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Hybrid PDSCH for out-of-band earth station interference cancelation

Abstract

Methods and apparatuses in a wireless communication system. A base station (BS) includes a transceiver and a processor. The processor is configured to receive, via the transceiver, a channel state information (CSI) report from at least one user equipment (UE). The processor is also configured to configure CSI-reference signal (RS) resources for the at least one UE. The processor is further configured to, based on the CSI report from the at least one UE, perform one of: set a transmission power to full power for transmission in a physical downlink shared channel (PDSCH); or apply a back-off percentage to the transmission power in the PDSCH.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS AND CLAIM OF PRIORITY (1) The present application claims priority to U.S. Provisional Patent Application No. 63/221,788, filed on Jul. 14, 2021. The content of the above-identified patent document is incorporated herein by reference.

TECHNICAL FIELD
(1) The present disclosure relates generally to a diverse networks and, more specifically, the present disclosure relates to a hybrid physical downlink shared channel for out of band Earth Station interference cancelation.
BACKGROUND
(2) Wireless communication has been one of the most successful innovations in modern history. Recently, the number of subscribers to wireless communication services exceeded five billion and continues to grow quickly. The demand of wireless data traffic is rapidly increasing due to the growing popularity among consumers and businesses of smart phones and other mobile data devices, such as tablets, "note pad" computers, net books, eBook readers, and machine type of devices. In order to meet the high growth in mobile data traffic and support new applications and deployments, improvements in radio interface efficiency, coverage, and quality of service are of paramount importance.
SUMMARY
(3) The present disclosure generally relates to diverse networks and, more specifically, the present disclosure relates to a hybrid physical downlink shared channel for out of band Earth Station

interference cancelation.

(4) In another embodiment, a base station (BS) in a wireless communication system is provided. The BS includes a transceiver and a processor. The processor is configured to receive, via the transceiver, a channel state information (CSI) report from at least one user equipment (UE). The processor is also configured to configure CSI-reference signal (RS) resources for the at least one UE. The processor is further configured to, based on the CSI report from the at least one UE, perform one of: set a transmission power to full power for transmission in a physical downlink shared channel (PDSCH); or apply a back-off percentage to the transmission power in the PDSCH.

(5) In one embodiment, a method of a base station (BS) a wireless communication system is provided. The method includes receiving, via a transceiver, a channel state information (CSI) report from at least one user equipment (UE). The method also includes configuring CSI-reference signal (RS) resources for the at least one UE. The method further includes, based on the CSI report from the at least one UE, performing one of: setting a transmission power to full power for transmission in a physical downlink shared channel (PDSCH); or applying a back-off percentage to the transmission power in the PDSCH.

(6) In yet another embodiment, a non-transitory computer readable medium is provided. The non-transitory computer readable medium includes instructions that, when executed by at least one processor, are configured to cause the at least one processor to: receive a channel state information (CSI) report from at least one user equipment (UE); configure CSI-reference signal (RS) resources for the at least one UE; and, based on the CSI report from the at least one UE, perform one of: set a transmission power to full power for transmission in a physical downlink shared channel (PDSCH); or apply a back-off percentage to the transmission power in the PDSCH.

(7) Other technical features may be readily apparent to one skilled in the art from the following figures, descriptions, and claims.

(8) Before undertaking the DETAILED DESCRIPTION below, it may be advantageous to set forth definitions of certain words and phrases used throughout this patent document. The term "couple" and its derivatives refer to any direct or indirect communication between two or more elements, whether or not those elements are in physical contact with one another. The terms "transmit," "receive," and "communicate," as well as derivatives thereof, encompass both direct and indirect communication. The terms "include" and "comprise," as well as derivatives thereof, mean inclusion without limitation. The term "or" is inclusive, meaning and/or. The phrase "associated with," as well as derivatives thereof, means to include, be included within, interconnect with, contain, be contained within, connect to or with, couple to or with, be communicable with, cooperate with, interleave, juxtapose, be proximate to, be bound to or with, have, have a property of, have a relationship to or with, or the like. The term "controller" means any device, system, or part thereof that controls at least one operation. Such a controller may be implemented in hardware or a combination of hardware and software and/or firmware. The functionality associated with any particular controller may be centralized or distributed, whether locally or remotely. The phrase "at least one of," when used with a list of items, means that different combinations of one or more of the listed items may be used, and only one item in the list may be needed. For example, "at least one of: A, B, and C" includes any of the following combinations: A, B, C, A and B, A and C, B and C, and A and B and C.

(9) Moreover, various functions described below can be implemented or supported by one or more computer programs, each of which is formed from computer readable program code and embodied in a computer readable medium. The terms "application" and "program" refer to one or more computer programs, software components, sets of instructions, procedures, functions, objects, classes, instances, related data, or a portion thereof adapted for implementation in a suitable computer readable program code. The phrase "computer readable program code" includes any type of computer code, including source code, object code, and executable code. The phrase "computer readable medium" includes any type of medium capable of being accessed by a computer, such as

read only memory (ROM), random access memory (RAM), a hard disk drive, a compact disc (CD), a digital video disc (DVD), or any other type of memory. A "non-transitory" computer readable medium excludes wired, wireless, optical, or other communication links that transport transitory electrical or other signals. A non-transitory computer readable medium includes media where data can be permanently stored and media where data can be stored and later overwritten, such as a rewritable optical disc or an erasable memory device.

(10) Definitions for other certain words and phrases are provided throughout this patent document. Those of ordinary skill in the art should understand that in many if not most instances, such definitions apply to prior as well as future uses of such defined words and phrases.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) For a more complete understanding of the present disclosure and its advantages, a reference is now made to the following description taken in conjunction with the accompanying drawings, in which like reference numerals represent like parts:

(2) FIG. **1** illustrates an example wireless network according to embodiments of the present disclosure;

(3) FIG. **2** illustrates an example gNB according to embodiments of the present disclosure;

(4) FIG. **3** illustrates an example UE according to embodiments of the present disclosure;

(5) FIGS. **4**A and **4**B illustrate example wireless transmit and receive paths according to this disclosure;

(6) FIG. **5** illustrates an example antenna according to embodiments of the present disclosure;

(7) FIG. **6** illustrates an example wireless communications network having terrestrial and non-terrestrial stations according to embodiments of the present disclosure;

(8) FIG. **7** illustrates an example 5G massive multiple input multiple output beams according to embodiments of the present disclosure;

(9) FIGS. **8-13** illustrate examples of a hybrid physical downlink shared channel according to embodiments of the present disclosure; and

(10) FIG. **14** illustrates a hybrid physical downlink shared channel process according to embodiments of the present disclosure.

DETAILED DESCRIPTION

(11) FIGS. **1** through **14**, discussed below, and the various embodiments used to describe the principles of the present disclosure in this patent document are by way of illustration only and should not be construed in any way to limit the scope of the disclosure. Those skilled in the art will understand that the principles of the present disclosure may be implemented in any suitably arranged system or device.

