TECHNIQUES FOR DETERMINING WHETHER AN EVM REQUIREMENT IS SATISFIED

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to techniques for determining whether an error vector magnitude (EVM) requirement is satisfied.

BACKGROUND

[0002] A wireless communications system may include one or multiple network communication devices, which may be known as a network equipment (NE), supporting wireless communications for one or multiple user communication devices, which may be otherwise known as user equipment (UE), or other suitable terminology. The wireless communications system may support wireless communications with one or multiple user communication devices by utilizing resources of the wireless communication system (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers, or the like). Additionally, the wireless communications system may support wireless communications across various radio access technologies including third generation (3G) radio access technology, fourth generation (4G) radio access technology, fifth generation (5G) radio access technology, among other suitable radio access technologies beyond 5G (e.g., 5G-Advanced (5G-A), sixth generation (6G), etc.).

SUMMARY

[0003] An article "a" before an element is unrestricted and understood to refer to "at least one" of those elements or "one or more" of those elements. The terms "a," "at least one," "one or more," and "at least one of one or more" may be interchangeable. As used herein, including in the claims, "or" as used in a list of items (e.g., a list of items prefaced by a phrase such as "at least one of" or "one or more of" or "one or both of) indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase "based on" shall not be construed as a reference to a closed set of conditions. For example, an

example step that is described as "based on condition A" may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase "based on" shall be construed in the same manner as the phrase "based at least in part on." Further, as used herein, including in the claims, a "set" may include one or more elements.

[0004] A test equipment for wireless communication is described. In some examples, the test equipment may implement, or may be implemented by, an NE. The test equipment may be configured to, capable of, or operable to receive an indication of a receiver algorithm for evaluating an EVM requirement and a maximum power reduction (MPR) table corresponding to the receiver algorithm; receive, from a user equipment (UE), a multiple-input, multiple-output (MIMO) signal corresponding to a plurality of transmit antennas, wherein a received power of the MIMO signal satisfies a threshold value based on a power class of the UE and the MPR table; determine an EVM for the UE based at least in part on an output of a receiver associated with the MIMO signal; and determine, for a modulation type and modulation constellation size, whether the UE satisfies the EVM requirement based on the EVM and the MPR table.

[0005] A processor for wireless communication is described. The processor may be configured to, capable of, or operable to receive an indication of a receiver algorithm for evaluating an EVM requirement and a MPR table corresponding to the receiver algorithm; receive, from a UE, a MIMO signal corresponding to a plurality of transmit antennas, wherein a received power of the MIMO signal satisfies a threshold value based on a power class of the UE and the MPR table; determine an EVM for the UE based at least in part on an output of a receiver associated with the MIMO signal; and determine, for a modulation type and modulation constellation size, whether the UE satisfies the EVM requirement based on the EVM and the MPR table.

[0006] A method performed or performable by a test equipment for wireless communication is described. The method may include receiving an indication of a receiver algorithm for evaluating an EVM requirement and a MPR table corresponding to the receiver algorithm; receiving, from a UE, a MIMO signal corresponding to a plurality of transmit antennas, wherein a received power of the MIMO signal satisfies a threshold value based on a power class of the UE and the MPR table; determining an EVM for the UE based at least in part on an output of a receiver associated with the MIMO signal; and

determining, for a modulation type and modulation constellation size, whether the UE satisfies the EVM requirement based on the EVM and the MPR table.

[0007] A UE for wireless communication is described. The UE may be configured to, capable of, or operable to receive an instruction to transmit a MIMO signal; transmit the MIMO signal using a plurality of transmit antennas; receive an indication to apply a MPR, wherein the MPR is based at least in part on an EVM associated with the MIMO signal and a number of transmit antennas of the UE; and perform one or more subsequent transmissions at a power level based on the MPR.

[0008] A processor for wireless communication is described. The processor may be configured to, capable of, or operable to receive an instruction to transmit a MIMO signal; transmit the MIMO signal using a plurality of transmit antennas; receive an indication to apply a MPR, wherein the MPR is based at least in part on an EVM associated with the MIMO signal and a number of transmit antennas of the UE; and perform one or more subsequent transmissions at a power level based on the MPR.

[0009] A method performed or performable by a UE for wireless communication is described. The method may include receiving an instruction to transmit a MIMO signal; transmit the MIMO signal using a plurality of transmit antennas; receiving an indication to apply a MPR, wherein the MPR is based at least in part on an EVM associated with the MIMO signal and a number of transmit antennas of the UE; and performing one or more subsequent transmissions at a power level based on the MPR.

[0010] A base station for wireless communication is described. In some examples, the base station may implement, or may be implemented by, an NE. The base station may be configured to, capable of, or operable to identify a set of MPR tables based at least in part on a receiver algorithm used by the base station; select a MPR table from the set of MPR tables based at least in part on an EVM requirement of a UE and a number of transmit antennas of the UE; transmit, to the UE, an indication to apply the selected MPR table; and receive one or more UL transmissions at a power level based on the MPR.

[0011] A processor for wireless communication is described. The processor may be configured to, capable of, or operable to identify a set of MPR tables based at least in part on a receiver algorithm used by the base station; select a MPR table from the set of MPR tables based at least in part on an EVM requirement of a UE and a number of transmit

antennas of the UE; transmit, to the UE, an indication to apply the selected MPR table; and receive one or more UL transmissions at a power level based on the MPR.

[0012] A method performed or performable by a UE for wireless communication is described. The method may include identifying a set of MPR tables based at least in part on a receiver algorithm used by the base station; selecting a MPR table from the set of MPR tables based at least in part on an EVM requirement of a UE and a number of transmit antennas of the UE; transmitting, to the UE, an indication to apply the selected MPR table; and receive one or more UL transmissions at a power level based on the MPR.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Figure 1 illustrates an example of a wireless communications system in accordance with aspects of the present disclosure.

[0014] Figure 2 illustrates an example of comparison of MPR to EVM in accordance with aspects of the present disclosure.

[0015] Figure 3 illustrates an example of a communication arrangement for calculating an EVM of a transmitter in accordance with aspects of the present disclosure.

[0016] Figure 4 illustrates an example of a procedure for calculating an EVM in accordance with aspects of the present disclosure.

[0017] Figure 5 illustrates an example of a UE in accordance with aspects of the present disclosure.

[0018] Figure 6 illustrates an example of a processor in accordance with aspects of the present disclosure.

[0019] Figure 7 illustrates an example of a network equipment (NE) in accordance with aspects of the present disclosure.

[0020] Figure 8 illustrates a flowchart of a method performed by a test equipment in accordance with aspects of the present disclosure.

[0021] Figure 9 illustrates a flowchart of a method performed by a UE in accordance with aspects of the present disclosure.

[0022] Figure 10 illustrates a flowchart of a method performed by a NE in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0023] In wireless communication devices, phase and amplitude distortion created by the power amplifier directly affects the quality of the communication. The most significant measurement for analyzing power amplifier performance in the latest communication system protocols is the EVM. This is a measure of modulation accuracy, or how well the power amplifier is transmitting information, represented by the varying phase and amplitude of a radio frequency (RF) signal. EVM measurements lend insight into the communication link and are a key measure of transmitter performance.

[0024] The EVM is used as a fundamental measure of the quality of transmitted modulation. Essentially, the EVM determines an upper bound on the signal-to-noise ratio that is achievable at the receiver in the absence of receiver noise or other interference. In general, a smaller EVM value is required for larger signal constellations because the benefit of larger signal constellations is only seen at higher signal-to-noise ratios.

[0025] For example, Table 1 (from the third generation partnership project (3GPP) technical specification (TS) 38.101-1) shows the EVM that is required as a function of the constellation size (and modulation type, such as binary phase-shift keying (BPSK), quadrature phase shift keying (QPSK), or quadrature amplitude modulation (QAM)). As can be seen from the table, the allowed EVM decreases from 30% for π/2-BPSK to 3.5% for 256 QAM.

