US 20250260540A1

(19) **United States**
(12) **Patent Application Publication**
Guo et al.

(10) **Pub. No.: US 2025/0260540 A1**
(43) **Pub. Date: Aug. 14, 2025**

(54) **REFERENCE SIGNAL ASSOCIATION FOR MULTIPLE UPLINK CODEWORDS**

(71) Applicant: **QUALCOMM INCORPORATED**, San Diego, CA (US)

(72) Inventors: **Shaozhen Guo**, Beijing (CN); **Mostafa Khoshnevisan**, San Diego, CA (US); **Jing Sun**, San Diego, CA (US); **Xiaoxia Zhang**, San Diego, CA (US)

(21) Appl. No.: **18/844,218**

(22) PCT Filed: **Apr. 29, 2022**

(86) PCT No.: **PCT/CN2022/090487**

§ 371 (c)(1),
(2) Date: **Sep. 5, 2024**

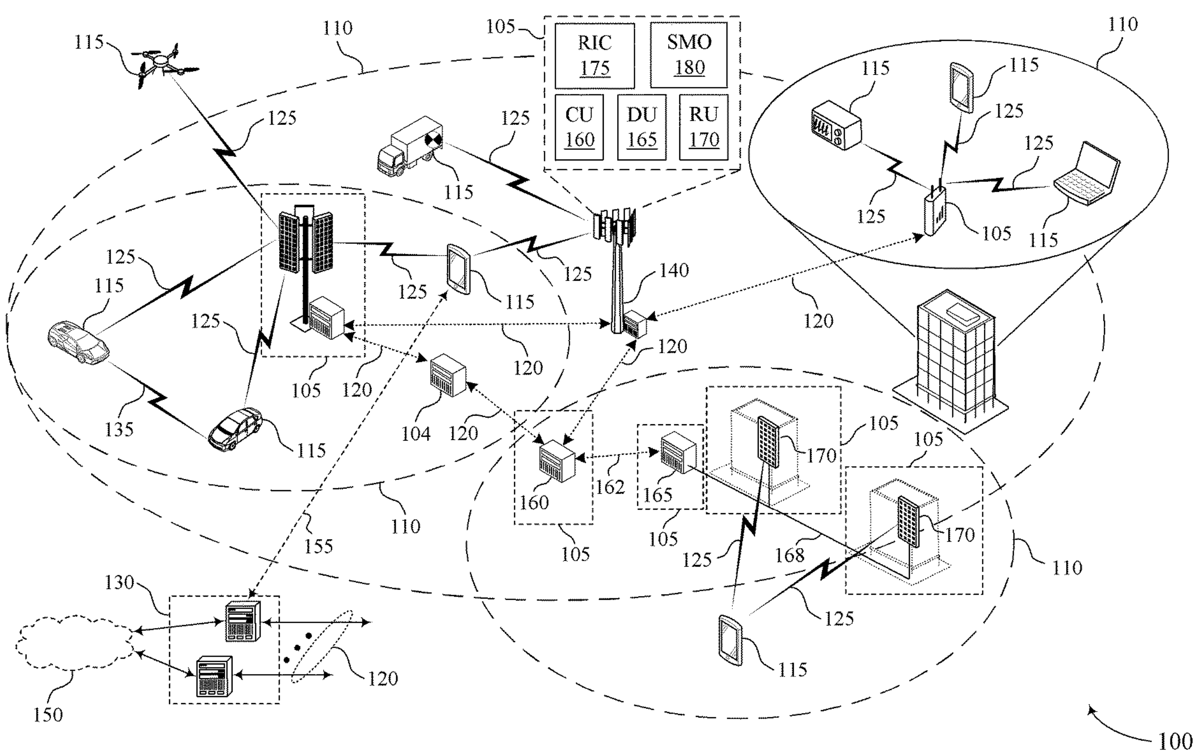
Publication Classification

(51) **Int. Cl.**
H04L 5/00 (2006.01)
H04W 72/231 (2023.01)

(52) **U.S. Cl.**
CPC ***H04L 5/0053*** (2013.01); ***H04L 5/0044*** (2013.01); ***H04L 5/0091*** (2013.01); ***H04W 72/231*** (2023.01)

(57) **ABSTRACT**

Methods, systems, and devices for wireless communications are described. A user equipment (UE) may receive radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel (PUSCH) and a phase tracking reference signal (PT-RS) configuration. The UE may receive downlink control information (DCI) including an indication of an association between PT-RS ports and demodulation reference signal (DM-RS) ports based on the PT-RS configuration. In some examples, the DCI schedules a first codeword and a second codeword for an uplink transmission. The UE may select a codeword from the first codeword and the second codeword for the uplink transmission, and may transmit, via the PUSCH according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with the selected codeword based on the association.