(12) To meet the demand for wireless data traffic having increased since deployment of 4G communication systems and to enable various vertical applications, efforts have been made to develop and deploy an improved 5G/NR or pre-5G/NR communication system. Therefore, the 5G/NR or pre-5G/NR communication system is also called a "beyond 4G network" or a "post LTE system." The 5G/NR communication system is considered to be implemented in higher frequency (mmWave) bands, e.g., 28 GHz or 60 GHz bands, so as to accomplish higher data rates or in lower frequency bands, such as 6 GHz, to enable robust coverage and mobility support. Aspects of the present disclosure may also be applied to deployment of 5G communication system, 6G or even later release which may use terahertz (THz) bands. To decrease propagation loss of the radio waves and increase the transmission distance, the beamforming, massive multiple-input multiple-output (MIMO), full dimensional MIMO (FD-MIMO), array antenna, an analog beam forming, large scale antenna techniques are discussed in 5G/NR communication systems.

(13) In addition, in 5G/NR communication systems, development for system network improvement is under way based on advanced small cells, cloud radio access networks (RANs), ultra-dense networks, device-to-device (D2D) communication, wireless backhaul, moving network, cooperative communication, coordinated multi-points (CoMP), reception-end interference cancelation and the like.

(14) The discussion of 5G systems and frequency bands associated therewith is for reference as certain embodiments of the present disclosure may be implemented in 5G systems. However, the present disclosure is not limited to 5G systems or the frequency bands associated therewith, and embodiments of the present disclosure may be utilized in connection with any frequency band. For example, aspects of the present disclosure may also be applied to deployment of 5G communication systems, 6G or even later releases which may use terahertz (THz) bands.

(15) In many cases, cellular networks are deployment in locations where satellite earth-stations (ES) exist. Cellular operation bands can be adjacent to ES operation band. There are harsh constraints on the amount of interference that ES can tolerate in their band of operation. Even though cellular networks are operating in a different adjacent band, out of band (OOB) emission still affects ES. Hence, transmission back-off is required to avoid OOB interference.

(16) Transmission power back-off deteriorate the throughput performance and reduces network coverage significantly, especially, for edge users who usually operate with lower ranks.

(17) Although PMI restriction is a feature that is supported in standards and we can avoid using the PMIs that are transmitting in the direction of the ES, high-rank beam shape is not guaranteed when it is measure OOB. Limiting the power in a certain direction OOB can only be guaranteed for rank-1 users.

(18) Embodiments of the present disclosure provide a hybrid solution for physical downlink shared channel (Hybrid PDSCH). In certain embodiments, a power reduction is applied for higher-rank users and for rank-1 users and a PMI-restriction is applied where the UE is configured to avoid using certain PMI codewords that will cause interference to ES direction. Embodiments of the disclosed Hybrid PDSCH method handles the mixture between these two modes (PMI-restriction for rank-1 users and power reduction for high-rank users) at a 5G node B (gNB) side to enhance throughput and coverage simultaneously.

(19) FIGS. **1-3** below describe various embodiments implemented in wireless communications systems and with the use of orthogonal frequency division multiplexing (OFDM) or orthogonal frequency division multiple access (OFDMA) communication techniques. The descriptions of FIGS. **1-3** are not meant to imply physical or architectural limitations to the manner in which different embodiments may be implemented. Different embodiments of the present disclosure may be implemented in any suitably-arranged communications system.

(20) FIG. **1** illustrates an example wireless network according to embodiments of the present disclosure. The embodiment of the wireless network shown in FIG. **1** is for illustration only. Other embodiments of the wireless network **100** could be used without departing from the scope of this disclosure.

(21) As shown in FIG. **1**, the wireless network includes a gNB **101** (e.g., base station, BS), a gNB **102**, and a gNB **103**. The gNB **101** communicates with the gNB **102** and the gNB **103**. The gNB **101** also communicates with at least one network **130**, such as the Internet, a proprietary Internet Protocol (IP) network, or other data network. In certain embodiments, the gNB **103** is a non-terrestrial BS. For example, gNB **103** can be a satellite positioned in a geosynchronous equatorial orbit (geostationary orbit, GEO) or in a low earth orbit (LEO).

(22) The gNB **102** provides wireless broadband access to the network **130** for a first plurality of UEs within a coverage area **120** of the gNB **102**. The first plurality of UEs includes a UE **111**, which may be located in a small business; a UE **112**, which may be located in an enterprise (E); a UE **113**, which may be located in a WiFi hotspot (HS); a UE **114**, which may be located in a first residence (R); a UE **115**, which may be located in a second residence (R); and a UE **116**, which

may be a mobile device (M), such as a cell phone, a wireless laptop, a wireless PDA, or the like. The gNB **103** provides wireless broadband access to the network **130** for a second plurality of UEs within a coverage area **125** of the gNB **103**. The coverage area **125** provided by gNB **103** can be part of a non-terrestrial network (NTN). The second plurality of UEs includes the UE **115** and the UE **116**. In some embodiments, one or more of the gNBs **101**-**103** may communicate with each other and with the UEs **111**-**116** using 5G/NR, LTE, LTE-A, WiMAX, WiFi, or other wireless communication techniques.

(23) Depending on the network type, the term "base station" or "BS" can refer to any component (or collection of components) configured to provide wireless access to a network, such as transmit point (TP), transmit-receive point (TRP), an enhanced base station (eNodeB or eNB), a 5G/NR base station (gNB), a macrocell, a femtocell, a WiFi access point (AP), or other wirelessly enabled devices. Base stations may provide wireless access in accordance with one or more wireless communication protocols, e.g., 5G/NR 3GPP new radio interface/access (NR), long term evolution (LTE), LTE advanced (LTE-A), high speed packet access (HSPA), Wi-Fi 802.11a/b/g/n/ac, etc. For the sake of convenience, the terms "BS" and "TRP" are used interchangeably in this patent document to refer to network infrastructure components that provide wireless access to remote terminals. Also, depending on the network type, the term "user equipment" or "UE" can refer to any component such as "mobile station," "subscriber station," "remote terminal," "wireless terminal," "receive point," or "user device." For the sake of convenience, the terms "user equipment" and "UE" are used in this patent document to refer to remote wireless equipment that wirelessly accesses a BS, whether the UE is a mobile device (such as a mobile telephone or smartphone) or is normally considered a stationary device (such as a desktop computer or vending machine).

(24) Dotted lines show the approximate extents of the coverage areas **120** and **125**, which are shown as approximately circular for the purposes of illustration and explanation only. It should be clearly understood that the coverage areas associated with gNBs, such as the coverage areas **120** and **125**, may have other shapes, including irregular shapes, depending upon the configuration of the gNBs and variations in the radio environment associated with natural and man-made obstructions.

(25) As described in more detail below, one or more of the UEs **111**-**116** include circuitry, programing, or a combination thereof for flexible quality of service control for diverse networks. In certain embodiments, and one or more of the gNBs **101**-**103** includes circuitry, programing, or a combination thereof for flexible quality of service control for diverse networks.

(26) Although FIG. **1** illustrates one example of a wireless network, various changes may be made to FIG. **1**. For example, the wireless network could include any number of gNBs and any number of UEs in any suitable arrangement. Also, the gNB **101** could communicate directly with any number of UEs and provide those UEs with wireless broadband access to the network **130**. Similarly, each gNB **102**-**103** could communicate directly with the network **130** and provide UEs with direct wireless broadband access to the network **130**. Further, the gNBs **101**, **102**, and/or **103** could provide access to other or additional external networks, such as external telephone networks or other types of data networks.