Parameter	Unit	Average EVM Level
π/2-BPSK	%	30
QPSK	%	17.5
16 QAM	%	12.5
64 QAM	%	8
256 QAM	%	3.5

Table 1: Requirements for Error Vector Magnitude

[0026] The purpose of the EVM requirement on the transmitter is to limit the noise floor at the receiver that is due to transmitter noise. For multiple-layer MIMO transmissions, the objective of the EVM requirement is to limit the noise/error floor due to transmitter noise for each MIMO layer.

[0027] However, the EVM is not the only requirement on the quality of the transmitter. Requirements are also defined for the adjacent channel leakage ratio (ACLR), the spectral emissions mask (SEM), spurious emissions (SEM), and in-band emissions requirements. All of these requirements together determine the maximum power reduction (MPR) that is allowed for a given modulation type. In some cases, there are additional emissions requirements for which additional maximum power reduction (A-MPR) is allowed. As a result, of these allowed power reductions, the transmission power can be reduced and consequently range, and coverage of the uplink (UL) is reduced.

[0028] For higher order modulations like 16-QAM, 64-QAM, and 256-QAM (and possibly 1024-QAM), the EVM requirement is the most difficult to meet, and so it is the EVM requirement that determines the MPR that is allowed for the modulation type. This can be seen from the MPR tables shown below for single antenna transmission in Table 2, and for two transmit antennas in Table 3 and Table 4.

[0029] For a single transmit antenna with power class 3, the allowed MPR for an inner resource block (RB) allocation increases from 2 dB for 16 QAM to 6.5 dB for 256 QAM. For two transmit antennas with power class 2, the increase in MPR for an inner RB allocation increases from 2.5 dB for 16 QAM to 8 dB for 256 QAM. For two transmit antennas with power class 1.5, the increase in MPR for an inner allocation increases from 2.5 dB for 16 QAM to 8.5 dB for 256 QAM.

[0030] Because of the very large MPR values allowed for larger constellations, the region over which the higher order modulation constellations can be used is much reduced relative to the region over which it could be used if the MPR values were reduced. Additionally, it can be noted that for power class 2 with two transmit antennas, the benefit of the 3 dB power increase is reduced by 1 dB for 16 QAM and 1.5 dB for 256 QAM due to the increased MPR allowed with two transmit antennas. Similarly, for power class 1.5 with two transmit antennas, the benefit of the 6 dB power increase (relative to power class 3), the benefit is reduced by 1.5 dB for 16 QAM and 2 dB for 64 QAM.

[0031] As a result of the above observations, it is evident that reducing the MPR allowed for these higher order modulations would be very useful for increasing the region over which the higher order modulations can be supported, such as those associated with the discrete Fourier transform spread orthogonal frequency division multiplexing (DFT-s-

OFDM) waveform and the cyclic prefix orthogonal frequency division multiplexing (DFT-s-OFDM) waveform. Furthermore, because the MPR for larger constellations is primarily driven by EVM, any means for reducing EVM would be very beneficial.

Modulation		MPR (dB)		
		Edge RB allocations	**Outer RB allocations**	**Inner RB allocations**
DFT-s-OFDM	π/2 BPSK	≤ 3.5[1]	≤ 1.2[1]	≤ 0.2[1]
		≤ 0.5[2,3]	≤ 0.5[2]	0[2]
	π 2 BPSK w π/2 BPSK DMRS	≤ 0.5[2,3]	0[2]	0[2]
	QPSK	≤ 1		0
	16 QAM	≤ 2		≤ 1
	64 QAM	≤ 2.5		
	256 QAM	≤ 4.5		
CP-OFDM	QPSK	≤ 3		≤ 1.5
	16 QAM	≤ 3		≤ 2
	64 QAM	≤ 3.5		
	256 QAM	≤ 6.5		
NOTE 1: Applicable for UE operating in time division duplex (TDD) mode with π/2 BPSK modulation and UE indicates support for UE capability *powerBoosting-pi2BPSK* and if the information element (IE) *powerBoostPi2BPSK* is set to 1 and 40 % or less slots in radio frame are used for UL transmission for bands n40, n41, n77, n78 and n79. The reference power of 0 dB MPR is 26 dBm.				
NOTE 2: Applicable for conditions where note 1 does not apply.				
NOTE 3: For 3 MHz channel bandwidth the π/2 BPSK edge allocation MPR is 1 dB.				

Table 2: MPR for power class 3

Modulation		MPR (dB)		
		Edge RB allocations	**Outer RB allocations**	**Inner RB allocations**
DFT-s-OFDM	π /2 BPSK	≤ 3.5	≤ 1	0
	QPSK	≤ 3.5	≤ 2	0.5
	16 QAM	≤ 3.5	≤ 2.5	≤ 1.5
	64 QAM	≤ 3.5	≤ 3	
	256 QAM	≤ 5.5		
CP-OFDM	QPSK	≤ 4.0	≤ 3.5	≤ 2
	16 QAM	≤ 4.0	≤ 3.5	≤ 2.5
	64 QAM	≤ 4.5		
	256 QAM	≤ 8.0		

Table 3: MPR for power class 2 with dual Tx

Modulation		MPR (dB)		
		Edge RB allocations	Outer RB allocations	Inner RB allocations
DFT-s-OFDM	π/2 BPSK	≤ 6	≤ [2]	≤ 0.5
	QPSK	≤ 6.5	≤ [2.5]	≤ 0.5
	16 QAM	≤ 6.5	≤ [3.5]	≤ 1.5
	64 QAM	≤ 6.5	≤ [4]	≤ 3.5
	256 QAM	≤ 6.5	≤ 6.5	≤ [6.5]
CP-OFDM	QPSK	≤ 6.5	≤ [4.5]	≤ 2
	16 QAM	≤ 6.5	≤ [4.5]	≤ 2.5
	64 QAM	≤ 6.5	≤ [5]	≤ 4.5
	256 QAM	≤ 8.5	≤ 8.5	≤ [8.5]

Table 4: MPR for power class 1.5 with dual Tx

[0032] Aspects of the present disclosure provide techniques for reducing the MPR allowed for higher order constellations. In certain aspects, the pseudo-inverse and unbiased linear minimum mean squared error (MMSE) receivers are used as reference receivers to define the EVM for transmit diversity, single-layer transmission, and for multi-layer transmission where the number of layers is less than the number of transmit antennas. In certain aspects, the gNB can signal if the UE is allowed or required to use the MPR tables associated with the new reference receivers and with the reduced MPR for higher order signal constellations.

[0033] Aspects of the present disclosure are described in the context of a wireless communications system.

[0034] **Figure 1** illustrates an example of a wireless communications system 100 in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more NE 102, one or more UE 104, and a core network (CN) 106. The wireless communications system 100 may support various radio access technologies. In some implementations, the wireless communications system 100 may be a 4G network, such as a Long-Term Evolution (LTE) network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communications system 100 may be a New Radio (NR) network, such as a 5G network, a 5G-Advanced (5G-A) network, or a 5G ultrawideband (5G-UWB) network.

[0035] In other implementations, the wireless communications system 100 may be a combination of a 4G network and a 5G network, or other suitable radio access technology (RAT) including Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), and IEEE 802.20. The wireless communications system 100 may support radio access technologies beyond 5G, for example, 6G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0036] The one or more NE 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the NE 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a network function, a network entity, a radio access network (RAN), a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. An NE 102 and a UE 104 may communicate via a communication link, which may be a wireless or wired connection. For example, an NE 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0037] An NE 102 may provide a geographic coverage area for which the NE 102 may support services for one or more UEs 104 within the geographic coverage area. For example, an NE 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, an NE 102 may be moveable, for example, a satellite associated with a non-terrestrial network (NTN). In some implementations, different geographic coverage areas associated with the same or different radio access technologies may overlap, but the different geographic coverage areas may be associated with different NE 102.

[0038] The one or more UE 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a remote unit, a mobile device, a wireless device, a remote device, a subscriber device, a transmitter device, a receiver device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as

an internet-of-things (IoT) device, an internet-of-everything (IoE) device, or machine-type communication (MTC) device, among other examples.