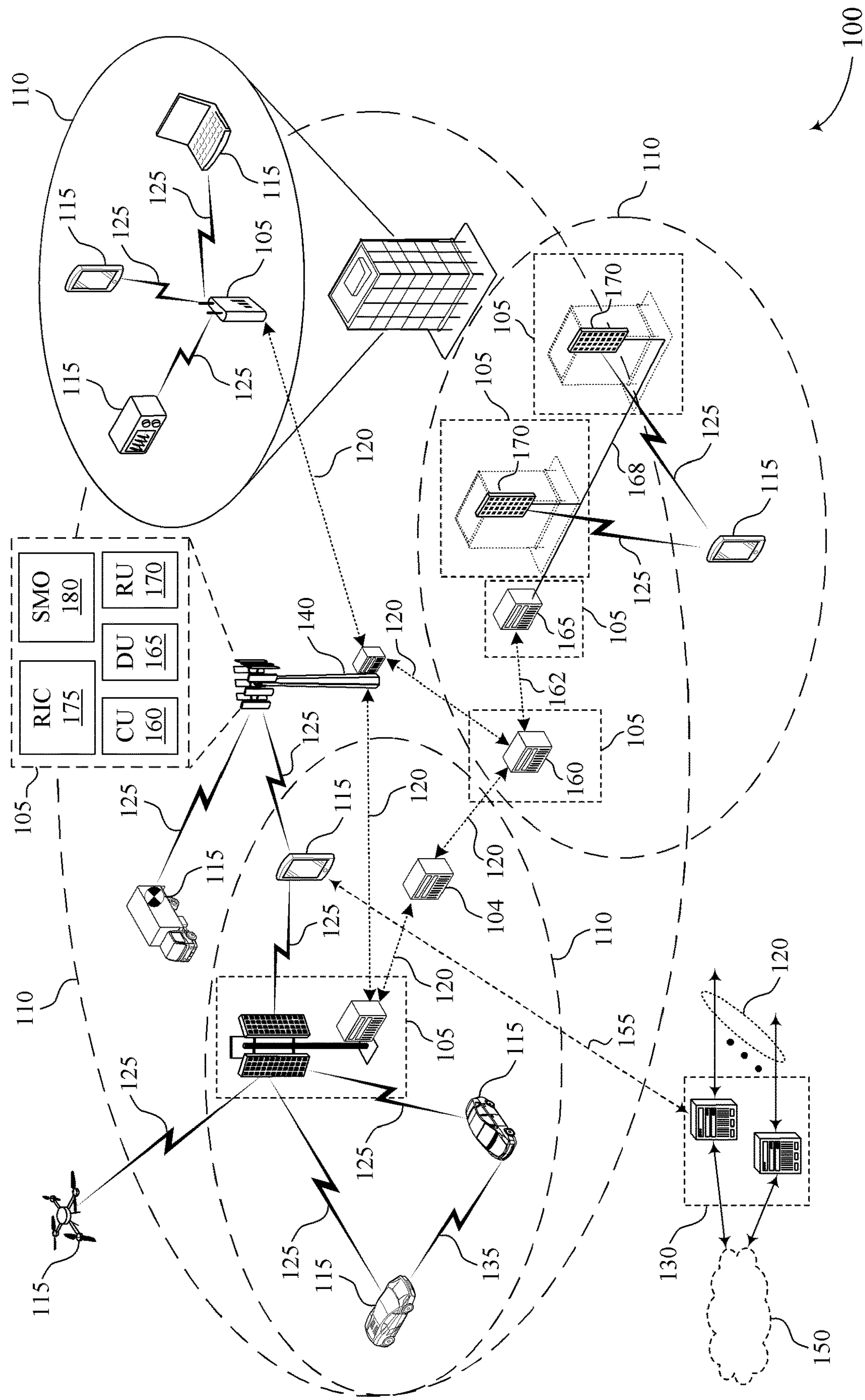


FIG. 1

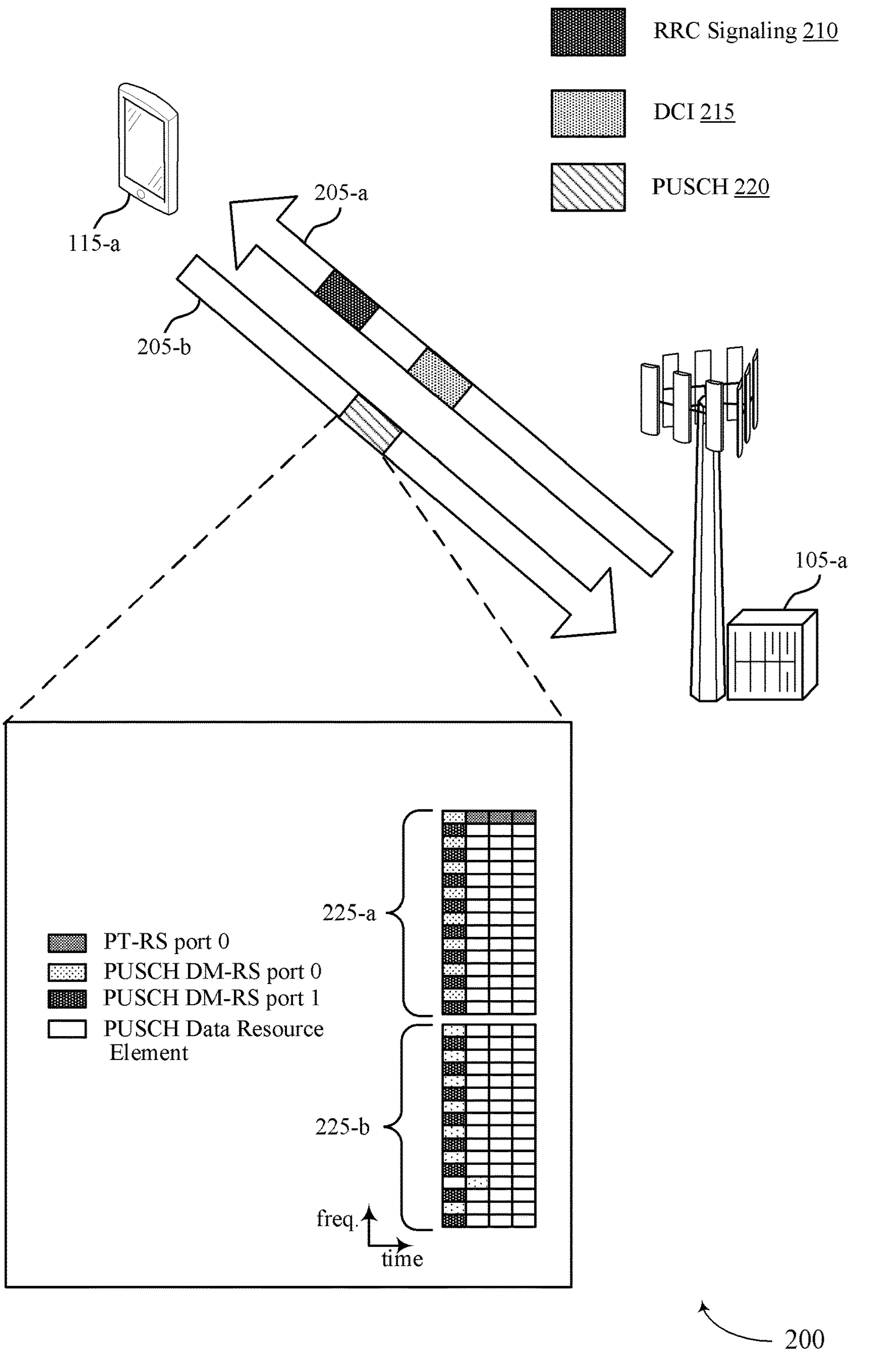

RRC Signaling 210
DCI 215
PUSCH 220
205-a
115-a
205-b
105-a
225-a
PT-RS port 0
PUSCH DM-RS port 0
PUSCH DM-RS port 1
PUSCH Data Resource Element
225-b
freq.
time
200