(27) FIG. **2** illustrates an example gNB **103** according to embodiments of the present disclosure. The embodiment of the gNB **103** illustrated in FIG. **2** is for illustration only, and the gNBs **101** and **102** of FIG. **1** could have the same or similar configuration. However, gNBs come in a wide variety of configurations, and FIG. **2** does not limit the scope of this disclosure to any particular implementation of a gNB.

(28) As shown in FIG. **2**, the gNB **103** includes multiple antennas **205***a*-**205***n*, multiple RF transceivers **210***a*-**210***n*, transmit (TX) processing circuitry **215**, and receive (RX) processing circuitry **220**. The gNB **103** also includes a controller/processor **225**, a memory **230**, and a backhaul or network interface **235**.

(29) The RF transceivers **210a-210n** receive, from the antennas **205a-205n**, incoming RF signals, such as signals transmitted by UEs in the network **100**. The RF transceivers **210a-210n** down-convert the incoming RF signals to generate IF or baseband signals. The IF or baseband signals are sent to the RX processing circuitry **220**, which generates processed baseband signals by filtering, decoding, and/or digitizing the baseband or IF signals. The RX processing circuitry **220** transmits the processed baseband signals to the controller/processor **225** for further processing.

(30) The TX processing circuitry **215** receives analog or digital data (such as voice data, web data, e-mail, or interactive video game data) from the controller/processor **225**. The TX processing circuitry **215** encodes, multiplexes, and/or digitizes the outgoing baseband data to generate processed baseband or IF signals. The RF transceivers **210a-210n** receive the outgoing processed baseband or IF signals from the TX processing circuitry **215** and up-converts the baseband or IF signals to RF signals that are transmitted via the antennas **205a-205n**.

(31) The controller/processor **225** can include one or more processors or other processing devices that control the overall operation of the gNB **103**. For example, the controller/processor **225** could control the reception of forward channel signals and the transmission of reverse channel signals by the RF transceivers **210a-210n**, the RX processing circuitry **220**, and the TX processing circuitry **215** in accordance with well-known principles. The controller/processor **225** could support additional functions as well, such as more advanced wireless communication functions. For instance, the controller/processor **225** could support beam forming or directional routing operations in which outgoing/incoming signals from/to multiple antennas **205a-205n** are weighted differently to effectively steer the outgoing signals in a desired direction. Any of a wide variety of other functions could be supported in the gNB **103** by the controller/processor **225**.

(32) The controller/processor **225** is also capable of executing programs and other processes resident in the memory **230**, such as an OS. The controller/processor **225** can move data into or out of the memory **230** as required by an executing process.

(33) The controller/processor **225** is also coupled to the backhaul or network interface **235**. The backhaul or network interface **235** allows the gNB **103** to communicate with other devices or systems over a backhaul connection or over a network. The interface **235** could support communications over any suitable wireless connection(s). When disposed as part of a terrestrial network, such as gNB **101** and gNB **102**, The interface **235** could support communications over any suitable wired or wireless connection(s). For example, when the gNB **103** is implemented as part of a cellular communication system (such as one supporting 5G/NR, LTE, or LTE-A), the interface **235** could allow the gNB **103** to communicate with other gNBs over a wireless backhaul connection while gNB **101** and gNB **102** can communicate with other gNBs over a wired or wireless backhaul connection. When the one or the gNBs **101-103** is implemented as an access point, the interface **235** could allow the gNB **102** to communicate over a wired or wireless local area network or over a wired or wireless connection to a larger network (such as the Internet). The interface **235** includes any suitable structure supporting communications over a wired or wireless connection, such as an Ethernet or RF transceiver.

(34) The memory **230** is coupled to the controller/processor **225**. Part of the memory **230** could include a RAM, and another part of the memory **230** could include a flash memory or other ROM.

(35) Although FIG. **2** illustrates one example of gNB **103**, various changes may be made to FIG. **2**. For example, the gNB **103**, and respectively gNB **101** and **102** as part of terrestrial networks, could include any number of each component shown in FIG. **2**. As a particular example, an access point could include a number of interfaces **235**, and the controller/processor **225** could support routing functions to route data between different network addresses. As another particular example, while shown as including a single instance of TX processing circuitry **215** and a single instance of RX processing circuitry **220**, the gNB **102** could include multiple instances of each (such as one per RF transceiver). Also, various components in FIG. **2** could be combined, further subdivided, or omitted and additional components could be added according to particular needs.

(36) FIG. **3** illustrates an example UE **116** according to embodiments of the present disclosure. The embodiment of the UE **116** illustrated in FIG. **3** is for illustration only, and the UEs **111**-**115** of FIG. **1** could have the same or similar configuration. However, UEs come in a wide variety of configurations, and FIG. **3** does not limit the scope of this disclosure to any particular implementation of a UE.

(37) As shown in FIG. **3**, the UE **116** includes an antenna **305**, a radio frequency (RF) transceiver **310**, TX processing circuitry **315**, a microphone **320**, and RX processing circuitry **325**. The UE **116** also includes a speaker **330**, a processor **340**, an input/output (I/O) interface (IF) **345**, a touchscreen **350**, a display **355**, and a memory **360**. The memory **360** includes an operating system (OS) **361** and one or more applications **362**.

(38) The RF transceiver **310** receives, from the antenna **305**, an incoming RF signal transmitted by a gNB of the network **100**. The RF transceiver **310** down-converts the incoming RF signal to generate an intermediate frequency (IF) or baseband signal. The IF or baseband signal is sent to the RX processing circuitry **325**, which generates a processed baseband signal by filtering, decoding, and/or digitizing the baseband or IF signal. The RX processing circuitry **325** transmits the processed baseband signal to the speaker **330** (such as for voice data) or to the processor **340** for further processing (such as for web browsing data).

(39) The TX processing circuitry **315** receives analog or digital voice data from the microphone **320** or other outgoing baseband data (such as web data, e-mail, or interactive video game data) from the processor **340**. The TX processing circuitry **315** encodes, multiplexes, and/or digitizes the outgoing baseband data to generate a processed baseband or IF signal. The RF transceiver **310** receives the outgoing processed baseband or IF signal from the TX processing circuitry **315** and up-converts the baseband or IF signal to an RF signal that is transmitted via the antenna **305**.

(40) The processor **340** can include one or more processors or other processing devices and execute the OS **361** stored in the memory **360** in order to control the overall operation of the UE **116**. For example, the processor **340** could control the reception of forward channel signals and the transmission of reverse channel signals by the RF transceiver **310**, the RX processing circuitry **325**, and the TX processing circuitry **315** in accordance with well-known principles. In some embodiments, the processor **340** includes at least one microprocessor or microcontroller.

(41) The processor **340** is also capable of executing other processes and programs resident in the memory **360**, such as processes for beam management. The processor **340** can move data into or out of the memory **360** as required by an executing process. In some embodiments, the processor **340** is configured to execute the applications **362** based on the OS **361** or in response to signals received from gNBs or an operator. The processor **340** is also coupled to the I/O interface **345**, which provides the UE **116** with the ability to connect to other devices, such as laptop computers and handheld computers. The I/O interface **345** is the communication path between these accessories and the processor **340**.

