a UE that the UE is either not associated with MUST transmission, or the UE is associated with MUST transmission but is not a NOMA Near UE (e.g., may be a NOMA Far UE).

[0083] In some embodiments, upon receipt of a DCI from the eNB, a UE may access the NOMA Near UE indication field 802 to determine if the UE is a NOMA Near UE. If the NOMA Near UE indication field indicates that the UE is a NOMA Near UE, the UE may apply an appropriate (e.g., enhanced) receive signal processing for demodulating the received DL signals. Merely as an example, the UE may perform R-ML (reduced complexity maximum likelihood) joint demodulation of the NOMA DL signals to the Near and Far UE.

[0084] On the other hand, if the NOMA Near UE indication field indicates that the UE is not a NOMA Near UE, the UE may apply appropriate (e.g., conventional) receive signal processing, e.g. perform a LMMSE-IRC (linear minimum mean square error (LMMSE)-interference rejection combining (IRC)) processing, merely as an example.

[0085] In some embodiments, the eNB may apply NOMA transmission over all PRBs where PDSCH is allocated. In some other embodiments, the eNB may not apply NOMA transmission over all the PRBs where PDSCH is allocated. For example, NOMA may be applied to partial resources of allocated PRB.

[0086] Accordingly, in some embodiments, the eNB may add a new information element or field to the DCI format, where the new information element or field may indicate or identify the resource blocks where a NOMA scheme is applied. Merely as an example, the information element or field may be referred to as “NOMA resource block identification field,” or as “NOMA PRB identification field” (although any other appropriate name may be used for the field). In some embodiments, the NOMA PRB identification field may indicate each PRB or a PRB group where MUST (e.g., NOMA) transmission is used. For example, **Fig. 9** illustrates a DCI 900 comprising a NOMA PRB identification field 902, wherein the

NOMA PRB identification field 902 may identify, to a Near UE, one or more PRBs and/or PRB groups for which NOMA transmission is used, according to some embodiments.

[0087] In some embodiments, the NOMA PRB identification field may be provided to the NOMA Near UEs (e.g., may be provided only to the NOMA Near UEs). For other UEs (e.g., non-MU UEs, OMA UEs, or NOMA Far UEs), the NOMA PRB identification field may be empty, absent, or zero. For example, other UEs (e.g., non-MU UEs, OMA UEs, or NOMA Far UEs), the NOMA PRB identification field may not indicate any PRB or PRB group where MUST (e.g., NOMA) transmission is used.

[0088] Thus, the NOMA PRB identification field may identify, to a Near UE, one or more PRBs and/or PRB groups for which NOMA transmission is used.

[0089] In some embodiments, the NOMA PRB identification field may be at least in part similar to the above discussed NOMA Near UE indication field. For example, if the NOMA PRB identification field is transmitted, transmission of the NOMA Near UE indication field may be redundant.

[0090] In some embodiments, the NOMA PRB identification field may be introduced in the form of a bit string, or other methods with a more compact Resource Block (RB) indication can be used.

[0091] In some embodiments, the DCI may include two resource block assignment fields. A first of the two resource block assignment fields may be a legacy field, and a second of the two resource block assignment fields may be used to indicate PRBs of NOMA transmissions (e.g., the second of the two resource block assignment fields may be the NOMA PRB identification field).

[0092] As illustrated in Table 2, a NOMA transmission scheme may be constructed with a combination of one of multiple power ratios and one of multiple constellation. In some embodiments, if many parameters and transmission assumptions are involved, UE blind detection may not always be feasible. In some embodiments, the network (e.g., a eNB) may transmit or share a pre-determined NOMA table (e.g., similar to the Table 2). Subsequently, the network may share an index through DCI to the UE. Thus, for example, the network may signal a plurality of pre-determined NOMA transmission sets, each of which may identify a corresponding QAM modulation, a corresponding power ratio, etc. In some embodiments, transmission of the pre-determined NOMA transmission sets may be via RRC signaling. Merely as an example, the pre-determined NOMA transmission sets may correspond to two or more rows (e.g., all the rows, or at least some rows) of the Table 2. In some embodiments, the network (e.g., the eNB) may also indicate, to a UE, an index of the NOMA transmission

set used for transmission to the UE. Merely as an example, the index may be referred to as a “NOMA index,” “NOMA indicator,” “MUST index,” “MUST power ratio index,” or the like. In some embodiments, the NOMA index may be transmitted to a UE through the DCI. For example, **Fig. 10** illustrates a DCI 1000 comprising a NOMA index 1004, wherein the NOMA index 1004 may be used to identify a NOMA transmission set of a plurality of NOMA transmission sets, and wherein parameters of the identified NOMA transmission set may be used for transmission from an eNB to a UE, according to some embodiments.

[0093] As an example, a first value of the NOMA index 1004 may be mapped to a corresponding first value of a parameter, a second value of the NOMA index 1004 may be mapped to a corresponding second value of the parameter, and so on. The parameter may be a NOMA parameter (e.g., a power ratio used for NOMA power multiplexing, a modulation order of a co-scheduled UE, etc.) that the eNB may use for transmission to at least two UEs in a NOMA transmission.

[0094] In some embodiments, the NOMA index 1004 may be transmitted to a UE when the UE is configured as a Near UE (e.g., configured for MUST near operation). For example, when the UE is not configured as a Near UE (e.g., is configured as a Far UE, or as a OMA UE, or does not participate in MU transmission), the DCI to the UE may not include the NOMA index 1004 (or the NOMA index 1004 may be present, but may have a null value).

[0095] In some embodiments, the NOMA index 1004 may be included in one or more DCI formats (e.g., one or more of the DCI formats of Table 3). In some embodiments, the NOMA index 1004 may identify a NOMA transmission set of the plurality of NOMA transmission sets. For example, the UE (e.g., which may be configured to operate as a MUST Near UE) may identify, based on the NOMA index 1004, a modulation order used for transmission, and/or one or more other parameters associated with NOMA transmission. In an example, the UE may use the NOMA index 1004 to identify a power ratio used for NOMA transmission. For example, the NOMA index 1004 to identify a parameter, and the parameter may be used to identify a power ratio used for NOMA transmission.

[0096] In some embodiments, the UE receiving the NOMA index may be configured as a Near UE. The UE may demodulate signals received from the eNB, based at least in part of the parameters derived from the NOMA index. In some embodiments, the UE may store the parameters in a memory of the UE.

[0097] Referring again to **Fig. 2**, as illustrated as information “B” and “C” (e.g., which are encircled by corresponding circles), MU UEs may be multiplexed by non-orthogonal pre-coders as follows:

[0098]
$$y = H_{MU1}x_{MU1} + H_{MU2}x_{MU2} + n$$
 Equation 1.

[0099] In equation 1, x_{MU1} and x_{MU2} are signals to be transmitted to a first MU UE and a second MU UE, respectively. P_{MU1} and P_{MU2} may be precoders for transmission to the first MU UE and the second MU UE, respectively, H may be the channel, and n may be complex AWGN.

[00100] In some embodiments, equation 1 may be used for non-orthogonal spatial multiplexing (e.g., NOMA with spatial multiplexing), and in such a case, precoders P_{MU1} and P_{MU2} may be non-orthogonal. In some embodiments, the network may signal one or more MU parameters to a UE, e.g., for performance enhancement from advanced receivers. Such network signaling may be used, for example, if UE blind detection is not available (or may be used even when UE blind detection is available).

[00101] In some embodiments, such network signaling may be used for some or all CRS-TM (Cell-specific Reference Signals – Transmission mode). For example, for transmission mode 4 and/or transmission mode 5, such network signaling may be used to transmit one or more NOMA spatial multiplexing parameters to a UE.

[00102] In some embodiments, the network (e.g., the eNB) may signal a co-scheduled UE's information (e.g., also referred to herein as “co-scheduled UE information”) to a UE. For example, as discussed with respect to equation 1, if the first UE and the second UE are co-scheduled for NOMA spatial multiplexing transmission, the eNB may transmit co-scheduled UE information to the first UE, where the co-scheduled UE information to the first UE may include information of the second UE. Additionally, or alternatively, the eNB may transmit co-scheduled UE information to the second UE, where the co-scheduled UE information to the second UE may include information of the first UE.

[00103] In some embodiments, co-scheduled UE information may be transmitted via DCI. For example, **Fig. 11A** illustrates a DCI 1100 comprising a co-scheduled UE information field 1104, wherein the DCI 110 may be transmitted to a first UE, to inform the first UE about information associated with a second UE that is co-scheduled with the first UE for NOMA spatial multiplexing transmission, according to some embodiments.

[00104] In some embodiments, co-scheduled UE information 1104 may comprise co-scheduled UE precoder information, e.g., information associated with the precoder of the co-

scheduled UE. For example, co-scheduled UE information 1104 may comprise a PMI, number of layers, a rank indicator, etc. associated with the co-scheduled UE.

[00105] In some embodiments, co-scheduled UE information 1104 may comprise modulation order of the co-scheduled UE. For example, if the eNB schedules a first UE and a second UE for NOMA transmission with spatial multiplexing, then the eNB may transmit the modulation order of the second UE to the first UE (e.g., in the form of the co-scheduled UE information 1104). In some embodiments, the first UE may use the information of the modulation order of the second UE for Successive Interference Cancellation (SIC), for reduced complexity ML (RML) detection, and/or the like.

[00106] In an example, when the co-scheduled UE information 1104 comprises modulation order of the co-scheduled UE, the co-scheduled UE information 1104 may also be referred to as MUST modulation order field. For example, **Fig. 11B** illustrates a DCI 1200 comprising a MUST modulation order field 1204, wherein the DCI 110 may be transmitted to a first UE, to inform the first UE about modulation order of a second UE that is co-scheduled with the first UE for NOMA spatial multiplexing transmission, according to some embodiments.

[00107] In some embodiments, the UE may receive the MUST modulation order field 1204 (e.g., via the DCI), may determine the modulation order of the co-scheduled UE, and may demodulate signals from the eNB based on the determined modulation order of the co-scheduled UE.

[00108] In some embodiments, in order to make the signaling concise and efficient, the network may reduce the number of signaling sets. For example, assuming there are codebook subsets for beamforming, the network may reduce the number of MU precoder sets through RRC, e.g., in order to shorten the signaling set size. This may result in shortening a bit string length in the DCI.

[00109] In some embodiments, the constellation set size may also be reduced. For example, although UE capability may be indicated with a high modulation order (e.g., 64QAM or 256QAM), when the UE is served by MU transmission scheme, constellation order may be restricted to a relatively few lower modulation orders. In some embodiments, the constellation order may be provided by the network via RRC signaling to the UE. Merely as an example, although 256QAM may be supported by an UE, the network may indicate that the MU transmission is served by up to 64QAM or 16QAM. In some other embodiments, the network may indicate fully signaling of constellation order and precoders of co-scheduled UEs through DCI.

[00110] **Fig. 12A** generally illustrates various MU communication scenarios and specifically illustrates non-orthogonal spatial multiplexing (SM) scenarios, and key parameters associated with the non-orthogonal spatial multiplexing (SM) scenarios, according to some embodiments. As discussed previously with respect to **Fig. 2** and as also illustrated in **Fig. 12A**, in general, different MU transmission schemes with different multiplexing approaches may exist. The UEs may be multiplexed in frequency and time domain resources, or spatial domain resources. Multiplexing in frequency and time domain resources may be regarded as OMA. Spatial domain multiplexing can be OMA or NOMA, e.g., depending on beamforming precoder design. On the top of the multiplexing schemes, NOMA power multiplexing can be applied using superposition transmissions. NOMA has several methods under 3GPP discussions. For example, in a first method, MU NOMA can be fulfilled with non-orthogonal precoder transmission. Multiple users may be scheduled on non-orthogonal spatial dimension, and the network expects MU UE implementation to handle intra-cell interferences using interference rejection combining (IRC) or non-linear detection. A second MU NOMA method is to use power multiplexing. Depending on propagation channel power, the eNB or eNodeB may assign different transmission power. These multiplexing scenario and parameters may be important for MU performances and the UE may preferably know about the specific information. A summary of the parameters and multiplexing schemes is illustrated in **Fig. 12A**.

[00111] In **Fig. 12A**, example receiver devices and receiver procedures of non-orthogonal precoder use cases are indicated in thick dotted boxes in **Fig. 12A**. For example, the main ideas are divided into two parts - one is low complexity multi-user parameter estimations, and another is UE detector behaviors for optimal performances.

[00112] Various embodiments discussed herein may include one or more of the following:

[00113] 1. In various embodiments, the network can multiplex multiple users by spatial multiplexing (SM) using non-orthogonal precoders.

[00114] 2. In various embodiments, MU parameters may be required for MU UE demodulations, e.g., depending transmission modes. The MU parameters can be either signaled from network, or blindly detected by UEs. Example MU parameters are shown by Table 4 below.

[00115] 3. In various embodiments, depending on parameter awareness of MU UEs and performance matrix, multiple UE detection strategies may be adapted (e.g., linear detection, non-linear detection, IRC strategies, etc.).

[00116] 4. In various embodiments, blind detection on the parameters are possible. Embodiments provide various low complexity algorithms with reasonable estimation accuracy.

[00117] Various embodiments of this disclosure provide (i) MU UE detection mechanisms for performance optimization based on UE parameter awareness assumption(s), and (ii) MU UE blind parameter estimation mechanisms for low complexity.

[00118] Table 4: MU parameters for demodulation

SM with non-orthogonal precoder	MU parameters
CRS-based TMs (e.g. TM5)	• Co-scheduled UE Existence • Number of multi-users • Precoder • Modulation order • Power offset (if different power ratio on MIMO layers is applicable)
DMRS-based TMs (e.g. TM9)	• Co-scheduled UE Existence • DMRS scrambling seed • Number of DMRS ports • Modulation order

[00119] Section 1. MU UE detection mechanisms for performance optimization

[00120] In some embodiments, MU UE detection mechanisms for performance optimization may be based on UE parameter awareness assumption(s). MU detection performance may be improved by multiple schemes, such as interference rejection and combining, non-linear detections, etc. Various embodiments may provide UE detection mechanisms that may optimize detection performance. Various embodiments may include minimum mean square error (MMSE)-based detection and maximum likelihood based detection mechanisms.

[00121] MMSE based algorithms

[00122] For MuST case 3 scenarios, the receive signal model may be written in the following form:

$$\mathbf{y} = \mathbf{H}(\mathbf{V}_S \mathbf{x}_S + \mathbf{V}_I \mathbf{x}_I) + \mathbf{n}$$

[00123]

[00124] where $\mathbf{H}$ is a channel transfer function, $\mathbf{V}_S$ and $\mathbf{V}_I$ are serving and interference cells precoder matrices, $\mathbf{x}_S$ and $\mathbf{x}_I$ are serving and interference cells transmit signals, and $\mathbf{n}$ is additive white Gaussian noise (AWGN).

[00125] MMSE solutions for the serving signal demodulation may be represented by the following equation:

$$\hat{\mathbf{x}}_S = \mathbf{W}_{MMSE} \mathbf{y} = \left(\hat{\mathbf{H}} \mathbf{V}_S \right)^H \hat{\mathbf{R}}_{S+I+N}^{-1} \mathbf{y}$$

[00126]

[00127] where $\hat{\mathbf{R}}_{S+I+N}$ is the joint covariance matrix estimation of serving signal, interference signal and AWGN, and $\hat{\mathbf{H}}$ is the channel transfer function estimation.

[00128] Depending on the approach for the joint covariance matrix estimation, different types of Linear MMSE (LMMSE) receivers may be used, such as LMMSE-IRC receivers with RS-based interference estimation and/or enhanced-LMMSE (E-LMMSE)-IRC receivers.

[00129] LMMSE-IRC receivers with RS-based interference estimation

[00130] In some embodiments, LMMSE-IRC receivers may be assumed to perform interference covariance matrix estimation on the serving cell reference signal (RS) resource elements (REs) after subtraction of the serving cell RS signals. Depending on scenarios, cell-specific reference signal (CRS) or demodulation reference signal (DMRS) REs may be used. In particular, in such embodiments, separate estimation of interference plus noise covariance matrix ($\hat{\mathbf{R}}_{I+N}$) and serving covariance matrix ($\hat{\mathbf{R}}_S$) may be applied, where:

$$\begin{aligned} \hat{\mathbf{y}}_N(k, l) &= \mathbf{y}(k, l) - \hat{\mathbf{H}}_{RS}(k, l) \mathbf{x}_{RS}(k, l) \\ \hat{\mathbf{R}}_N &= \left\langle \hat{\mathbf{y}}_N(k, l) \hat{\mathbf{y}}_N^H(k, l) \right\rangle_{k, l \in RS} \\ \hat{\mathbf{R}}_S &= \left\langle \left(\hat{\mathbf{H}} \mathbf{V}_S \right) \left(\hat{\mathbf{H}} \mathbf{V}_S \right)^H \right\rangle \\ \hat{\mathbf{R}}_{S+I+N} &= \hat{\mathbf{R}}_S + \hat{\mathbf{R}}_N \end{aligned}$$

[00131] E-LMMSE-IRC receivers

[00132] In some embodiments, the intra-cell interference covariance matrix may be estimated based on the detected/signaled MU-multiple input multiple output (MIMO) precoding vector. The total signal covariance matrix may be estimated as follows:

$$\begin{aligned}
\hat{\mathbf{y}}_N(k, l) &= \mathbf{y}(k, l) - \hat{\mathbf{H}}_{RS}(k, l) \mathbf{x}_{RS}(k, l) \\
\mathbf{R}_N &= \left\langle \hat{\mathbf{y}}_N(k, l) \hat{\mathbf{y}}_N^H(k, l) \right\rangle_{k, l \in RS} \\
\hat{\mathbf{R}}_S &= \left\langle (\hat{\mathbf{H}} \mathbf{V}_S) (\hat{\mathbf{H}} \mathbf{V}_S)^H \right\rangle \\
\hat{\mathbf{R}}_I &= \left\langle (\hat{\mathbf{H}} \mathbf{V}_I) (\hat{\mathbf{H}} \mathbf{V}_I)^H \right\rangle \\
\hat{\mathbf{R}}_{S+I+N} &= \hat{\mathbf{R}}_S + \hat{\mathbf{R}}_I + \hat{\mathbf{R}}_N
\end{aligned}$$

[00133] In various embodiments, this receiver may allow more accurate estimation of interference covariance matrix using per-RE co-scheduled UE channel estimate. Therefore, when compared to the LMMSE-IRC receivers, it may require additional information on the interference structure including MU-MIMO signal presence and precoder of the co-scheduled UE with per-physical resource block (PRB) granularity.

[00134] In embodiments, MU parameters for ELMSE-IRC detection may include:

[00135] (i) CRS-transmission mode (TM): MU Existence, the number of co-scheduled UEs, MU precoder; and

[00136] (ii) DMRS-TM: MU existence, the number of co-scheduled UEs, DMRS scrambling seed.

[00137] Nonlinear detector (Reduced maximum likelihood (RML) receiver)

[00138] In some embodiments, the demodulation may be performed using joint detection of serving and interference signals using maximum likelihood (ML) principle, as follows:

$$\begin{bmatrix} \hat{\mathbf{x}}_S \\ \hat{\mathbf{x}}_I \end{bmatrix} = \arg \min_{\mathbf{x}_S, \mathbf{x}_I} \left\| \mathbf{y} - \mathbf{H} [\mathbf{V}_S, \mathbf{V}_I] \begin{bmatrix} \mathbf{x}_S \\ \mathbf{x}_I \end{bmatrix} \right\|^2$$

[00139] Such embodiments may be similar or equivalent to the network assisted interference cancellation and suppression (NAICS) reduced complexity ML (R-ML) receivers with the exception that intra-cell interference is used instead of inter-cell

interference. Such an R-ML receiver may require knowledge of channel coefficients, precoder matrices, and modulations of both signals.

[00140] In some embodiments, MU parameters for ML detection may include one or both of:

[00141] (i) CRS-TM : parameters for EMMSE-IRC + MU modulation orders; and

[00142] (ii) DMRS-TM : parameters for EMMSE-IRC + MU modulation orders.

[00143] Other non-linear detection algorithms such as symbol-level or codeword level successive interference cancellation also may be adapted or included with the example embodiments.

[00144] Detector performance study on SM using non-orthogonal precoders

[00145] **Figs. 12B-12D and 12E-12G** illustrate link level results for scenarios with CRS-based and DMRS-based TMs, respectively, according to some embodiments. For MMSE based receivers, results for scenarios with QPSK interference are provided (since performance does not depend on the co-scheduled UE interference) and the results for R-ML receiver are provided for the case of using different modulations for the co-scheduled UE.

Figs. 12B-12D are associated with CRS-TM MU multiple detector performance, and **Figs. 12E-12G** are associated with DMRS-TM MU multiple detector performance.

[00146] One or more of the following observation may be drawn from **Figs. 12B-12D** on CRS-TM MU multiple detector performance:

[00147] (i) LMMSE-IRC receivers do not provide acceptable performance for scenarios with Serving UE modulation and coding scheme (MCS)10 and MCS17;

[00148] (ii) E-LMMSE-IRC receivers may have reliable performance for the considered scenarios; and

[00149] (iii) R-ML receivers may provide performance improvement over E-LMMSE-IRC for the limited set of scenarios.

[00150] One or more of the following observation may be drawn from **Figs. 12E-12G** on DMRS-TM MU multiple detector performance:

[00151] (i) LMMSE-IRC and EMMSE-IRC shows relatively steady performance; and

[00152] (ii) R-ML receiver allows achieving performance improvement over E-LMMSE-IRC for the limited set of scenarios.

[00153] The R-ML detector may have high complexity and high computation loading for non-linear detections, and additionally it does not always show the gain over E-LMMSE-IRC detector. Explicit gain of R-ML is observed in specific use cases when the serving UE

utilizes high MCS and the co-scheduled UE utilizes low modulation order MCS. In conclusion, the UE may not have to utilize R-ML to obtain the best performance.

[00154] Adaptive MU detector mechanism selection

[00155] 1. In some embodiments, an MU UE detection mechanism may be adapted between linear detection and non-linear detection.

[00156] 2. In some embodiments, an E-LMMSE-IRC mechanism may be selected based on: 2a. When a serving modulation order is low or an interference modulation order is high; and/or b. When blind detection on MU modulation order is not reliable.

[00157] 3. In some embodiments, an ML mechanism (and/or R-ML mechanism) may be selected based on: 3a. When a serving modulation order is high and Interference modulation order is medium or low; and/or 3b. When blind detection on MU parameters are reliable.

[00158] Section 2: MU UE blind parameter estimation mechanisms for low complexity

[00159] In some embodiments, the interference parameters may be detected using ML principles. In particular, such embodiments can be applied for the joint detection of signal presence, precoding vector and modulation format. In various embodiments, an ML based algorithm may estimate a probability of receive signal for different transmit parameters hypothesis and find the hypothesis which provides the maximum of this probability:

$$\left[\hat{\mathbf{V}}_I, \hat{M}_I \right] = \arg \max_{i=0 \dots N, j=1 \dots 3} p(\mathbf{y} | \mathbf{V}_I(i), M_I(j))$$

[00160] where M_I is modulation format of the interference signals.

[00161] Section 2.1: Low complexity covariance matrix comparison for CRS-based TM precoder detection

[00162] In some embodiments, the co-scheduled UE signal existence (presence) and precoder can be detected using receive signal covariance matrix processing via multi-hypothesis testing. In various embodiments, a UE may be capable of reconstructing the receive signal covariance matrices under various receive (RX) signal hypothesis and compare it against the actual receive signal covariance matrix estimated on the data REs. For the detection, we compare covariance matrices based on Euclidean distance. When a received signal is given as:

$$\mathbf{y} = \mathbf{H}(\mathbf{V}_s \mathbf{x}_s + \mathbf{V}_I \mathbf{x}_I) + \mathbf{n},$$

[00163] A UE can make the following hypothesis:

[00164] (i) Hypothesis on SU-MIMO, precoder $V_I(i) = 0$, where $i = 0$

[00165] (ii) Hypothesis on MU-MIMO + Precoder $V_I(i)$, where $i = 1, \dots, N$,

[00166] where N is the number of precoders. With hypothesis above, an UE can reconstruct a covariance matrix of $\hat{\mathbf{R}}(i)$, and select the hypothesis with the minimum mismatch vs estimated RX signal covariance matrix:

$$\hat{\mathbf{V}}_I = \arg \min_{i=0 \dots N} \left\| \hat{\mathbf{R}}_y - \hat{\mathbf{R}}(i) \right\|_F.$$

[00167] Section 2.2: Low complexity hybrid detection method for CRS-based TMs (partial ML search and partial covariance matrix comparison)

[00168] In various embodiments, ML and covariance matrix comparison can be combined. In such embodiments, the interference signal presence and precoder can be detected using the covariance matrix. Once these parameters are detected, the modulation format can be further detected using ML under assumption of known signal presence and precoder.

[00169] Embodiments discussed in section 2.1 may be applicable for E-LMMSE-IRC receivers, and embodiments discussed in section 2.2 may be applicable for R-ML receivers, which may require information on the signal modulation format (see e.g., table 4).