FIG. 2

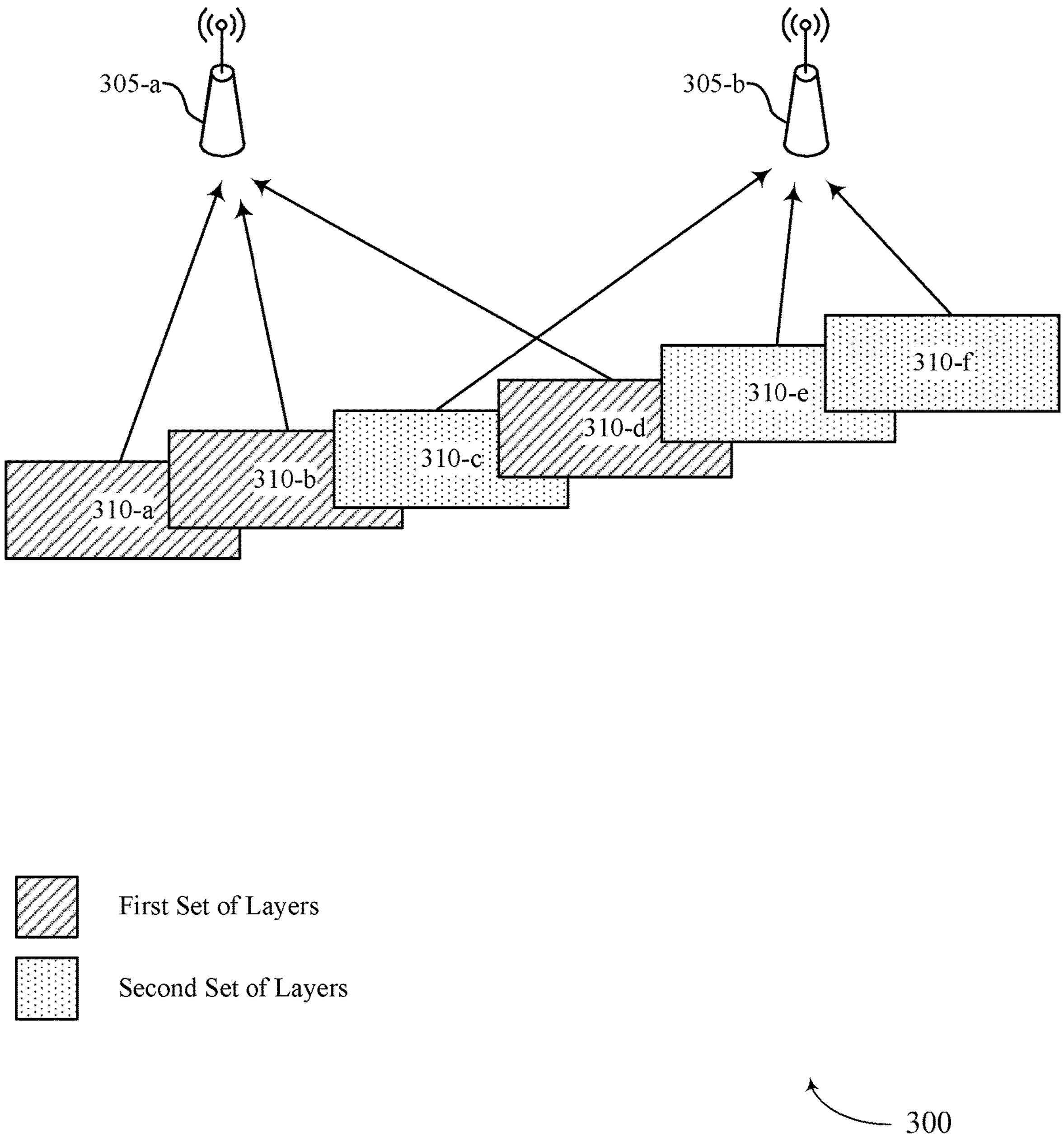

305-a
305-b
310-a
310-b
310-c
310-d
310-e
310-f
First Set of Layers
Second Set of Layers
300