(42) The processor **340** is also coupled to the touchscreen **350** and the display **355**. The operator of the UE **116** can use the touchscreen **350** to enter data into the UE **116**. The display **355** may be a liquid crystal display, light emitting diode display, or other display capable of rendering text and/or at least limited graphics, such as from web sites.

(43) The memory **360** is coupled to the processor **340**. Part of the memory **360** could include a random access memory (RAM), and another part of the memory **360** could include a Flash memory or other read-only memory (ROM).

(44) Although FIG. **3** illustrates one example of UE **116**, various changes may be made to FIG. **3**. For example, various components in FIG. **3** could be combined, further subdivided, or omitted and additional components could be added according to particular needs. As a particular example, the processor **340** could be divided into multiple processors, such as one or more central processing units (CPUs) and one or more graphics processing units (GPUs). Also, while FIG. **3** illustrates the UE **116** configured as a mobile telephone or smartphone, UEs could be configured to operate as

other types of mobile or stationary devices.

(45) A communication system includes a downlink (DL) that refers to transmissions from a base station or one or more transmission points to UEs and an uplink (UL) that refers to transmissions from UEs to a base station or to one or more reception points.

(46) A time unit for DL signaling or for UL signaling on a cell is referred to as a slot and can include one or more symbols. A symbol can also serve as an additional time unit. A frequency (or bandwidth (BW)) unit is referred to as a resource block (RB). One RB includes a number of sub-carriers (SCs). For example, a slot can have duration of 0.5 milliseconds or 1 millisecond, include 14 symbols and an RB can include 12 SCs with inter-SC spacing of 15 KHz or 30 KHz, and so on.

(47) DL signals include data signals conveying information content, control signals conveying DL control information (DCI), and reference signals (RS) that are also known as pilot signals. A gNB transmits data information or DCI through respective physical DL shared channels (PDSCHs) or physical DL control channels (PDCCHs). A PDSCH or a PDCCH can be transmitted over a variable number of slot symbols including one slot symbol. For brevity, a DCI format scheduling a PDSCH reception by a UE is referred to as a DL DCI format and a DCI format scheduling a physical uplink shared channel (PUSCH) transmission from a UE is referred to as an UL DCI format.

(48) A gNB transmits one or more of multiple types of RS including channel state information RS (CSI-RS) and demodulation RS (DMRS). A CSI-RS is primarily intended for UEs to perform measurements and provide channel state information (CSI) to a gNB. For channel measurement, non-zero power CSI-RS (NZP CSI-RS) resources are used. For interference measurement reports (IMRs), CSI interference measurement (CSI-IM) resources associated with a zero power CSI-RS (ZP CSI-RS) configuration are used. A CSI process consists of NZP CSI-RS and CSI-IM resources.

(49) A UE can determine CSI-RS transmission parameters through DL control signaling or higher layer signaling, such as radio resource control (RRC) signaling, from a gNB. Transmission instances of a CSI-RS can be indicated by DL control signaling or be configured by higher layer signaling. A DMRS is transmitted only in the BW of a respective PDCCH or PDSCH and a UE can use the DMRS to demodulate data or control information.

(50) FIG. **4**A and FIG. **4**B illustrate example wireless transmit and receive paths according to this disclosure. In the following description, a transmit path **400** may be described as being implemented in a gNB (such as the gNB **102**), while a receive path **450** may be described as being implemented in a UE (such as a UE **116**). However, it may be understood that the receive path **450** can be implemented in a gNB and that the transmit path **400** can be implemented in a UE. In some embodiments, the receive path **450** is configured to support adapting a channel sensing threshold as described in embodiments of the present disclosure.

(51) The transmit path **400** as illustrated in FIG. **4**A includes a channel coding and modulation block **405**, a serial-to-parallel (S-to-P) block **410**, a size N inverse fast Fourier transform (IFFT) block **415**, a parallel-to-serial (P-to-S) block **420**, an add cyclic prefix block **425**, and an up-converter (UC) **430**. The receive path **450** as illustrated in FIG. **4**B includes a down-converter (DC) **455**, a remove cyclic prefix block **460**, a serial-to-parallel (S-to-P) block **465**, a size N fast Fourier transform (FFT) block **470**, a parallel-to-serial (P-to-S) block **475**, and a channel decoding and demodulation block **485**.

(52) As illustrated in FIG. **4**A, the channel coding and modulation block **405** receives a set of information bits, applies coding (such as a low-density parity check (LDPC) coding), and modulates the input bits (such as with quadrature phase shift keying (QPSK) or quadrature amplitude modulation (QAM)) to generate a sequence of frequency-domain modulation symbols.

(53) The serial-to-parallel block **410** converts (such as de-multiplexes) the serial modulated symbols to parallel data in order to generate N parallel symbol streams, where N is the IFFT/FFT size used in the gNB **102** and the UE **116**. The size N IFFT block **415** performs an IFFT operation on the N parallel symbol streams to generate time-domain output signals. The parallel-to-serial

block **420** converts (such as multiplexes) the parallel time-domain output symbols from the size N IFFT block **415** in order to generate a serial time-domain signal. The add cyclic prefix block **425** inserts a cyclic prefix to the time-domain signal. The up-converter **430** modulates (such as up-converts) the output of the add cyclic prefix block **425** to an RF frequency for transmission via a wireless channel. The signal may also be filtered at baseband before conversion to the RF frequency.

(54) A transmitted RF signal from the gNB **102** arrives at the UE **116** after passing through the wireless channel, and reverse operations to those at the gNB **102** are performed at the UE **116**.

(55) As illustrated in FIG. **4**B, the down-converter **455** down-converts the received signal to a baseband frequency, and the remove cyclic prefix block **460** removes the cyclic prefix to generate a serial time-domain baseband signal. The serial-to-parallel block **465** converts the time-domain baseband signal to parallel time domain signals. The size N FFT block **470** performs an FFT algorithm to generate N parallel frequency-domain signals. The parallel-to-serial block **475** converts the parallel frequency-domain signals to a sequence of modulated data symbols. The channel decoding and demodulation block **485** demodulates and decodes the modulated symbols to recover the original input data stream.

(56) Each of the gNBs **101**-**103** may implement a transmit path **400** as illustrated in FIG. **4**A that is analogous to transmitting in the downlink to UEs **111**-**116** and may implement a receive path **450** as illustrated in FIG. **4**B that is analogous to receiving in the uplink from UEs **111**-**116**. Similarly, each of UEs **111**-**116** may implement the transmit path **400** for transmitting in the uplink to the gNBs **101**-**103** and may implement the receive path **450** for receiving in the downlink from the gNBs **101**-**103**.

(57) Each of the components in FIG. **4**A and FIG. **4**B can be implemented using only hardware or using a combination of hardware and software/firmware. As a particular example, at least some of the components in FIG. **4**A and FIG. **4**B may be implemented in software, while other components may be implemented by configurable hardware or a mixture of software and configurable hardware. For instance, the FFT block **470** and the IFFT block **415** may be implemented as configurable software algorithms, where the value of size N may be modified according to the implementation.