[0039] A UE 104 may be able to support wireless communication directly with other UEs 104 over a communication link. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0040] An NE 102 may support communications with the CN 106, or with another NE 102, or both. For example, an NE 102 may interface with other NE 102 or the CN 106 through one or more backhaul links (e.g., S1, N2, N3, or network interface). In some implementations, the NE 102 may communicate with each other directly. In some other implementations, the NE 102 may communicate with each other or indirectly (e.g., via the CN 106). In some implementations, one or more NE 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

[0041] The CN 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The CN 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more NE 102 associated with the CN 106.

[0042] The CN 106 may communicate with a packet data network over one or more backhaul links (e.g., via an S1, N2, N3, or another network interface). The packet data

network may include an application server. In some implementations, one or more UEs 104 may communicate with the application server. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or a PDN connection, or the like) with the CN 106 via an NE 102. The CN 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the CN 106 (e.g., one or more network functions of the CN 106).

[0043] In the wireless communications system 100, the NEs 102 and the UEs 104 may use resources of the wireless communications system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the NEs 102 and the UEs 104 may support different resource structures. For example, the NEs 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the NEs 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the NEs 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The NEs 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0044] One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., μ=0) may be associated with a first subcarrier spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., μ=0) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., μ=1) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., μ=2) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., μ=3) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., μ=4) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0045] A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

[0046] Additionally, or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., μ=0, μ=1, μ=2, μ=3, μ=4) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively.

[0047] Each slot may include a number (e.g., quantity) of symbols (e.g., orthogonal frequency domain multiplexing (OFDM) symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., μ=0) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0048] In the wireless communications system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71

GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the NEs 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the NEs 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the NEs 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0049] FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., μ=0), which includes 15 kHz subcarrier spacing; a second numerology (e.g., μ=1), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., μ=3), which includes 120 kHz subcarrier spacing.

[0050] Wireless communication in unlicensed spectrum (also referred to as "shared spectrum") in contrast to licensed spectrum offer some obvious cost advantages allowing communication to obviate overlaying operator's licensed spectrum and rather use license free spectrum according to local regulation in specific geographies. From the 3GPP technology perspective, the unlicensed operation can be on the Uu interface (referred to as NR-U) or also on sidelink interface (e.g., SL-U).

[0051] For initial access, a UE 104 detects a candidate cell and performs downlink (DL) synchronization. For example, the gNB (e.g., an embodiment of the NE 102) may transmit a synchronization signal and physical broadcast channel (SS/PBCH) transmission, referred to as a synchronization signal block (SSB). In various embodiments, the SSB comprises the primary synchronization signal (PSS), the secondary synchronization signal (SSS), and the master information block (MIB). The synchronization signal (i.e., comprising the PSS and SSS) is a predefined data sequence known to the UE 104 (or derivable using information already stored at the UE 104) and is in a predefined location in time relative to frame/subframe boundaries, etc. The UE 104 searches for the SSB and uses the SSB to obtain DL timing information (e.g., symbol timing) for the DL synchronization. The UE 104 may also decode system information

(SI) based on the SSB. Note that with beam-based communication, each DL beam may be associated with a respective SSB.

[0052] After performing DL synchronization and acquiring essential system information, such as the MIB and the system information block type 1 (SIB1), the UE 104 performs UL synchronization and resource request by performing a random-access procedure, referred to as "RACH procedure" by selecting and transmitting a preamble on the physical random access channel (PRACH). The PRACH preamble is transmitted during a random access channel (RACH) occasion, i.e., a predetermined set of time-frequency resources that are available for the reception of the PRACH preamble. Note that with beam-based communication, the UE 104 may select a certain DL beam and transmit the PRACH preamble on a corresponding UL beam. In such embodiments, there may be a mapping between SSB and RACH occasion, allowing the network to determine which beam the UE 104 has selected.

[0053] In 3GPP New Radio (NR), the gNB may transmit the maximum 64 SSBs and the maximum 64 corresponding copies of physical downlink control channel (PDCCH) and/or physical downlink shared channel (PDSCH) for delivery of SIB1 in high frequency bands (e.g., 28 GHz). This may cause significant network energy consumption even for a very low traffic load condition. According to 3GPP Technical Report (TR) 38.864 (v18.1.0), for network energy savings, on-demand SSB and/or SIB1 (SSB/SIB1) transmissions and a cell without SSB/SIB1 transmission were considered. When a cell does not transmit SSB/SIB1, for a UE 104 to access the cell, the UE 104 should obtain SI of the cell from other associated carriers/cells and synchronize from other associated carriers/cells. When a cell is in a long period of cell inactivity, a UE 104 served by the cell can trigger SSB/SIB1 transmissions by sending a request to the cell.

[0054] **Figure 2** is a block diagram illustrating one embodiment of a communication arrangement 200 for calculating an EVM of a transmitter. The arrangement 200 involves a transmitter 202 and an evaluator 208 for calculating an EVM of the transmitter 202. As depicted, the transmitter 202 comprises a plurality of antennas. In some embodiments, the plurality of transmitter antennas (Tx antennas) is arranged into one or more antenna ports (i.e., Tx antenna ports), each antenna port comprising multiple antennas and with an antenna connector for each antenna. In certain embodiments, the transmitter 202 is one embodiment of the UE 104 and the evaluator 208 is an embodiment of a test equipment,

such as an NE 102, or another UE 104. However, in other embodiments the transmitter 202 may be an embodiment of the NE 102, wherein the evaluator 208 is an embodiment of a test equipment, another NE 102, or a UE 104.

[0055] The transmitter 202 generates a multiple-layer transmission signal for MIMO and transmits the multiple-layer transmission signal 204 (e.g., a multiple-layer MIMO signal) to the evaluator 208 via a propagation channel 206. The evaluator 208 measures the multiple-layer transmission signal 204 using a MIMO receiver 210 (e.g., by taking the pseudo-inverse of the channel matrix) and calculates an EVM of the transmitter 202, according to the below descriptions.

[0056] Note that the MIMO receiver 210 of the evaluator 208 may comprise a plurality of antennas. In some embodiments, the plurality of receiver antennas (Rx antennas) is arranged into one or more antenna ports (i.e., Rx antenna ports), each antenna port comprising multiple antennas and with an antenna connector for each antenna. To improve EVM accuracy, the multiple-layer transmission signal 204 may be received by the MIMO receiver 210 using the same number of antennas as used by the transmitter 202. For example, the number of Rx antennas may be the same as the number of Tx antennas. Similarly, the number of Rx antenna ports may be the same as the number of Tx antenna ports.

[0057] The EVM definitions in 3GPP are defined at the output of a reference receiver. As a result, the EVM definition is tied to the receiver used to evaluate the EVM. The following cases can be found in 3GPP TS 38.101-1 and TS 38.101-2.

[0058] Regarding the use case of single antenna transmission in FR1, the EVM is measured at the output of a zero-forcing frequency domain equalizer for CP-OFDM modulation. For DFT-s-OFDM, the EVM is measured at the output of the discrete Fourier transform (DFT) that follows the frequency domain equalizer. The zero-forcing equalizer multiplies each output of the fast Fourier transform (FFT) by the inverse of the corresponding channel estimate.

[0059] Regarding use case of transmit diversity with two antennas in FR1, the EVM for transmit diversity with two antennas is defined as the average of the EVM's for the first and second antennas, measured separately, using the single antenna zero-forcing equalizer. EVM_1 and EVM_2 denote the first EVM and the second EVM, respectively.

[0060] This EVM calculation corresponds to a zero-forcing MIMO receiver with two receive antennas with worst-case correlation of the transmitter noise (correlation coefficient =1). The zero-forcing receiver is uniquely defined as the inverse of the channel matrix 2×2 channel matrix **H** but is virtual here in the sense that there is no second layer and no reference symbols associated with the second layer.

[0061] The zero-forcing receiver is known to be inferior to the linear unbiased MMSE receiver, and the difference can be substantial. In the best case in which the transmitter noise is independent, the EVM is reduced by 3 dB relative to the receiver based on inverting the channel **H** with the zero-forcing receiver.