FIG. 3

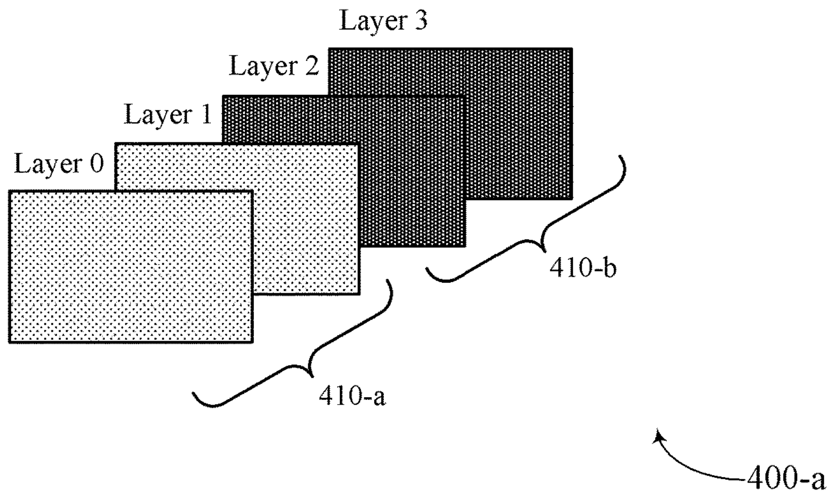


FIG. 4A

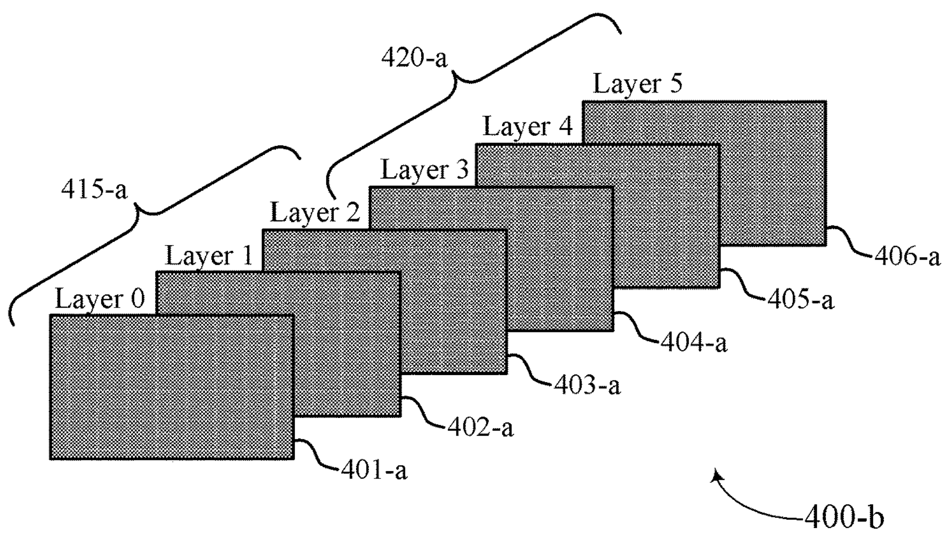


FIG. 4B

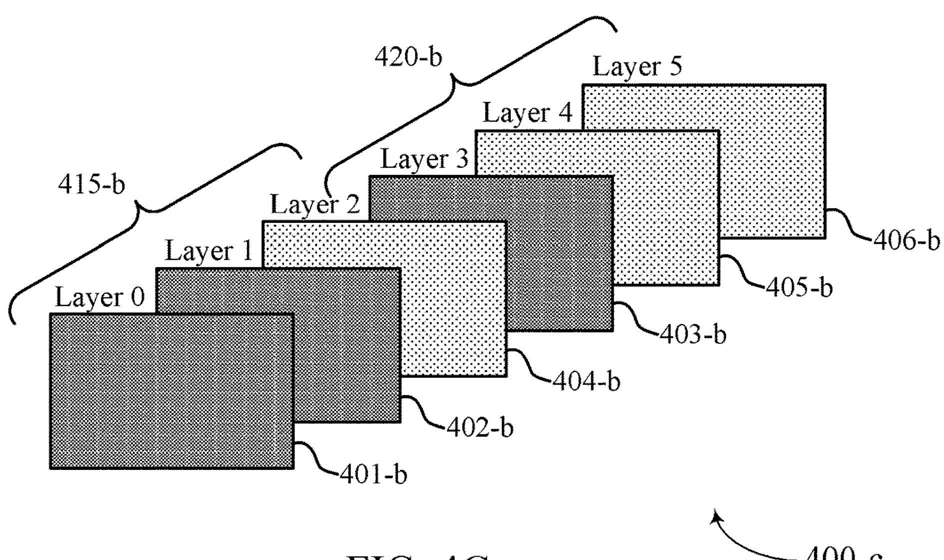


FIG. 4C

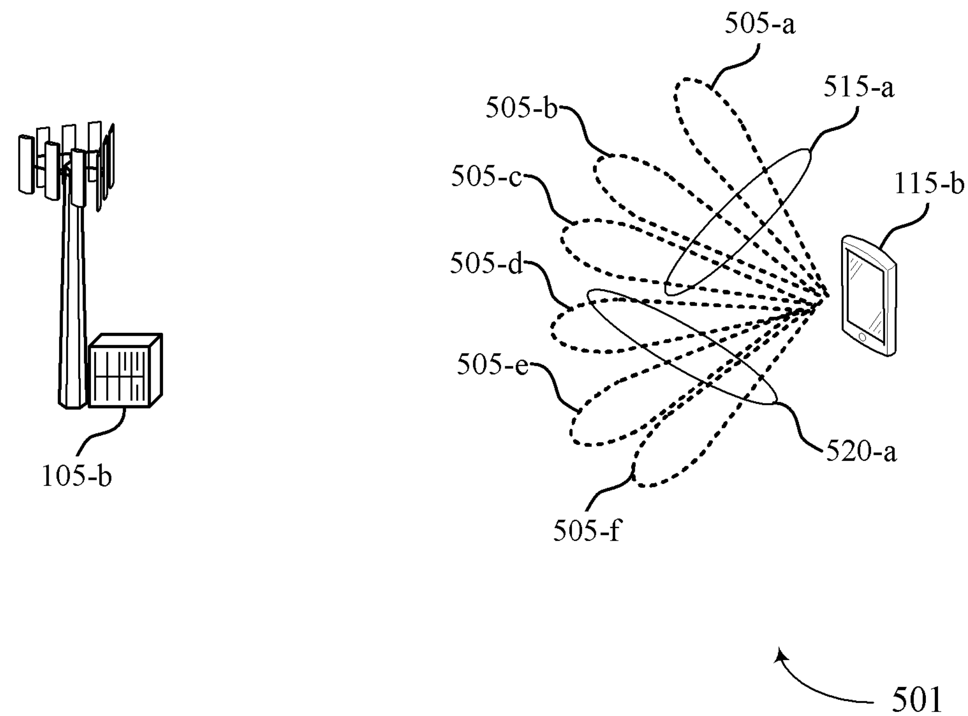

505-a
505-b
515-a
505-c
115-b
505-d
505-e
520-a
105-b
505-f
501

FIG. 5A

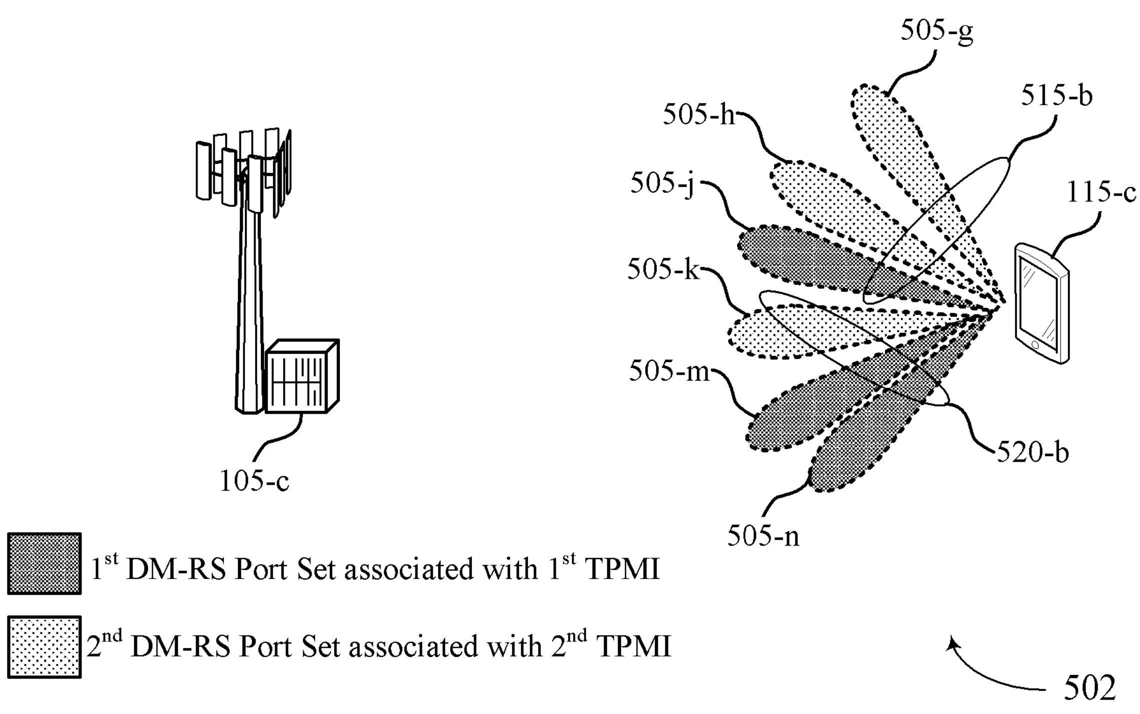

505-g
505-h
515-b
505-j
115-c
505-k
505-m
520-b
105-c
505-n
1st DM-RS Port Set associated with 1st TPMI
2nd DM-RS Port Set associated with 2nd TPMI
502