[00170] Section 2.3. DMRS-TM parameter detection using threshold test

[00171] In some embodiments, a TM9 UE may detect co-scheduled UE existence. A practical existence, scrambling seed detection algorithm is designed based on channel power of DMRS AP. On $AP_i (SCID_i) \notin \text{-serving DMRS APs where } SCID_i \in \{n_{RNTI} = 0 \text{ or } 1\}$.

$$\left\langle \mathbf{H}_{AP_i(SCID_i)}, \mathbf{H}_{AP_j(SCID_j)}^H \right\rangle > \gamma \mathbf{R}_n$$

[00172] The threshold detection may declare the co-scheduled UE existence. The threshold of detection is given based on noise variance multiplied by a scalar γ , which is an optimization factor. Depending on the orthogonal correction code (OCC) level, embodiments may investigate antenna ports (AP) 7,8 or AP 7,8,11,12.

[00173] In embodiments where the electronic device 100 is implemented in or by an eNB or TRP, the electronic device 100 may be to multiplex multiple users (MU) in a MU-MIMO system using SM with non-orthogonal precoders.

[00174] In embodiments where the electronic device 100 is implemented in or by a UE, the electronic device 100 may be to detect MU parameters to be used for receiving signals in an MU- MIMO system that uses SM with non-orthogonal precoders.

[00175] **Fig. 13** illustrates an eNB and a UE, in accordance with some embodiments of the disclosure. **Fig. 13** includes block diagrams of an eNB 1310 and a UE 1330 which are operable to co-exist with each other and other elements of an LTE network. High-level, simplified architectures of eNB 1310 and UE 1330 are described so as not to obscure the embodiments. It should be noted that in some embodiments, eNB 1310 may be a stationary non-mobile device.

[00176] eNB 1310 is coupled to one or more antennas 1305, and UE 1330 is similarly coupled to one or more antennas 1325. However, in some embodiments, eNB 1310 may incorporate or comprise antennas 1305, and UE 1330 in various embodiments may incorporate or comprise antennas 1325.

[00177] In some embodiments, antennas 1305 and/or antennas 1325 may comprise one or more directional or omni-directional antennas, including monopole antennas, dipole antennas, loop antennas, patch antennas, microstrip antennas, coplanar wave antennas, or other types of antennas suitable for transmission of RF signals. In some MIMO (multiple-input and multiple output) embodiments, antennas 1305 are separated to take advantage of spatial diversity.

[00178] eNB 1310 and UE 1330 are operable to communicate with each other on a network, such as a wireless network. eNB 1310 and UE 1330 may be in communication with each other over a wireless communication channel 1350, which has both a downlink path from eNB 1310 to UE 1330 and an uplink path from UE 1330 to eNB 1310.

[00179] As illustrated in **Fig. 13**, in some embodiments, eNB 1310 may include a physical layer circuitry 1312, a MAC (media access control) circuitry 1314, a processor 1316, a memory 1318, and a hardware processing circuitry 1320. A person skilled in the art will appreciate that other components not shown may be used in addition to the components shown to form a complete eNB.

[00180] In some embodiments, physical layer circuitry 1312 includes a transceiver 1313 for providing signals to and from UE 1330. Transceiver 1313 provides signals to and from UEs or other devices using one or more antennas 1305. In some embodiments, MAC circuitry 1314 controls access to the wireless medium. Memory 1318 may be, or may include, a storage media/medium such as a magnetic storage media (e.g., magnetic tapes or magnetic disks), an optical storage media (e.g., optical discs), an electronic storage media

(e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any tangible storage media or non-transitory storage media. Hardware processing circuitry 1320 may comprise logic devices or circuitry to perform various operations. In some embodiments, processor 1316 and memory 1318 are arranged to perform the operations of hardware processing circuitry 1320, such as operations described herein with reference to logic devices and circuitry within eNB 1310 and/or hardware processing circuitry 1320.

[00181] Accordingly, in some embodiments, eNB 1310 may be a device comprising an application processor, a memory, one or more antenna ports, and an interface for allowing the application processor to communicate with another device.

[00182] As is also illustrated in **Fig. 13**, in some embodiments, UE 1330 may include a physical layer circuitry 1332, a MAC circuitry 1334, a processor 1336, a memory 1338, a hardware processing circuitry 1340, a wireless interface 1342, and a display 1344. A person skilled in the art would appreciate that other components not shown may be used in addition to the components shown to form a complete UE.

[00183] In some embodiments, physical layer circuitry 1332 includes a transceiver 1333 for providing signals to and from eNB 1310 (as well as other eNBs). Transceiver 1333 provides signals to and from eNBs or other devices using one or more antennas 1325. In some embodiments, MAC circuitry 1334 controls access to the wireless medium. Memory 1338 may be, or may include, a storage media/medium such as a magnetic storage media (e.g., magnetic tapes or magnetic disks), an optical storage media (e.g., optical discs), an electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any tangible storage media or non-transitory storage media. Wireless interface 1342 may be arranged to allow the processor to communicate with another device. Display 1344 may provide a visual and/or tactile display for a user to interact with UE 1330, such as a touch-screen display. Hardware processing circuitry 1340 may comprise logic devices or circuitry to perform various operations. In some embodiments, processor 1336 and memory 1338 may be arranged to perform the operations of hardware processing circuitry 1340, such as operations described herein with reference to logic devices and circuitry within UE 1330 and/or hardware processing circuitry 1340.

[00184] Accordingly, in some embodiments, UE 1330 may be a device comprising an application processor, a memory, one or more antennas, a wireless interface for allowing the application processor to communicate with another device, and a touch-screen display.

[00185] Elements of **Fig. 13**, and elements of other figures having the same names or reference numbers, can operate or function in the manner described herein with respect to any

such figures (although the operation and function of such elements is not limited to such descriptions). For example, **Fig. 13** also depicts embodiments of eNBs, hardware processing circuitry of eNBs, UEs, and/or hardware processing circuitry of UEs, and the embodiments described with respect to **Fig. 13**.

[00186] In addition, although eNB 1310 and UE 1330 are each described as having several separate functional elements, one or more of the functional elements may be combined and may be implemented by combinations of software-configured elements and/or other hardware elements. In some embodiments of this disclosure, the functional elements can refer to one or more processes operating on one or more processing elements. Examples of software and/or hardware configured elements include Digital Signal Processors (DSPs), one or more microprocessors, Field-Programmable Gate Arrays (FPGAs), Application Specific Integrated Circuits (ASICs), Radio-Frequency Integrated Circuits (RFICs), and so on.

[00187] **Fig. 14** illustrates hardware processing circuitries for an eNB for establishing and transmitting parameters associated with MUST transmissions to one or more UEs, according to some embodiments. With reference to **Fig. 13**, an eNB may include various hardware processing circuitries discussed below, which may in turn comprise logic devices and/or circuitry operable to perform various operations. For example, in **Fig. 13**, eNB 1310 (or various elements or components therein, such as hardware processing circuitry 1320, or combinations of elements or components therein) may include part of, or all of, these hardware processing circuitries.

[00188] In some embodiments, one or more devices or circuitries within these hardware processing circuitries may be implemented by combinations of software-configured elements and/or other hardware elements. For example, processor 1316 (and/or one or more other processors which eNB 1310 may comprise), memory 1318, and/or other elements or components of eNB 1310 (which may include hardware processing circuitry 1320) may be arranged to perform the operations of these hardware processing circuitries, such as operations described herein with reference to devices and circuitry within these hardware processing circuitries. In some embodiments, processor 1316 (and/or one or more other processors which eNB 1310 may comprise) may be a baseband processor.

[00189] Returning to **Fig. 14**, an apparatus of eNB 1310 (or another eNB or base station), which may be operable to communicate with one or more UEs on a wireless network, may comprise hardware processing circuitry 1400. In some embodiments, hardware processing circuitry 1400 may comprise one or more antenna ports 1405 operable to provide

various transmissions over a wireless communication channel (such as wireless communication channel 1350). Antenna ports 1405 may be coupled to one or more antennas 1407 (which may be antennas 1305). In some embodiments, hardware processing circuitry 1400 may incorporate antennas 1407, while in other embodiments, hardware processing circuitry 1400 may merely be coupled to antennas 1407.

[00190] Antenna ports 1405 and antennas 1407 may be operable to provide signals from an eNB to a wireless communications channel and/or a UE, and may be operable to provide signals from a UE and/or a wireless communications channel to an eNB. For example, antenna ports 1405 and antennas 1407 may be operable to provide transmissions from eNB 1310 to wireless communication channel 1350 (and from there to UE 1330, or to another UE). Similarly, antennas 1407 and antenna ports 1405 may be operable to provide transmissions from a wireless communication channel 1350 (and beyond that, from UE 1330, or another UE) to eNB 1310.

[00191] Hardware processing circuitry 1400 may comprise various circuitries operable in accordance with the various embodiments discussed herein. With reference to **Fig. 14**, hardware processing circuitry 1400 may comprise a first circuitry 1410 and/or a second circuitry 1420.

[00192] In some embodiments, the first circuitry 1410 may be configured to establish an index that is to identify a parameter. The parameter may be associated with MUST transmission from the eNB to a first UE configured as a Near UE and a second UE configured as a Far UE. In some embodiments, the second circuitry 1420 may be configured to generate a DCI including the index. The DCI may be for transmission to at least one of the first UE or the second UE. In some embodiments, one or more memory of the eNB may store one or more of the index, the parameter, or DCI. In some embodiments, the eNB may comprise an interface to output the DCI, including the index, to a transceiver circuitry, for transmission to at least one of the first UE or the second UE. In some embodiments, the parameter may be a power ratio α used by the eNB to weight symbols for transmission to the Near UE and the Far UE. In some embodiments, the parameter may be one or both a first modulation order for transmission to the first UE and a second modulation order for transmission to the second UE. In some embodiments, the DCI may be transmitted to the first UE configured as the Near UE. In some embodiments, the DCI may be transmitted to the first UE configured as the Near UE, to enable the first UE to map the index to a first value of the parameter.

[00193] In some embodiments, the first circuitry 1410 may be configured to establish an indicator that is to identify a modulation order associated with transmission from the eNB to a first UE, wherein the eNB is to co-schedule transmission in accordance with Multi-user Superposition Transmission (MUST) to a first UE and a second UE. In some embodiments, the second circuitry 1420 may be configured to generate a DCI including the indicator, the DCI for transmission to the second UE. In some embodiments, the eNB may further comprise an interface to output the DCI, including the indicator, to a transceiver circuitry, for transmission to the second UE. In some embodiments, the modulation order may be one of Quadrature Phase Shift Keying (QPSK), 16 Quadrature amplitude modulation (16QAM), 64QAM, or 256QAM. In some embodiments, the Multi-user Superposition Transmission to the first UE and a second UE may be in accordance with NOMA spatial multiplexing. In some embodiments, the DCI may be transmitted to the second UE, to enable the second UE to identify the modulation order associated with the co-scheduled first UE, based on the indicator.

[00194] In some embodiments, the first circuitry 1410 and/or the second circuitry 1420 may be implemented as separate circuitries. In other embodiments, the first circuitry 1410 and the second circuitry 1420 may be combined and implemented together in a circuitry without altering the essence of the embodiments.

[00195] **Fig. 15** illustrates hardware processing circuitries for a UE for receiving an indicator via a DCI from an eNB, and map the indicator to a parameter associated with MUST transmission, according to some embodiments. With reference to **Fig. 13**, a UE may include various hardware processing circuitries discussed below, which may in turn comprise logic devices and/or circuitry operable to perform various operations. For example, in **Fig. 13**, UE 1330 (or various elements or components therein, such as hardware processing circuitry 1340, or combinations of elements or components therein) may include part of, or all of, these hardware processing circuitries.

[00196] In some embodiments, one or more devices or circuitries within these hardware processing circuitries may be implemented by combinations of software-configured elements and/or other hardware elements. For example, processor 1336 (and/or one or more other processors which UE 1330 may comprise), memory 1338, and/or other elements or components of UE 1330 (which may include hardware processing circuitry 1340) may be arranged to perform the operations of these hardware processing circuitries, such as operations described herein with reference to devices and circuitry within these hardware

processing circuitries. In some embodiments, processor 1336 (and/or one or more other processors which UE 1330 may comprise) may be a baseband processor.

[00197] Returning to **Fig. 15**, an apparatus of UE 1330 (or another UE or mobile handset), which may be operable to communicate with one or more eNBs on a wireless network, may comprise hardware processing circuitry 1500. In some embodiments, hardware processing circuitry 1500 may comprise one or more antenna ports 1505 operable to provide various transmissions over a wireless communication channel (such as wireless communication channel 1350). Antenna ports 1505 may be coupled to one or more antennas 1507 (which may be antennas 1325). In some embodiments, hardware processing circuitry 1500 may incorporate antennas 1507, while in other embodiments, hardware processing circuitry 1500 may merely be coupled to antennas 1507.

[00198] Antenna ports 1505 and antennas 1507 may be operable to provide signals from a UE to a wireless communications channel and/or an eNB, and may be operable to provide signals from an eNB and/or a wireless communications channel to a UE. For example, antenna ports 1505 and antennas 1507 may be operable to provide transmissions from UE 1330 to wireless communication channel 1350 (and from there to eNB 1310, or to another eNB). Similarly, antennas 1507 and antenna ports 1505 may be operable to provide transmissions from a wireless communication channel 1350 (and beyond that, from eNB 1310, or another eNB) to UE 1330.

[00199] Hardware processing circuitry 1500 may comprise various circuitries operable in accordance with the various embodiments discussed herein. With reference to **Fig. 15**, hardware processing circuitry 1500 may comprise a first circuitry 1510 and/or a second circuitry 1520.

[00200] In some embodiments, the first circuitry 1510 may be configured to process a Downlink Control Information (DCI), the DCI including an index. In some embodiments, the second circuitry 1520 may be configured to map the index to a parameter, the parameter associated with Multi-user Superposition Transmission (MUST) from the eNB to a first UE configured as a Near UE and a second UE configured as a Far UE. The first UE configured as a Near UE may be the UE of **Fig. 15**. In some embodiments, the UE may comprise a memory for storing the parameter. In some embodiments, the UE may comprise an interface to receive the DCI, including the index, from a transceiver circuitry. In some embodiments, the UE of **Fig. 15** may demodulate Downlink (DL) signals received from the eNB, based at least in part on the parameter. In some embodiments, the parameter may be a power ratio α used by the eNB to weight symbols for transmission to the Near UE and the Far UE. In some

embodiments, the parameter may be one or both a first modulation order for transmission to the first UE and a second modulation order for transmission to the second UE.

[00201] In some embodiments, the first circuitry 1510 may be configured to process a DCI received from an eNB, the DCI including an indicator, wherein the eNB is to co-schedule transmission in accordance with Multi-user Superposition Transmission (MUST) to a first UE and a second UE. The first UE, for example, may be the UE of **Fig. 15**. In some embodiments, the second circuitry 1520 may be configured to identify a modulation order associated with transmission from the eNB to the second UE, based on the indicator. In some embodiments, the UE may comprise a memory for storing the modulation order. In some embodiments, the UE of **Fig. 15** may be configured to process DL signals received from the eNB, based on the identification of the modulation order. In some embodiments, the modulation order may be one of QPSK, 16 QAM, 64 QAM, or 256 QAM. In some embodiments, where the first UE may receive transmissions, along with the co-scheduled second UE, from the eNB in accordance with NOMA spatial multiplexing.

[00202] In some embodiments, first circuitry 1510 and/or second circuitry 1520 may be implemented as separate circuitries. In other embodiments, first circuitry 1510 and second circuitry 1520 may be combined and implemented together in a circuitry without altering the essence of the embodiments.

[00203] **Figs. 16 and 17A** illustrate methods 1600 and 1700, respectively, for an eNB to transmit indicators identifying MUST parameters to one or more UEs, according to some embodiments. **Fig. 17B** illustrates a method 1750 for an eNB to transmit MU parameters to an UE, according to some embodiments.

[00204] With reference to **Fig. 13**, methods 1600, 1700 and 1750 that may relate to eNB 1310 and hardware processing circuitry 1320 are discussed below. Although the actions in each of methods 1600, 1700 and 1750 of **Figs. 16, 17A, and 17B** are shown in a particular order, the order of the actions can be modified. Thus, the illustrated embodiments can be performed in a different order, and some actions may be performed in parallel. Some of the actions and/or operations listed in **Figs. 16, 17A, and/or 17B** may be optional in accordance with certain embodiments. The numbering of the actions presented is for the sake of clarity and is not intended to prescribe an order of operations in which the various actions must occur. Additionally, operations from the various flows may be utilized in a variety of combinations.

[00205] Moreover, in some embodiments, machine readable storage media may have executable instructions that, when executed, cause eNB 1310 and/or hardware processing

circuitry 1320 to perform an operation comprising the methods of **Figs. 16, 17A** and/or **17B**. Such machine readable storage media may include any of a variety of storage media, like magnetic storage media (e.g., magnetic tapes or magnetic disks), optical storage media (e.g., optical discs), electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any other tangible storage media or non-transitory storage media.

[00206] In some embodiments, an apparatus may comprise means for performing various actions and/or operations of each of the methods of **Figs. 16, 17A** and/or **17B**.

[00207] Returning to **Fig. 16**, the method 1600 may be in accordance with the various embodiments discussed herein. A method 1600 may comprise, at 1604, establishing an index that is to identify a parameter. In some embodiments, the parameter may be associated with MUST from the eNB to a first UE configured as a Near UE and second UE configured as a Far UE. Merely as an example, the index may be any one index or indicator discussed with respect to **Figs. 8-12**. The method 1600 may further comprise, at 1608, generating a DCI including the index, the DCI for transmission to at least one of the first UE or the second UE. In some embodiments, one or more memory of the eNB may store one or more of the index, the parameter, or the generated DCI. In some embodiments, the DCI, including the index, may be output to a transceiver circuitry, for transmission to at least one of the first UE or the second UE. In some embodiments, the parameter may be a power ratio α used by the eNB to weight symbols for transmission to the Near UE and the Far UE. In some embodiments, the parameter may be one or both a first modulation order for transmission to the first UE and a second modulation order for transmission to the second UE. In some embodiments, the DCI may be transmitted to the first UE configured as the Near UE. In some embodiments, the DCI may be transmitted to the first UE configured as the Near UE, to enable the first UE to map the index to a first value of the parameter.

[00208] Referring now to **Fig. 17A**, the method 1700 may be in accordance with the various embodiments discussed herein. The method 1700 may comprise, at 1704, establishing an indicator that is to identify a modulation order associated with transmission from the eNB to a first UE, wherein the eNB is to co-schedule transmission in accordance with MUST to a first UE and a second UE. The method 1700 may further comprise, at 1708, generating a DCI including the indicator, the DCI for transmission to the second UE. In some embodiments, the DCI, including the indicator, may be output to a transceiver circuitry, for transmission to the second UE. In some embodiments, the modulation order may be one of QPSK, 16 QAM, 64 QAM, and/or 256 QAM. In some embodiments, the Multi-User

Superposition Transmission to the first UE and a second UE may be in accordance with NOMA spatial multiplexing. In some embodiments, the DCI may be transmitted to the second UE, to enable the second UE to identify the modulation order associated with the co-scheduled first UE, based on the indicator.

[00209] Returning to **Fig. 17B**, the method 1750 may be in accordance with the various embodiments discussed herein. The method 1750 may comprise, at 1754, multiplexing or causing to multiplex multiple users in a MU-MIMO system using SM with Non-orthogonal precoders. The method 1750 may further comprise, at 1758, transmitting (or causing to transmit) MU parameters to a UE.

[00210] **Fig. 18** illustrates a method 1800 for a UE to receive an index that identifies a parameter associated with MUST transmission, according to some embodiments. **Fig. 19A** illustrates a method 1900 for a UE to receive an indicator that identifies a modulator order of a co-scheduled UE, according to some embodiments. **Fig. 19B** illustrates a method 1950 for a UE to receive ME parameters, according to some embodiments.

[00211] With reference to **Fig. 13**, methods 1800, 1900 and/or 1950 that may relate to UE 1330 and hardware processing circuitry 1340 are discussed below. Although the actions in the methods 1800, 1900 and/or 1950 are shown in a particular order, the order of the actions can be modified. Thus, the illustrated embodiments can be performed in a different order, and some actions may be performed in parallel. Some of the actions and/or operations listed in **Figs. 18, 19A and/or 19B** may be optional in accordance with certain embodiments. The numbering of the actions presented is for the sake of clarity and is not intended to prescribe an order of operations in which the various actions must occur. Additionally, operations from the various flows may be utilized in a variety of combinations.

[00212] Moreover, in some embodiments, machine readable storage media may have executable instructions that, when executed, cause UE 1330 and/or hardware processing circuitry 1340 to perform an operation comprising the methods 1800, 1900 and/or 1950. Such machine readable storage media may include any of a variety of storage media, like magnetic storage media (e.g., magnetic tapes or magnetic disks), optical storage media (e.g., optical discs), electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any other tangible storage media or non-transitory storage media.

[00213] In some embodiments, an apparatus may comprise means for performing various actions and/or operations of each of the methods 1800, 1900 and/or 1950.

[00214] Returning to **Fig. 18**, the method 1800 may be in accordance with the various embodiments discussed herein. The method 1800 may comprise, at 1804, processing a DCI, the DCI including an index. The method 1800 may comprise, at 1808, mapping the index to a parameter, the parameter associated with MUST from the eNB to the UE configured as a Near UE and another UE configured as a Far UE. In some embodiments, a memory of the UE may store the parameter. In some embodiments, the UE may receive the DCI, including the index, from a transceiver circuitry. In some embodiments, the UE may demodulate DL signals received from the eNB, based at least in part on the parameter. In some embodiments, the parameter may be a power ratio α used by the eNB to weight symbols for transmission to the Near UE and the Far UE. In some embodiments, the parameter may be one or both a first modulation order for transmission to the first UE and a second modulation order for transmission to the second UE.

[00215] Returning to **Fig. 19A**, the method 1900 may be in accordance with the various embodiments discussed herein. The method 1900 may comprise, at 1904, processing a DCI received from the eNB, the DCI including an indicator, wherein the eNB is to co-schedule transmission in accordance with MUST to the UE and another UE. The method 1800 may comprise, at 1808, identifying a modulation order associated with transmission from the eNB to the another UE, based on the indicator. In some embodiments, the UE may process Downlink (DL) signals received from the eNB, based on the identification of the modulation order. In some embodiments, the modulation order may be one of Quadrature Phase Shift Keying (QPSK), 16 Quadrature amplitude modulation (16QAM), 64QAM, or 256QAM. In some embodiments, the first UE may receive transmissions, along with the co-scheduled another UE, from the eNB in accordance with NOMA spatial multiplexing.

[00216] Returning to **Fig. 19B**, the method 1950 may be in accordance with the various embodiments discussed herein. The method 1950 may comprise, at 1954, detecting (or causing to detect) MU parameters to be used for receiving signals in an MU-MIMO system that uses SM with non-orthogonal precoders. The method 1950 may comprise, at 1958, select (or causing to select) a detection mechanism to detect the MU parameters. The method 1950 may comprise, at 1962, receiving (or causing to receive) MU parameters.

[00217] **Fig. 20** illustrates an architecture of a system 2000 of a network in accordance with some embodiments. The system 2000 is shown to include a user equipment (UE) 2001 and a UE 2002. The UEs 2001 and 2002 are illustrated as smartphones (e.g., handheld touchscreen mobile computing devices connectable to one or more cellular networks), but may also comprise any mobile or non-mobile computing device, such as Personal Data

Assistants (PDAs), pagers, laptop computers, desktop computers, wireless handsets, or any computing device including a wireless communications interface.

[00218] In some embodiments, any of the UEs 2001 and 2002 can comprise an Internet of Things (IoT) UE, which can comprise a network access layer designed for low-power IoT applications utilizing short-lived UE connections. An IoT UE can utilize technologies such as machine-to-machine (M2M) or machine-type communications (MTC) for exchanging data with an MTC server or device via a public land mobile network (PLMN), Proximity-Based Service (ProSe) or device-to-device (D2D) communication, sensor networks, or IoT networks. The M2M or MTC exchange of data may be a machine-initiated exchange of data. An IoT network describes interconnecting IoT UEs, which may include uniquely identifiable embedded computing devices (within the Internet infrastructure), with short-lived connections. The IoT UEs may execute background applications (e.g., keep-alive messages, status updates, etc.) to facilitate the connections of the IoT network.

[00219] The UEs 2001 and 2002 may be configured to connect, e.g., communicatively couple, with a Radio Access Network (RAN) — in this embodiment, an Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN) 2010. The UEs 2001 and 2002 utilize connections 2003 and 2004, respectively, each of which comprises a physical communications interface or layer (discussed in further detail below); in this example, the connections 2003 and 2004 are illustrated as an air interface to enable communicative coupling, and can be consistent with cellular communications protocols, such as a Global System for Mobile Communications (GSM) protocol, a code-division multiple access (CDMA) network protocol, a Push-to-Talk (PTT) protocol, a PTT over Cellular (POC) protocol, a Universal Mobile Telecommunications System (UMTS) protocol, a 3GPP Long Term Evolution (LTE) protocol, a fifth generation (5G) protocol, a New Radio (NR) protocol, and the like.

[00220] In this embodiment, the UEs 2001 and 2002 may further directly exchange communication data via a ProSe interface 2005. The ProSe interface 2005 may alternatively be referred to as a sidelink interface comprising one or more logical channels, including but not limited to a Physical Sidelink Control Channel (PSCCH), a Physical Sidelink Shared Channel (PSSCH), a Physical Sidelink Discovery Channel (PSDCH), and a Physical Sidelink Broadcast Channel (PSBCH).