(58) Furthermore, although described as using FFT and IFFT, this is by way of illustration only and may not be construed to limit the scope of this disclosure. Other types of transforms, such as discrete Fourier transform (DFT) and inverse discrete Fourier transform (IDFT) functions, can be used. It may be appreciated that the value of the variable N may be any integer number (such as 1, 2, 3, 4, or the like) for DFT and IDFT functions, while the value of the variable N may be any integer number that is a power of two (such as 1, 2, 4, 8, 16, or the like) for FFT and IFFT functions.

(59) Although FIG. **4**A and FIG. **4**B illustrate examples of wireless transmit and receive paths, various changes may be made to FIG. **4**A and FIG. **4**B. For example, various components in FIG. **4**A and FIG. **4**B can be combined, further subdivided, or omitted and additional components can be added according to particular needs. Also, FIG. **4**A and FIG. **4**B are meant to illustrate examples of the types of transmit and receive paths that can be used in a wireless network. Any other suitable architectures can be used to support wireless communications in a wireless network.

(60) FIG. **5** illustrates an example antenna blocks **500** according to embodiments of the present disclosure. The embodiment of the antenna **500** illustrated in FIG. **5** is for illustration only. FIG. **5** does not limit the scope of this disclosure to any particular implementation of the antenna **500**. In certain embodiments, one or more of gNB **102** or UE **116** include the antenna **500**. For example, one or more of antenna **205** and its associated systems or antenna **305** and its associated systems can be configured the same as antenna **500**.

(61) Rel.14 LTE and Rel.15 NR support up to 32 CSI-RS antenna ports which enable an eNB to be equipped with a large number of antenna elements (such as 64 or 128). In this case, a plurality of

antenna elements is mapped onto one CSI-RS port. For mmWave bands, although the number of antenna elements can be larger for a given form factor, the number of CSI-RS ports—which can correspond to the number of digitally precoded ports—tends to be limited due to hardware constraints (such as the feasibility to install a large number of ADCs/DACs at mmWave frequencies).

(62) In the example shown in FIG. **5**, the antenna **500** includes analog phase shifters **505**, an analog beamformer (BF) **510**, a hybrid BF **515**, a digital BF **520**, and one or more antenna arrays **525**. In this case, one CSI-RS port is mapped onto a large number of antenna elements in antenna arrays **525**, which can be controlled by the bank of analog phase shifters **505**. One CSI-RS port can then correspond to one sub-array which produces a narrow analog beam through analog beamforming by analogy BF **510**. The analog beam can be configured to sweep **530** across a wider range of angles by varying the phase shifter bank **505** across symbols or subframes. The number of sub-arrays (equal to the number of RF chains) is the same as the number of CSI-RS ports N.sub.CSI-PORT. A digital BF **515** performs a linear combination across N.sub.CSI-PORT analog beams to further increase precoding gain. While analog beams are wideband (hence not frequency-selective), digital precoding can be varied across frequency sub-bands or resource blocks.

(63) Since the above system utilizes multiple analog beams for transmission and reception (wherein one or a small number of analog beams are selected out of a large number, for instance, after a training duration—to be performed from time to time), the term "multi-beam operation" is used to refer to the overall system aspect. This includes, for the purpose of illustration, indicating the assigned DL or UL transmit (TX) beam (also termed "beam indication"), measuring at least one reference signal for calculating and performing beam reporting (also termed "beam measurement" and "beam reporting", respectively), and receiving a DL or UL transmission via a selection of a corresponding receive (RX) beam.

(64) Additionally, the antenna **500** system is also applicable to higher frequency bands such as >52.6 GHz (also termed the FR4). In this case, the system can employ only analog beams. Due to the O.sub.2 absorption loss around 60 GHz frequency (˜10 decibels (dB) additional loss @100 m distance), larger number of and sharper analog beams (hence larger number of radiators in the array) will be needed to compensate for the additional path loss.

(65) FIG. **6** illustrates an example wireless communications network having terrestrial and non-terrestrial stations according to embodiments of the present disclosure. The embodiment of the network **600** shown in FIG. **6** is for illustration only. Other embodiments could be used without departing from the scope of the present disclosure.

(66) In many cases, cellular networks are deployed in locations where satellite earth-stations (ES) **605** exist. In the present disclosure, one or multiple approaches described below can be implemented to realize the concept for diverse networks including a non-terrestrial network (NTN) and a high-capacity network. In certain embodiments, for the NTN architecture, gNB **103** comprises a gNB-distributed unit (gNB-DU) disposed on the satellite **610** and a gNB-centralized unit (gNB-CU) disposed on the ES **605**. In such case, the gNB-CU on the ES **605** can control the amount of data being sent to the gNB-DU on the satellite **610** based on gNB-DU memory capabilities. In an implementation-specific manner, the gNB-CU on the ES **605** can take care most of the storage (e.g., at the packet data convergence protocol (PDCP) layer) to alleviate any significant memory requirements on the gNB-DU.

(67) Cellular operation bands, such as via gNB **102**, can be adjacent to ES **605** operation band. For example, 5G emission **615** from gNB **102** can interfere with communications from the on the ES **605**. Additionally, there are harsh constraints on the amount of interference that 605 can tolerate in their band of operation. Even though cellular networks are operating in a different adjacent band, out of band (OOB) emission still affects ES **605**, hence, transmission power back-off may be required in some cases to avoid OOB interference.

(68) In certain scenarios, to mitigate OOB interference, gNB **102** may perform power reduction. In

response, ES **605** continues to measure the interference while gNB **102** continues to reduce the power so that the interference coming from gNB **102** would comply with the regulations.

(69) In certain situations, if gNB **102** only reduces the power, for example, if gNB **102** transmits 40 decibels (dB), the received power is 25 dB. A problem with this power back off is that it deteriorates the through-put or performance. That is, reducing the power to reduce the interference may affect the performance of the system as well.

(70) FIG. **7** illustrates an example 5G massive multiple input multiple output (MIMO) beams according to embodiments of the present disclosure. The embodiment of the 5G massive MIMO unit (MMU) beams **700** shown in FIG. **7** is for illustration only. Other embodiments could be used without departing from the scope of the present disclosure.

(71) In the example shown in FIG. **7**, a precoding matrix indicator (PMI) restriction is illustrated. A 5G MMU, such as gNB **102**, transmits beams to UE **115**. The gNB **102** transmits the beams based on the codebook in gNB **102**. The codebook indicates which beams that gNB **102** will use to communicate with UE **115**. UE **115** transmits a feedback signal to gNB **102** informing gNB **102** the best direction for transmission to UE **115**. In response, gNB **102** will apply some beam forming and direct the power in a direction, such as that a first beam **705** servers UE **115** and a second beam **710** serves UE **116**.

(72) Since gNB **102** knows the direction of the beams **705**, **710** based on its codebook, then gNB **102** can just restrict some of the beams **715** to not be transmitted. That is gNB **102** selects not to transmits beams **715**, which would be the beams **715** that would be in the direction of, or interfering with, ES **605**. As such, gNB **102** restricts any codeword that would make gNB **102** transmit a beam **715** in the direction of ES **605**. Accordingly, gNB **102** instructs UE **115** and UE **116** to report a beam in any direction other than the direction of restricted beams **715**. So if there is a user here. UE **115** and UE **116** cannot choose the direction of restricted beams **715** because gNB **102** has informed UE **115** and UE **116** that this direction is restricted. In response, UE **115** and UE **116** will choose a second best if the best beam matches the restricted beams **715**.