FIG. 5B

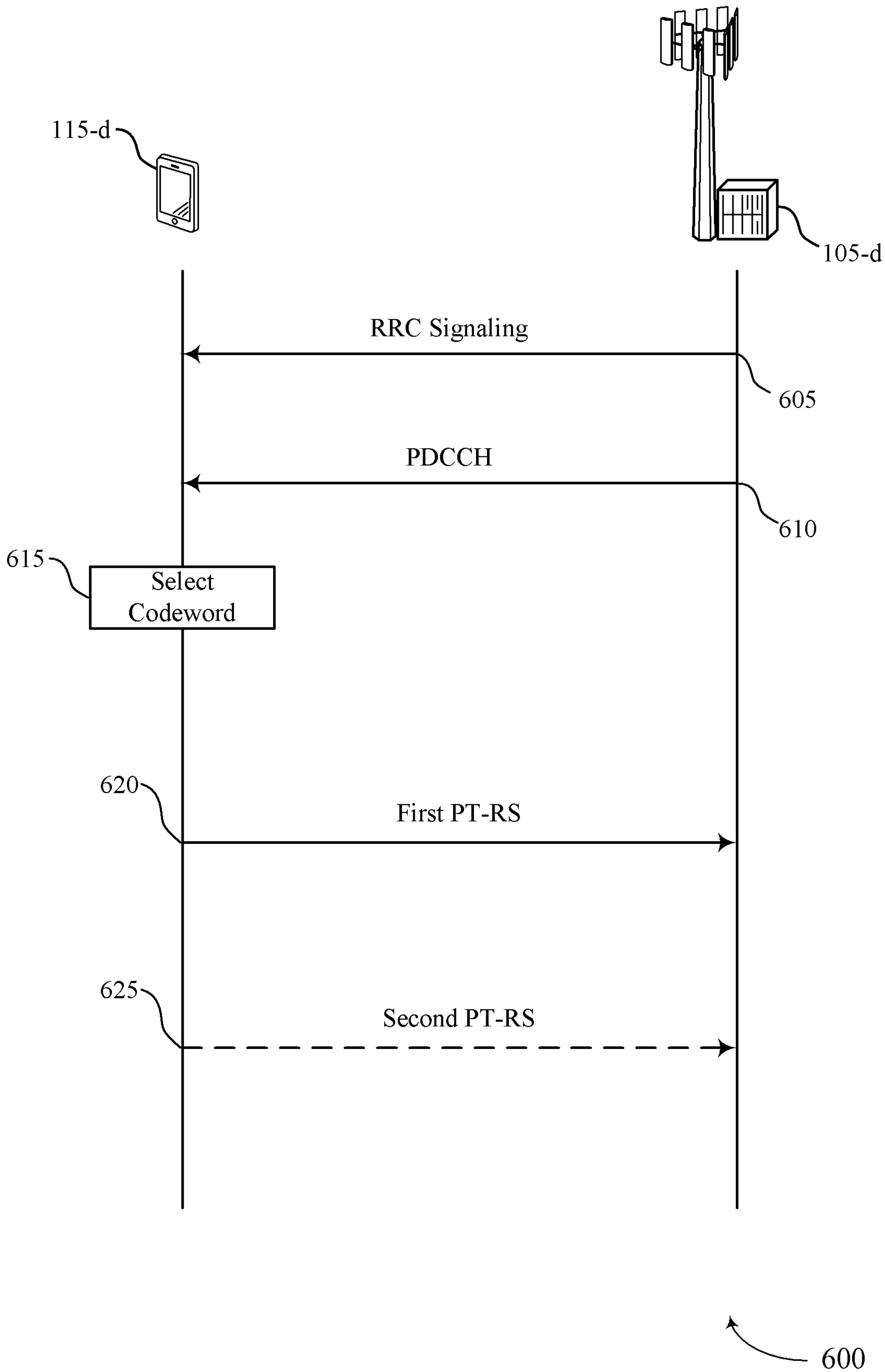

115-d
105-d
RRC Signaling
605
PDCCH
610
615
Select Codeword
620
First PT-RS
625
Second PT-RS
600