[00221] The UE 2002 is shown to be configured to access an access point (AP) 2006 via connection 2007. The connection 2007 can comprise a local wireless connection, such as a connection consistent with any IEEE 802.11 protocol, wherein the AP 2006 would

comprise a wireless fidelity (WiFi®) router. In this example, the AP 2006 is shown to be connected to the Internet without connecting to the core network of the wireless system (described in further detail below).

[00222] The E-UTRAN 2010 can include one or more access nodes that enable the connections 2003 and 2004. These Access Nodes (ANs) can be referred to as base stations (BSs), NodeBs, evolved NodeBs (eNBs), next Generation NodeBs (gNB), RAN nodes, and so forth, and can comprise ground stations (e.g., terrestrial access points) or satellite stations providing coverage within a geographic area (e.g., a cell). The E-UTRAN 2010 may include one or more RAN nodes for providing macrocells, e.g., macro RAN node 2011, and one or more RAN nodes for providing femtocells or picocells (e.g., cells having smaller coverage areas, smaller user capacity, or higher bandwidth compared to macrocells), e.g., low power (LP) RAN node 2012.

[00223] Any of the RAN nodes 2011 and 2012 can terminate the air interface protocol and can be the first point of contact for the UEs 2001 and 2002. In some embodiments, any of the RAN nodes 2011 and 2012 can fulfill various logical functions for the E-UTRAN 2010 including, but not limited to, radio network controller (RNC) functions such as radio bearer management, uplink and downlink dynamic radio resource management and data packet scheduling, and mobility management.

[00224] In accordance with some embodiments, the UEs 2001 and 2002 can be configured to communicate using Orthogonal Frequency-Division Multiplexing (OFDM) communication signals with each other or with any of the RAN nodes 2011 and 2012 over a multicarrier communication channel in accordance with various communication techniques, such as, but not limited to, an Orthogonal Frequency-Division Multiple Access (OFDMA) communication technique (e.g., for downlink communications) or a Single Carrier Frequency Division Multiple Access (SC-FDMA) communication technique (e.g., for uplink and ProSe or sidelink communications), although the scope of the embodiments is not limited in this respect. The OFDM signals can comprise a plurality of orthogonal subcarriers.

[00225] In some embodiments, a downlink resource grid can be used for downlink transmissions from any of the RAN nodes 2011 and 2012 to the UEs 2001 and 2002, while uplink transmissions can utilize similar techniques. The grid can be a time-frequency grid, called a resource grid or time-frequency resource grid, which is the physical resource in the downlink in each slot. Such a time-frequency plane representation is a common practice for OFDM systems, which makes it intuitive for radio resource allocation. Each column and each row of the resource grid corresponds to one OFDM symbol and one OFDM subcarrier,

respectively. The duration of the resource grid in the time domain corresponds to one slot in a radio frame. The smallest time-frequency unit in a resource grid is denoted as a resource element. Each resource grid comprises a number of resource blocks, which describe the mapping of certain physical channels to resource elements. Each resource block comprises a collection of resource elements; in the frequency domain, this may represent the smallest quantity of resources that currently can be allocated. There are several different physical downlink channels that are conveyed using such resource blocks.

[00226] The physical downlink shared channel (PDSCH) may carry user data and higher-layer signaling to the UEs 2001 and 2002. The physical downlink control channel (PDCCH) may carry information about the transport format and resource allocations related to the PDSCH channel, among other things. It may also inform the UEs 2001 and 2002 about the transport format, resource allocation, and H-ARQ (Hybrid Automatic Repeat Request) information related to the uplink shared channel. Typically, downlink scheduling (assigning control and shared channel resource blocks to the UE 102 within a cell) may be performed at any of the RAN nodes 2011 and 2012 based on channel quality information fed back from any of the UEs 2001 and 2002. The downlink resource assignment information may be sent on the PDCCH used for (e.g., assigned to) each of the UEs 2001 and 2002.

[00227] The PDCCH may use control channel elements (CCEs) to convey the control information. Before being mapped to resource elements, the PDCCH complex-valued symbols may first be organized into quadruplets, which may then be permuted using a sub-block interleaver for rate matching. Each PDCCH may be transmitted using one or more of these CCEs, where each CCE may correspond to nine sets of four physical resource elements known as resource element groups (REGs). Four Quadrature Phase Shift Keying (QPSK) symbols may be mapped to each REG. The PDCCH can be transmitted using one or more CCEs, depending on the size of the downlink control information (DCI) and the channel condition. There can be four or more different PDCCH formats defined in LTE with different numbers of CCEs (e.g., aggregation level, $L=1, 2, 4$, or 8).

[00228] Some embodiments may use concepts for resource allocation for control channel information that are an extension of the above-described concepts. For example, some embodiments may utilize an enhanced physical downlink control channel (EPDCCH) that uses PDSCH resources for control information transmission. The EPDCCH may be transmitted using one or more enhanced the control channel elements (ECCEs). Similar to above, each ECCE may correspond to nine sets of four physical resource elements known as

enhanced resource element groups (EREGs). An ECCE may have other numbers of EREGs in some situations.

[00229] The E-UTRAN 2010 is shown to be communicatively coupled to a core network — in this embodiment, an Evolved Packet Core (EPC) network 2020 via an S1 interface 2013. In this embodiment the S1 interface 2013 is split into two parts: the S1-U interface 2014, which carries traffic data between the RAN nodes 2011 and 2012 and the serving gateway (S-GW) 2022, and the S1-mobility management entity (MME) interface 2015, which is a signaling interface between the RAN nodes 2011 and 2012 and MMEs 2021.

[00230] In this embodiment, the EPC network 2020 comprises the MMEs 2021, the S-GW 2022, the Packet Data Network (PDN) Gateway (P-GW) 2023, and a home subscriber server (HSS) 2024. The MMEs 2021 may be similar in function to the control plane of legacy Serving General Packet Radio Service (GPRS) Support Nodes (SGSN). The MMEs 2021 may manage mobility aspects in access such as gateway selection and tracking area list management. The HSS 2024 may comprise a database for network users, including subscription-related information to support the network entities' handling of communication sessions. The EPC network 2020 may comprise one or several HSSs 2024, depending on the number of mobile subscribers, on the capacity of the equipment, on the organization of the network, etc. For example, the HSS 2024 can provide support for routing/roaming, authentication, authorization, naming/addressing resolution, location dependencies, etc.

[00231] The S-GW 2022 may terminate the S1 interface 2013 towards the E-UTRAN 2010, and route data packets between the E-UTRAN 2010 and the EPC network 2020. In addition, the S-GW 2022 may be a local mobility anchor point for inter-RAN node handovers and also may provide an anchor for inter-3GPP mobility. Other responsibilities may include lawful intercept, charging, and some policy enforcement.

[00232] The P-GW 2023 may terminate an SGi interface toward a PDN. The P-GW 2023 may route data packets between the EPC network 2020 and external networks such as a network including the application server 2030 (alternatively referred to as application function (AF)) via an Internet Protocol (IP) interface 2025. Generally, the application server 2030 may be an element offering applications that use IP bearer resources with the core network (e.g., UMTS Packet Services (PS) domain, LTE PS data services, etc.). In this embodiment, the P-GW 2023 is shown to be communicatively coupled to an application server 2030 via an IP communications interface 2025. The application server 2030 can also be configured to support one or more communication services (e.g., Voice-over-Internet

Protocol (VoIP) sessions, PTT sessions, group communication sessions, social networking services, etc.) for the UEs 2001 and 2002 via the EPC network 2020.

[00233] The P-GW 2023 may further be a node for policy enforcement and charging data collection. Policy and Charging Enforcement Function (PCRF) 2026 is the policy and charging control element of the EPC network 2020. In a non-roaming scenario, there may be a single PCRF in the Home Public Land Mobile Network (HPLMN) associated with a UE's Internet Protocol Connectivity Access Network (IP-CAN) session. In a roaming scenario with local breakout of traffic, there may be two PCRFs associated with a UE's IP-CAN session: a Home PCRF (H-PCRF) within a HPLMN and a Visited PCRF (V-PCRF) within a Visited Public Land Mobile Network (VPLMN). The PCRF 2026 may be communicatively coupled to the application server 2030 via the P-GW 2023. The application server 2030 may signal the PCRF 2026 to indicate a new service flow and select the appropriate Quality of Service (QoS) and charging parameters. The PCRF 2026 may provision this rule into a Policy and Charging Enforcement Function (PCEF) (not shown) with the appropriate traffic flow template (TFT) and QoS class of identifier (QCI), which commences the QoS and charging as specified by the application server 2030.

[00234] **Fig. 21** illustrates example components of a device 2100 in accordance with some embodiments. In some embodiments, the device 2100 may include application circuitry 2102, baseband circuitry 2104, Radio Frequency (RF) circuitry 2106, front-end module (FEM) circuitry 2108, one or more antennas 2110, and power management circuitry (PMC) 2112 coupled together at least as shown. The components of the illustrated device 2100 may be included in a UE or a RAN node. In some embodiments, the device 2100 may include less elements (e.g., a RAN node may not utilize application circuitry 2102, and instead include a processor/controller to process IP data received from an EPC). In some embodiments, the device 2100 may include additional elements such as, for example, memory/storage, display, camera, sensor, or input/output (I/O) interface. In other embodiments, the components described below may be included in more than one device (e.g., said circuitries may be separately included in more than one device for Cloud-RAN (C-RAN) implementations).

[00235] The application circuitry 2102 may include one or more application processors. For example, the application circuitry 2102 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with or may include

memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications or operating systems to run on the device 2100. In some embodiments, processors of application circuitry 2102 may process IP data packets received from an EPC.

[00236] The baseband circuitry 2104 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 2104 may include one or more baseband processors or control logic to process baseband signals received from a receive signal path of the RF circuitry 2106 and to generate baseband signals for a transmit signal path of the RF circuitry 2106. Baseband processing circuitry 2104 may interface with the application circuitry 2102 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 2106. For example, in some embodiments, the baseband circuitry 2104 may include a third generation (3G) baseband processor 2104A, a fourth generation (4G) baseband processor 2104B, a fifth generation (5G) baseband processor 2104C, or other baseband processor(s) 2104D for other existing generations, generations in development or to be developed in the future (e.g., second generation (2G), sixth generation (6G), etc.). The baseband circuitry 2104 (e.g., one or more of baseband processors 2104A-D) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 2106. In other embodiments, some or all of the functionality of baseband processors 2104A-D may be included in modules stored in the memory 2104G and executed via a Central Processing Unit (CPU) 2104E. 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 2104 may include Fast-Fourier Transform (FFT), precoding, or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 2104 may include convolution, tail-biting convolution, turbo, Viterbi, or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

[00237] In some embodiments, the baseband circuitry 2104 may include one or more audio digital signal processor(s) (DSP) 2104F. The audio DSP(s) 2104F 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 2104 and the application circuitry 2102 may be implemented together such as, for example, on a system on a chip (SOC).

[00238] In some embodiments, the baseband circuitry 2104 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 2104 may support communication with an evolved universal terrestrial radio access network (EUTRAN) or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 2104 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[00239] RF circuitry 2106 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 2106 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 2106 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 2108 and provide baseband signals to the baseband circuitry 2104. RF circuitry 2106 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 2104 and provide RF output signals to the FEM circuitry 2108 for transmission.

[00240] In some embodiments, the receive signal path of the RF circuitry 2106 may include mixer circuitry 2106a, amplifier circuitry 2106b and filter circuitry 2106c. In some embodiments, the transmit signal path of the RF circuitry 2106 may include filter circuitry 2106c and mixer circuitry 2106a. RF circuitry 2106 may also include synthesizer circuitry 2106d for synthesizing a frequency for use by the mixer circuitry 2106a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 2106a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 2108 based on the synthesized frequency provided by synthesizer circuitry 2106d. The amplifier circuitry 2106b may be configured to amplify the down-converted signals and the filter circuitry 2106c 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 2104 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

2106a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[00241] In some embodiments, the mixer circuitry 2106a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 2106d to generate RF output signals for the FEM circuitry 2108. The baseband signals may be provided by the baseband circuitry 2104 and may be filtered by filter circuitry 2106c.

[00242] In some embodiments, the mixer circuitry 2106a of the receive signal path and the mixer circuitry 2106a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and upconversion, respectively. In some embodiments, the mixer circuitry 2106a of the receive signal path and the mixer circuitry 2106a 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 2106a of the receive signal path and the mixer circuitry 2106a may be arranged for direct downconversion and direct upconversion, respectively. In some embodiments, the mixer circuitry 2106a of the receive signal path and the mixer circuitry 2106a of the transmit signal path may be configured for super-heterodyne operation.

[00243] 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 2106 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 2104 may include a digital baseband interface to communicate with the RF circuitry 2106.

[00244] 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.

[00245] In some embodiments, the synthesizer circuitry 2106d 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 2106d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[00246] The synthesizer circuitry 2106d may be configured to synthesize an output frequency for use by the mixer circuitry 2106a of the RF circuitry 2106 based on a frequency

input and a divider control input. In some embodiments, the synthesizer circuitry 2106d may be a fractional $N/N+1$ synthesizer.

[00247] 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 2104 or the applications processor 2102 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 2102.

[00248] Synthesizer circuitry 2106d of the RF circuitry 2106 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.

[00249] In some embodiments, synthesizer circuitry 2106d 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 an LO frequency (fLO). In some embodiments, the RF circuitry 2106 may include an IQ/polar converter.

[00250] FEM circuitry 2108 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 2110, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 2106 for further processing. FEM circuitry 2108 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 2106 for transmission by one or more of the one or more antennas 2110. In various embodiments, the amplification through the transmit or receive

signal paths may be done solely in the RF circuitry 2106, solely in the FEM 2108, or in both the RF circuitry 2106 and the FEM 2108.

[00251] In some embodiments, the FEM circuitry 2108 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry may include an LNA to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 2106). The transmit signal path of the FEM circuitry 2108 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 2106), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 2110).

[00252] In some embodiments, the PMC 2112 may manage power provided to the baseband circuitry 2104. In particular, the PMC 2112 may control power-source selection, voltage scaling, battery charging, or DC-to-DC conversion. The PMC 2112 may often be included when the device 2100 is capable of being powered by a battery, for example, when the device is included in a UE. The PMC 2112 may increase the power conversion efficiency while providing desirable implementation size and heat dissipation characteristics.

[00253] While **Fig. 21** shows the PMC 2112 coupled only with the baseband circuitry 2104. However, in other embodiments, the PMC 2112 may be additionally or alternatively coupled with, and perform similar power management operations for, other components such as, but not limited to, application circuitry 2102, RF circuitry 2106, or FEM 2108.

[00254] In some embodiments, the PMC 2112 may control, or otherwise be part of, various power saving mechanisms of the device 2100. For example, if the device 2100 is in an RRC_Connected state, where it is still connected to the RAN node as it expects to receive traffic shortly, then it may enter a state known as Discontinuous Reception Mode (DRX) after a period of inactivity. During this state, the device 2100 may power down for brief intervals of time and thus save power.

[00255] If there is no data traffic activity for an extended period of time, then the device 2100 may transition off to an RRC_Idle state, where it disconnects from the network and does not perform operations such as channel quality feedback, handover, etc. The device 2100 goes into a very low power state and it performs paging where again it periodically wakes up to listen to the network and then powers down again. The device 2100 may not receive data in this state, in order to receive data, it must transition back to RRC_Connected state.

[00256] An additional power saving mode may allow a device to be unavailable to the network for periods longer than a paging interval (ranging from seconds to a few hours). During this time, the device is totally unreachable to the network and may power down completely. Any data sent during this time incurs a large delay and it is assumed the delay is acceptable.

[00257] Processors of the application circuitry 2102 and processors of the baseband circuitry 2104 may be used to execute elements of one or more instances of a protocol stack. For example, processors of the baseband circuitry 2104, alone or in combination, may be used execute Layer 3, Layer 2, or Layer 1 functionality, while processors of the application circuitry 2104 may utilize data (e.g., packet data) received from these layers and further execute Layer 4 functionality (e.g., transmission communication protocol (TCP) and user datagram protocol (UDP) layers). As referred to herein, Layer 3 may comprise a radio resource control (RRC) layer, described in further detail below. As referred to herein, Layer 2 may comprise a medium access control (MAC) layer, a radio link control (RLC) layer, and a packet data convergence protocol (PDCP) layer, described in further detail below. As referred to herein, Layer 1 may comprise a physical (PHY) layer of a UE/RAN node, described in further detail below.

[00258] **Fig. 22** illustrates example interfaces of baseband circuitry in accordance with some embodiments. As discussed above, the baseband circuitry 2104 of **Fig. 21** may comprise processors 2104A-2104E and a memory 2104G utilized by said processors. Each of the processors 2104A-2104E may include a memory interface, 2204A-2204E, respectively, to send/receive data to/from the memory 2104G.

[00259] The baseband circuitry 2104 may further include one or more interfaces to communicatively couple to other circuitries/devices, such as a memory interface 2212 (e.g., an interface to send/receive data to/from memory external to the baseband circuitry 2104), an application circuitry interface 2214 (e.g., an interface to send/receive data to/from the application circuitry 2102 of FIG. 21), an RF circuitry interface 2216 (e.g., an interface to send/receive data to/from RF circuitry 2106 of FIG. 21), a wireless hardware connectivity interface 2218 (e.g., an interface to send/receive data to/from Near Field Communication (NFC) components, Bluetooth® components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components), and a power management interface 2220 (e.g., an interface to send/receive power or control signals to/from the PMC 2112).

[00260] Reference in the specification to "an embodiment," "one embodiment," "some embodiments," or "other embodiments" means that a particular feature, structure, or

characteristic described in connection with the embodiments is included in at least some embodiments, but not necessarily all embodiments. The various appearances of "an embodiment," "one embodiment," or "some embodiments" are not necessarily all referring to the same embodiments. If the specification states a component, feature, structure, or characteristic "may," "might," or "could" be included, that particular component, feature, structure, or characteristic is not required to be included. If the specification or claim refers to "a" or "an" element, that does not mean there is only one of the elements. If the specification or claims refer to "an additional" element, that does not preclude there being more than one of the additional element.

[00261] Furthermore, the particular features, structures, functions, or characteristics may be combined in any suitable manner in one or more embodiments. For example, a first embodiment may be combined with a second embodiment anywhere the particular features, structures, functions, or characteristics associated with the two embodiments are not mutually exclusive.

[00262] While the disclosure has been described in conjunction with specific embodiments thereof, many alternatives, modifications and variations of such embodiments will be apparent to those of ordinary skill in the art in light of the foregoing description. For example, other memory architectures e.g., Dynamic RAM (DRAM) may use the embodiments discussed. The embodiments of the disclosure are intended to embrace all such alternatives, modifications, and variations as to fall within the broad scope of the appended claims.

[00263] In addition, well known power/ground connections to integrated circuit (IC) chips and other components may or may not be shown within the presented figures, for simplicity of illustration and discussion, and so as not to obscure the disclosure. Further, arrangements may be shown in block diagram form in order to avoid obscuring the disclosure, and also in view of the fact that specifics with respect to implementation of such block diagram arrangements are highly dependent upon the platform within which the present disclosure is to be implemented (i.e., such specifics should be well within purview of one skilled in the art). Where specific details (e.g., circuits) are set forth in order to describe example embodiments of the disclosure, it should be apparent to one skilled in the art that the disclosure can be practiced without, or with variation of, these specific details. The description is thus to be regarded as illustrative instead of limiting.

[00264] The following examples pertain to further embodiments. Specifics in the clauses may be used anywhere in one or more embodiments. All optional features of the apparatus described herein may also be implemented with respect to a method or process.

[00265] Example 1. An apparatus of an Evolved Node B (eNB) operable to communicate with a User Equipment (UE) on a wireless network, comprising: a memory to store instructions; and one or more processors to execute the instructions to perform operations comprising: establish an index that is to identify a parameter, wherein the parameter is associated with Multi-user Superposition Transmission (MUST) from the eNB to a first UE configured as a Near UE and a second UE configured as a Far UE, and generate a Downlink Control Information (DCI) for transmission to at least one of the first UE or the second UE, the DCI including the index.

[00266] Example 2. The apparatus of example 1 or any other examples, further comprising: an interface to output the DCI, including the index, to a transceiver circuitry, for transmission to at least one of the first UE or the second UE.

[00267] Example 3. The apparatus of example 1 or any other examples, wherein the parameter is a power ratio α used by the eNB for transmission to the Near UE and the Far UE.

[00268] Example 4. The apparatus of example 1 or any other examples, wherein the parameter is at least one of: a first modulation order for transmission to the first UE, or a second modulation order for transmission to the second UE.

[00269] Example 5. The apparatus of any of examples 1-4 or any other examples, wherein the MUST to the first UE and a second UE is in accordance with Power multiplexing.

[00270] Example 6. The apparatus of any of examples 1-4 or any other examples, wherein the DCI is to be transmitted to the first UE configured as the Near UE.

[00271] Example 7. The apparatus of any of examples 1-4 or any other examples, wherein the DCI is to be transmitted to the first UE configured as the Near UE, to enable the first UE to map the index to a first value of the parameter.

[00272] Example 8. An Evolved Node B (eNB) device comprising an application processor, a memory, one or more antenna ports, and an interface for allowing the application processor to communicate with another device, the eNB device including the apparatus of any of examples 1-7 or any other examples.

[00273] Example 9. Machine readable storage media having machine executable instructions that, when executed, cause one or more processors of an Evolved Node B (eNB)

to perform an operation comprising: establish an index that is to identify a parameter, wherein the parameter is associated with Multi-user Superposition Transmission (MUST) from the eNB to a first User Equipment (UE) configured as a Near UE and a second UE configured as a Far UE, and generate a Downlink Control Information (DCI) for transmission to at least one of the first UE or the second UE, the DCI including the index.

[00274] Example 10. The machine readable storage media of example 9 or any other examples, wherein the operation comprises: output the DCI, including the index, to a transceiver circuitry, for transmission to at least one of the first UE or the second UE.

[00275] Example 11. The machine readable storage media of example 9 or any other examples, wherein the parameter is a power ratio α used by the eNB for transmission to the Near UE and the Far UE.

[00276] Example 12. The machine readable storage media of example 9 or any other examples, wherein the parameter is at least one of: a first modulation order for transmission to the first UE, or a second modulation order for transmission to the second UE.

[00277] Example 13. The machine readable storage media of any of examples 9-12 or any other examples, wherein the MUST to the first UE and the second UE is in accordance with Power multiplexing.

[00278] Example 14. The machine readable storage media of any of examples 9-12 or any other examples, wherein the DCI is to be transmitted to the first UE configured as the Near UE.

[00279] Example 15. The machine readable storage media of any of examples 9-12 or any other examples, wherein the DCI is to be transmitted to the first UE configured as the Near UE, to enable the first UE to map the index to a first value of the parameter.

[00280] Example 16. An apparatus of a first User Equipment (UE) operable to communicate with an Evolved Node B (eNB) on a wireless network, comprising: one or more processors to: process a Downlink Control Information (DCI), the DCI including an index, and map the index to a parameter, the parameter associated with Multi-user Superposition Transmission (MUST) from the eNB to the first UE configured as a Near UE and a second UE configured as a Far UE; and a memory to store the parameter.

[00281] Example 17. The apparatus of example 16 or any other examples, further comprising: an interface to input the DCI, including the index, from a transceiver circuitry.

[00282] Example 18. The apparatus of example 16 or any other examples, wherein the one or more processors are to: demodulate Downlink (DL) signals received from the eNB, based on the parameter.

[00283] Example 19. The apparatus of any of examples 16-18 or any other examples, wherein the Multi-User Superposition Transmission to the first UE and a second UE is in accordance with Power multiplexing.

[00284] Example 20. The apparatus of any of examples 16-18 or any other examples, wherein the parameter is a power ratio α used by the eNB for transmission to the Near UE and the Far UE.

[00285] Example 21. The apparatus of any of examples 16-18 or any other examples, wherein the parameter is at least one of: a first modulation order for transmission to the first UE, or a second modulation order for transmission to the second UE.

[00286] Example 22. The apparatus of any of examples 16-21 or any other examples, further comprising: a transceiver circuitry for generating transmissions and processing transmissions.

[00287] Example 23. A User Equipment (UE) device comprising an application processor, a memory, one or more antennas, a wireless interface for allowing the application processor to communicate with another device, and a touch-screen display, the UE device including the apparatus of any of examples 16 to 22 or any other examples.

[00288] Example 24. Machine readable storage media having machine executable instructions that, when executed, cause one or more processors of a User Equipment (UE) to perform an operation comprising: process a Downlink Control Information (DCI), the DCI including an index; and map the index to a parameter, the parameter associated with Multi-user Superposition Transmission (MUST) from an Evolved Node B (eNB) to the first UE configured as a Near UE and a second UE configured as a Far UE.

[00289] Example 25. The machine readable storage media of example 24 or any other examples, wherein the operation comprises: input the DCI, including the index, from a transceiver circuitry.

[00290] Example 26. The machine readable storage media of example 24 or any other examples, wherein the operation comprises: demodulate Downlink (DL) signals received from the eNB, based at least in part on the parameter.