(73) The PMI restriction does not address a scenario in which UE **115** receives more that a single beam **705**. That is, in certain scenarios, UE **115** receives multiple streams from gNB **102**. The use of multiple beams by gNB **102** for a single UE **115** is referred to as rank. For example, gNB **102** can transmit a Rank-1 beam, Rank-2 beam, or both Rank-1 and Rank-2 beams. Rank-1 means that gNB **102** transmits the first layer to UE **115** and Rank-2 is the second layer to UE **115**. As such, gNB **102** may not just send one stream of information UE **115**; instead, gNB **102** can send two or three or four streams of information to UE **115**.

(74) In certain examples, UE **115** may include eight receive antennas. As such, gNB **102** can send up to eight streams to UE **115**, and those eight streams may use different beams. With PMI restriction, for Rank-1 UEs, or if you transmit a single direction, then gNB **102** knows where the beam is going to point. If gNB **102** transmits in two directions; then those two directions are sent simultaneously. For example, if gNB **102** is sending in a direction of the first beam **705** and a third beam **720**, the first beam **705** and third beam **720** may combine and produce a beam in the direction of the restricted beam **715**.

(75) Therefore, an issue with power reduction is that it deteriorates the overall network performance. Additionally, an issue with PMI restriction is that it is useful for Rank-1 users; but PMI restriction cannot be applied to any users that have more than Rank-1.

(76) Embodiments of the present disclosure combine both power reduction and PMI restriction. Certain embodiments provide for a hybrid physical downlink shared channel (PDSCH). Hybrid refers to combining two technologies or combining power reduction and PMI restriction together depending upon the situation.

(77) FIG. **8** illustrates an example hybrid physical downlink shared channel (PDSCH) according to embodiments of the present disclosure. While the flow chart depicts a series of sequential steps, unless explicitly stated, no inference should be drawn from that sequence regarding specific order

of performance, performance of steps or portions thereof serially rather than concurrently or in an overlapping manner, or performance of the steps depicted exclusively without the occurrence of intervening or intermediate steps. The process **800** depicted in the example depicted is implemented by a processor and transmitter chain in, for example, a base station.

(78) In certain embodiments, gNB **102** receives channel state information (CSI) report from UE **115** including precoding matrix indicator (PMI), rank indicator (RI) and channel quality indicator (CQI). Based on each UE's report, gNB **102** decides whether to use full-power transmission in PDSCH or apply some back-off percentage to transmission power. The goal is to guarantee the required interference level from OOB emission for ES **605** operating in neighboring band. This mixture operation is referred to as Hybrid PDSCH scheme. This is an alternative to applying the same power back-off for all UEs.

(79) In certain embodiments, a Hybrid PDSCH is applied. In operation **805**, a single CSI-RS resource is configured to all UEs in the network. When transmitting the CSI-RS signal, a predefined X-dB power back off is applied to CSI-RS transmission to avoid the OOB interference. In certain embodiments, one single CSI-RS measurement report is configured for UEs. In this measurement report, a restricted PMI bitmap based on offline calculations and restricted rank of 1 is configured. In certain embodiments, dual CSI-RS measurement reports are configured, among which one report is configured with restricted PMI bitmap while the other measurement report is configured with no restriction on PMI bitmap.

(80) In a next stage of operation, a gNB receives CSI-RS report from each user. Due to the fact that rank-1 beams are guaranteed to be nulled efficiently of OOB interference based on PMI-restriction, then power back-off is not required for those users; therefore, this information of UE rank is used in UE classification phase. In the UE classification phase, gNB **102** determines whether UE **115** is performing better with rank-1 and full power in operation **810**; or if UE **115** is performing better with higher ranks and X-db less power in operation **815**.

(81) In operation **810** for users performing better with rank-1 transmission, a full-power transmission of PDSCH is applied in operation **820**, and the CQI in measurement report will be boosted in operation **825** with the same amount of back-off applied to CSI-RS resource set, as in the first step, XdB. This will cause modulation coding scheme (MCS) selection matching the full-power transmission instead of being conservative following CSI-RS power back-off.

(82) In response to operation **815** for higher rank users, in operation **830**, a same X-dB power back-off for PDSCH transmission is applied and the CQI reporting from CSI-RS report with unrestricted PMI bitmap will be used (either from the single report or in the case of dual report, then we use the information from the second report as it contains unrestricted PMIs). This way even though the higher-rank beam nulling is not performed in the direction of ES, the power back-off will guarantee the limitation of the interference level.

(83) FIG. **9** illustrates another example hybrid physical downlink shared channel (PDSCH) according to embodiments of the present disclosure. While the flow chart depicts a series of sequential steps, unless explicitly stated, no inference should be drawn from that sequence regarding specific order of performance, performance of steps or portions thereof serially rather than concurrently or in an overlapping manner, or performance of the steps depicted exclusively without the occurrence of intervening or intermediate steps. The process **900** depicted in the example depicted is implemented by a processor and transmitter chain in, for example, a base station.

(84) In certain embodiments, in operation **905** all UEs are configured with a single CSI-RS report with PMI-restriction based on offline table configured. The RI feedback is utilized for users' classification. In the UE classification phase, gNB **102** determines whether UE **115** is performing better with rank-1 and full power in operation **910**; or if UE **115** is performing better with higher ranks and X-db less power in operation **915**. In response to operation **915** for users whose RI=1, in operation **920** gNB **102** applies PMI-restriction with full-power and CQI boosting in operation **925**.

In response to operation **915** for users whose RI>1, in operation **930** a CQI report with PDSCH power back-off with the same amount of CSI-RS power back-off (X-dB) is followed.

(85) FIG. **10** illustrates another example hybrid physical downlink shared channel (PDSCH) according to embodiments of the present disclosure. While the flow chart depicts a series of sequential steps, unless explicitly stated, no inference should be drawn from that sequence regarding specific order of performance, performance of steps or portions thereof serially rather than concurrently or in an overlapping manner, or performance of the steps depicted exclusively without the occurrence of intervening or intermediate steps. The process **1000** depicted in the example depicted is implemented by a processor and transmitter chain in, for example, a base station.

(86) In certain embodiments, all UEs are configured with two CSI-RS reports in operation **1005**. That is, in operation **1005**, a single CSI-RS resource & dual report with X-dB power back-off & rank-1 PMI restriction on 1.sup.st report and only rank-1 reporting is allowed & 2.sup.nd report unrestricted and up to rank-4 reporting. In the first report, in the process **800**, feedback is limited to rank-1 only and rank-1 PMI-restriction based on offline table is used. The second CSI-RS report allows up to rank-4 reporting and does not have any restricted codewords. The RI feedback of the second CSI-RS report (the unrestricted report) is utilized for users' classification in the UE classification stage. In the UE classification phase, gNB **102** determines whether UE **115** is rank-1 in a second report uses first CSI-RS report feedback in operation **1010**; or if UE **115** is performing better with higher ranks and uses a second CSI-RS report feedback in operation **1015**.