[0062] Regarding the use case of transmit diversity with four antennas in FR1, this EVM calculation corresponds to a zero-forcing MIMO receiver with four receive antennas with worst-case correlation of the transmitter noise (correlation coefficient =1). The zero-forcing receiver is uniquely defined as the inverse of the 4×4 channel matrix **H** but is virtual here in the sense that there is only one layer and there are no reference symbols associated with the second, third, and fourth layers.

[0063] Regarding the use case of multi-layer MIMO transmission (e.g., two layers) in FR1, here the EVM is defined per layer, and both layers must meet the EVM requirement. The EVM is measured at the output of a zero-forcing MIMO receiver which is uniquely defined as the inverse of the 2×2 channel matrix **H**. This receiver is actually implemented (not virtual) using per-layer reference symbols and possibly also decision directed channel estimates. The data symbol estimate $\boldsymbol{x}$ is given as:

$$\boldsymbol{x} = \boldsymbol{H}^{-1}\,\boldsymbol{y}$$

where $\boldsymbol{y}$ is the 2×1 signal at the antenna connectors and $\boldsymbol{H}$ is the 2×2 channel. If a 2×2 precoding matrix $\boldsymbol{W}$ is applied to the data symbol prior to transmission, then the receiver is given as:

$$\boldsymbol{x} = (\boldsymbol{HW})^{-1}\,\boldsymbol{y}\,.$$

[0064] For FR1, all of the measurements are conductive and are made at the antenna connectors. For FR2, all measurements are radiated.

[0065] Additionally, for FR2, the UE may transmit a single layer from two different polarizations. For FR2, the reference receiver used by the test equipment is the pseudo-inverse receiver given as:

$$\boldsymbol{x} = (\boldsymbol{H}^H \boldsymbol{H})^{-1}\boldsymbol{H}^H \boldsymbol{y},$$

where $\boldsymbol{y}$ is the 2×1 signal at the antenna connectors, $\boldsymbol{H}$ is the 2×2 channel, the superscript H denotes the conjugate transpose of the matrix, and $\boldsymbol{x}$ is the estimate of the data symbol.

[0066] If a 2×1 precoding vector $\boldsymbol{w}$ is applied to the data symbol prior to transmission, then the pseudo-inverse receiver is given as:

$$\boldsymbol{x} = ((\boldsymbol{Hw})^H \boldsymbol{Hw})^{-1}(\boldsymbol{Hw})^H \boldsymbol{y}.$$

[0067] One disadvantage of the pseudo-inverse receiver is that performance is not independent of the channel between the UE and the gNB or between the UE and the test equipment receiver. This means that the EVM seen at the receiver depends on the channel between the transmitter and the receiver, whereas ideally, a transmitter quality metric should not depend on the channel between the transmitter and receiver. A second disadvantage of the pseudo-inverse receiver is that it is not optimal in that it does not address the correlation of the transmitter noise. However, in the case that the transmitter noise is uncorrelated and equal in variance, the transmitter noise is reduced by 3 dB relative to the zero-forcing receiver.

[0068] A more optimal linear receiver would be the unbiased linear MMSE receiver which exploits the correlation of the transmitter noise. For the unbiased linear MMSE receiver, it can be shown that the EVM is not worse than the EVM of the better of the two transmit antennas. In any case, the unbiased linear MMSE receiver is always as good as or better than the pseudo-inverse receiver. The unbiased linear MMSE receiver for single layer transmission is given as:

$$\boldsymbol{x} = \mathbf{A}_{\mathrm{MMSE,U}}\, \boldsymbol{y}$$

where

$$\mathbf{A}_{\mathrm{MMSE,U}} = \frac{\boldsymbol{w}^H\mathbf{H}^H(\mathbf{H}\,\mathbf{w}\,\boldsymbol{w}^H\mathbf{H}^H + \boldsymbol{H}\,\boldsymbol{\Sigma}\,\mathbf{H}^H)^{-1}}{\boldsymbol{w}^H\mathbf{H}^H(\mathbf{H}\,\mathbf{w}\,\boldsymbol{w}^H\mathbf{H}^H + \boldsymbol{H}\,\boldsymbol{\Sigma}\,\mathbf{H}^H)^{-1}\mathbf{H}\,\mathbf{w}}.$$

[0069] In this expression, **H** denotes the $M\times1$ channel matrix, **w** denotes the $M\times1$ precoding vector, and **Σ** is the covariance of the transmitter noise. The EVM corresponding to the MMSE receiver is given as:

$$EVM = 100 \cdot \sqrt{(\boldsymbol{w}^H \boldsymbol{\Sigma}^{-1} \boldsymbol{w})^{-1}}.$$

[0070] For FR2 with two-layer transmission, the reference receiver is the zero-forcing receiver defined uniquely as the inverse of the 2×2 channel matrix **H**.

[0071] At least in the case of single layer transmission in FR1 with two or four transmit antennas, the virtual zero-forcing receiver was used in order to be most similar to the receiver used for the single antenna EVM definition. Also, the worst-case correlation of the transmitter noise was assumed in defining the test because this receiver was not actually implemented by the test equipment. Instead, the EVM was measured separately for each antenna connector. As a result, it would not be possible to observe the effects of the transmitter noise correlation in the test, and so the worst-case assumption was made. Another reason for the assumption of worst-case transmitter noise in deriving the EVM was in order to allow for the fact that one of the mechanisms for correlating the transmitter noise, the coupling of the antennas, is not present in a conductive test.

[0072] At the time the EVM test was being defined, test equipment vendors were not willing to implement an EVM definition that required joint processing of the signals at the two antenna connectors. However, since the test equipment vendors have now agreed to implement the zero-forcing MIMO receiver for two-layer transmission, the test equipment is no longer an impediment to allowing EVM definitions using receivers that require joint processing of the signals at multiple antennas.

[0073] In order to improve UL range, coverage, capacity and to reduce operator capital expenditure, it is desirable to have devices transmit more power on the UL. As discussed above, for larger QAM constellations 16-QAM, 64-QAM, and 256-QAM (and possibly 1024-QAM), the MPR requirement should be developed separately for more advanced receivers. In particular, it should be possible to reduce the MPR allowed for multi-antenna transmission with advanced receivers.

[0074] **Figure 3** depicts a chart 300 showing a comparison between the NR MPR and the EVM for CP-OFDM inner allocation. As depicted in Figure 3, the MPR that is allowed is a function of EVM for single antenna transmission.

[0075] For smaller signal constellations like QAM, as the PA power is reduced, the EVM requirement is met before the ACLR and SEM requirements, and so the allowed MPR is the power reduction needed to meet the ACLR and SEM requirements. Conversely, for larger constellations like 64 QAM and 256 QAM, the ACLR and SEM requirements are met before the EVM requirements. As a result, the allowed MPR for 64 QAM and 256 QAM is the power reduction needed to meet the EVM requirements.

[0076] If the transmitter noise is independent and equal variance on two transmit antennas, then the EVM at the output of the pseudo-inverse or MMSE receiver will be reduced by one-half relative to that of the EVM of the antennas measured separately. Similarly, if the transmitter noise is independent and equal variance on four transmit antennas, then the EVM at the output of the pseudo-inverse or MMSE receiver will be reduced by one-fourth relative to that of the EVM of the antennas measured separately.

[0077] Thus, for two and four antenna transmission of a single layer, the EVM of each of the antennas can be increased by factors of $\sqrt{2}$ and 2, respectively, and still meet the EVM requirements. For this reason, it is reasonable to consider the used of these more advanced receivers to define EVM for FR1 single layer transmission.

[0078] From Figure 3, it can be seen that a relaxation of EVM by a factor of $\sqrt{2}$ corresponds to a 1 dB reduction in the needed MPR. From the same Figure 3, it can be seen that a relaxation of EVM by a factor of 2 corresponds to a reduction of the needed MPR by approximately 2 dB.

[0079] There are at least two cases where more advanced receivers can be used to reduce the MPR that is needed (and allowed) for transmission of larger signal constellations like 64 QAM and 256 QAM. The two cases are: i) transmit diversity or single layer transmission with M antennas; and ii) multi-layer transmission where the number of layers is less than the number of transmit antennas.