[00291] Example 27. The machine readable storage media of any of examples 24-26 or any other examples, wherein the Multi-User Superposition Transmission to the first UE and a second UE is in accordance with Power multiplexing.

[00292] Example 28. The machine readable storage media of any of examples 24-26 or any other examples, wherein the parameter is a power ratio α used by the eNB for transmission to the Near UE and the Far UE.

[00293] Example 29. The machine readable storage media of any of examples 24-26 or any other examples, wherein the parameter is at least one of: a first modulation order for transmission to the first UE, or a second modulation order for transmission to the second UE.

[00294] Example 30. An apparatus of an Evolved Node B (eNB) operable to communicate with a User Equipment (UE) on a wireless network, comprising: a memory to store instructions; and one or more processors to execute the instructions to perform operations comprising: establish an indicator that is to identify a modulation order associated with transmission from the eNB to a first UE, wherein the eNB is to co-schedule transmission in accordance with Multi-user Superposition Transmission (MUST) to the first UE and a second UE, and generate a Downlink Control Information (DCI) for transmission to the second UE, the DCI including the indicator.

[00295] Example 31. The apparatus of example 30 or any other examples, further comprising: an interface to output the DCI, including the indicator, to a transceiver circuitry, for transmission to the second UE.

[00296] Example 32. The apparatus of example 30 or any other examples, wherein the modulation order is one of Quadrature Phase Shift Keying (QPSK), 16 Quadrature amplitude modulation (16QAM), 64QAM, or 256QAM.

[00297] Example 33. The apparatus of any of examples 30-32 or any other examples, wherein the Multi-User Superposition Transmission to the first UE and a second UE is in accordance with Non-Orthogonal Multiple Access (NOMA) spatial multiplexing.

[00298] Example 34. The apparatus of any of examples 30-32 or any other examples, wherein the DCI is to be transmitted to the second UE, to enable the second UE to identify the modulation order associated with the co-schedule first UE, based on the indicator.

[00299] Example 35. An Evolved Node B (eNB) device comprising an application processor, a memory, one or more antenna ports, and an interface for allowing the application processor to communicate with another device, the eNB device including the apparatus of any of examples 30-34 or any other examples.

[00300] Example 36. Machine readable storage media having machine executable instructions that, when executed, cause one or more processors of an Evolved Node B (eNB) to perform an operation comprising: establish an indicator that is to identify a modulation order associated with transmission from the eNB to a first User Equipment (UE), wherein the eNB is to co-schedule transmission in accordance with Multi-user Superposition Transmission (MUST) to the first UE and a second UE; and generate a Downlink Control Information (DCI) for transmission to the second UE, the DCI including the indicator.

[00301] Example 37. The machine readable storage media of example 36 or any other examples, wherein the operation comprises: output the DCI, including the indicator, to a transceiver circuitry, for transmission to the second UE.

[00302] Example 38. The machine readable storage media of example 36 or any other examples, wherein the modulation order is one of Quadrature Phase Shift Keying (QPSK), 16 Quadrature amplitude modulation (16QAM), 64QAM, or 256QAM.

[00303] Example 39. The machine readable storage media of any of examples 36-38 or any other examples, wherein the Multi-User Superposition Transmission to the first UE and a second UE is in accordance with Non-Orthogonal Multiple Access (NOMA) spatial multiplexing.

[00304] Example 40. The machine readable storage media of any of examples 36-38 or any other examples, wherein the DCI is to be transmitted to the second UE, to enable the second UE to identify the modulation order associated with the co-schedule first UE, based on the indicator.

[00305] Example 41. An apparatus of a first User Equipment (UE) operable to communicate with an Evolved Node B (eNB) on a wireless network, comprising: one or more processors to: process a Downlink Control Information (DCI) received from the eNB, the DCI including an indicator, wherein transmission is co-scheduled by the eNB in accordance with Multi-user Superposition Transmission (MUST) to the first UE and a second UE, and identify a modulation order associated with transmission from the eNB to the second UE, based on the indicator; and a memory to store the identification of the modulation order.

[00306] Example 42. The apparatus of example 41 or any other examples, wherein the one or more processors are to: process Downlink (DL) signals received from the eNB, based on the identification of the modulation order.

[00307] Example 43. The apparatus of example 41 or any other examples, wherein the modulation order is one of Quadrature Phase Shift Keying (QPSK), 16 Quadrature amplitude modulation (16QAM), 64QAM, or 256QAM.

[00308] Example 44. The apparatus of any of examples 41-43 or any other examples, wherein the first UE is to receive transmissions, along with the co-scheduled second UE, from the eNB in accordance with Non-Orthogonal Multiple Access (NOMA) spatial multiplexing.

[00309] Example 45. The apparatus of any of examples 41-43 or any other examples, further comprising: a transceiver circuitry for generating transmissions and processing transmissions.

[00310] Example 46. A User Equipment (UE) device comprising an application processor, a memory, one or more antennas, a wireless interface for allowing the application processor to communicate with another device, and a touch-screen display, the UE device including the apparatus of any of examples 41 to 45 or any other examples.

[00311] Example 47. Machine readable storage media having machine executable instructions that, when executed, cause one or more processors of a first User Equipment (UE) to perform an operation comprising: process a Downlink Control Information (DCI) received from an Evolved Node B (eNB), the DCI including an indicator, wherein transmission is co-scheduled by the eNB in accordance with Multi-user Superposition Transmission (MUST) to the first UE and a second UE; and identify a modulation order associated with transmission from the eNB to the second UE, based on the indicator.

[00312] Example 48. The machine readable storage media of example 47 or any other examples, wherein the operation comprises: process Downlink (DL) signals received from the eNB, based on the identification of the modulation order.

[00313] Example 49. The machine readable storage media of example 47 or any other examples, wherein the modulation order is one of Quadrature Phase Shift Keying (QPSK), 16 Quadrature amplitude modulation (16QAM), 64QAM, or 256QAM.

[00314] Example 50. The machine readable storage media of any of examples 47-49 or any other examples, wherein the first UE is to receive transmissions, along with the co-scheduled second UE, from the eNB in accordance with Non-Orthogonal Multiple Access (NOMA) spatial multiplexing.

[00315] Example 51. A method to be performed by an Evolved Node B (eNB), comprising: establishing an index that is to identify a parameter, wherein the parameter is associated with Multi-user Superposition Transmission (MUST) from the eNB to a first User Equipment (UE) configured as a Near UE and a second UE configured as a Far UE; and generating a Downlink Control Information (DCI) for transmission to at least one of the first UE or the second UE, the DCI including the index.

[00316] Example 52. The method of example 51 or any other examples, wherein the parameter is a power ratio α used by the eNB for transmission to the Near UE and the Far UE.

[00317] Example 53. The method of example 51 or any other examples, wherein the parameter is at least one of: a first modulation order for transmission to the first UE, or a second modulation order for transmission to the second UE.

[00318] Example 54. The method of any of examples 51-53 or any other examples, wherein the MUST to the first UE and the second UE is in accordance with Power multiplexing.

[00319] Example 55. The method of any of examples 51-53 or any other examples, wherein the DCI is to be transmitted to the first UE configured as the Near UE.

[00320] Example 56. The method of any of examples 51-53 or any other examples, wherein the DCI is to be transmitted to the first UE configured as the Near UE, to enable the first UE to map the index to a first value of the parameter.

[00321] Example 57. One or more non-transitory computer-readable storage media to store instructions that, when executed by a processor, cause the processor to execute a method of any of the examples 51-56 or any other examples.

[00322] Example 58 may include an apparatus comprising: means for multiplexing multiple users in a multiple user (MU) multiple input multiple output (MIMO) system using spatial multiplexing (SM) with non-orthogonal precoders.

[00323] Example 59 may include the apparatus of example 58 and/or some other examples herein, wherein the SM with non-orthogonal precoders is based on a cell-specific reference signal (CRS)-transmission mode (TM) or a demodulation references signal (DMRS)-TM.

[00324] Example 60 may include the apparatus of example 58 and/or some other examples herein, wherein MU parameters for the CRS-TM comprise one or more of co-scheduled UE existence, number of multi-users, precoder, modulation order, and power offset; and wherein MU parameters for the DMRS-TM comprise one or more of co-scheduled UE existence, DMRS scrambling seed, number of DMRS ports, and modulation order.

[00325] Example 61 may include the apparatus of example 60 and/or some other examples herein, further comprising: means for signaling the MU parameters to a user equipment (UE).

[00326] Example 62 may include the apparatus of example 60 or 61 and/or some other examples herein, wherein a UE is to detect the MU parameters based on a detection means.

[00327] Example 63 may include the apparatus of example 62 and/or some other examples herein, wherein the detection means is adapted between linear detection means and non-linear detection means.

[00328] Example 64 may include the apparatus of example 63 and/or some other examples herein, wherein: an enhanced-linear-minimum mean square error (E-LMMSE)-

interference rejection combining (IRC) means is selected as the detection means when a serving modulation order is low or an interference modulation order is high; and/or when blind detection on a MU modulation order is not reliable; and a maximum likelihood (ML) means is selected as the detection means when the serving modulation order is high and an interference modulation order is medium or low; and/or when blind detection on the MU parameters is reliable.

[00329] Example 65A may include the apparatus of examples 63-64 and/or some other examples herein, wherein when the detection means is the ML means, the ML means is for estimating a probability of receive signal for different transmit parameters hypotheses and determine a hypothesis of the hypotheses that has a maximum value.

[00330] Example 65B may include the apparatus of examples 64-65A and/or some other examples herein, wherein the ML means comprises a reduced complexity ML (R-ML) means.

[00331] Example 66 may include the apparatus of examples 63-64 and/or some other examples herein, wherein the detection means is to reconstruct receive signal covariance matrices under various receive (RX) signal hypotheses and compare the hypotheses against an actual receive signal covariance matrix estimated on one or more data resource elements (REs), wherein the comparison of covariance matrices is based on Euclidean distance.

[00332] Example 67 may include the apparatus of examples 65A-66 and/or some other examples herein, wherein the detection means includes the ML means and the covariance matrix comparison, wherein an interference signal presence and precoder are detected using the covariance matrix comparison, and a modulation format is detected using the ML means upon detection of the MU parameters using the covariance matrix comparison.

[00333] Example 68 may include the apparatus of example 67 and/or some other examples herein, wherein the detection means includes detection of co-scheduled UE existence based on when channel power of DMRS antenna port (AP) is above or below a threshold, and wherein the AP to be monitored for the channel power is based on an orthogonal correction code (OCC) level.

[00334] Example 69 may include the apparatus of examples 58-68, wherein the apparatus is an evolved node B (eNB) or a portion thereof, or the apparatus is a transmission reception point (TRP) or a portion thereof.

[00335] Example 70 may include an apparatus comprising: means for detecting multiple user (MU) parameters to be used for receiving signals in an MU-multiple input

multiple output (MIMO) system that uses spatial multiplexing (SM) with non-orthogonal precoders.

[00336] Example 71 may include the apparatus of example 70 and/or some other examples herein, wherein the SM with non-orthogonal precoders is based on a cell-specific reference signal (CRS)-transmission mode (TM) or a demodulation references signal (DMRS)-TM.

[00337] Example 72 may include the apparatus of example 71 and/or some other examples herein, wherein MU parameters for the CRS-TM comprise one or more of co-scheduled UE existence, number of multi-users, precoder, modulation order, and power offset; and wherein MU parameters for the DMRS-TM comprise one or more of co-scheduled UE existence, DMRS scrambling seed, number of DMRS ports, and modulation order.

[00338] Example 73 may include the apparatus of example 72 and/or some other examples herein, further comprising: means for receiving the MU parameters based whether the SM with non-orthogonal precoders is based on the CRS-TM or the DMRS-TM.

[00339] Example 74 may include the apparatus of examples 72-73 and/or some other examples herein, further comprising: means for selecting a detection means to detect the MU parameters.

[00340] Example 75 may include the apparatus of example 74 and/or some other examples herein, wherein the detection means is adapted between linear detection means and non-linear detection means.

[00341] Example 76 may include the apparatus of example 75 and/or some other examples herein, wherein the means for selecting the detection means comprises: means for selecting an enhanced-linear-minimum mean square error (E-LMMSE)-interference rejection combining (IRC) means when a serving modulation order is low or an interference modulation order is high; and/or when blind detection on a MU modulation order is not reliable; and means for selecting a maximum likelihood (ML) means when the serving modulation order is high and an interference modulation order is medium or low; and/or when blind detection on the MU parameters is reliable.

[00342] Example 77 may include the apparatus of examples 75-76 and/or some other examples herein, wherein the ML means is for estimating a probability of receive signal for different transmit parameters hypotheses and determine a hypothesis of the hypotheses that has a maximum value.

[00343] Example 78 may include the apparatus of example 77 and/or some other examples herein, wherein the E-LMMSE-IRC means comprises: means for reconstructing receive signal covariance matrices under various receive (Rx) signal hypotheses; and means for comparing the hypotheses against an actual receive signal covariance matrix estimated on one or more data resource elements (REs), wherein the comparison of covariance matrices is based on Euclidean distance.

[00344] Example 79A may include the apparatus of examples 77-78 and/or some other examples herein, wherein the ML means comprises the ML means and the means for comparing the covariance matrices, wherein: the means for comparing the covariance matrices comprises means for detecting an interference signal presence and precoder, and the ML means comprises means for detecting a modulation format upon detection of the MU parameters using the covariance matrix comparison, wherein the modulation format is based on obtained information regarding the modulation format.

[00345] Example 79B may include the apparatus of examples 76-79A and/or some other examples herein, wherein the ML means comprises a reduced complexity ML (R-ML) means.

[00346] Example 80 may include the apparatus of examples 79A-79B and/or some other examples herein, wherein the detection means comprises: means for detecting a co-scheduled UE existence comprising: means for monitoring a channel power of a DMRS antenna port (AP), wherein the AP to be monitored for the channel power is based on an orthogonal correction code (OCC) level; and means for determining whether the monitored AP is above or below a threshold.

[00347] Example 81 may include the apparatus of examples 70-80, wherein the apparatus is a user equipment (UE) or a portion thereof.

[00348] Example 82 may include an apparatus to: multiplex, using spatial multiplexing (SM) with non-orthogonal precoders, multiple user (MU) signals in a MU-multiple input multiple output (MIMO) system.

[00349] Example 83 may include the apparatus of example 82 and/or some other examples herein, wherein the SM with non-orthogonal precoders is based on a cell-specific reference signal (CRS)-transmission mode (TM) or a demodulation references signal (DMRS)-TM.

[00350] Example 84 may include the apparatus of example 83 and/or some other examples herein, wherein MU parameters for the CRS-TM comprise one or more of co-scheduled UE existence, number of multi-users, precoder, modulation order, and power

offset; and wherein MU parameters for the DMRS-TM comprise one or more of co-scheduled UE existence, DMRS scrambling seed, number of DMRS ports, and modulation order.

[00351] Example 85 may include the apparatus of example 84 and/or some other examples herein, wherein the apparatus is to: signal the MU parameters to a user equipment (UE).

[00352] Example 86 may include the apparatus of example 84-85 and/or some other examples herein, wherein a UE is to detect the MU parameters based on a detection mechanism.

[00353] Example 87 may include the apparatus of example 86 and/or some other examples herein, wherein the detection mechanism is adapted between linear detection mechanism and non-linear detection mechanism.

[00354] Example 88 may include the apparatus of example 30 and/or some other examples herein, wherein: an enhanced-linear-minimum mean square error (E-LMMSE)-interference rejection combining (IRC) mechanism is selected as the detection mechanism when a serving modulation order is low or an interference modulation order is high; and/or when blind detection on a MU modulation order is not reliable; and a maximum likelihood (ML) mechanism is selected as the detection mechanism when the serving modulation order is high and an interference modulation order is medium or low; and/or when blind detection on the MU parameters is reliable.

[00355] Example 89A may include the apparatus of examples 87-88 and/or some other examples herein, wherein when the detection mechanism is the ML mechanism, wherein the ML mechanism is to estimate a probability of receive signal for different transmit parameters hypotheses and determine a hypothesis of the hypotheses that has a maximum value.

[00356] Example 89B may include the apparatus of examples 88-89A and/or some other examples herein, wherein the ML mechanism comprises a reduced complexity ML (R-ML) mechanism.

[00357] Example 90 may include the apparatus of examples 87-88 and/or some other examples herein, wherein the detection mechanism is to reconstruct receive signal covariance matrices under various receive (RX) signal hypotheses and compare the hypotheses against an actual receive signal covariance matrix estimated on one or more data resource elements (REs), wherein the comparison of covariance matrices is based on Euclidean distance.

[00358] Example 91 may include the apparatus of examples 89A-90 and/or some other examples herein, wherein the detection mechanism includes the ML mechanism and the

covariance matrix comparison, wherein an interference signal presence and precoder are detected using the covariance matrix comparison, and a modulation format is detected using the ML mechanism upon detection of the MU parameters using the covariance matrix comparison.

[00359] Example 92 may include the apparatus of example 91 and/or some other examples herein, wherein the detection mechanism includes detection of co-scheduled UE existence based on when channel power of DMRS antenna port (AP) is above or below a threshold, and wherein the AP to be monitored for the channel power is based on an orthogonal correction code (OCC) level.

[00360] Example 93 may include the apparatus of examples 82-92, wherein the apparatus is an evolved node B (eNB) or a portion thereof, or the apparatus is a transmission reception point (TRP) or a portion thereof.

[00361] Example 94 may include an apparatus comprising: detect multiple user (MU) parameters to be used for receiving signals in an MU-multiple input multiple output (MIMO) system that uses spatial multiplexing (SM) with non-orthogonal precoders.

[00362] Example 95 may include the apparatus of example 94 and/or some other examples herein, wherein the SM with non-orthogonal precoders is based on a cell-specific reference signal (CRS)-transmission mode (TM) or a demodulation references signal (DMRS)-TM.

[00363] Example 96 may include the apparatus of example 38 and/or some other examples herein, wherein MU parameters for the CRS-TM comprise one or more of co-scheduled UE existence, number of multi-users, precoder, modulation order, and power offset; and wherein MU parameters for the DMRS-TM comprise one or more of co-scheduled UE existence, DMRS scrambling seed, number of DMRS ports, and modulation order.

[00364] Example 97 may include the apparatus of example 96 and/or some other examples herein, further comprising: receive the MU parameters in a configuration message.

[00365] Example 98 may include the apparatus of examples 96-97 and/or some other examples herein, wherein the apparatus is to: select a detection mechanism to detect the MU parameters.

[00366] Example 99 may include the apparatus of example 98 and/or some other examples herein, wherein the selected detection mechanism is a linear detection mechanism or non-linear detection mechanism.

[00367] Example 100 may include the apparatus of example 99 and/or some other examples herein, wherein the apparatus is to: select an enhanced-linear-minimum mean square error (E-LMMSE)-interference rejection combining (IRC) mechanism when a serving modulation order is low or an interference modulation order is high; and/or when blind detection on a MU modulation order is not reliable; and select a maximum likelihood (ML) mechanism when the serving modulation order is high and an interference modulation order is medium or low; and/or when blind detection on the MU parameters is reliable.

[00368] Example 101A may include the apparatus of examples 99-100 and/or some other examples herein, wherein the ML mechanism is to estimate a probability of receive signal for different transmit parameters hypotheses and determine a hypothesis of the hypotheses that has a maximum value.

[00369] Example 101B may include the apparatus of examples 100-101A and/or some other examples herein, wherein the ML mechanism comprises a reduced complexity ML (R-ML) mechanism.

[00370] Example 102 may include the apparatus of examples 101A-101B and/or some other examples herein, wherein when the E-LMMSE-IRC mechanism is selected, the apparatus is to: reconstruct receive signal covariance matrices under various receive (Rx) signal hypotheses; and compare the hypotheses against an actual receive signal covariance matrix estimated on one or more data resource elements (REs), wherein the comparison of covariance matrices is based on Euclidean distance.

[00371] Example 103 may include the apparatus of examples 101A-102 and/or some other examples herein, wherein the ML mechanism comprises the ML mechanism and the E-LMMSE-IRC mechanism, and wherein the apparatus is to: compare the covariance matrices to detect an interference signal presence and precoder, and detect a modulation format upon detection of the MU parameters using the comparison of the covariance matrices.

[00372] Example 104 may include the apparatus of example 103 and/or some other examples herein, wherein the apparatus is to: detect a co-scheduled UE existence, and wherein to detect the co-scheduled UE, the apparatus is to: monitor a channel power of a DMRS antenna port (AP), wherein the AP to be monitored for the channel power is based on an orthogonal correction code (OCC) level; and determine whether the monitored AP is above or below a threshold.

[00373] Example 105 may include the apparatus of examples 94-104, wherein the apparatus is a user equipment (UE) or a portion thereof.

[00374] Example 106 may include a method comprising: multiplexing or causing to multiplex multiple users in a multiple user (MU) multiple input multiple output (MIMO) system using spatial multiplexing (SM) with non-orthogonal precoders.

[00375] Example 107 may include the method of example 106 and/or some other examples herein, wherein the SM with non-orthogonal precoders is based on a cell-specific reference signal (CRS)-transmission mode (TM) or a demodulation references signal (DMRS)-TM.

[00376] Example 108 may include the method of example 107 and/or some other examples herein, wherein MU parameters for the CRS-TM comprise one or more of co-scheduled UE existence, number of multi-users, precoder, modulation order, and power offset; and wherein MU parameters for the DMRS-TM comprise one or more of co-scheduled UE existence, DMRS scrambling seed, number of DMRS ports, and modulation order.

[00377] Example 109 may include the method of example 108 and/or some other examples herein, further comprising: transmitting or causing to transmit the MU parameters to a user equipment (UE).

[00378] Example 110 may include the method of example 108-109 and/or some other examples herein, wherein a UE is to detect the MU parameters based on a detection mechanism.

[00379] Example 111 may include the method of example 110 and/or some other examples herein, wherein the detection mechanism is adapted between linear detection mechanism and non-linear detection mechanism.

[00380] Example 112 may include the method of example 111 and/or some other examples herein, wherein: an enhanced-linear-minimum mean square error (E-LMMSE)-interference rejection combining (IRC) mechanism is selected as the detection mechanism when a serving modulation order is low or an interference modulation order is high; and/or when blind detection on a MU modulation order is not reliable; and a maximum likelihood (ML) mechanism is selected as the detection mechanism when the serving modulation order is high and an interference modulation order is medium or low; and/or when blind detection on the MU parameters is reliable.

[00381] Example 113A may include the method of examples 111-112 and/or some other examples herein, wherein the ML mechanism is to estimate a probability of receive signal for different transmit parameters hypotheses and determine a hypothesis of the hypotheses that has a maximum value.

[00382] Example 113B may include the apparatus of examples 112-113A and/or some other examples herein, wherein the ML mechanism comprises a reduced complexity ML (R-ML) mechanism.

[00383] Example 114 may include the method of examples 111-112 and/or some other examples herein, wherein the detection mechanism is to reconstruct receive signal covariance matrices under various receive (RX) signal hypotheses and compare the hypotheses against an actual receive signal covariance matrix estimated on one or more data resource elements (REs), wherein the comparison of covariance matrices is based on Euclidean distance.

[00384] Example 115 may include the method of examples 113A-114 and/or some other examples herein, wherein the detection mechanism includes the ML mechanism and the covariance matrix comparison, wherein an interference signal presence and precoder are detected using the covariance matrix comparison, and a modulation format is detected using the ML mechanism upon detection of the MU parameters using the covariance matrix comparison.

[00385] Example 116 may include the method of example 115 and/or some other examples herein, wherein the detection mechanism includes detection of co-scheduled UE existence based on when channel power of DMRS antenna port (AP) is above or below a threshold, and wherein the AP to be monitored for the channel power is based on an orthogonal correction code (OCC) level.

[00386] Example 117 may include the method of examples 106-116, wherein the apparatus is an evolved node B (eNB) or a portion thereof, or the apparatus is a transmission reception point (TRP) or a portion thereof.

[00387] Example 118 may include a method comprising: detecting or causing to detect multiple user (MU) parameters to be used for receiving signals in an MU-multiple input multiple output (MIMO) system that uses spatial multiplexing (SM) with non-orthogonal precoders.

[00388] Example 119 may include the method of example 118 and/or some other examples herein, wherein the SM with non-orthogonal precoders is based on a cell-specific reference signal (CRS)-transmission mode (TM) or a demodulation references signal (DMRS)-TM.

[00389] Example 120 may include the method of example 119 and/or some other examples herein, wherein MU parameters for the CRS-TM comprise one or more of co-scheduled UE existence, number of multi-users, precoder, modulation order, and power offset; and wherein MU parameters for the DMRS-TM comprise one or more of co-

scheduled UE existence, DMRS scrambling seed, number of DMRS ports, and modulation order.

[00390] Example 121 may include the method of example 120 and/or some other examples herein, further comprising: receiving or causing to receive the MU parameters based whether the SM with non-orthogonal precoders is based on the CRS-TM or the DMRS-TM.

[00391] Example 122 may include the method of examples 120-121 and/or some other examples herein, further comprising: selecting or causing to select a detection mechanism to detect the MU parameters.

[00392] Example 123 may include the method of example 122 and/or some other examples herein, wherein the detection mechanism is adapted between linear detection mechanism and non-linear detection mechanism.