(87) In response to operation **1010** for users whose RI=1 in the second report, gNB **102** applies PMI-restriction (following PMI feedback from first CSI-RS report) with full-power in operation **1020** and CQI boosting to leverage the benefit of full-power transmission in operation **1025**. In response to operation **1015** for users whose RI>1 on the second report, in operation **1030** gNB **102** follows the second report following its CQI report with PDSCH power back-off equal to the same amount of CSI-RS power back-off (X-dB).

(88) FIG. **11** illustrates another example hybrid physical downlink shared channel (PDSCH) according to embodiments of the present disclosure. While the flow chart depicts a series of sequential steps, unless explicitly stated, no inference should be drawn from that sequence regarding specific order of performance, performance of steps or portions thereof serially rather than concurrently or in an overlapping manner, or performance of the steps depicted exclusively without the occurrence of intervening or intermediate steps. The process **1100** depicted in the example depicted is implemented by a processor and transmitter chain in, for example, a base station.

(89) In certain embodiments, a single CSI-RS report allowing only rank-1 reporting and applying rank-1 PMI-restriction in operation **1105**. In this case, no UE classification stage is needed. That is, in operation **1110** UE classification is not performed because only rank-1 reporting is allowed. Therefore, in operation **1115**, gNB **102** always follows the same procedure as RI=1, such as in operations **920** and **925** in FIG. **9**.

(90) FIG. **12** illustrates another example hybrid physical downlink shared channel (PDSCH) according to embodiments of the present disclosure. While the flow chart depicts a series of sequential steps, unless explicitly stated, no inference should be drawn from that sequence regarding specific order of performance, performance of steps or portions thereof serially rather than concurrently or in an overlapping manner, or performance of the steps depicted exclusively without the occurrence of intervening or intermediate steps. The process **1200** depicted in the example depicted is implemented by a processor and transmitter chain in, for example, a base station.

(91) In certain embodiments, in operation **1205** gNB **102** relies on UE's RSRP measurement to configure its CSI-RS reports. In the UE classification phase, gNB **102** determines whether UE **115** has an RSRP<Y dB (RSRP is lower than a threshold RSRP) and CSI-RS feedback report in

operation **1210**; or if UE **115** has an RSRP>Y dB and uses an unrestricted and up to rank-4 CSI-RS report feedback in operation **1215**.

(92) In response to operation **1210** for users whose RSRP is lower than a threshold RSRP, rank-1 PMI-restriction with full-power in operation **1220** and CSI-RS report is configured to be rank-1 restricted in operation **1225**. In response to operation **1215** for users with larger than a threshold RSRP, in operation **1230** a CSI-RS report is configured allowing up to rank-4 reporting and no PMI-restriction is applied. PDSCH transmission stage is the same as in process **1000**.

(93) FIG. **13** illustrates another example hybrid physical downlink shared channel (PDSCH) according to embodiments of the present disclosure. While the flow chart depicts a series of sequential steps, unless explicitly stated, no inference should be drawn from that sequence regarding specific order of performance, performance of steps or portions thereof serially rather than concurrently or in an overlapping manner, or performance of the steps depicted exclusively without the occurrence of intervening or intermediate steps. The process **1300** depicted in the example depicted is implemented by a processor and transmitter chain in, for example, a base station.

(94) In certain embodiments, all UEs are configured with two CSI-RS reports in operation **1305**. In the first report, gNB **102** limits feedback to rank-1 only and gNB **102** uses a rank-1 PMI-restriction based on offline table. While the second CSI-RS report allows up to rank-4 reporting and does not have any restricted codewords.

(95) In the UE classification stage, gNB **102** calculates the achievable rate following the 1.sup.st CSI-RS report in operation **1305** and re-calculates the achievable rate following the 2.sup.nd CSI-RS report in operation **1310**. If the first achievable rate is higher in operation **1305**, then gNB **102** follows the 1.sup.st CSI-RS report with full-power in PDSCH transmission in operation **1315** and CQI boosting with X-dB in operation **1320**. If the second achievable rate (following the 2.sup.nd CSI-RS report) is higher in operation **1310**, then gNB **102** follows the 2.sup.nd CSI-RS report with X-dB back-off in PDSCH transmission power in operation **1325**.

(96) One method of calculating the achievable rate is as follows:

$$R=RI*\log_2(1+SINR*\alpha) \qquad (1)$$

(97) In Equation 1, RI is the rank index, which is obtained from UE CSI feedback, SINR is the signal to interference plus noise ratio which is converted from channel quality index CQI that is further from the UE CSI RS report, in case of CQI boosting, the SINR is converted from boosted CQI, and α is the ORLC parameter.

(98) FIG. **14** illustrates a hybrid physical downlink shared channel (PDSCH) process according to embodiments of the present disclosure. While the flow chart depicts a series of sequential steps, unless explicitly stated, no inference should be drawn from that sequence regarding specific order of performance, performance of steps or portions thereof serially rather than concurrently or in an overlapping manner, or performance of the steps depicted exclusively without the occurrence of intervening or intermediate steps. The process **1400** depicted in the example depicted is implemented by a processor and transmitter chain in, for example, a base station.

(99) In operation **1405**, the base station receives a CSI report from at least one UE. Based on the received CSI report, in operation **1410**, the base station configures the CSI-RS resource for the UE. Based on a determination of the UE classification in operation **1415**, the base station either: 1) sets a transmission power to full power for transmission in a physical downlink shared channel (PDSCH) in operation **1420**; or 2) applies a back-off percentage to the transmission power in the PDSCH in operation **1425**.

(100) The above flowcharts illustrate example methods that can be implemented in accordance with the principles of the present disclosure and various changes could be made to the methods illustrated in the flowcharts herein. For example, while shown as a series of steps, various steps in each figure could overlap, occur in parallel, occur in a different order, or occur multiple times. In another example, steps may be omitted or replaced by other steps.

(101) Although the present disclosure has been described with exemplary embodiments, various changes and modifications may be suggested to one skilled in the art. It is intended that the present disclosure encompass such changes and modifications as fall within the scope of the appended claims. None of the description in this application should be read as implying that any particular element, step, or function is an essential element that must be included in the claims scope. The scope of patented subject matter is defined by the claims.

Claims

1. A base station (BS) in a wireless communication system, the BS comprising: a transceiver; and a processor configured to: receive, via the transceiver, a channel state information (CSI) report from at least one user equipment (UE); configure CSI—reference signal (RS) resources for at least one user equipment (UE); and based on the CSI report from the at least one UE and a classification including a layer of the at least one UE to receive multiple beams, perform one of operations to: set a transmission power to full power for a physical downlink shared channel (PDSCH) transmission; or apply a back-off percentage to the transmission power in the PDSCH transmission, wherein the classification is determined based on an achievable rate comprising a first achievable rate associated with a first CSI-RS report and a second achievable rate associated with a second CSI-RS report that are compared to identify a level of power in the PDSCH transmission.

2. The BS of claim 1, wherein the CSI report from the at least one UE comprises one or more of: a precoding matrix indicator (PMI), a rank indicator (RI), and a channel quality indicator (CQI).

3. The BS of claim 2, wherein, to perform setting the full power or applying the back-off percentage, the processor is further configured to: determine the layer of the at least one UE included in the classification of the at least one UE, the layer being identified based on a number of beams that the at least one UE receives from the BS.