FIG. 6

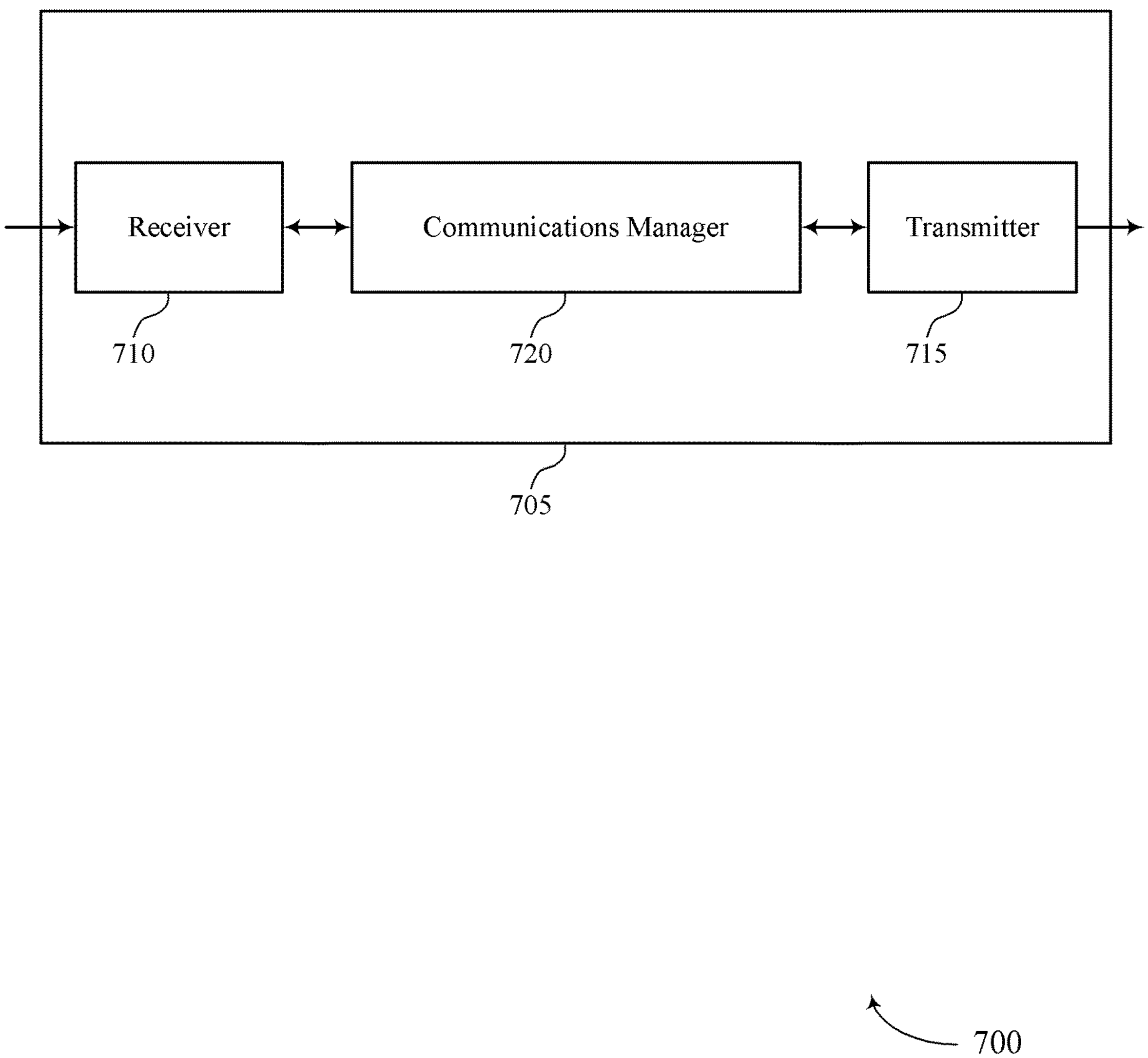

Receiver
Communications Manager
Transmitter
710
720
715
705
700

FIG. 7

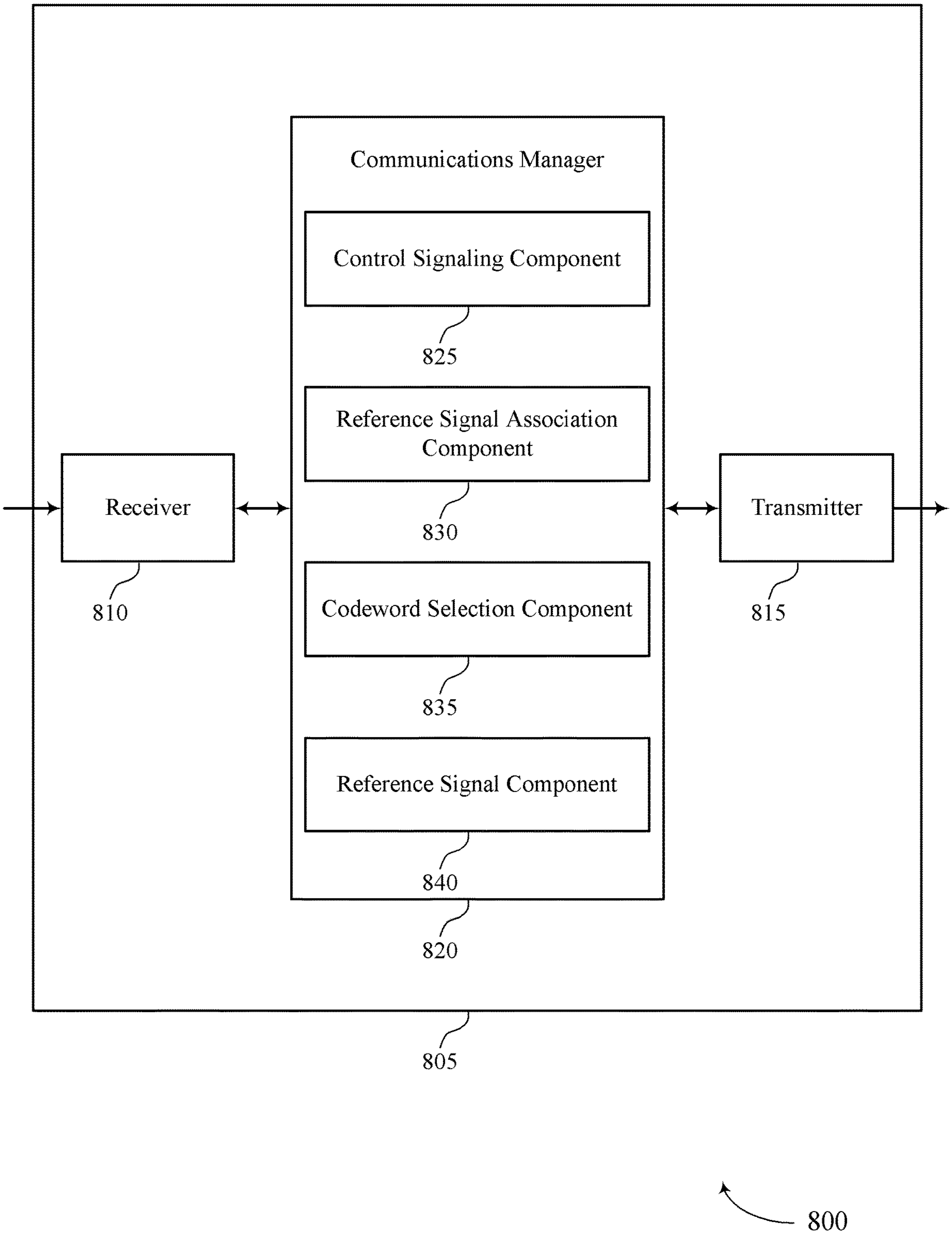

Communications Manager
Control Signaling Component
825
Reference Signal Association Component
830
Receiver
810
Transmitter
815
Codeword Selection Component
835
Reference Signal Component
840
820
805
800

FIG. 8

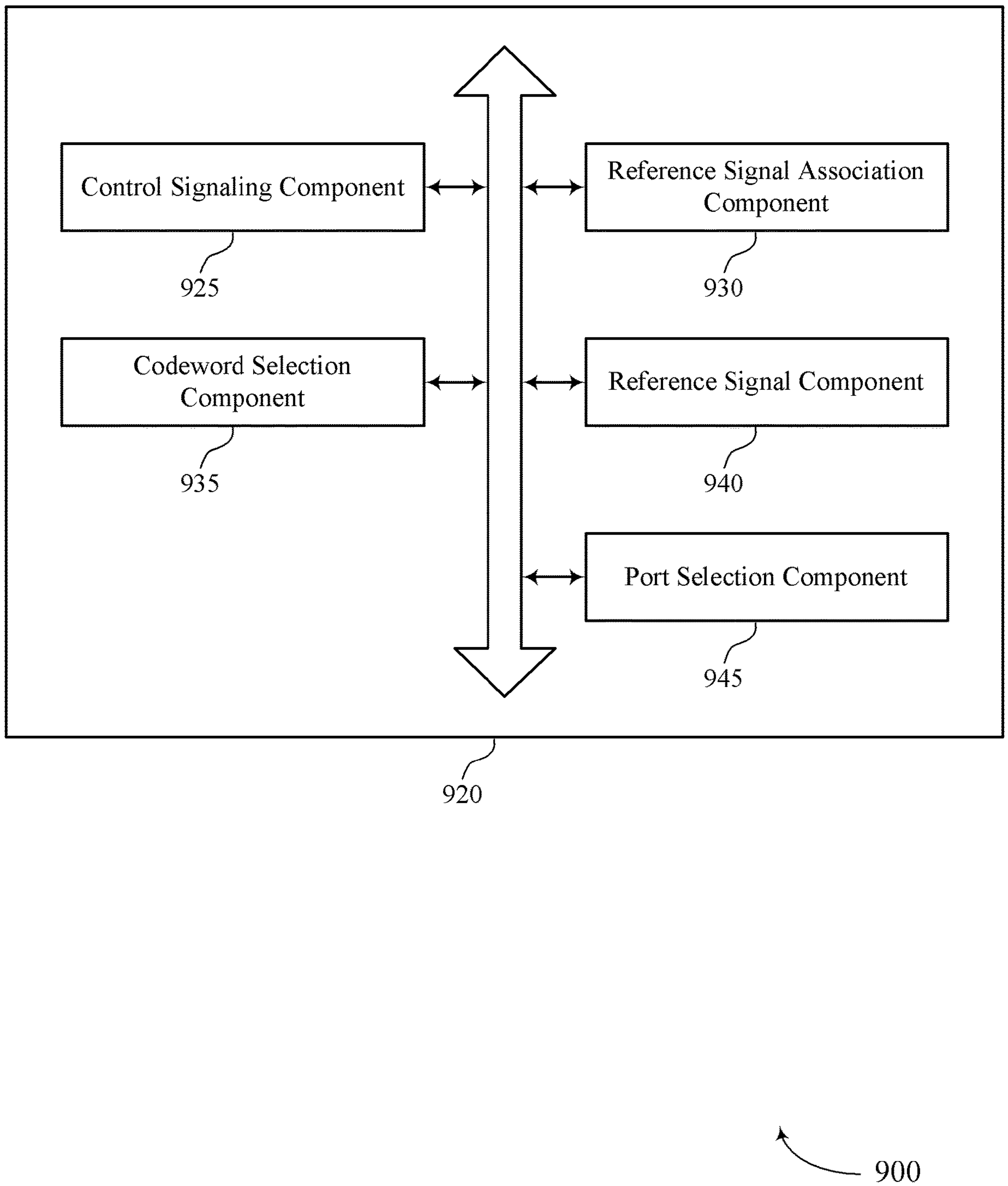

Control Signaling Component
925
Reference Signal Association Component
930
Codeword Selection Component
935
Reference Signal Component
940
Port Selection Component
945
920
900