[00393] Example 124 may include the method of example 123 and/or some other examples herein, wherein the selecting the detection mechanism comprises: selecting or causing to select an enhanced-linear-minimum mean square error (E-LMMSE)-interference rejection combining (IRC) mechanism when a serving modulation order is low or an interference modulation order is high; and/or when blind detection on a MU modulation order is not reliable; and selecting or causing to select a maximum likelihood (ML) mechanism when the serving modulation order is high and an interference modulation order is medium or low; and/or when blind detection on the MU parameters is reliable.

[00394] Example 125A may include the method of examples 123-124 and/or some other examples herein, wherein the ML mechanism is to estimate a probability of receive signal for different transmit parameters hypotheses and determine a hypothesis of the hypotheses that has a maximum value.

[00395] Example 125B may include the method of examples 124-125A and/or some other examples herein, wherein the ML mechanism comprises a low complexity ML mechanism or a reduced complexity ML (R-ML) mechanism.

[00396] Example 126 may include the method of examples 125A-125B and/or some other examples herein, wherein the E-LMMSE-IRC mechanism comprises: reconstructing or causing to reconstruct receive signal covariance matrices under various receive (Rx) signal hypotheses; and comparing or causing to compare the hypotheses against an actual receive signal covariance matrix estimated on one or more data resource elements (REs), wherein the comparison of covariance matrices is based on Euclidean distance.

[00397] Example 127 may include the method of examples 125A-126 and/or some other examples herein, wherein the ML mechanism comprises the ML mechanism and the E-LMMSE-IRC mechanism, and the method comprises: comparing or causing to compare the covariance matrices comprises to detect an interference signal presence and precoder, and detecting or causing to detect a modulation format after the detecting of the interference signal presence and precoder.

[00398] Example 128 may include the method of example 127 and/or some other examples herein, further comprising: detecting or causing to detect a co-scheduled UE existence comprising: monitoring or causing to monitor a channel power of a DMRS antenna port (AP), wherein the AP to be monitored for the channel power is based on an orthogonal correction code (OCC) level; and determining or causing to determine whether the monitored AP is above or below a threshold.

[00399] Example 129 may include the method of examples 118-128, wherein the method is performed by a user equipment (UE) or a portion thereof.

[00400] Example 130 may include a method and network that can multiplex multiple users by spatial multiplexing (SM) using non-orthogonal precoders, wherein the MU UEs in the network may be aware of MU parameters for the best performance.

[00401] Example 131 may include the method and network of example 130 and/or some other examples herein, wherein, for the best performance, the MU UEs can take multiple detection strategies, wherein a detection strategy can adapted depending on UE's parameter awareness and performance gain.

[00402] Example 132 may include the method and network of examples 130-131 and/or some other examples herein, wherein, for UE's parameter awareness, network assistance signaling can be provided, which may include any combination of: for linear detection in CRS-TMs, existence, number of multi-users and precoder are required. for linear detection in DMRS TMs, existence, DMRS scrambling seed and Number of DMRS ports are required. for non-linear detection in CRS-TMs, modulation order of MU UEs are additionally required. for non-linear detection in DMRS-TMs, modulation order of MU UEs are additionally required.

[00403] Example 133 may include the method and network of examples 130-132 and/or some other examples herein, wherein, if there is no network signaling, UE can blindly detect on the parameters.

[00404] Example 134 may include the method and network of examples 130-133 and/or some other examples herein, wherein, linear detection with interference rejection and

combining can be effectively selected for the best performance when: serving modulation order is low OR Interference modulation order is high, blind detection on modulation orders are not accurate.

[00405] Example 135 may include the method and network of examples 130-134 and/or some other examples herein, wherein, non-linear detection is selected effectively when: serving modulation order is high and Interference modulation order is medium or low, and blind detection on MU parameters are reliable.

[00406] Example 136 may include the method and network of examples 134-135 and/or some other examples herein, wherein the network can be adapted per a MU transmission.

[00407] Example 137 may include the method and network of example 133 and/or some other examples herein, wherein low complexity algorithms are designed, which may include any combination of: for CRS-TM precoder estimation, a MU UE compare a received signal covariance matrix and reconstructed covariance matrix with a precoder hypothesis, using a precoder detection of the CRS-TM, only modulation order can be effectively searched within one or a few limited precoder hypothesis, for DMRS-TM, a power threshold test on each AP channel covariance matrix is applied with the number of users and scrambling seed hypothesis.

[00408] Example 138 may include an apparatus comprising means to perform one or more elements of a method described in or related to any of examples 58-137, or any other method or process described herein.

[00409] Example 139 may include one or more non-transitory computer-readable media comprising instructions to cause an electronic device, upon execution of the instructions by one or more processors of the electronic device, to perform one or more elements of a method described in or related to any of examples 58-137, or any other method or process described herein.

[00410] Example 140 may include an apparatus comprising logic, modules, and/or circuitry to perform one or more elements of a method described in or related to any of examples 58-137, or any other method or process described herein.

[00411] Example 141 may include a method, technique, or process as described in or related to any of examples 58-137, or portions or parts thereof.

[00412] Example 142 may include an apparatus comprising: one or more processors and one or more computer readable media comprising instructions that, when executed by the

one or more processors, cause the one or more processors to perform the method, techniques, or process as described in or related to any of examples 58-137, or portions thereof.

[00413] Example 143 may include a method of communicating in a wireless network as shown and described herein.

[00414] Example 144 may include a system for providing wireless communication as shown and described herein.

[00415] Example 145 may include a device for providing wireless communication as shown and described herein.

[00416] An abstract is provided that will allow the reader to ascertain the nature and gist of the technical disclosure. The abstract is submitted with the understanding that it will not be used to limit the scope or meaning of the claims. The following claims are hereby incorporated into the detailed description, with each claim standing on its own as a separate embodiment.

CLAIMS

We claim:

1. An apparatus of an Evolved Node B (eNB) operable to communicate with a User Equipment (UE) on a wireless network, comprising:
 - a memory to store instructions; and
 - one or more processors to execute the instructions to perform operations comprising:
 - establish an index that is to identify a parameter, wherein the parameter is associated with Multi-user Superposition Transmission (MUST) from the eNB to a first UE configured as a Near UE and a second UE configured as a Far UE, and
 - generate a Downlink Control Information (DCI) for transmission to at least one of the first UE or the second UE, the DCI including the index.
2. The apparatus of claim 1, further comprising:
 - an interface to output the DCI, including the index, to a transceiver circuitry, for transmission to at least one of the first UE or the second UE.
3. The apparatus of claim 1, wherein the parameter is a power ratio α used by the eNB for transmission to the Near UE and the Far UE.
4. The apparatus of claim 1, wherein the parameter is at least one of: a first modulation order for transmission to the first UE, or a second modulation order for transmission to the second UE.
5. The apparatus of any of claims 1-4, wherein the MUST to the first UE and a second UE is in accordance with Power multiplexing.
6. The apparatus of any of claims 1-4, wherein the DCI is to be transmitted to the first UE configured as the Near UE.
7. The apparatus of any of claims 1-4, wherein the DCI is to be transmitted to the first UE configured as the Near UE, to enable the first UE to map the index to a first value of the parameter.

8. Machine readable storage media having machine executable instructions that, when executed, cause one or more processors of an Evolved Node B (eNB) to perform an operation comprising:

establish an index that is to identify a parameter, wherein the parameter is associated with Multi-user Superposition Transmission (MUST) from the eNB to a first User Equipment (UE) configured as a Near UE and a second UE configured as a Far UE, and

generate a Downlink Control Information (DCI) for transmission to at least one of the first UE or the second UE, the DCI including the index.

9. The machine readable storage media of claim 8, wherein the operation comprises:

output the DCI, including the index, to a transceiver circuitry, for transmission to at least one of the first UE or the second UE.

10. The machine readable storage media of claim 8, wherein the parameter is a power ratio α used by the eNB for transmission to the Near UE and the Far UE.

11. The machine readable storage media of claim 8, wherein the parameter is at least one of: a first modulation order for transmission to the first UE, or a second modulation order for transmission to the second UE.

12. The machine readable storage media of any of claims 8-11, wherein the MUST to the first UE and the second UE is in accordance with Power multiplexing.

13. The machine readable storage media of any of claims 8-11, wherein the DCI is to be transmitted to the first UE configured as the Near UE.

14. The machine readable storage media of any of claims 8-11, wherein the DCI is to be transmitted to the first UE configured as the Near UE, to enable the first UE to map the index to a first value of the parameter.

15. An apparatus of a first User Equipment (UE) operable to communicate with an Evolved Node B (eNB) on a wireless network, comprising:

one or more processors to:

process a Downlink Control Information (DCI), the DCI including an index,
and

map the index to a parameter, the parameter associated with Multi-user
Superposition Transmission (MUST) from the eNB to the first UE configured as a Near UE
and a second UE configured as a Far UE; and
a memory to store the parameter.

16. The apparatus of claim 15, further comprising:
an interface to input the DCI, including the index, from a transceiver circuitry.
17. The apparatus of claim 15, wherein the one or more processors are to:
demodulate Downlink (DL) signals received from the eNB, based on the parameter.
18. The apparatus of any of claims 15-17, wherein the Multi-User Superposition
Transmission to the first UE and a second UE is in accordance with Power multiplexing.
19. The apparatus of any of claims 15-17, wherein the parameter is a power ratio α used
by the eNB for transmission to the Near UE and the Far UE.
20. The apparatus of any of claims 15-17, wherein the parameter is at least one of: a first
modulation order for transmission to the first UE, or a second modulation order for
transmission to the second UE.
21. An apparatus of an Evolved Node B (eNB) operable to communicate with a User
Equipment (UE) on a wireless network, comprising:
a memory to store instructions; and
one or more processors to execute the instructions to perform operations comprising:
establish an indicator that is to identify a modulation order associated with
transmission from the eNB to a first UE, wherein the eNB is to co-schedule transmission in
accordance with Multi-user Superposition Transmission (MUST) to the first UE and a second
UE, and
generate a Downlink Control Information (DCI) for transmission to the second
UE, the DCI including the indicator.

22. The apparatus of claim 21, further comprising:
an interface to output the DCI, including the indicator, to a transceiver circuitry, for transmission to the second UE.
23. The apparatus of claim 21, wherein the modulation order is one of Quadrature Phase Shift Keying (QPSK), 16 Quadrature amplitude modulation (16QAM), 64QAM, or 256QAM.
24. The apparatus of any of claims 21-23, wherein the Multi-User Superposition Transmission to the first UE and a second UE is in accordance with Non-Orthogonal Multiple Access (NOMA) spatial multiplexing.
25. The apparatus of any of claims 21-23, wherein the DCI is to be transmitted to the second UE, to enable the second UE to identify the modulation order associated with the co-schedule first UE, based on the indicator.

AMENDED CLAIMS

received by the International Bureau on 16 November 2017 (16.11.2017)

1. An apparatus of an Evolved Node B (eNB) operable to communicate with a User Equipment (UE) on a wireless network, comprising:
 - one or more processors to:
 - establish an index that is to at least in part identify a parameter, wherein the parameter is associated with Multi-user Superposition Transmission (MUST) from the eNB to a UE configured as a Near UE, and
 - generate a Downlink Control Information (DCI) for transmission to the UE, the DCI including the index; and
 - an interface to output the DCI, including the index, to a transceiver circuitry, for transmission to the UE.
2. The apparatus of claim 1, wherein the parameter is a power ratio α used by the eNB for transmission to the UE.
3. The apparatus of claim 1, wherein the DCI is to be transmitted to the UE configured as the Near UE, to enable the UE to identify a first value of the parameter based at least in part on the index.
4. The apparatus of any of claims 1-3, wherein the parameter is at least one of: a first modulation order for transmission to the UE, or a second modulation order for transmission to a second UE configured as a Far UE.
5. The apparatus of any of claims 1-3, wherein the MUST to the UE and another UE configured as a Far UE is in accordance with Power multiplexing.
6. The apparatus of any of claims 1-3, wherein the index is a MUST ID (Must Identification).

7. Machine readable storage media having machine executable instructions that, when executed, cause one or more processors of an Evolved Node B (eNB) to perform an operation comprising:
 - establish an index that is to at least in part identify a parameter, wherein the parameter is associated with Multi-user Superposition Transmission (MUST) from the eNB to a User Equipment (UE) configured as a Near UE; and
 - generate a Downlink Control Information (DCI) for transmission to the UE, the DCI including the index.
8. The machine readable storage media of claim 7, wherein the parameter is a power ratio α used by the eNB for transmission to the UE.
9. The machine readable storage media of claim 7, wherein the DCI is to be transmitted to the UE configured as the Near UE, to enable the UE to identify a first value of the parameter based at least in part on the index.
10. The machine readable storage media of any of claims 7-9, wherein the parameter is at least one of: a first modulation order for transmission to the UE, or a second modulation order for transmission to a second UE configured as a Far UE.
11. The machine readable storage media of any of claims 7-9, wherein the MUST to the UE and a second UE configured as a far UE is in accordance with Power multiplexing.
12. An apparatus of a User Equipment (UE) operable to communicate with an Evolved Node B (eNB) on a wireless network, comprising:
 - one or more processors to:
 - process a Downlink Control Information (DCI), the DCI including an index, and
 - determine a parameter based at least in part on the index, the parameter associated with Multi-user Superposition Transmission (MUST) from the eNB to the UE configured as a Near UE; and
 - a memory to store the parameter.

13. The apparatus of claim 12, further comprising:
an interface to input the DCI, including the index, from a transceiver circuitry.
14. The apparatus of claim 12, wherein the one or more processors are to:
demodulate Downlink (DL) signals received from the eNB, based on the parameter.
15. The apparatus of any of claims 12-14, wherein the parameter is a power ratio α used by the eNB for transmission to the UE configured as the Near UE and another UE configured as a Far UE.
16. The apparatus of any of claims 12-14, wherein the parameter is at least one of: a first modulation order for transmission to the UE, or a second modulation order for transmission to another UE configured as a Far UE.
17. Machine readable storage media having machine executable instructions that, when executed, cause one or more processors of a User Equipment (UE) to perform an operation comprising:
process a Downlink Control Information (DCI), the DCI including an index; and
determine a parameter based at least in part on the index, the parameter associated with Multi-user Superposition Transmission (MUST) from an Evolved Node B (eNB) to the UE configured as a Near UE.
18. The machine readable storage media of claim 17, wherein the operation comprises:
input the DCI, including the index, from a transceiver circuitry.
19. The machine readable storage media of claim 17, wherein the operation comprises:
demodulate Downlink (DL) signals received from the eNB, based at least in part on the parameter.

20. The machine readable storage media of any of claims 17-19, wherein the parameter is a power ratio α used by the eNB for transmission to the UE configured as the Near UE and another UE configured as a Far UE.
21. The machine readable storage media of any of claims 17-19, wherein the parameter is at least one of: a first modulation order for transmission to the UE, or a second modulation order for transmission to another UE configured as a Far UE.
22. An apparatus of an Evolved Node B (eNB) operable to communicate with a User Equipment (UE) on a wireless network, comprising:
one or more processors to:
 establish an indicator that is to identify a modulation order associated with transmission from the eNB to a first UE, wherein the eNB is to co-schedule transmission in accordance with Multi-user Superposition Transmission (MUST) to the first UE and a second UE, and
 generate a Downlink Control Information (DCI) for transmission to the second UE, the DCI including the indicator; and
 a memory to store the DCI.
23. The apparatus of claim 22, further comprising:
 an interface to output the DCI, including the indicator, to a transceiver circuitry, for transmission to the second UE.
24. The apparatus of claim 22, wherein the modulation order is one of Quadrature Phase Shift Keying (QPSK), 16 Quadrature amplitude modulation (16QAM), 64QAM, or 256QAM.
25. The apparatus of any of claims 22-24, wherein the Multi-User Superposition Transmission to the first UE and a second UE is in accordance with Non-Orthogonal Multiple Access (NOMA) spatial multiplexing.

26. The apparatus of any of claims 22-24, wherein the DCI is to be transmitted to the second UE, to enable the second UE to identify the modulation order associated with the co-schedule first UE, based on the indicator.

100

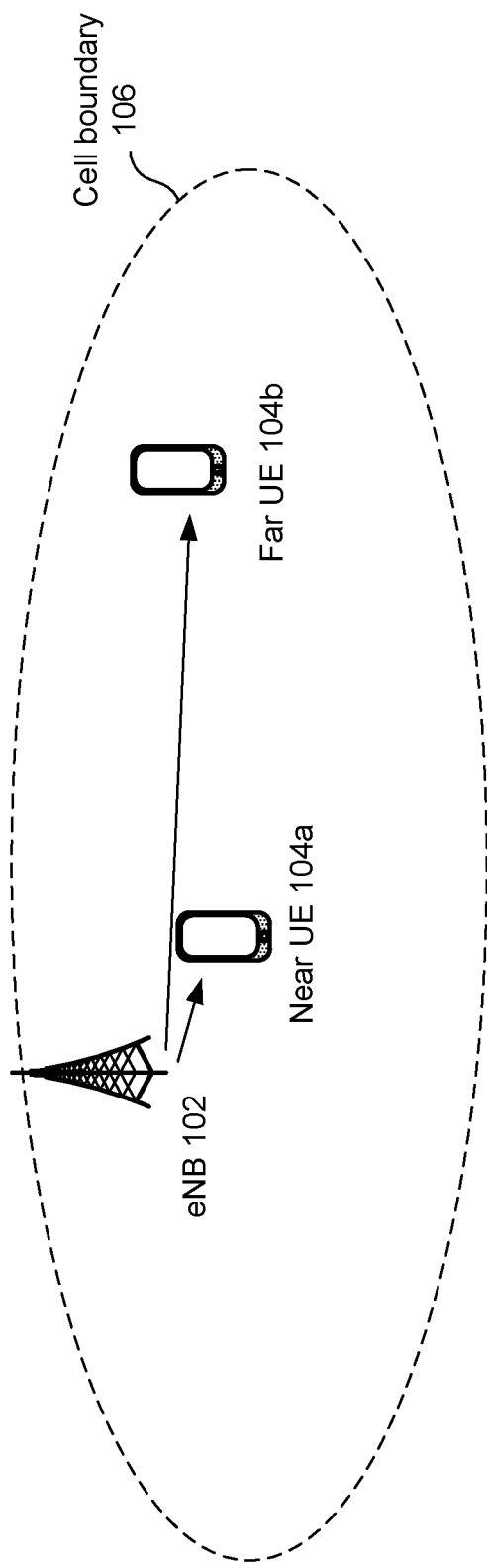


Fig. 1

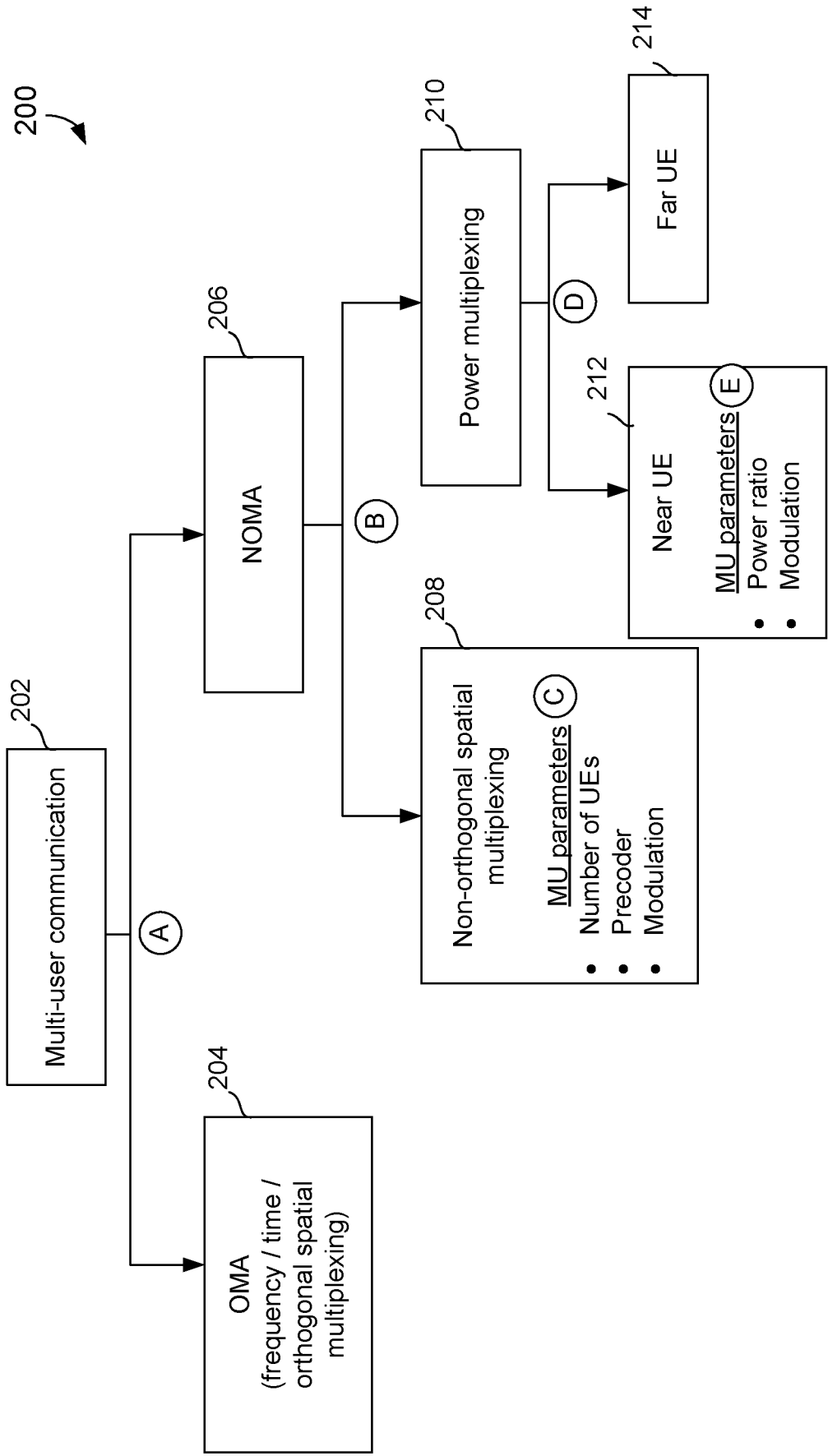


Fig. 2

Fig. 3A

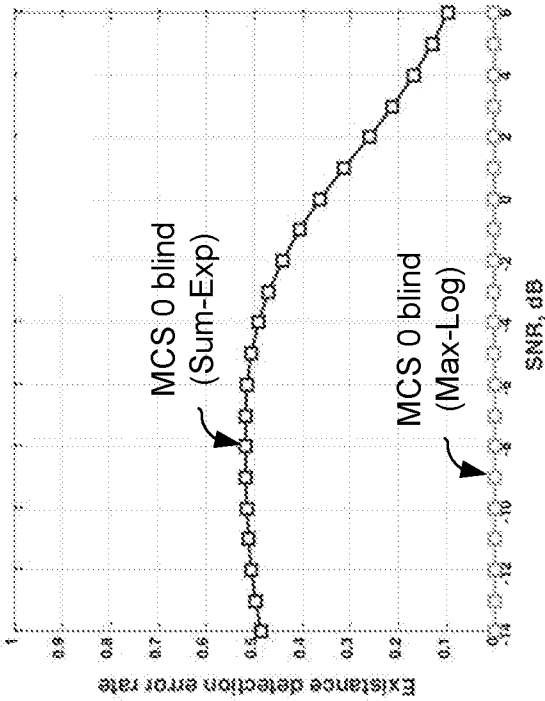


Fig. 3B

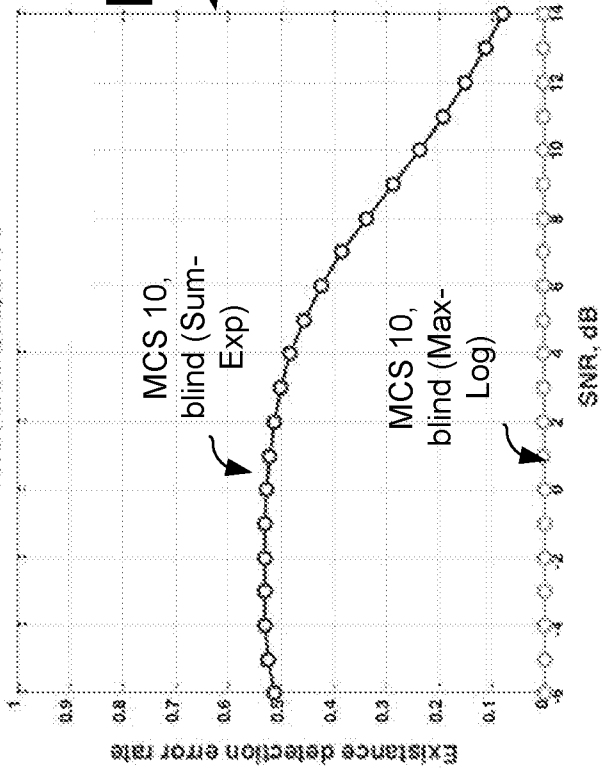
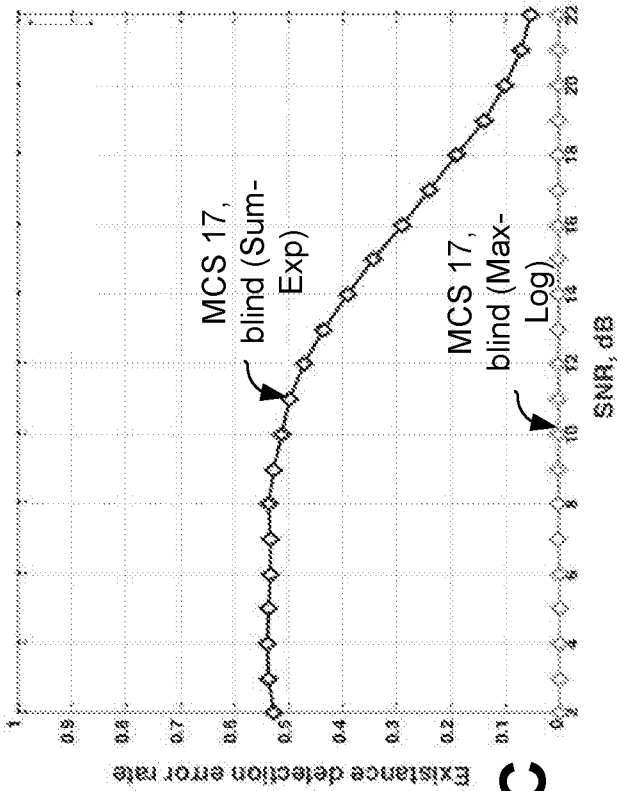