[0080] Regarding the use case of transmit diversity or single layer transmission with M antennas, if the transmitter noise is uncorrelated, then the EVM can be reduced by a factor of $\sqrt{M}$ if the transmitter noise is uncorrelated for single layer transmission. Even with worst-case correlation of the transmitter noise, the EVM is no worse than the maximum of the EVM's of the M antennas evaluated separately at the antenna connectors. In general, it is not reasonable to assume that the transmitter noise on all M

antennas is fully correlated given that not all pairs of antennas are adjacent. For example, if the polarizations of the transmitter antennas are not aligned, or are orthogonal, minimal coupling of the antennas can be assumed.

[0081] Since it cannot be assumed that the transmitter noise is uncorrelated, it is not sufficient to simply reduce the required EVM by the $\sqrt{M}$. Instead, the test equipment can implement the actual receiver for M antennas which can be the linear unbiased MMSE receiver, where the data symbol $\boldsymbol{x}$ is estimated as:

$$\boldsymbol{x} = \mathbf{A}_{\mathrm{MMSE,U}}\, \boldsymbol{y}\,,$$

and

$$\mathbf{A}_{\mathrm{MMSE,U}} = \frac{\boldsymbol{w}^H \mathbf{H}^H (\mathbf{H}\,\mathbf{w}\,\boldsymbol{w}^H \mathbf{H}^H + \boldsymbol{H}\,\boldsymbol{\Sigma}\,\mathbf{H}^H)^{-1}}{\boldsymbol{w}^H \mathbf{H}^H (\mathbf{H}\,\mathbf{w}\,\boldsymbol{w}^H \mathbf{H}^H + \boldsymbol{H}\,\boldsymbol{\Sigma}\,\mathbf{H}^H)^{-1} \mathbf{H}\,\mathbf{w}}$$

where $\mathbf{H}$ denotes the $M\times 1$ channel matrix, $\mathbf{w}$ denotes the M×1 precoding vector, and $\boldsymbol{\Sigma}$ is the covariance of the transmitter noise. Alternatively, the pseudo-inverse receiver can be used which is given as:

$$\boldsymbol{x} = ((\boldsymbol{Hw})^H\, \boldsymbol{Hw})^{-1} (\boldsymbol{Hw})^H\, \boldsymbol{y}\,.$$

[0082] Either of these receivers (i.e., linear unbiased MMSE or pseudo-inverse receiver) can be used to evaluate EVM and to develop new reduced MPR values relative to those in the specification. However, as not all gNBs would use these advanced receivers, it may be necessary for the gNB to signal that the UE is to use the MPR table associated with the more advanced receiver. More specifically, the gNB may signal a set of one or more MPR tables to use. In one embodiment, where the UE is preconfigured with the MPR tables, the gNB may signal its receiver type or an indication of which MPR table(s) to use.

[0083] In some cases, it may be necessary to consider correlation of the transmitter due to antenna coupling which occurs when the antennas are used but which is not observed in conductive testing. The EVM measured at the output of the receiver in a conductive measurement will only reflect the correlation of the transmitter noise within the UE itself. If necessary, this correlation due to the antennas can be handled in several ways:

[0084] First, by an agreed margin, either in terms of the MPR allowed or in terms of tightening of the EVM requirement at the output of the receiver relative to the requirements in Table 1 (above). Second, by the introduction of coupling across the antenna connectors.

[0085] This second approach has some challenges in terms of the implementation, especially regarding an agreement on the coupling amplitude, or, because performance might be dependent on the phase of the coupler, it may be necessary to apply multiple phases when testing emissions.

[0086] When applying multiple phases, the UE antenna coupling would be evaluated, and the corresponding coupling coefficient would be applied in the test. Alternatively, based on the coupling coefficient measurement, the coupling measured in dB could be categorized into one of several categories such as the following: 10 to 15, 15 to 20, 20 to 25, etc. Here a coupling coefficient of X dB means that the coupled power from one antenna into an adjacent antenna is attenuated by X dB. For each category, the coupling coefficient applied during the test would be the smaller of the two isolation values defining the category (e.g., for the category with coupling of 10 dB to 15 dB, a value of 10 dB would be used).

[0087] Additionally, the determination of the antenna coupling for more than two antennas requires determining the coupling for all pairs of antennas. Thus, for four antennas, the number of antenna pairs is 6.

[0088] To summarize, the benefits of transmitting a single layer using M antennas are the following: i) the transmit power can be increased by a factor of M; ii) the EVM requirement per antenna can be reduced by a factor of $\sqrt{M}$ relative to the same power for single antenna transmission; iii) the MPR needed to meet the EVM requirement can be reduced by several dB as can be observed by the plot of EVM vs. MPR in Figure 3.

[0089] For the case of transmit diversity or single layer transmission from multiple antennas, defining the new reduced MPR requirements for improved receivers includes 1) defining EVM as the output of the output of a linear unbiased MMSE receiver or a pseudo-inverse receiver; 2) determining the MPR needed to meet EVM with these receivers; 3) generating MPR tables based on these MPR values; and 4) signaling (e.g., by the gNB) whether the UE can use the improved MPR tables.

[0090] Note that the MPR must be specified corresponding to the number of transmit antennas used. For example, MPR could be specified for two, three, four, and eight transmit antennas.

[0091] Regarding the use case of MIMO transmission with the number of MIMO layers L less than the number of transmit antennas M, the pseudo-inverse and unbiased linear MMSE receivers can also be defined for the transmission of L MIMO layers from M antennas, where L is less than or equal to M. As before, the pseudo-inverse receiver is given as:

$$\boldsymbol{x} = ((\boldsymbol{HW})^H \boldsymbol{HW})^{-1}(\boldsymbol{HW})^H \boldsymbol{y}.$$

[0092] Here, $\boldsymbol{y}$ has dimension $M\times 1$, $\boldsymbol{x}$ has dimensions $L\times 1$, the channel $\boldsymbol{H}$ has dimension $M\times M$, and the precoding matrix $\boldsymbol{W}$ has dimension $M\times L$. The unbiased linear MMSE receiver for this case is given as:

$$\boldsymbol{x} = \mathbf{A}_{MMSE,U}\,\mathbf{y}$$

where

$$\mathbf{A}_{MMSE,U} = \mathbf{P}^{-1}\,\mathbf{W}^H\,\mathbf{H}^H(\mathbf{H}\,\mathbf{W}\,\mathbf{W}^H\mathbf{H}^H + \mathbf{H}\,\boldsymbol{\Sigma}\,\mathbf{H}^H)^{-1}$$

and $\mathbf{P}$ is the diagonal matrix given by $diag(\mathrm{Q}_{11}, \mathrm{Q}_{22}, \ldots, \mathrm{Q}_{MM})$, where

$$\boldsymbol{Q} = \mathbf{W}^H\,\mathbf{H}^H(\mathbf{H}\,\mathbf{W}\,\mathbf{W}^H\mathbf{H}^H + \mathbf{H}\,\boldsymbol{\Sigma}\,\mathbf{H}^H)^{-1}\mathbf{H}\,\mathbf{W}.$$

[0093] When the number of layers L is less than the number of transmit antennas M and the transmitter noise is uncorrelated and equal variance, it can be shown that the transmitter noise at the output of the pseudo-inverse and unbiased linear MMSE receivers is reduced by a factor of M/L for each layer and the EVM for each layer is reduced by $\sqrt{M/L}$.

[0094] Accordingly, for the case of an L layer MIMO transmission with L less than the number of transmit antennas M, defining the new reduced MPR requirements for improved receivers includes 1) defining EVM as the output of a linear unbiased MMSE receiver or a pseudo-inverse receiver; 2) determining the MPR needed to meet EVM with these receivers for different values of L less than M; 3) generating MPR tables based on these MPR values; and 4) signaling (e.g., by the gNB) whether the UE can use the improved MPR tables.

[0095] Note that the MPR must be specified corresponding to the number of transmit antennas used. For example, MPR could be specified for two, three, four, and eight transmit antennas.