FIG. 9

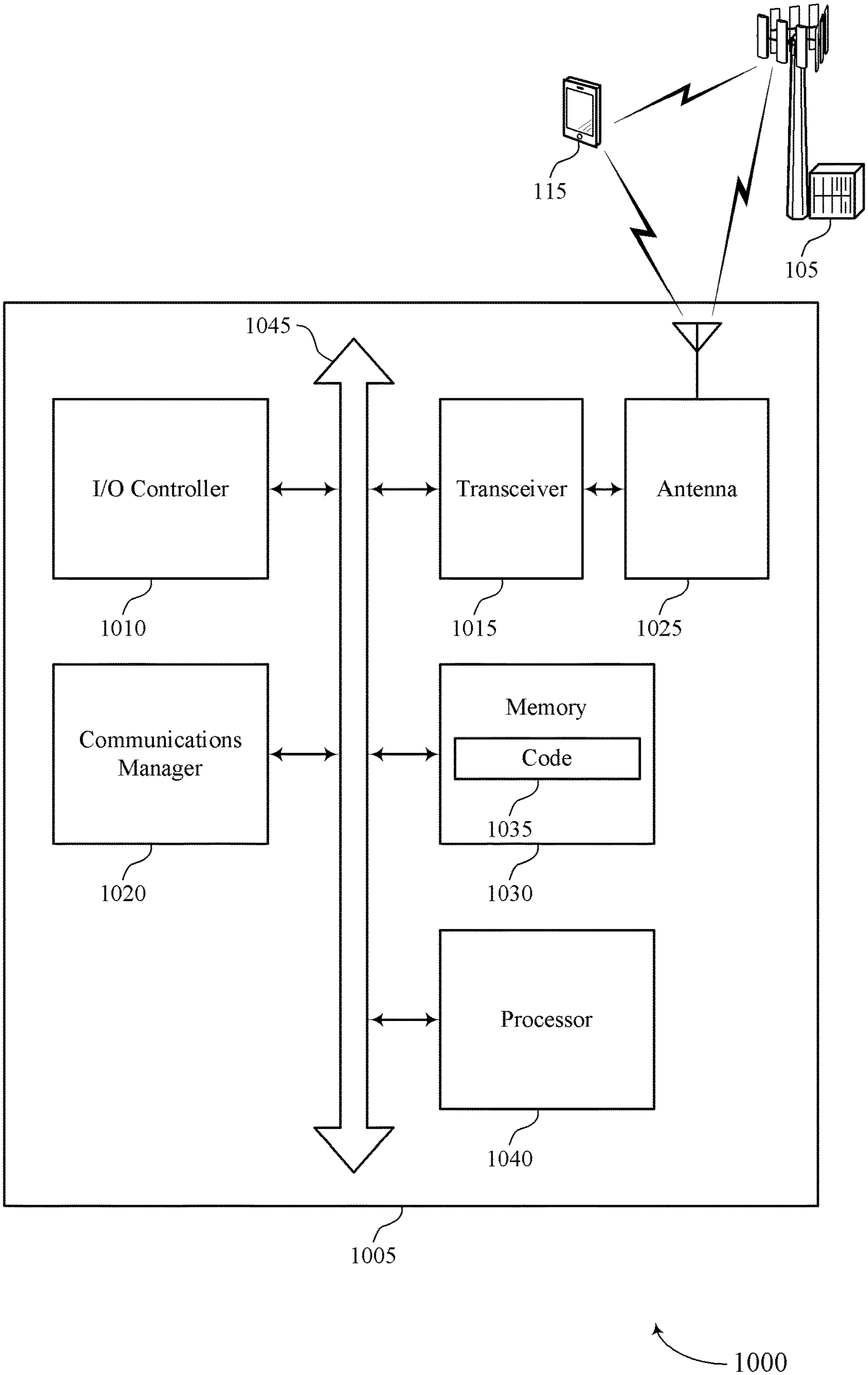

115
105
1045
I/O Controller
Transceiver
Antenna
1010
1015
1025
Communications Manager
Memory
Code
1035
1020
1030
Processor
1040
1005
1000