Fig. 3C



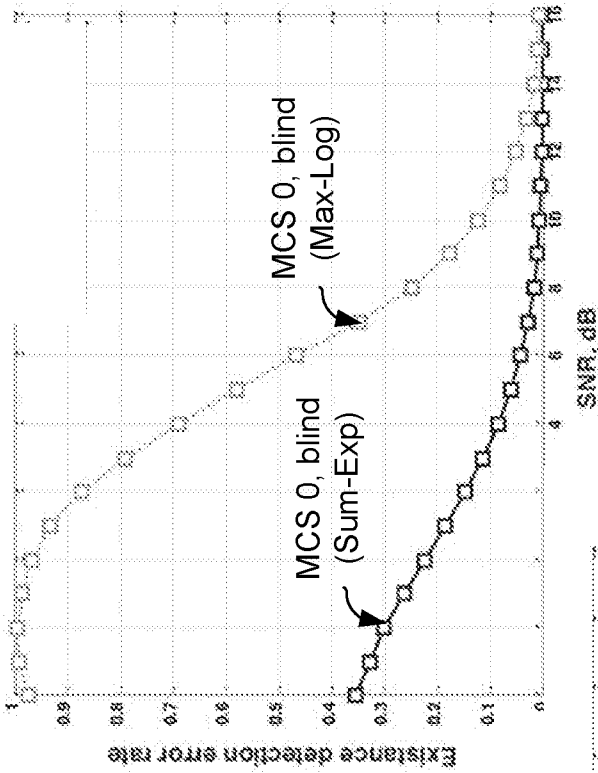


Fig. 4A

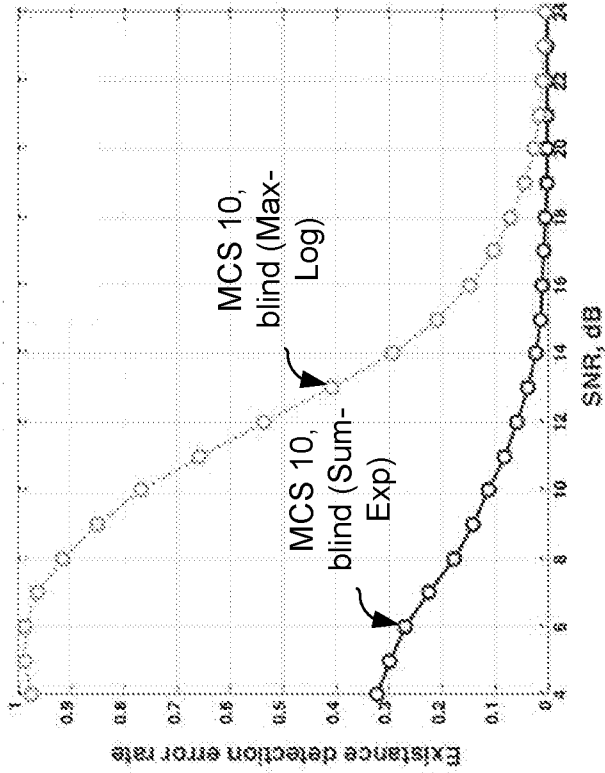


Fig. 4B

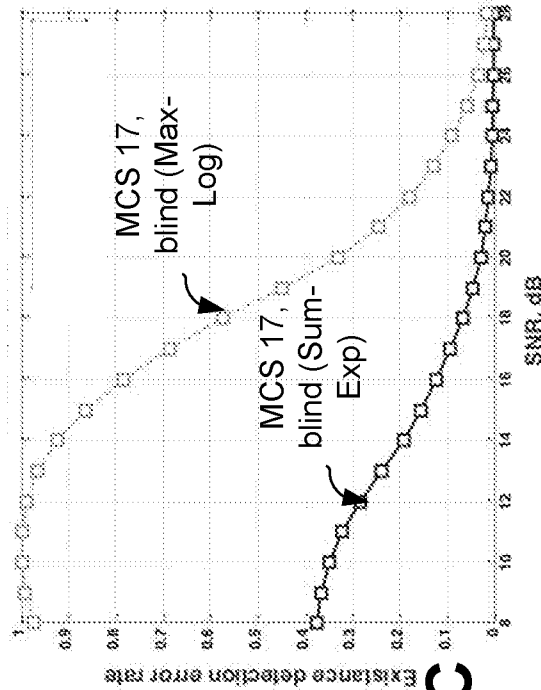


Fig. 4C

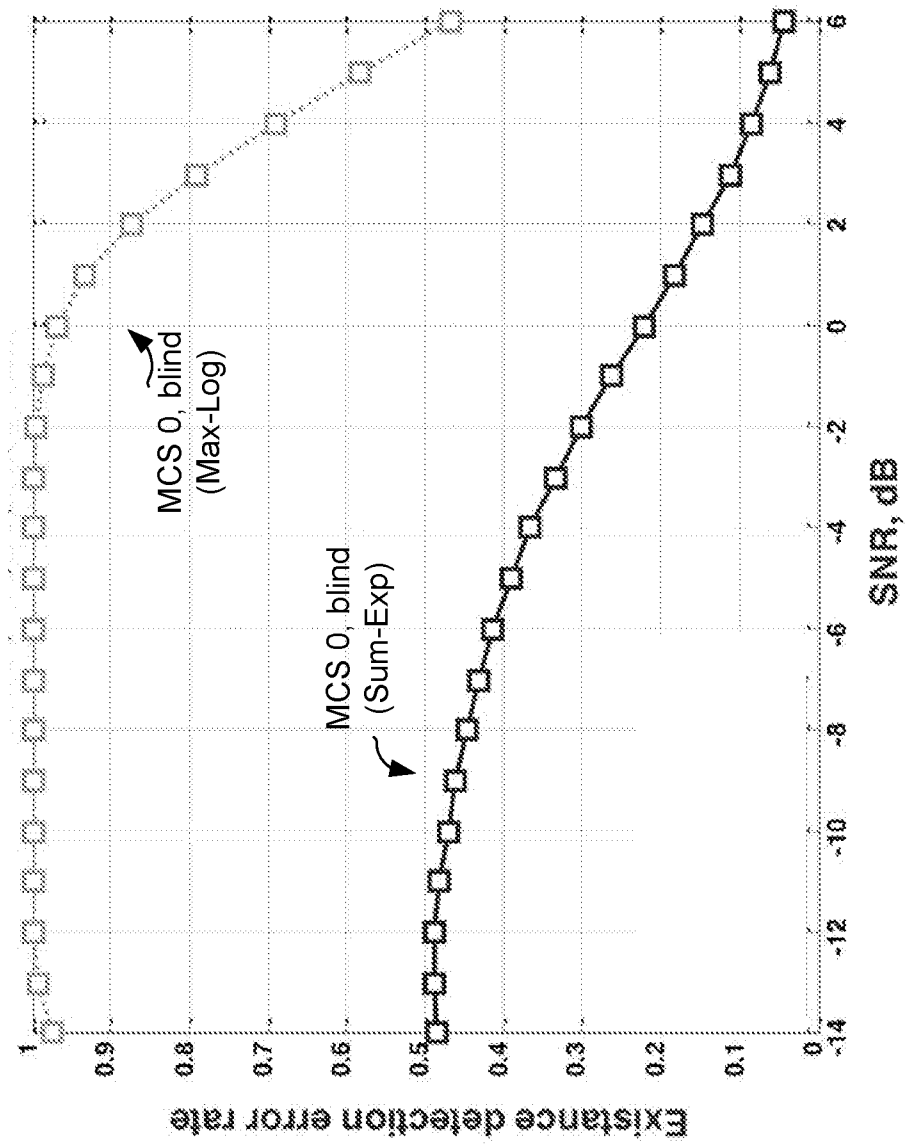


Fig. 5

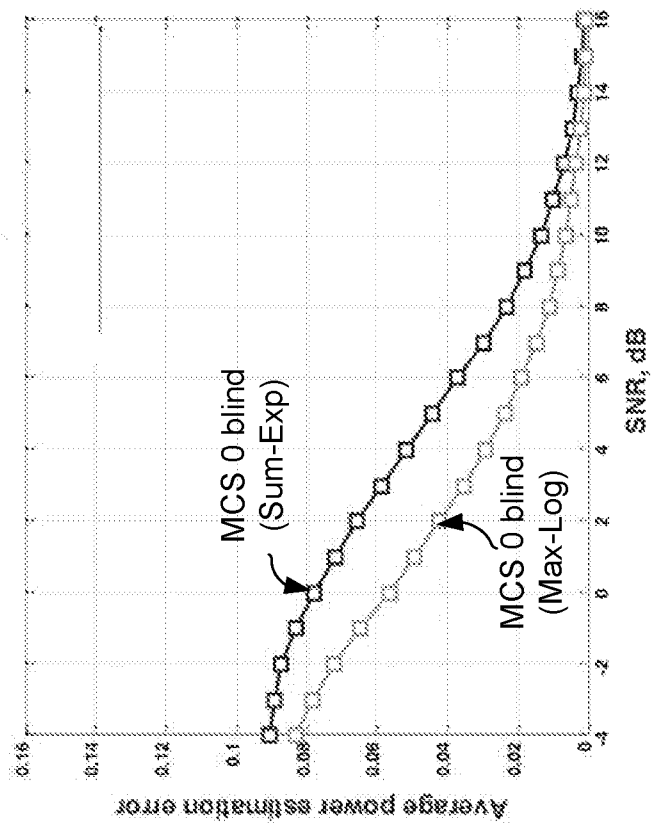


Fig. 6A

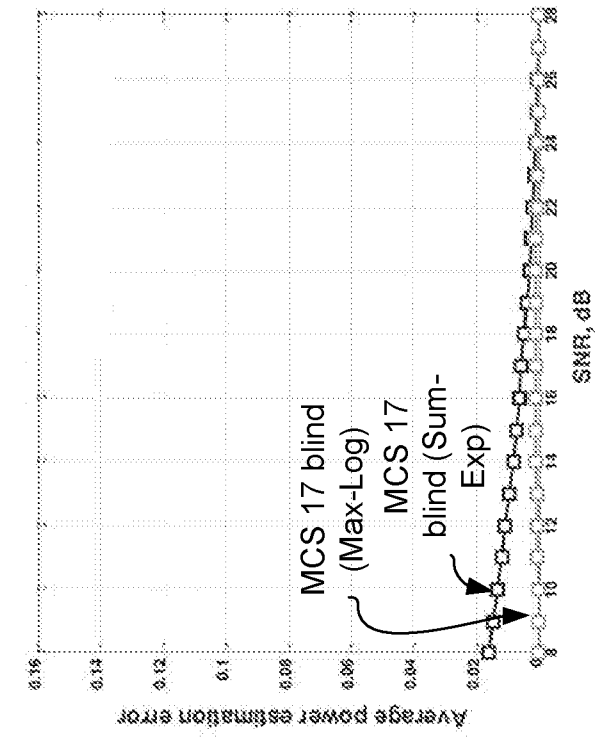


Fig. 6B

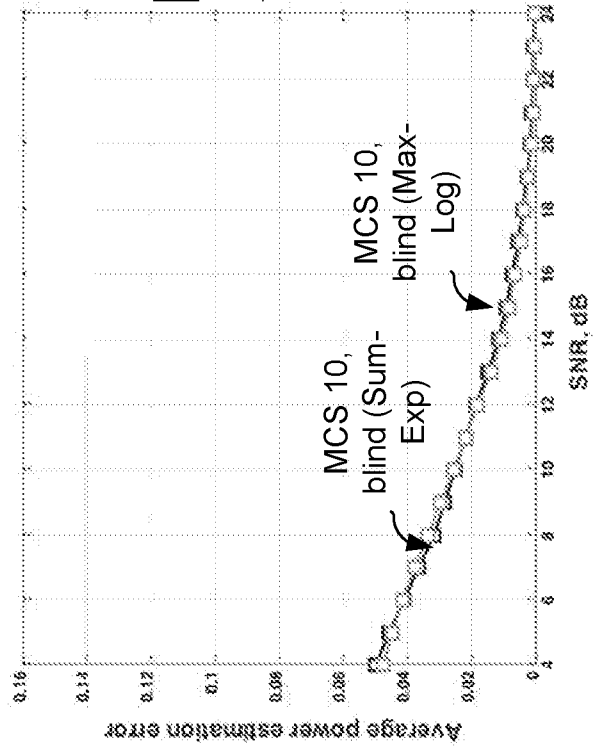


Fig. 6C

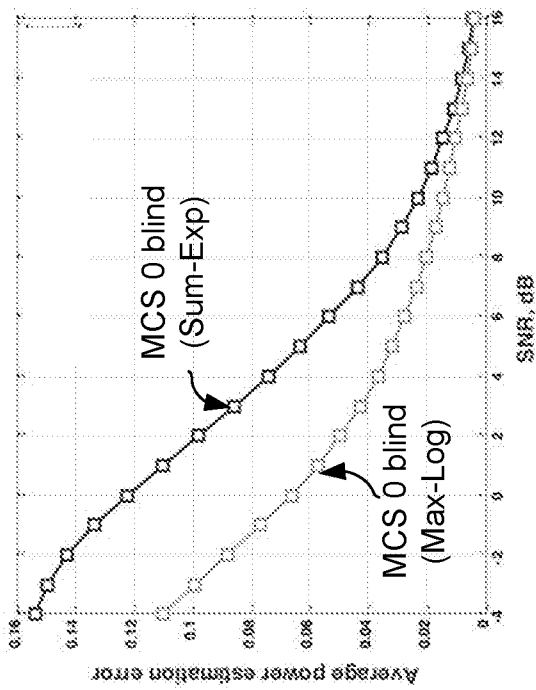


Fig. 7A

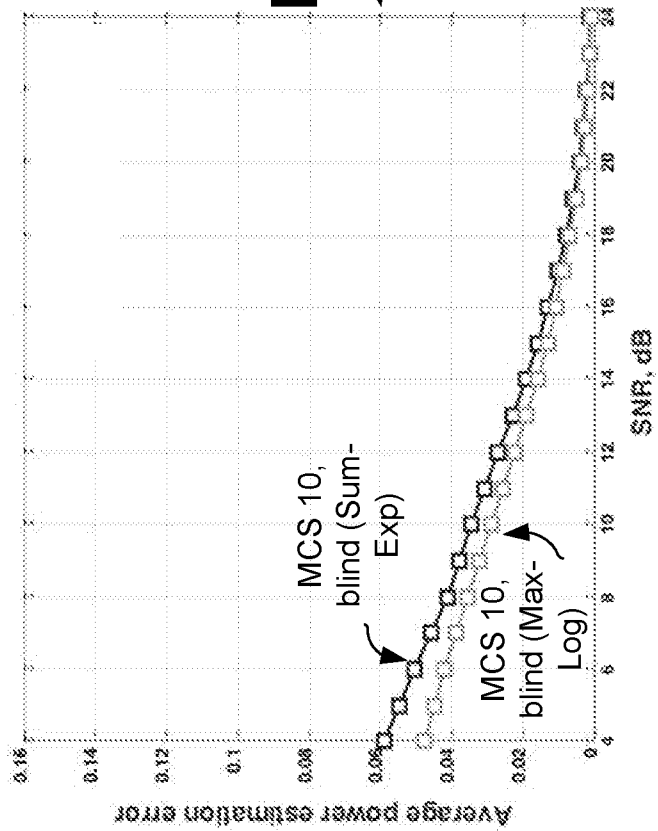


Fig. 7B

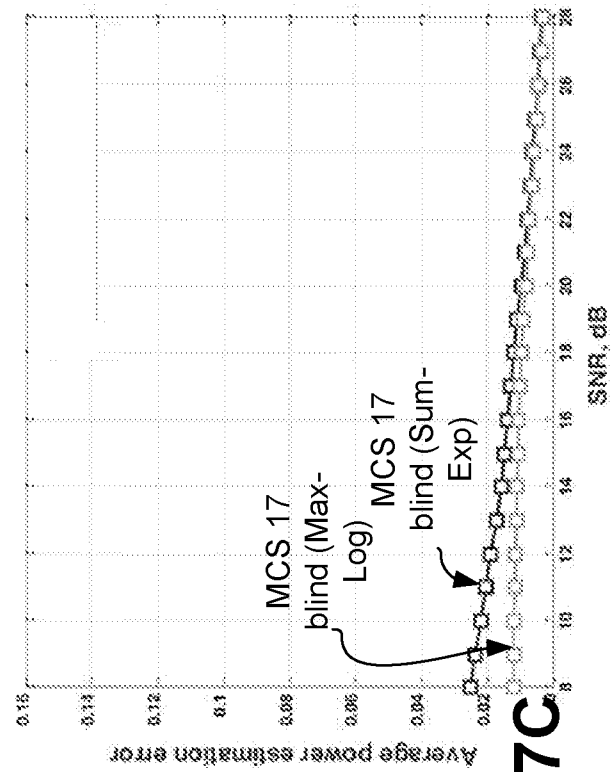
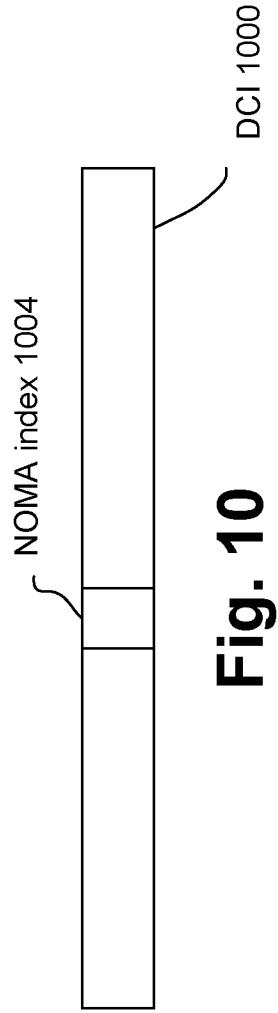
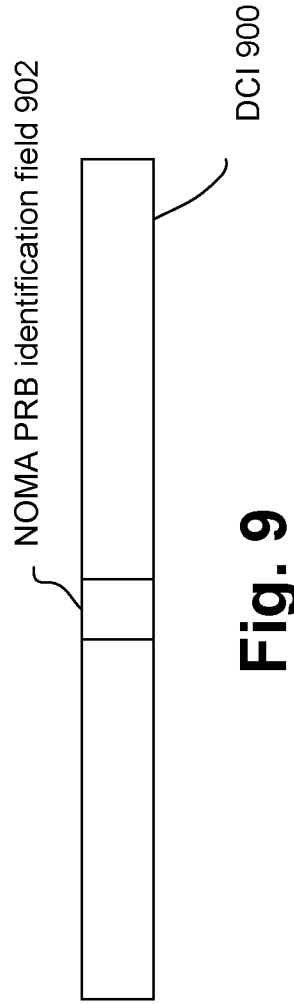
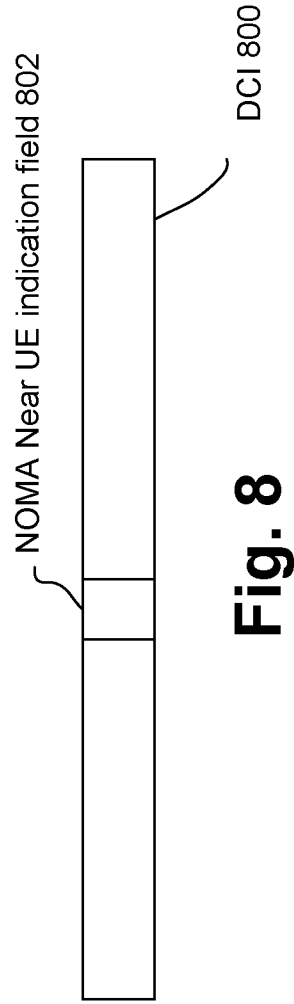


Fig. 7C



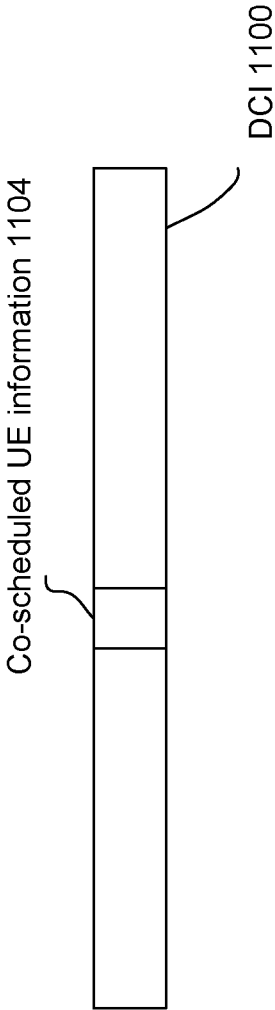


Fig. 11A

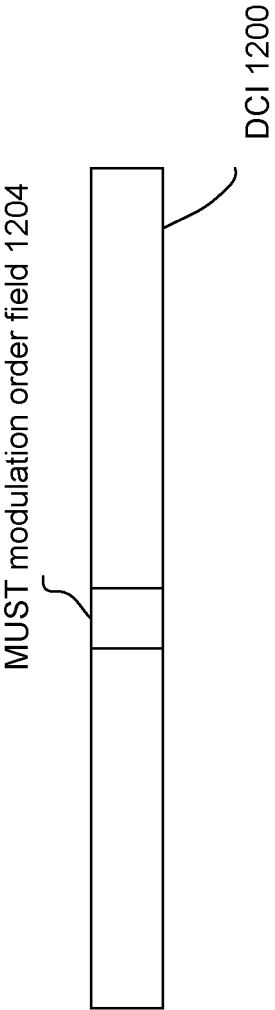


Fig. 11B

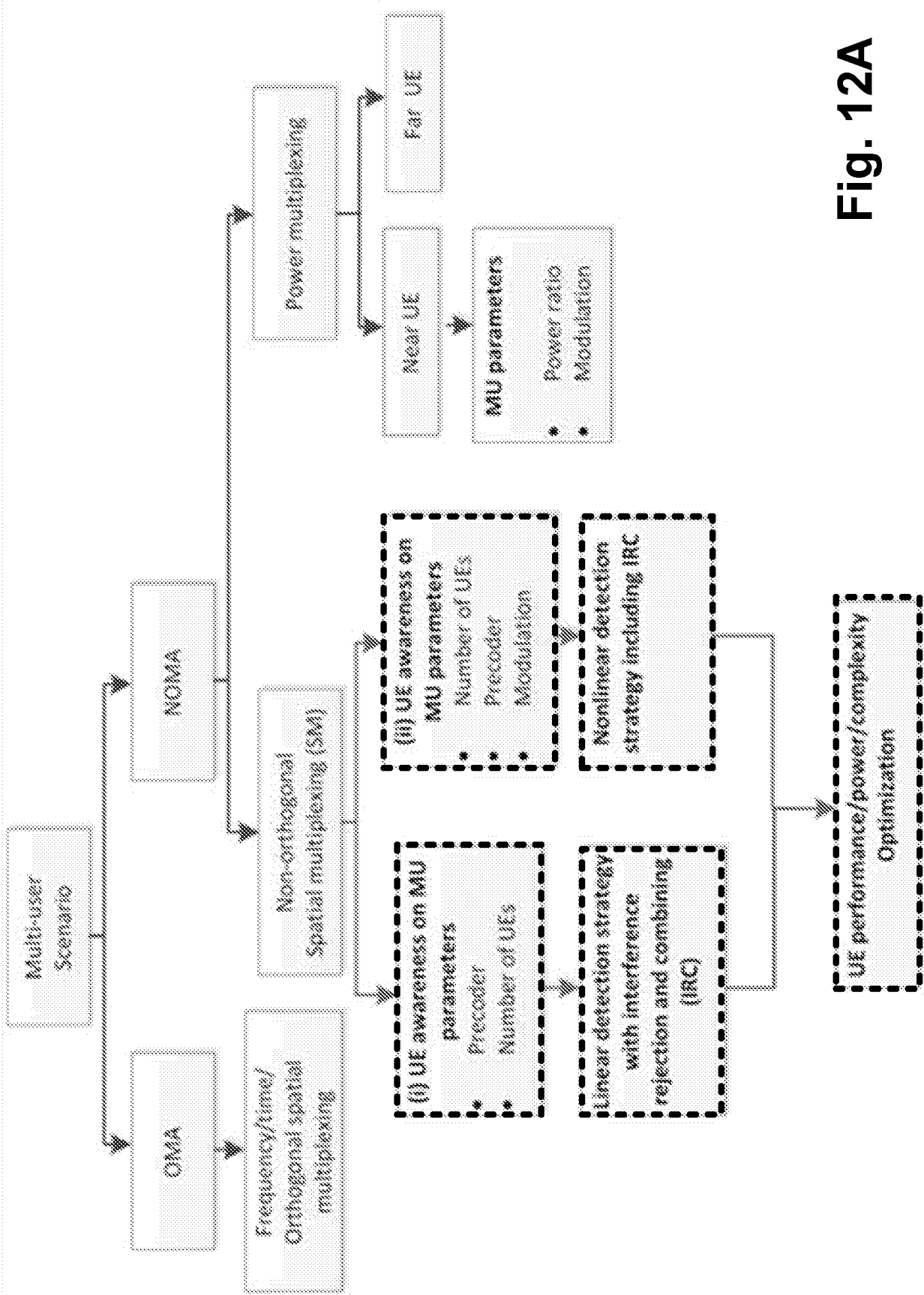
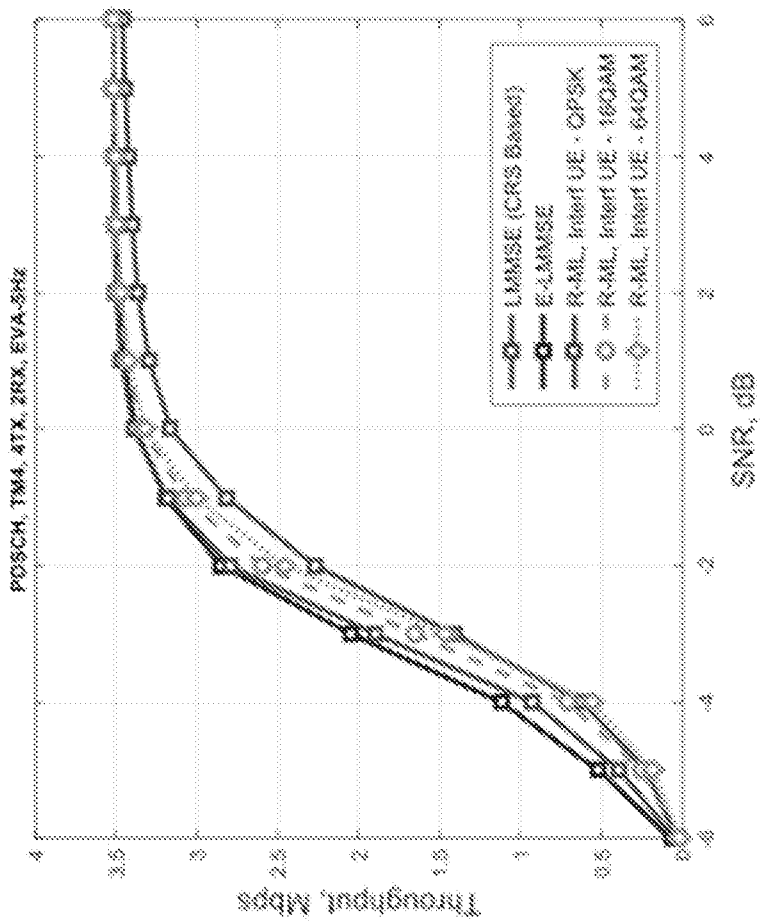