4. The BS of claim 3, wherein the classification of the at least one UE comprises one of: the at least one UE performing with a rank-1; or the at least one UE performing with a rank-2 or greater.

5. The BS of claim 4, wherein: the at least one UE performing with the rank-1 further comprises a transmission at the full power; and the at least one UE performing with the rank-2 or greater further comprises a transmission at power less than the full power.

6. The BS of claim 3, wherein, when the at least one UE performs with a rank-1, the processor is further configured to: set the transmission power to the full power and boost a channel quality indicator (CQI).

7. The BS of claim 3, wherein, when the at least one UE performs with a rank-2 or greater, the processor is further configured to: follow the CSI report and apply the back-off percentage to the transmission power.

8. The BS of claim 3, wherein the achievable rate is calculated according to: Rate=RI*log.sub.2(1+α*SINR) where the α is an outer loop control parameter and the SINR is a signal to interference plus noise ratio that is converted from the CQI, and wherein: when the first achievable rate is higher than the second achievable rate, then the first CSI-RS report is used with the full power in the PDSCH transmission and a CQI boosting, and when the second achievable rate following the second CSI-RS report is higher than the first achievable rate, then the second CSI-RS report is used with back-off power in the PDSCH transmission.

9. The BS of claim 3, wherein the achievable rate is calculated according to: when a reference signal received power (RSRP) is lower than a threshold, the CSI report is configured to be rank-1 restricted and rank-1 PMI-restriction is applied; and when the RSRP is greater than a threshold, the CSI report is configured to allow up to rank-4 reporting and no PMI-restriction is applied.

10. A method of a base station (BS), the method comprising: receiving, via a transceiver, a channel state information (CSI) report from at least one user equipment (UE); configuring CSI—reference signal (RS) resources for the at least one UE; and based on the CSI report from the at least one UE

and a classification including a layer of the at least one UE to receive multiple beams, performing one of: setting a transmission power to full power for a physical downlink shared channel (PDSCH) transmission; or applying a back-off percentage to the transmission power in the PDSCH transmission, wherein the classification is determined based on an achievable rate comprising a first achievable rate associated with a first CSI-RS report and a second achievable rate associated with a second CSI-RS report that are compared to identify a level of power in the PDSCH transmission.

11. The method of claim 10, wherein the CSI report from the at least one UE comprises one or more of: a precoding matrix indicator (PMI), a rank indicator (RI), and a channel quality indicator (CQI).

12. The method of claim 11, wherein performing setting the full power or applying the back-off percentage comprises: determining the layer of the at least one UE included in the classification of the at least one UE, the layer being identified based on a number of beams that the at least one UE receives from the BS.

13. The method of claim 12, wherein the classification of the at least one UE comprises one of: the at least one UE performing with a rank-1; or the at least one UE performing with a rank-2 or greater.

14. The method of claim 13, wherein: the at least one UE performing with the rank-1 further comprises a transmission at the full power; and the at least one UE performing with the rank-2 or greater further comprises a transmission at power less than the full power.

15. The method of claim 12, wherein, when the at least one UE performs with a rank-1, further comprising: setting the transmission power to the full power and boost a channel quality indicator (CQI).

16. The method of claim 12, wherein, when the at least one UE performs with a rank-2 or greater, further comprising: following the CSI report and applying the back-off percentage to the transmission power.

17. The method of claim 12, wherein the achievable rate is calculated according to: Rate=RI*log.sub.2(1+α*SINR) where the α is an outer loop control parameter and the SINR is a signal to interference plus noise ratio that is converted from the CQI, and wherein: when the first achievable rate is higher than the second achievable rate, then the first CSI-RS report is used with the full power in the PDSCH transmission and a CQI boosting, and when the second achievable rate following the second CSI-RS report is higher than the first achievable rate, then the second CSI-RS report is used with back-off power in the PDSCH transmission.

18. The method of claim 12, wherein the classification of the at least one UE is determined based on an achievable rate calculated according to: when a reference signal received power (RSRP) is lower than a threshold, the CSI report is configured to be rank-1 restricted and rank-1 PMI-restriction is applied; and when the RSRP is greater than a threshold, the CSI report is configured to allow up to rank-4 reporting and no PMI-restriction is applied.

19. A non-transitory computer readable medium comprising instructions that, when executed by at least one processor, cause the at least one processor to: receive a channel state information (CSI) report from at least one user equipment (UE); configure CSI—reference signal (RS) resources for the at least one UE; and based on the CSI report from the at least one UE and a classification including a layer of the at least one UE to receive multiple beams, perform one of operations to: set a transmission power to full power for a physical downlink shared channel (PDSCH) transmission; or apply a back-off percentage to the transmission power in the PDSCH transmission, wherein the classification is determined based on an achievable rate comprising a first achievable rate associated with a first CSI-RS report and a second achievable rate associated with a second CSI-RS report that are compared to obtain to identify a level of power in the PDSCH transmission.

20. The non-transitory computer readable medium of claim 19, wherein the CSI report from the at least one UE comprises one or more of: a precoding matrix indicator (PMI), a rank indicator (RI),

and a channel quality indicator (CQI).

21. The non-transitory computer readable medium of claim 20, wherein to set the full power or apply the back-off percentage, the instructions are further configured to cause the at least one processor to: determine the layer of the at least one UE included in the classification of the at least one UE, the layer being identified based on a number of beams that the at least one UE receives from a base station.

22. The non-transitory computer readable medium of claim 21, wherein the classification of the at least one UE comprises one of: the at least one UE performing with a rank-1; or the at least one UE performing with a rank-2 or greater.

23. The non-transitory computer readable medium of claim 22, wherein: the at least one UE performing with the rank-1 further comprises a transmission at the full power; and the at least one UE performing with the rank-2 or greater further comprises a transmission at power less than the full power.

24. The non-transitory computer readable medium of claim 21, wherein, when the at least one UE performs with a rank-1, the instructions are further configured to cause the at least one processor to: set the transmission power to the full power and boost a channel quality indicator (CQI).

25. The non-transitory computer readable medium of claim 21, wherein, when the at least one UE performs with a rank-2 or greater, the instructions are further configured to cause the at least one processor to: follow the CSI report and apply the back-off percentage to the transmission power.

26. The non-transitory computer readable medium of claim 21, wherein the achievable rate is calculated according to:

$Rate = RI * \log_2(1 + \alpha * SINR)$ where the α is an outer loop control parameter and the SINR is a signal to interference plus noise ratio that is converted from the CQI, and wherein: when the first achievable rate is higher than the second achievable rate, then the first CSI-RS report is used with the full power in the PDSCH transmission and a CQI boosting, and when the second achievable rate following the second CSI-RS report is higher than the first achievable rate, then the second CSI-RS report is used with back-off power in the PDSCH transmission.

27. The non-transitory computer readable medium of claim 21, wherein the achievable rate is calculated according to: when a reference signal received power (RSRP) is lower than a threshold, the CSI report is configured to be rank-1 restricted and rank-1 PMI-restriction is applied; and when the RSRP is greater than a threshold, the CSI report is configured to allow up to rank-4 reporting and no PMI-restriction is applied.