[0096] **Figure 4** depicts a procedure 400 for calculating an EVM of a transmitting device, such as the UE 402, in accordance with aspects of the present disclosure. The procedure 400 involves the UE 402 (e.g., an implementation of the UE 104 and the transmitter 202), a test equipment 404 (e.g., an implementation of the evaluator 208), and a network node 406 (e.g., an implementation of the NE 102, the CN 106, and/or an gNB).

[0097] At Step 1, the test equipment 404 identifies a receiver algorithm for evaluating an EVM requirement, e.g., of the UE 402 (see block 408). Optionally, the test equipment 404 may receive, e.g., from network node 406, an indication of the receiver algorithm to be used to evaluate the EVM requirement.

[0098] At Step 2, the test equipment 404 receives an MPR table corresponding to the receiver algorithm (see block 410). In one implementation, the network node 406 may transmit an indication of one or more MPR tables to the test equipment 404. Alternatively, the test equipment 404 may be pre-configured with the MPR table, wherein at Step 2 the test equipment retrieves, e.g., from memory, one or more MPR tables that correspond to the receiver algorithm.

[0099] Note that the MPR tables are used by the test equipment, they are not generated by the test equipment. In some embodiments, the MPR tables for the receiver type and the number of layers will be determined by simulation or measurement. In such embodiments, the MPR tables may be specified (e.g., captured in the 3GPP specification).

[0100] At Step 3, the test equipment 404 transmits (and the UE 402 receives) an instruction to transmit a MIMO signal (see signaling 412).

[0101] At Step 4, the UE 402 transmits (and the test equipment 404 receives) a MIMO signal corresponding to a plurality of transmit antennas (see signaling 414). Here, the received power of the MIMO signal satisfies a threshold value (e.g., is no less than the threshold value) based on a power class of the UE and the MPR table.

[0102] At Step 5, the test equipment 404 determines an EVM for the UE based at least in part on an output of a receiver associated with the MIMO signal (see block 416).

[0103] At Step 6, the test equipment 404 determines, for a modulation type and modulation constellation size, whether the UE satisfies the EVM requirement based on the EVM and the MPR table (see signaling 418).

[0104] At Step 7, the UE 402 receives an indication to apply an MPR (e.g., an improved MPR as described above), wherein the MPR based at least in part on an EVM associated with the MIMO signal and a number of transmit antennas of the UE (see block 420). In the depicted embodiment, the indication is received from the network node 406. For example, the network node 406 may transmit an indication to apply the selected MPR table. In another implementation, the UE 402 may receive an indication of the MPR from the test equipment 404.

[0105] At Step 8, the UE 402 transmits (and the network node 406 receives) one or more UL transmissions at a power level based on the MPR (see signaling 422). Accordingly, the UE 402 may use the improved MPR for subsequent transmissions to the network.

[0106] **Figure 5** illustrates an example of a UE 500 in accordance with aspects of the present disclosure. The UE 500 may include a processor 502, a memory 504, a controller 506, and a transceiver 508. The processor 502, the memory 504, the controller 506, or the transceiver 508, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0107] The processor 502, the memory 504, the controller 506, or the transceiver 508, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0108] The processor 502 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a central processing unit (CPU), an ASIC, a field programmable gate array (FPGA), or any combination thereof). In some implementations, the processor 502 may be configured to operate the memory 504. In some other

implementations, the memory 504 may be integrated into the processor 502. The processor 502 may be configured to execute computer-readable instructions stored in the memory 504 to cause the UE 500 to perform various functions of the present disclosure.

[0109] The memory 504 may include volatile or non-volatile memory. The memory 504 may store computer-readable, computer-executable code including instructions that, when executed by the processor 502, cause the UE 500 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such the memory 504 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

[0110] In some implementations, the processor 502 and the memory 504 coupled with the processor 502 may be configured to cause the UE 500 to perform various functions (e.g., operations, signaling) described herein (e.g., executing, by the processor 502, instructions stored in the memory 504). In some implementations, the processor 502 may include multiple processors and the memory 504 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may be individually or collectively, configured to perform various functions (e.g., operations, signaling) of the UE 500 as disclosed herein.

[0111] The processor 502 coupled with the memory 504 may be configured to cause the UE 500 to receive an instruction to transmit a MIMO signal and means for transmitting the MIMO signal using a plurality of transmit antennas. In some embodiments, the MIMO signal comprises an integer number of transmission layers, and wherein the integer number of transmission layers is less than the number of transmit antennas.

[0112] The processor 502 coupled with the memory 504 may be configured to cause the UE 500 to receive an indication to apply a MPR and a means for performing one or more subsequent transmissions at a power level based on the MPR, where the MPR based at least in part on an EVM associated with the MIMO signal and a number of transmit antennas of the UE.

[0113] In some embodiments, the processor 502 coupled with the memory 504 may be configured to cause the UE 500 to apply a set of MPR tables. In certain embodiments, the set of MPR tables is further based on a receiver algorithm, and wherein the receiver algorithm comprises a linear unbiased MMSE receiver or a pseudo-inverse MIMO receiver.

[0114] In certain embodiments, the set of MPR tables is further based on a number of transmission layers associated with the MIMO signal. In certain embodiments, the indication to apply the MPR further comprises an indication of which MPR tables of the set of MPR tables to use for the one or more subsequent transmissions.

[0115] The controller 506 may manage input and output signals for the UE 500. The controller 506 may also manage peripherals not integrated into the UE 500. In some implementations, the controller 506 may utilize an operating system (OS) such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 506 may be implemented as part of the processor 502.

[0116] In some implementations, the UE 500 may include at least one transceiver 508. In some other implementations, the UE 500 may have more than one transceiver 508. The transceiver 508 may represent a wireless transceiver. The transceiver 508 may include one or more receiver chains 510, one or more transmitter chains 512, or a combination thereof.

[0117] A receiver chain 510 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 510 may include one or more antennas for receiving the signal over the air or wireless medium. The receiver chain 510 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 510 may include at least one demodulator configured to demodulate the received signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 510 may include at least one decoder for decoding/ processing the demodulated signal to receive the transmitted data.

[0118] A transmitter chain 512 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 512 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for

transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 512 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 512 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0119] **Figure 6** illustrates an example of a processor 600 in accordance with aspects of the present disclosure. The processor 600 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 600 may include a controller 602 configured to perform various operations in accordance with examples as described herein. The processor 600 may optionally include at least one memory 604, which may be, for example, an L1/L2/L3 cache. Additionally, or alternatively, the processor 600 may optionally include one or more arithmetic-logic units (ALUs) 606. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0120] The processor 600 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 600) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[0121] The controller 602 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 600 to cause the processor 600 to support various operations in accordance with

examples as described herein. For example, the controller 602 may operate as a control unit of the processor 600, generating control signals that manage the operation of various components of the processor 600. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0122] The controller 602 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 604 and determine subsequent instruction(s) to be executed to cause the processor 600 to support various operations in accordance with examples as described herein. The controller 602 may be configured to track memory address of instructions associated with the memory 604. The controller 602 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 602 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 600 to cause the processor 600 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 602 may be configured to manage flow of data within the processor 600. The controller 602 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 600.

[0123] The memory 604 may include one or more caches (e.g., memory local to or included in the processor 600 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementations, the memory 604 may reside within or on a processor chipset (e.g., local to the processor 600). In some other implementations, the memory 604 may reside external to the processor chipset (e.g., remote to the processor 600).

[0124] The memory 604 may store computer-readable, computer-executable code including instructions that, when executed by the processor 600, cause the processor 600 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 602 and/or the processor 600 may be configured to execute computer-readable instructions stored in the memory 604 to cause the processor 600 to perform various functions. For example, the processor 600 and/or the controller 602 may be coupled with or to the memory 604, the processor 600, the controller 602, and the memory 604 may be

configured to perform various functions described herein. In some examples, the processor 600 may include multiple processors and the memory 604 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

[0125] The one or more ALUs 606 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 606 may reside within or on a processor chipset (e.g., the processor 600). In some other implementations, the one or more ALUs 606 may reside external to the processor chipset (e.g., the processor 600). One or more ALUs 606 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 606 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 606 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 606 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 606 to handle conditional operations, comparisons, and bitwise operations.