Fig. 12A



Graph for serving UE with MCS 5

Fig. 12B

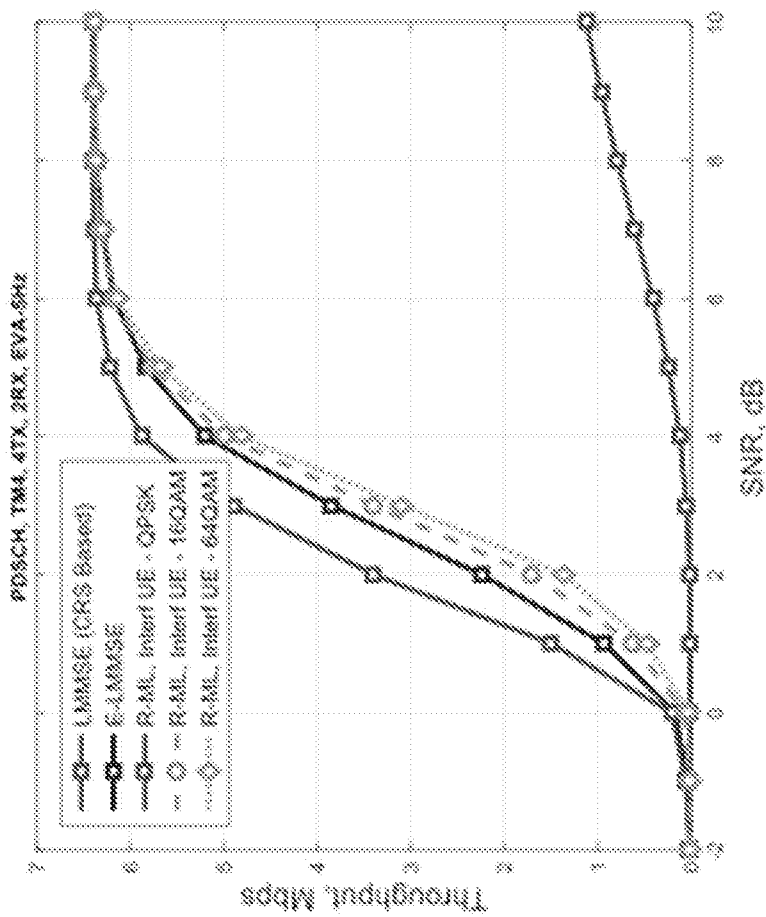
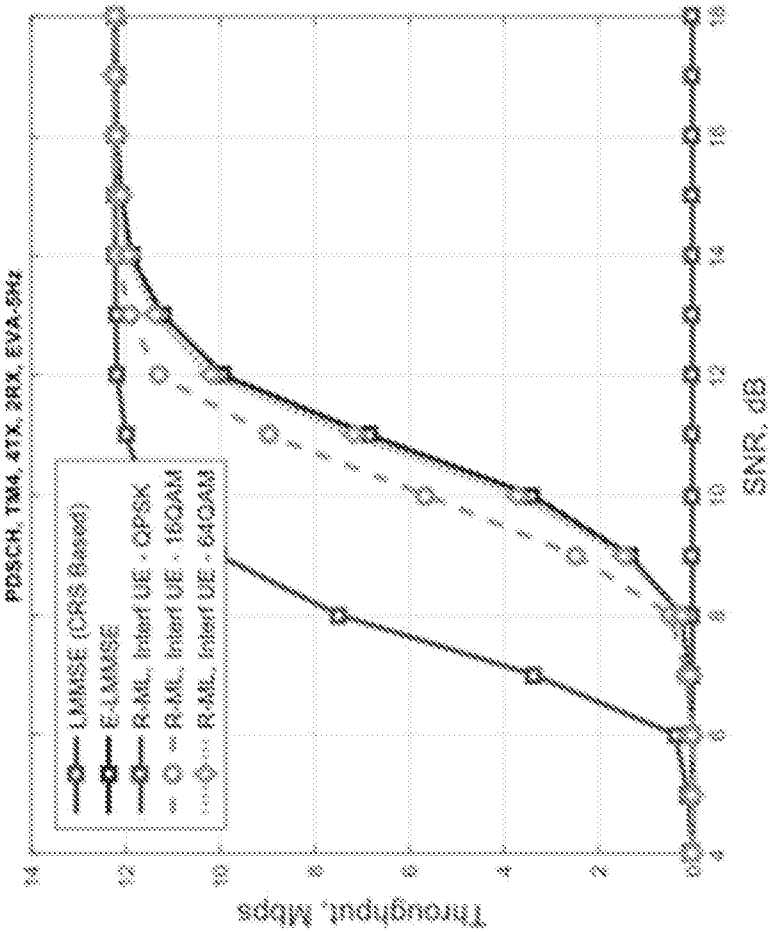


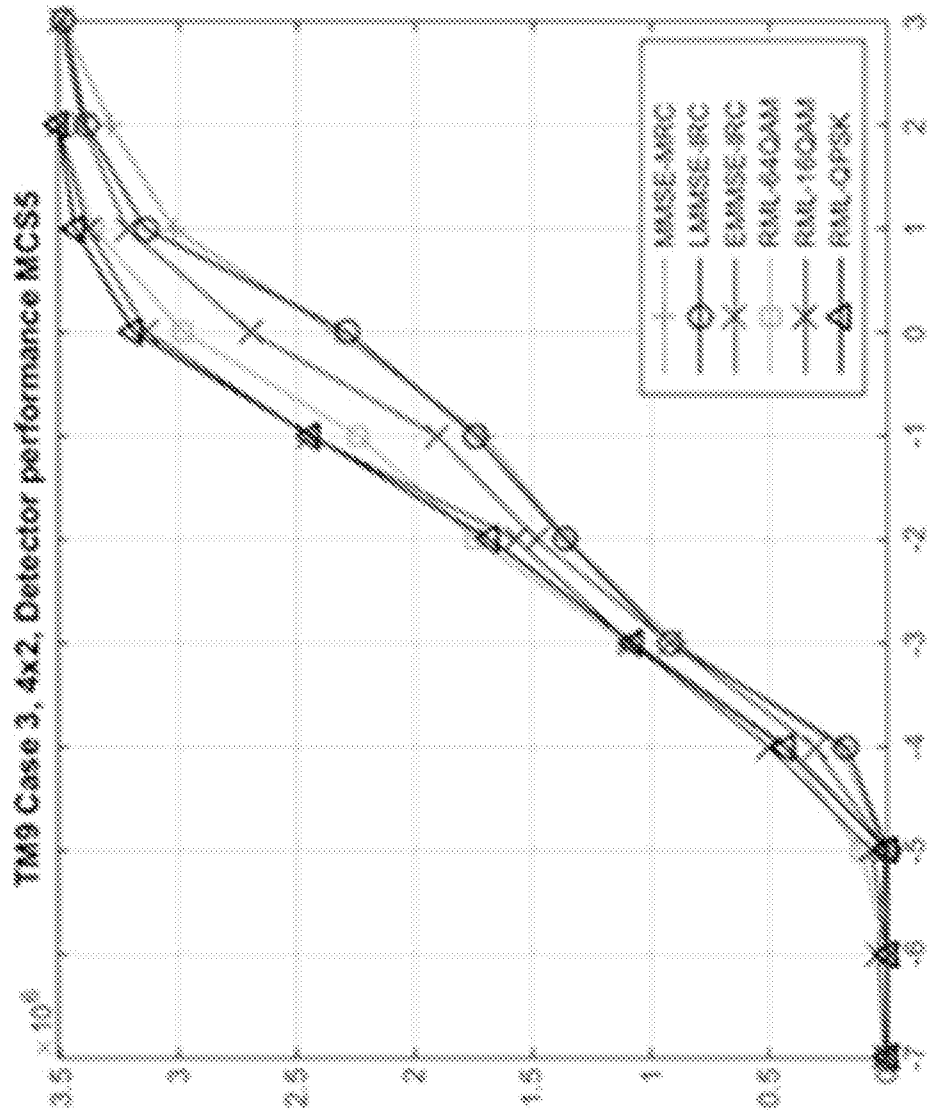
Fig. 12C

Graph for serving UE with MCS 10



Graph for serving UE with MCS 5

Fig. 12D



Graph for serving UE with MCS 5

Fig. 12E

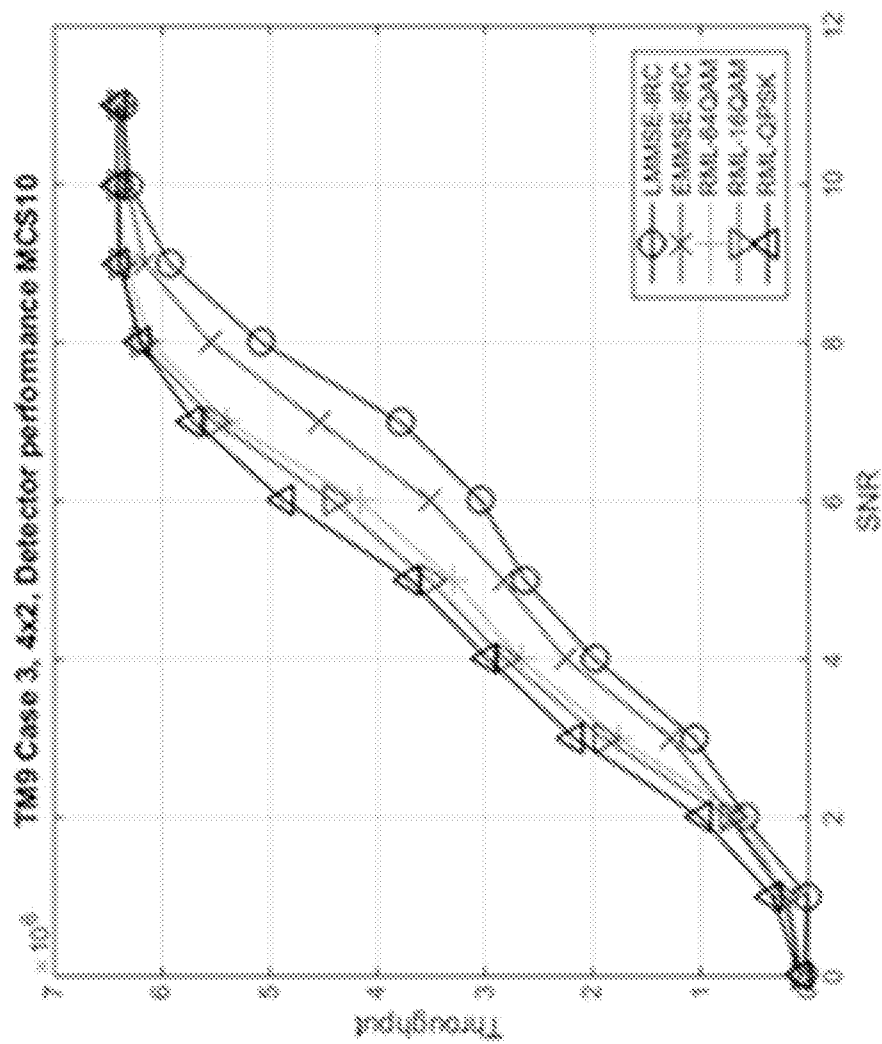
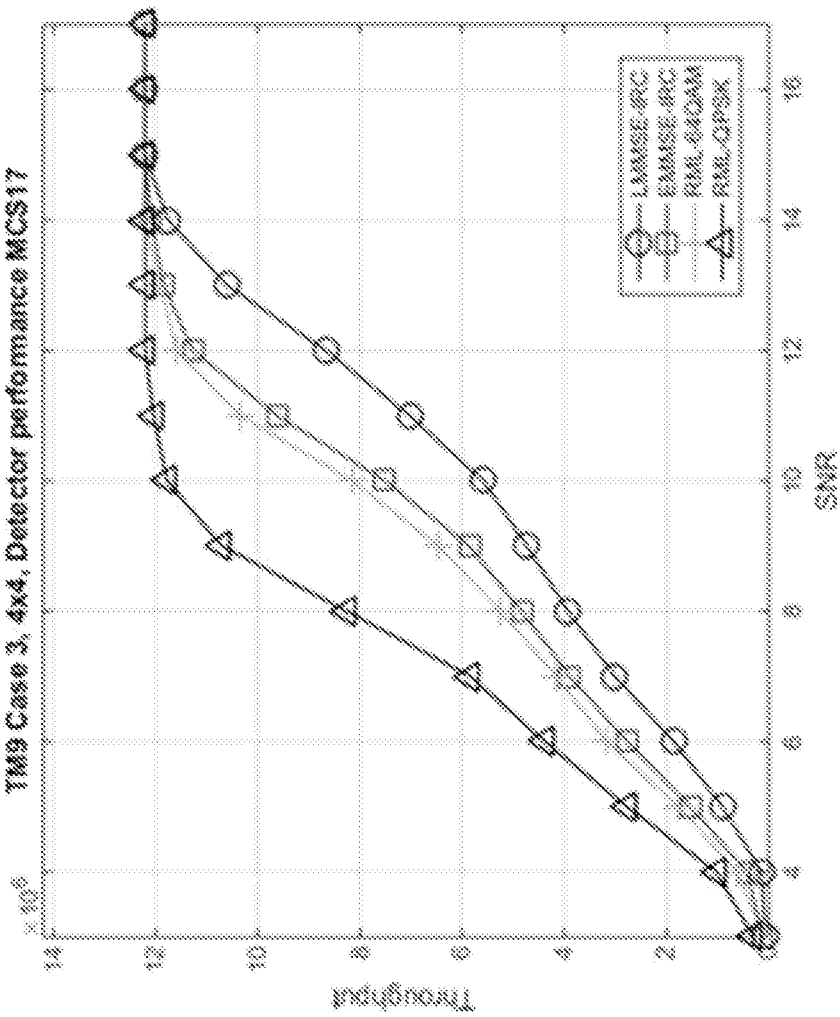