[0126] In various implementations, the processor 600 may support various functions (e.g., operations, signaling) in accordance with examples as disclosed herein. For example, the controller 602 coupled with the memory 604 may be configured to, capable of, or operable to cause the processor 600 to receive an instruction to transmit a MIMO signal; transmit the MIMO signal using a plurality of transmit antennas; receive an indication to apply a MPR, wherein the MPR is based at least in part on an EVM associated with the MIMO signal and a number of transmit antennas of the UE; and perform one or more subsequent transmissions at a power level based on the MPR. Additionally, the controller 602 coupled with the memory 604 may be configured to, capable of, or operable to cause the processor 600 to perform one or more functions (e.g., operations, signaling) of the UE as described herein.

[0127] In various implementations, the processor 600 may support the functions of a test equipment, in accordance with examples as disclosed herein. For example, the

controller 602 coupled with the memory 604 may be configured to, capable of, or operable to cause the processor 600 to receive an indication of a receiver algorithm for evaluating an EVM requirement and an MPR table corresponding to the receiver algorithm; receive, from a UE, a MIMO signal corresponding to a plurality of transmit antennas, wherein a received power of the MIMO signal satisfies a threshold value based on a power class of the UE and the MPR table; determine an EVM for the UE based at least in part on an output of a receiver associated with the MIMO signal; and determine, for a modulation type and modulation constellation size, whether the UE satisfies the EVM requirement based on the EVM and the MPR table. Additionally, the controller 602 coupled with the memory 604 may be configured to, capable of, or operable to cause the processor 600 to perform one or more functions (e.g., operations, signaling) of the test equipment as described herein.

[0128] In various implementations, the processor 600 may support the functions of a base station or gNB, in accordance with examples as disclosed herein. For example, the controller 602 coupled with the memory 604 may be configured to, capable of, or operable to cause the processor 600 to identify a set of MPR tables based at least in part on a receiver algorithm used by the base station; select a MPR table from the set of MPR tables based at least in part on an EVM requirement of a UE and a number of transmit antennas of the UE; transmit, to the UE, an indication to apply the selected MPR table; and receive one or more UL transmissions at a power level based on the MPR. In some embodiments, the receiver algorithm comprises a linear unbiased MMSE receiver or a pseudo-inverse MIMO receiver. Additionally, the controller 602 coupled with the memory 604 may be configured to, capable of, or operable to cause the processor 600 to perform one or more functions (e.g., operations, signaling) of the NE as described herein.

[0129] **Figure 7** illustrates an example of a NE 700 in accordance with aspects of the present disclosure. The NE 700 may include a processor 702, a memory 704, a controller 706, and a transceiver 708. The processor 702, the memory 704, the controller 706, or the transceiver 708, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0130] The processor 702, the memory 704, the controller 706, or the transceiver 708, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0131] The processor 702 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 702 may be configured to operate the memory 704. In some other implementations, the memory 704 may be integrated into the processor 702. The processor 702 may be configured to execute computer-readable instructions stored in the memory 704 to cause the NE 700 to perform various functions of the present disclosure.

[0132] The memory 704 may include volatile or non-volatile memory. The memory 704 may store computer-readable, computer-executable code including instructions when executed by the processor 702 cause the NE 700 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such the memory 704 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

[0133] In some implementations, the processor 702 and the memory 704 coupled with the processor 702 may be configured to cause the NE 700 to perform various functions (e.g., operations, signaling) described herein (e.g., executing, by the processor 702, instructions stored in the memory 704). In some implementations, the processor 702 may include multiple processors and the memory 704 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may be individually or collectively, configured to perform various functions (e.g., operations, signaling) of the NE 700 as disclosed herein.

[0134] In various implementations, the NE 700 may support the functions of a test equipment, in accordance with examples as disclosed herein. For example, the processor

702 coupled with the memory 704 may be configured to cause the NE 700 to receive, from a UE, a MIMO signal corresponding to a plurality of transmit antennas, wherein a received power of the MIMO signal satisfies (e.g., is not less than) a threshold value based on a power class of the UE and the MPR table.

[0135] The processor 702 coupled with the memory 704 may be configured to cause the NE 700 to determine an EVM for the UE based at least in part on an output of a receiver associated with the MIMO signal and a means for determining, for a modulation type and modulation constellation size, whether the UE satisfies the EVM requirement based on the EVM and the MPR table.

[0136] In some embodiments, the EVM is further based on the receiver algorithm. In some embodiments, the receiver algorithm comprises a linear unbiased MMSE receiver or a pseudo-inverse MIMO receiver.

[0137] In some embodiments, the MPR table further corresponds to a number of transmit antennas associated with the MIMO signal, and the MIMO signal comprises an integer number of transmission layers, where the integer number of transmission layers is less than the number of transmit antennas.

[0138] In some embodiments, the MPR table is further based on a number of transmission layers associated with the MIMO signal. In some embodiments, the EVM is further based on radiative measurements of the MIMO signal. In some embodiments, the MPR is further based on a transmitter noise correlation based on an antenna coupling of the plurality of transmit antennas.

[0139] In various implementations, the NE 700 may support the functions of a base station or gNB, in accordance with examples as disclosed herein. For example, the processor 702 coupled with the memory 704 may be configured to cause the NE 700 to identify a set of MPR tables based at least in part on a receiver algorithm used by the base station. In some embodiments, the receiver algorithm comprises a linear unbiased MMSE receiver or a pseudo-inverse MIMO receiver.

[0140] The processor 702 coupled with the memory 704 may be configured to cause the NE 700 to select an MPR table from the set of MPR tables based at least in part on an EVM requirement of a UE and a number of transmit antennas of the UE. In some embodiments, the set of MPR tables is further based on a number of transmission layers

associated the one or more UL transmissions, and the EVM requirement is based at least in part on the receiver algorithm.

[0141] In some embodiments, the processor 702 coupled with the memory 704 may be configured to cause the NE 700 to select the MPR table further based on an EVM measurement associated with the number of transmit antennas of the UE. In some embodiments, the selected MPR table corresponds to a number of transmit antennas of the UE and a number of transmission layers associated with the MIMO signal.

[0142] The processor 702 coupled with the memory 704 may be configured to cause the NE 700 to transmit, to the UE, an indication to apply the selected MPR table. The processor 702 coupled with the memory 704 may be configured to cause the NE 700 to receive one or more UL transmissions at a power level based on the MPR.

[0143] The controller 706 may manage input and output signals for the NE 700. The controller 706 may also manage peripherals not integrated into the NE 700. In some implementations, the controller 706 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 706 may be implemented as part of the processor 702.

[0144] In some implementations, the NE 700 may include at least one transceiver 708. In some other implementations, the NE 700 may have more than one transceiver 708. The transceiver 708 may represent a wireless transceiver. The transceiver 708 may include one or more receiver chains 710, one or more transmitter chains 712, or a combination thereof.

[0145] A receiver chain 710 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 710 may include one or more antennas for receiving the signal over the air or wireless medium. The receiver chain 710 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 710 may include at least one demodulator configured to demodulate the received signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 710 may include at least one decoder for decoding/ processing the demodulated signal to receive the transmitted data.

[0146] A transmitter chain 712 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 712 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 712 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 712 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0147] **Figure 8** depicts one embodiment of a method 800 in accordance with aspects of the present disclosure. In various embodiments, the operations of the method 800 may be implemented by a test equipment, such as the NE, as described herein. In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0148] At step 802, the method 800 may include receiving an indication of a receiver algorithm for evaluating an EVM requirement and an MPR table corresponding to the receiver algorithm. The operations of step 802 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of step 802 may be performed by a NE, as described with reference to Figure 7.

[0149] At step 804, the method 800 may include receiving, from a UE, a MIMO signal corresponding to a plurality of transmit antennas, wherein a received power of the MIMO signal satisfies a threshold value based on a power class of the UE and the MPR table. The operations of step 804 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of step 804 may be performed by a NE, as described with reference to Figure 7.

[0150] At step 806, the method 800 may include determining an EVM for the UE based at least in part on an output of a receiver associated with the MIMO signal. The operations of step 806 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of step 806 may be performed by a NE, as described with reference to Figure 7.

[0151] At step 808, the method 800 may include determining, for a modulation type and modulation constellation size, whether the UE satisfies the EVM requirement based on the EVM and the MPR table. The operations of step 808 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of step 808 may be performed by a NE, as described with reference to Figure 7.

[0152] It should be noted that the method 800 described herein describes one possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0153] **Figure 9** depicts one embodiment of a method 900 in accordance with aspects of the present disclosure. In various embodiments, the operations of the method 900 may be implemented by a radio node, such as the UE or NE, as described herein. In some implementations, the UE may execute a set of instructions to control the function elements of the UE to perform the described functions. In other implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0154] At step 902, the method 900 may include receiving an instruction to transmit a MIMO signal. The operations of step 902 may be performed in accordance with examples as described herein. In some implementations, aspects of the operation of step 902 may be performed by a UE, as described with reference to Figure 5.

[0155] At step 904, the method 900 may include transmitting the MIMO signal using a plurality of transmit antennas. The operations of step 904 may be performed in accordance with examples as described herein. In some implementations, aspects of the operation of step 904 may be performed by a UE, as described with reference to Figure 5.

[0156] At step 906, the method 900 may include receiving an indication to apply an MPR based at least in part on an EVM associated with the MIMO signal and a number of transmit antennas of the UE. The operations of step 906 may be performed in accordance with examples as described herein. In some implementations, aspects of the operation of step 906 may be performed by a UE, as described with reference to Figure 5.

[0157] At step 908, the method 900 may include performing one or more subsequent transmissions at a power level based on the MPR. The operations of step 908 may be

performed in accordance with examples as described herein. In some implementations, aspects of the operation of step 908 may be performed by a UE, as described with reference to Figure 5.

[0158] It should be noted that the method 900 described herein describes one possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0159] **Figure 10** depicts one embodiment of a method 1000 in accordance with aspects of the present disclosure. In various embodiments, the operations of the method 1000 may be implemented by a base station, such as the NE, as described herein. In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0160] At step 1002, the method 1000 may include identifying a set of MPR tables based at least in part on a receiver algorithm used by the base station. The operations of step 1002 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of step 1002 may be performed by a NE, as described with reference to Figure 7.

[0161] At step 1004, the method 1000 may include selecting an MPR table from the set of MPR tables based at least in part on an EVM requirement of a UE and a number of transmit antennas of the UE. The operations of step 1004 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of step 1004 may be performed by a NE, as described with reference to Figure 7.

[0162] At step 1006, the method 1000 may include transmitting, to the UE, an indication to apply the selected MPR table. The operations of step 1006 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of step 1006 may be performed by a NE, as described with reference to Figure 7.

[0163] At step 1008, the method 1000 may include receiving one or more UL transmissions at a power level based on the MPR. The operations of step 1008 may be performed in accordance with examples as described herein. In some implementations,

aspects of the operations of step 1008 may be performed by a NE, as described with reference to Figure 7.

[0164] It should be noted that the method 1000 described herein describes one possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0165] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

CLAIMS

What is claimed is:

1. A test equipment for wireless communication, comprising:
at least one memory; and
at least one processor coupled with the at least one memory and configured to cause the test equipment to:
receive an indication of a receiver algorithm for evaluating an error vector magnitude (EVM) requirement and a maximum power reduction (MPR) table corresponding to the receiver algorithm;
receive, from a user equipment (UE), a multiple-input, multiple-output (MIMO) signal corresponding to a plurality of transmit antennas, wherein a received power of the MIMO signal satisfies a threshold value based on a power class of the UE and the MPR table;
determine an EVM for the UE based at least in part on an output of a receiver associated with the MIMO signal; and
determine, for a modulation type and modulation constellation size, whether the UE satisfies the EVM requirement based on the EVM and the MPR table.

2. The test equipment of claim 1, wherein the EVM is further based on the receiver algorithm.

3. The test equipment of claim 1, wherein the receiver algorithm comprises a linear unbiased minimum mean squared error (MMSE) receiver or a pseudo-inverse MIMO receiver.

4. The test equipment of claim 1, wherein the MPR table further corresponds to a number of transmit antennas associated with the MIMO signal, wherein the MIMO signal comprises an integer number of transmission layers, and wherein the integer number of transmission layers is less than the number of transmit antennas.

5. The test equipment of claim 1, wherein the MPR table is further based on a number of transmission layers associated with the MIMO signal.

6. The test equipment of claim 1, wherein the EVM is further based on radiative measurements of the MIMO signal.

7. The test equipment of claim 1, wherein the MPR is further based on a transmitter noise correlation based on an antenna coupling of the plurality of transmit antennas.

8. The test equipment of claim 1, wherein the at least one processor is configured to cause the test equipment to indicate the MPR to the UE.

9. A user equipment (UE) for wireless communication, comprising:
at least one memory; and
at least one processor coupled with the at least one memory and configured to
cause the UE to:
receive an instruction to transmit a multiple-input, multiple-output (MIMO) signal;
transmit the MIMO signal using a plurality of transmit antennas;
receive an indication to apply a maximum power reduction (MPR), wherein the MPR based at least in part on an error vector magnitude (EVM) associated with the MIMO signal and a number of transmit antennas of the UE; and
perform one or more subsequent transmissions at a power level based on the MPR.

10. The UE of claim 9, wherein the MIMO signal comprises an integer number of transmission layers, and wherein the integer number of transmission layers is less than the number of transmit antennas.

11. The UE of claim 9, wherein the at least one processor is configured to cause the UE to apply a set of MPR tables.

12. The UE of claim 11, wherein the set of MPR tables is further based on a receiver algorithm, and wherein the receiver algorithm comprises a linear unbiased minimum mean squared error (MMSE) receiver or a pseudo-inverse MIMO receiver.

13. The UE of claim 11, wherein the set of MPR tables is further based on a number of transmission layers associated with the MIMO signal.

14. The UE of claim 11, wherein the indication to apply the MPR further comprises an indication of which MPR tables of the set of MPR tables to use for the one or more subsequent transmissions.

15. A method performed by a user equipment (UE), the method comprising:
receiving an instruction to transmit a multiple-input, multiple-output (MIMO) signal;
transmitting the MIMO signal using a plurality of transmit antennas;
receiving an indication to apply a maximum power reduction (MPR), wherein the MPR based at least in part on an error vector magnitude (EVM) associated with the MIMO signal and a number of transmit antennas of the UE; and
performing one or more subsequent transmissions at a power level based on the MPR.

16. A base station for wireless communication, comprising:
at least one memory; and
at least one processor coupled with the at least one memory and configured to cause the base station to:
identify a set of maximum power reduction (MPR) tables based at least in part on a receiver algorithm used by the base station;
select a MPR table from the set of MPR tables based at least in part on an error vector magnitude (EVM) requirement of a user equipment (UE) and a number of transmit antennas of the UE;
transmit, to the UE, an indication to apply the selected MPR table; and
receive one or more uplink (UL) transmissions at a power level based on the MPR.

17. The base station of claim 16, wherein the receiver algorithm comprises a linear unbiased minimum mean squared error (MMSE) receiver or a pseudo-inverse multiple-input, multiple-output (MIMO) receiver.

18. The base station of claim 16, wherein the set of MPR tables is further based on a number of transmission layers associated the one or more UL transmissions, and wherein the EVM requirement is based at least in part on the receiver algorithm.

19. The base station of claim 16, wherein the at least one processor is configured to cause the base station to select the MPR table further based on an EVM measurement associated with the number of transmit antennas of the UE.

20. The base station of claim 16, wherein the selected MPR table corresponds to the number of transmit antennas of the UE and a number of transmission layers associated with a multiple-input, multiple-output (MIMO) signal.