Fig. 12F

Graph for serving UE with MCS 10



Graph for serving UE with MCS 17

Fig. 12G

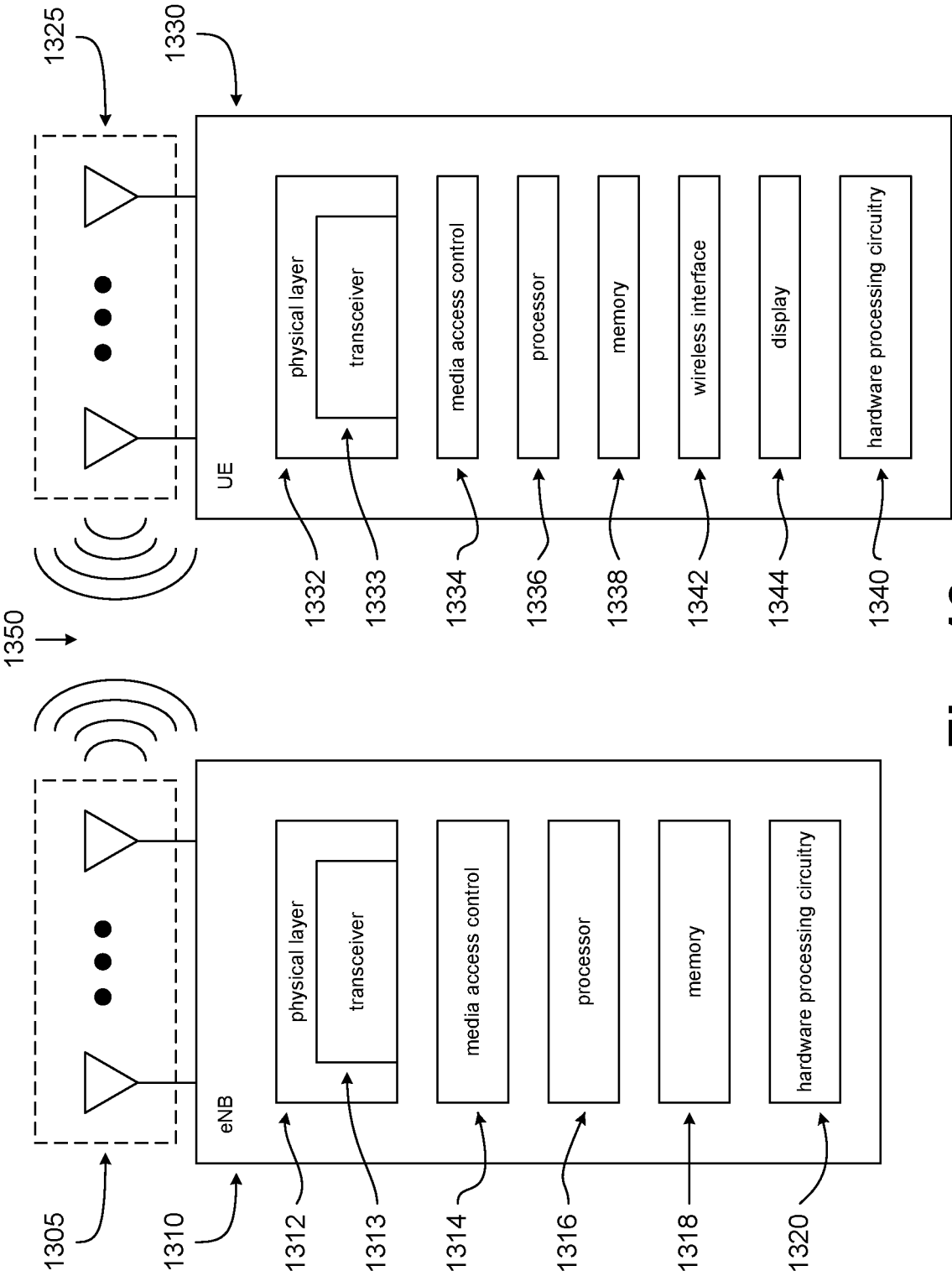


Fig. 13

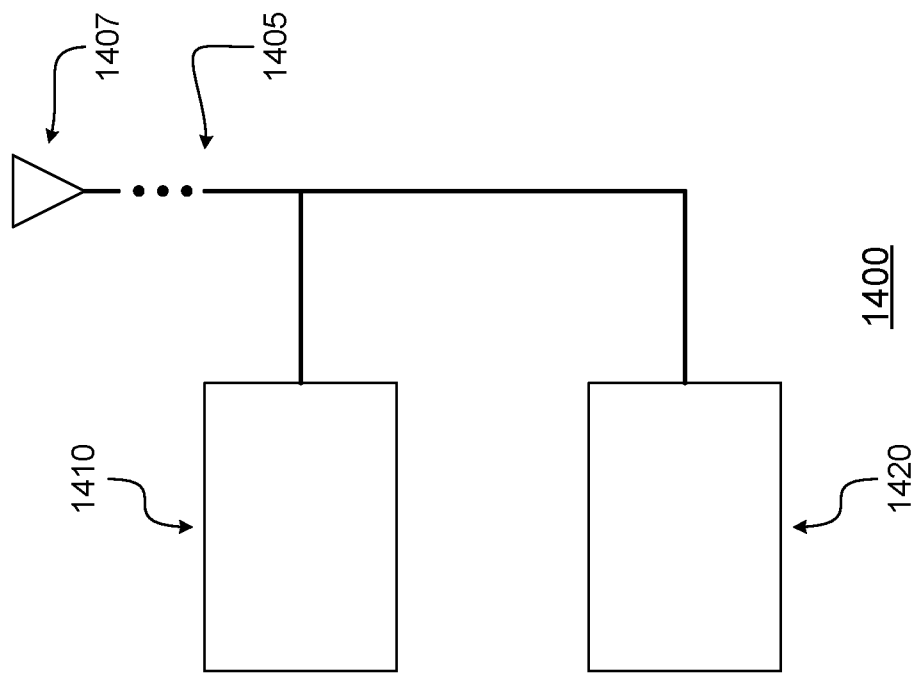


Fig. 14

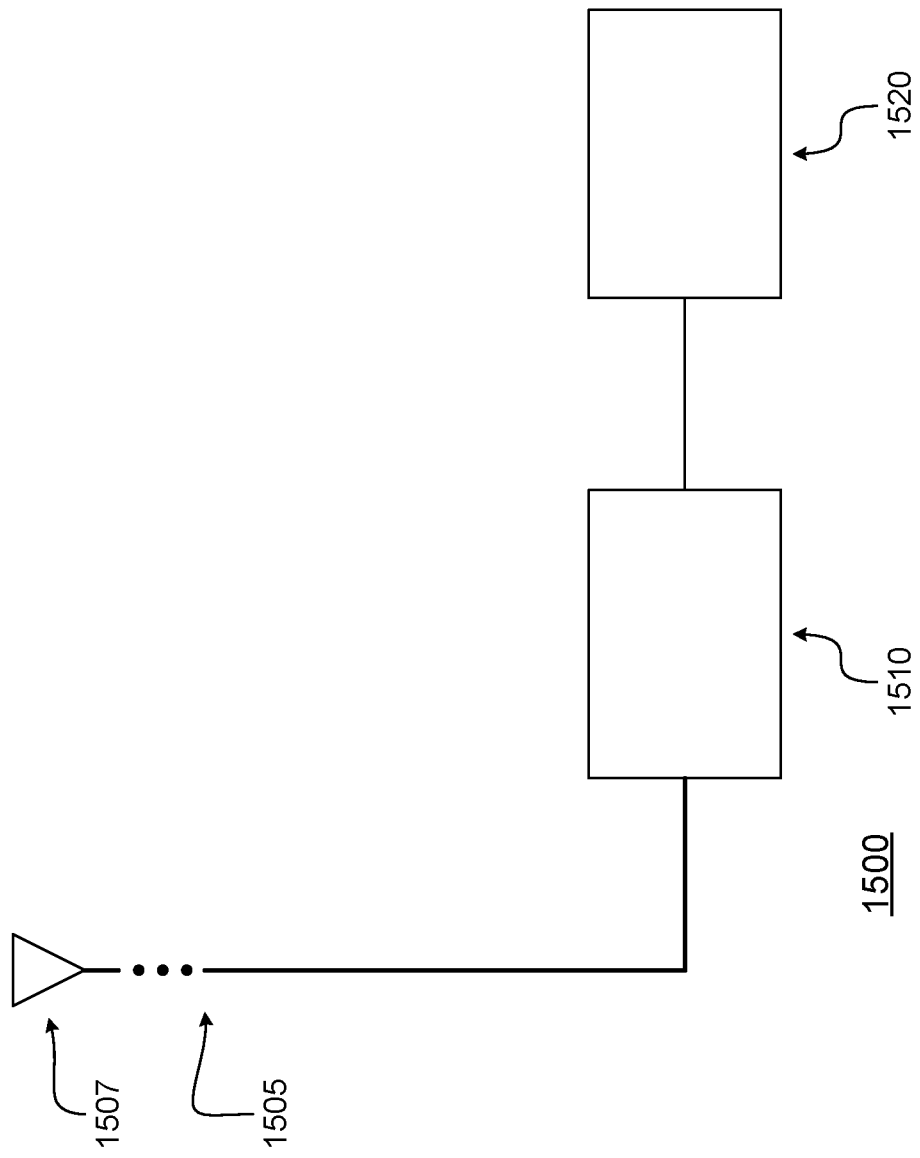


Fig. 15

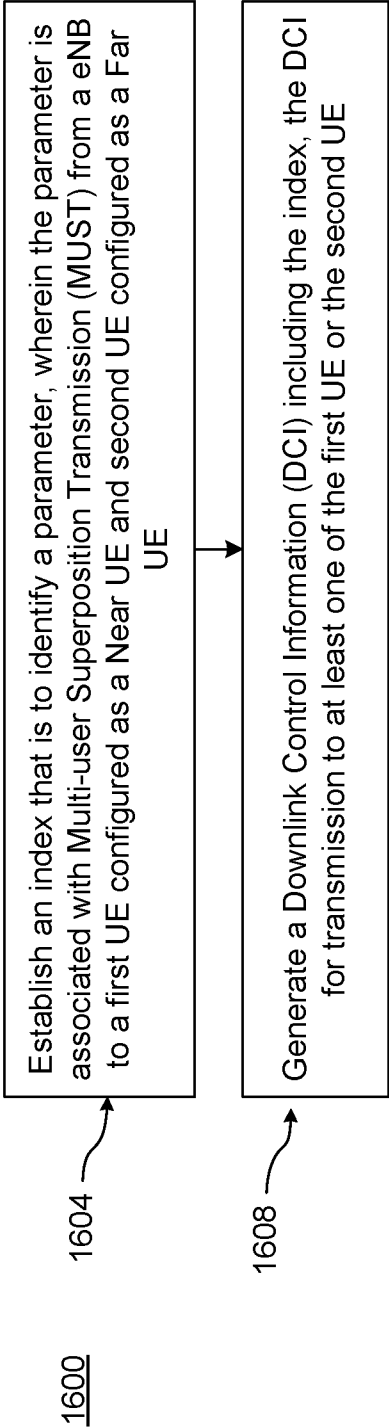


Fig. 16

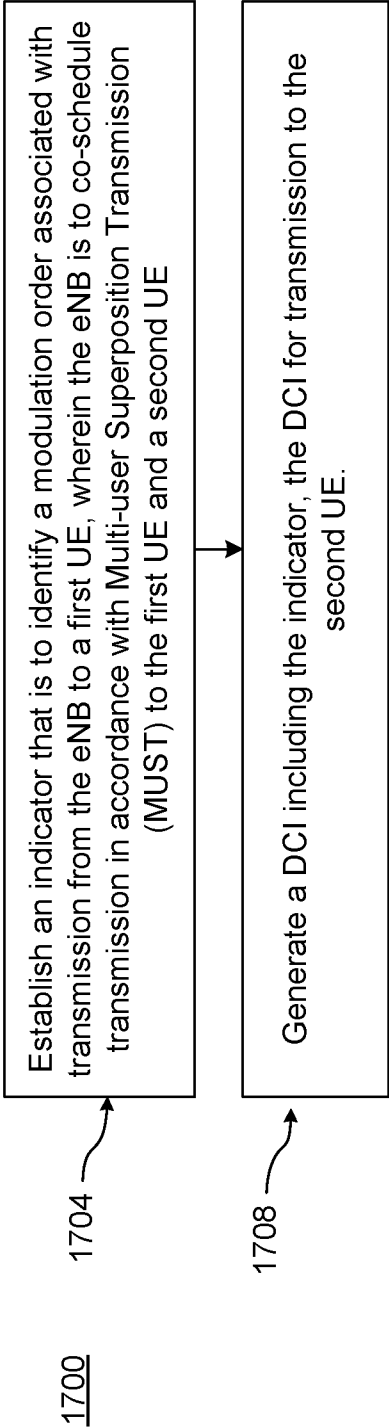


Fig. 17A

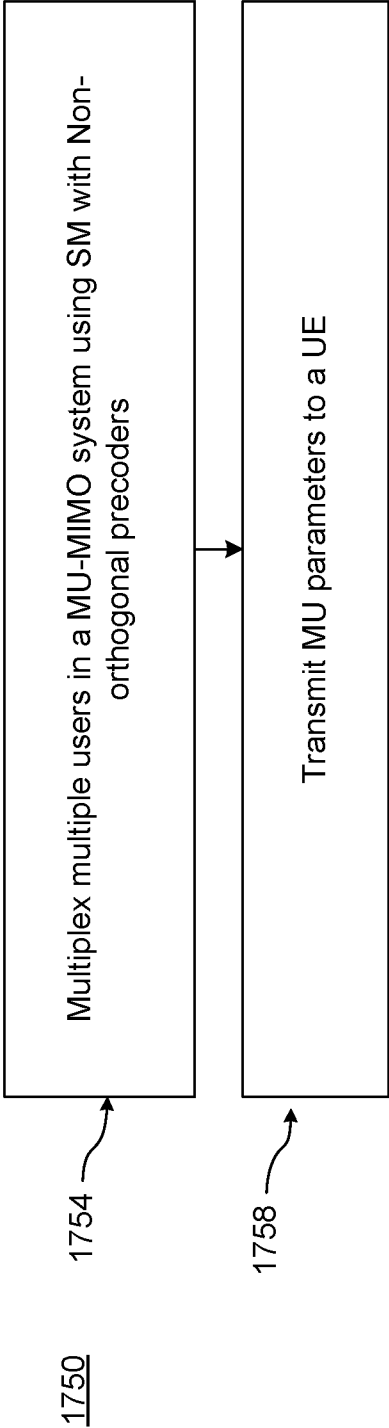


Fig. 17B

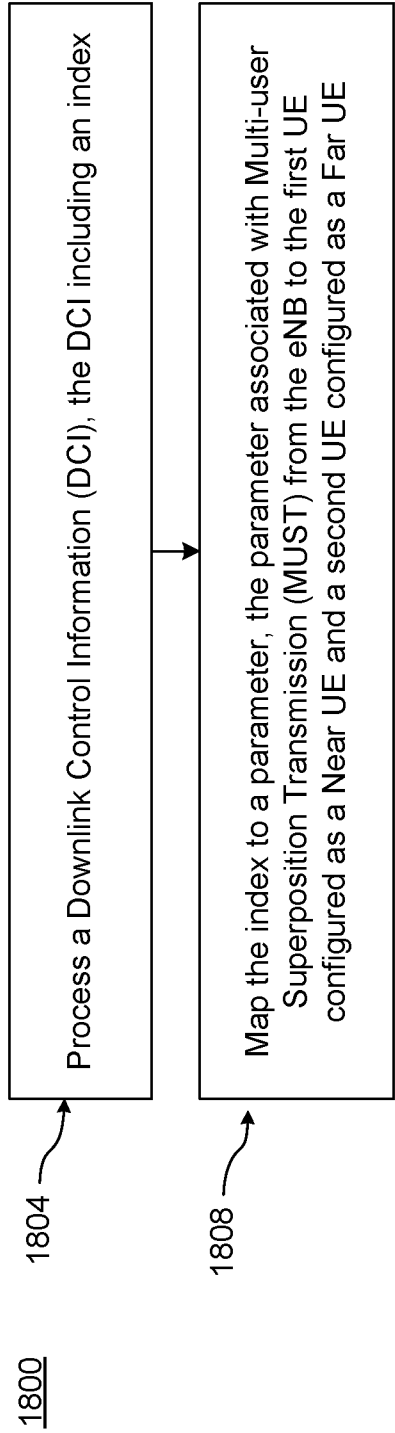


Fig. 18

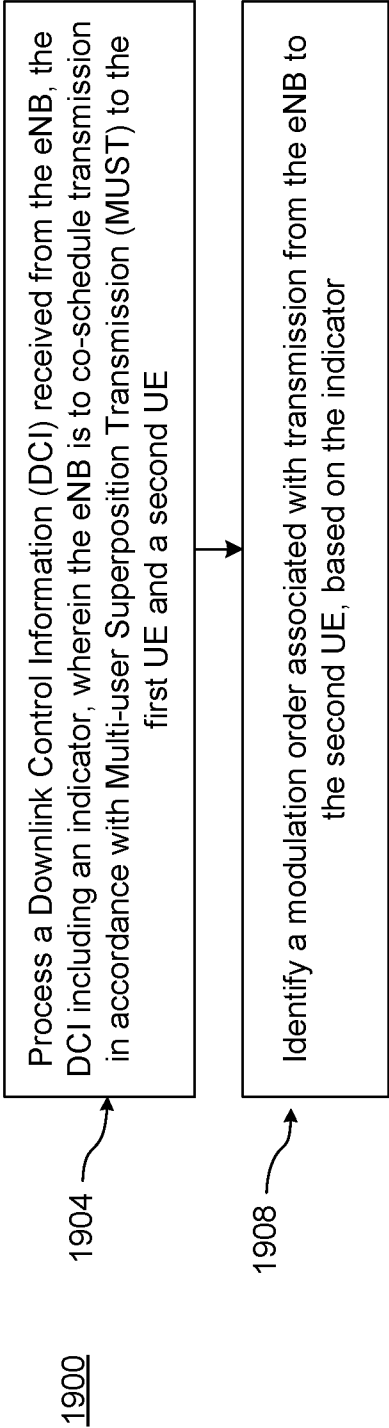


Fig. 19A

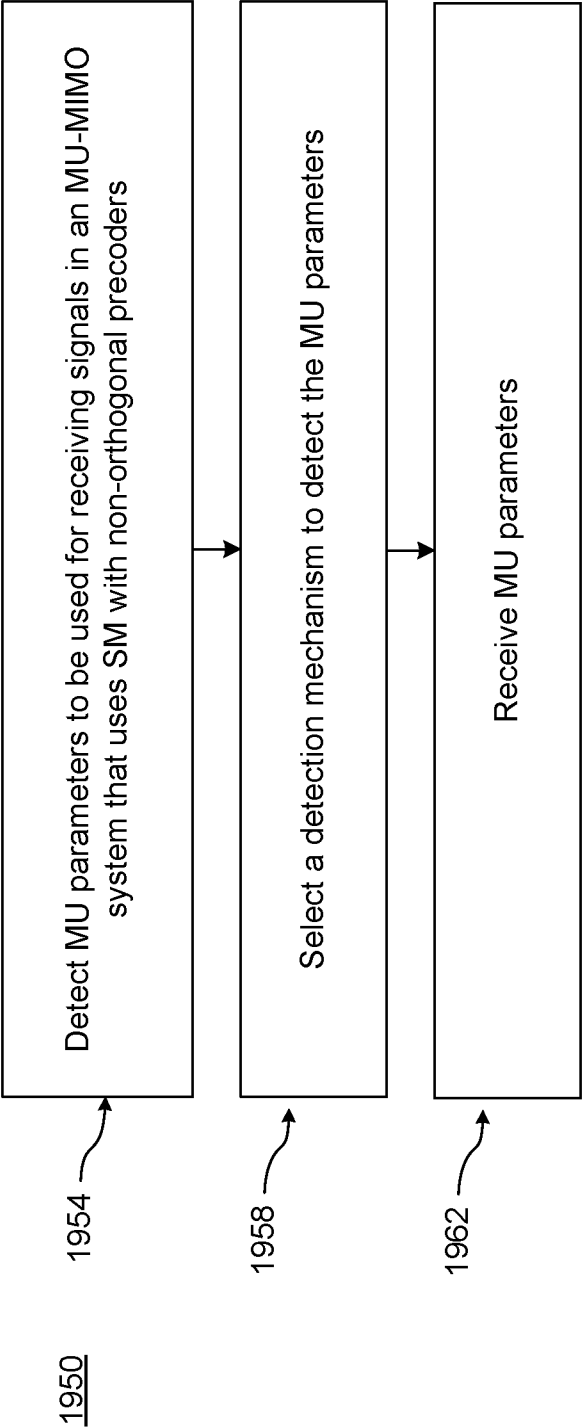


Fig. 19B

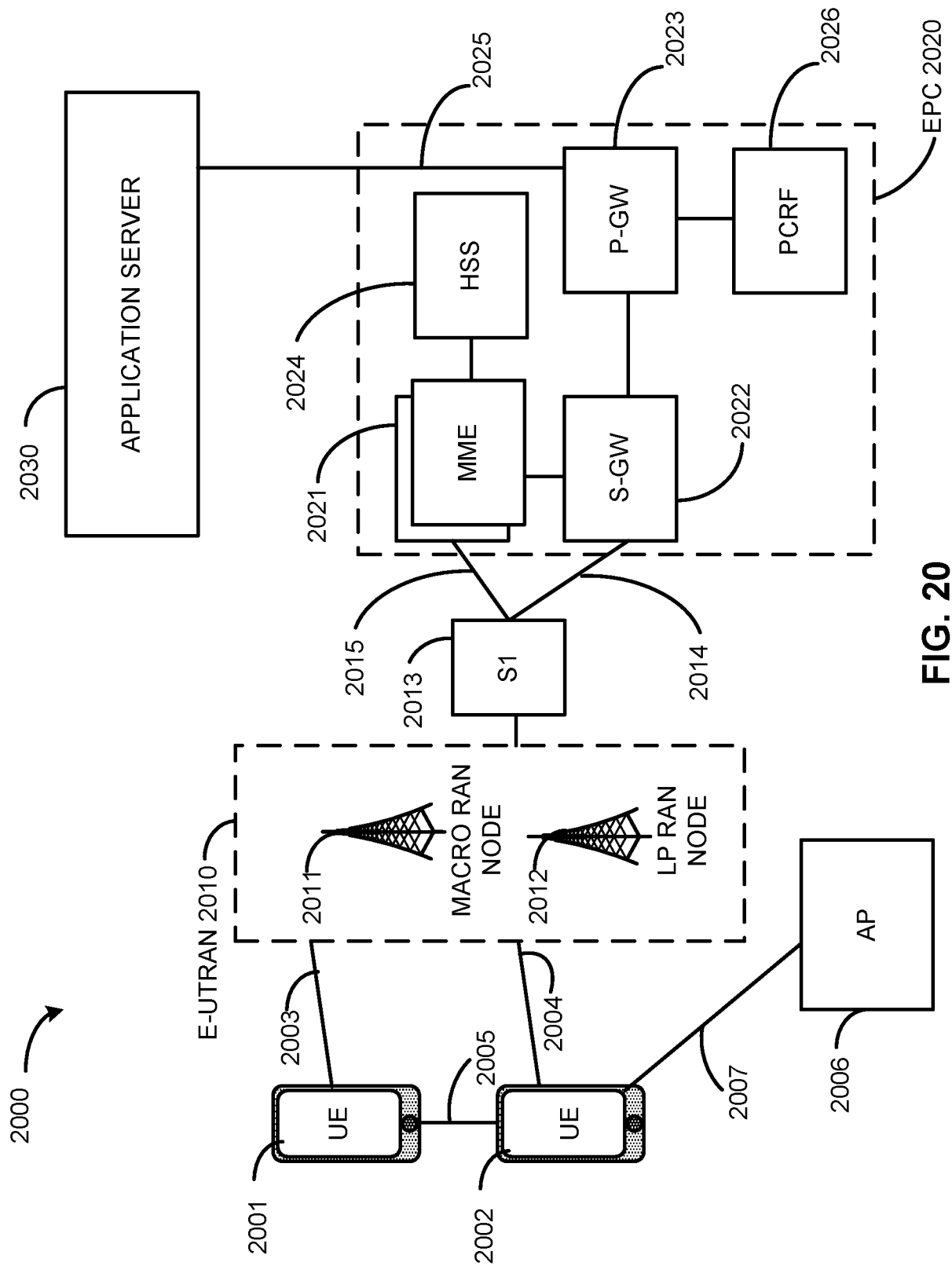


FIG. 20

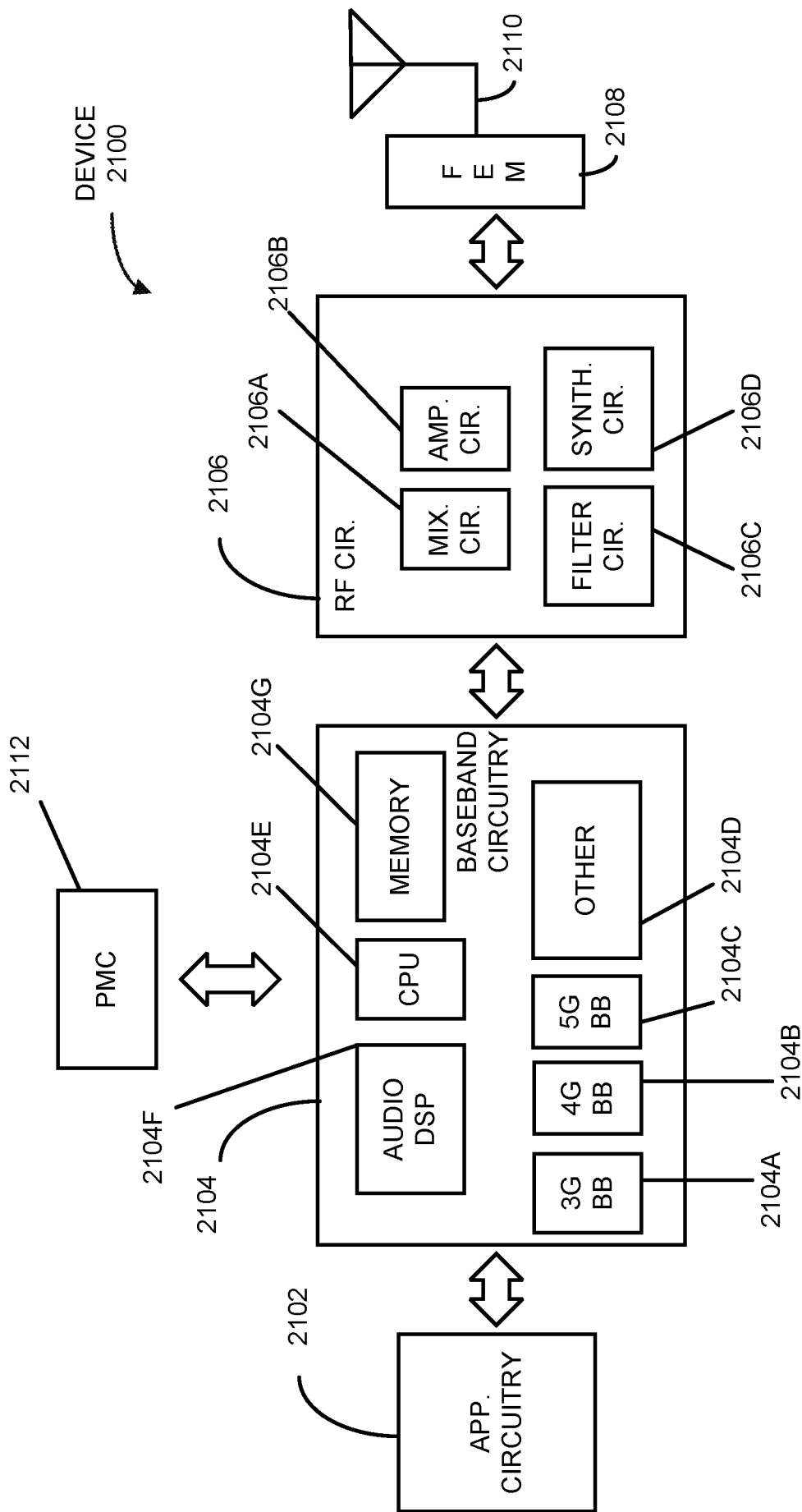


FIG. 21

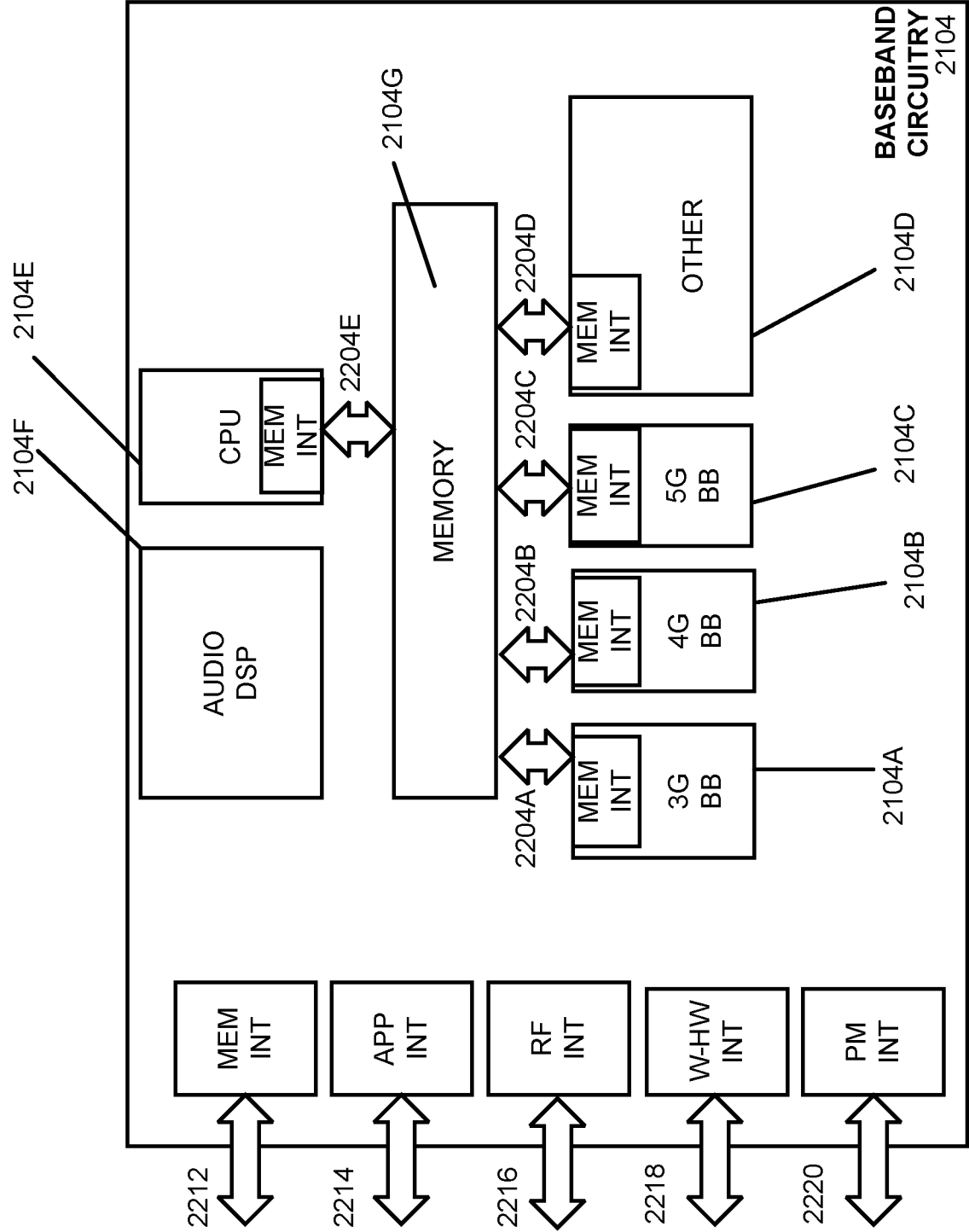


FIG. 22

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/047986

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04L5/00 H04J11/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04L H04J

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)

EP0-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	MEDIATEK INC: "Multiuser Superposition Transmission Scheme for LTE", 3GPP DRAFT; R1-154454 MULTIUSER SUPERPOSITION SCHEME, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Beijing, China; 20150824 - 20150828 23 August 2015 (2015-08-23), XP051001744, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN1/Docs/ [retrieved on 2015-08-23] Sections 2 and 3 ----- -/-	1-25

☒ 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

20 October 2017

Date of mailing of the international search report

30/10/2017

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Anghe1, Paul

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2017/047986

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015/351081 A1 (ZHU YUAN [CN] ET AL) 3 December 2015 (2015-12-03) paragraph [0019] - paragraph [0021] paragraph [0041] - paragraph [0042] figures 2,3	1-25
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