FIG. 10

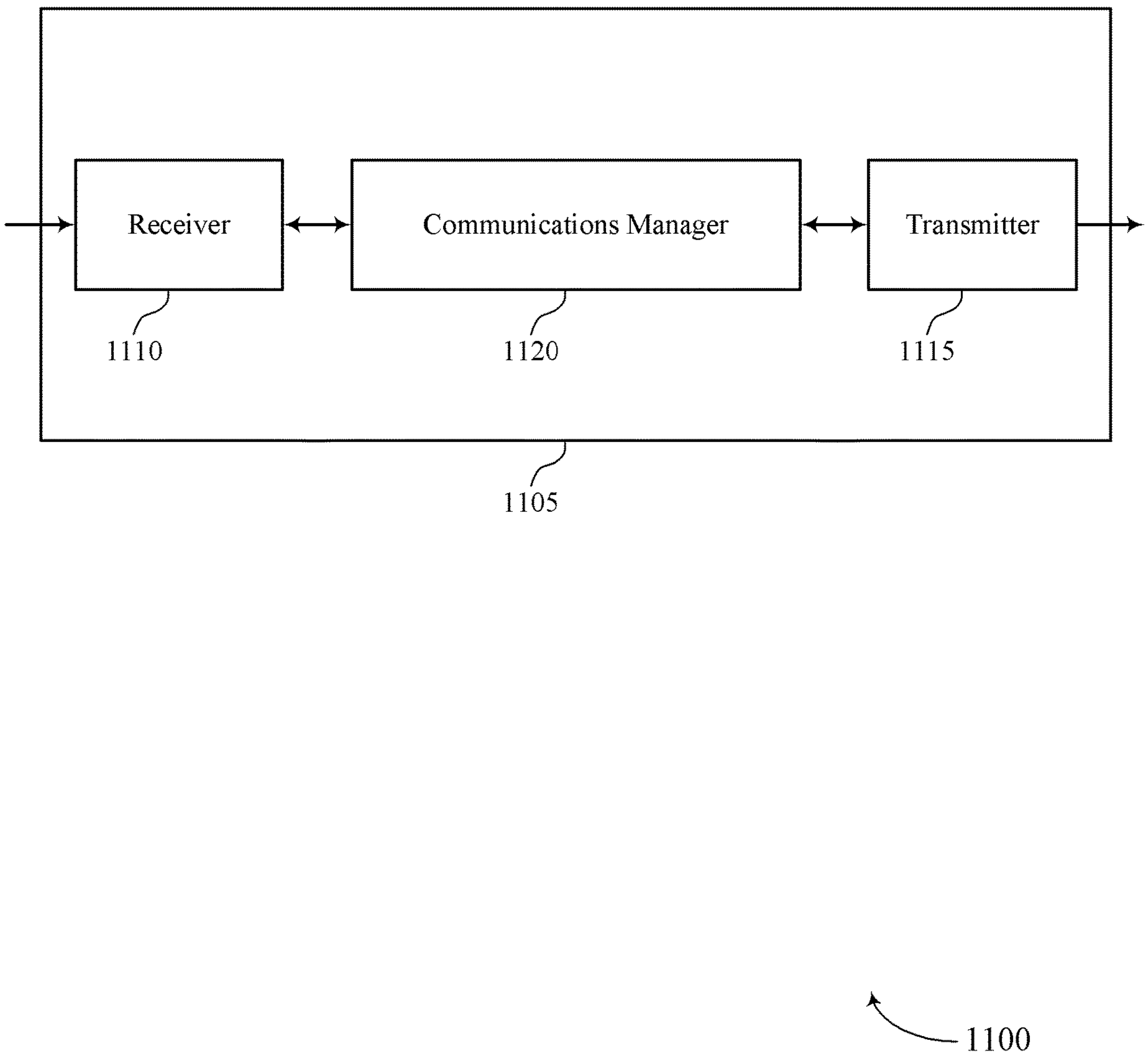

Receiver
Communications Manager
Transmitter
1110
1120
1115
1105
1100

FIG. 11

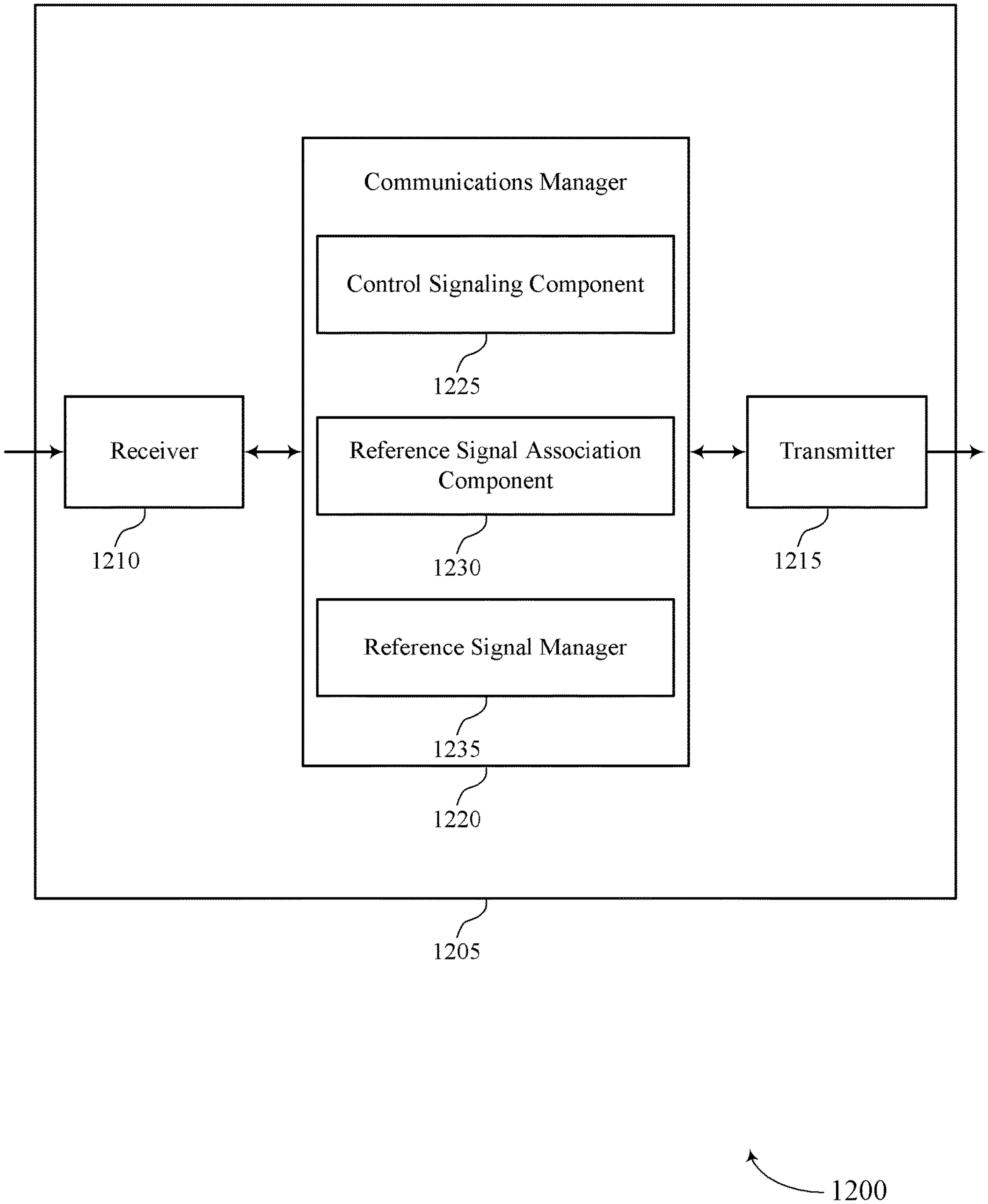
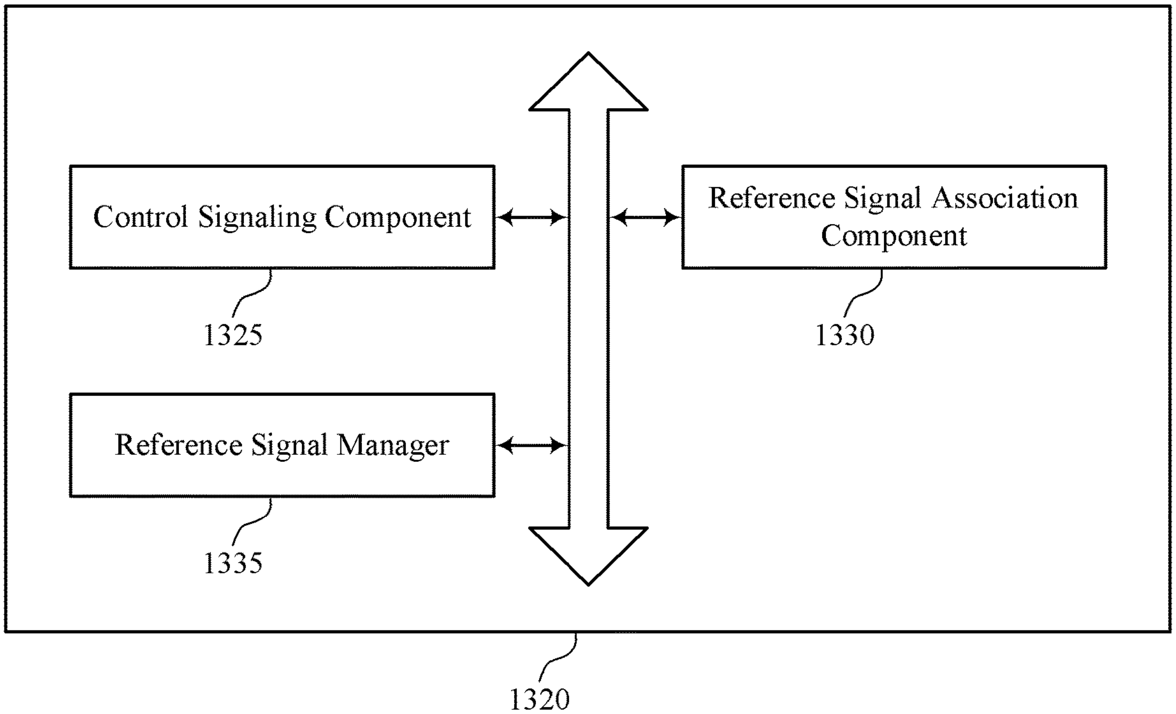

Communications Manager
Control Signaling Component
1225
Receiver
Reference Signal Association Component
Transmitter
1210
1230
1215
Reference Signal Manager
1235
1220
1205
1200

FIG. 12


Control Signaling Component
Reference Signal Association Component
Reference Signal Manager
1325
1330
1335
1320

1300

FIG. 13

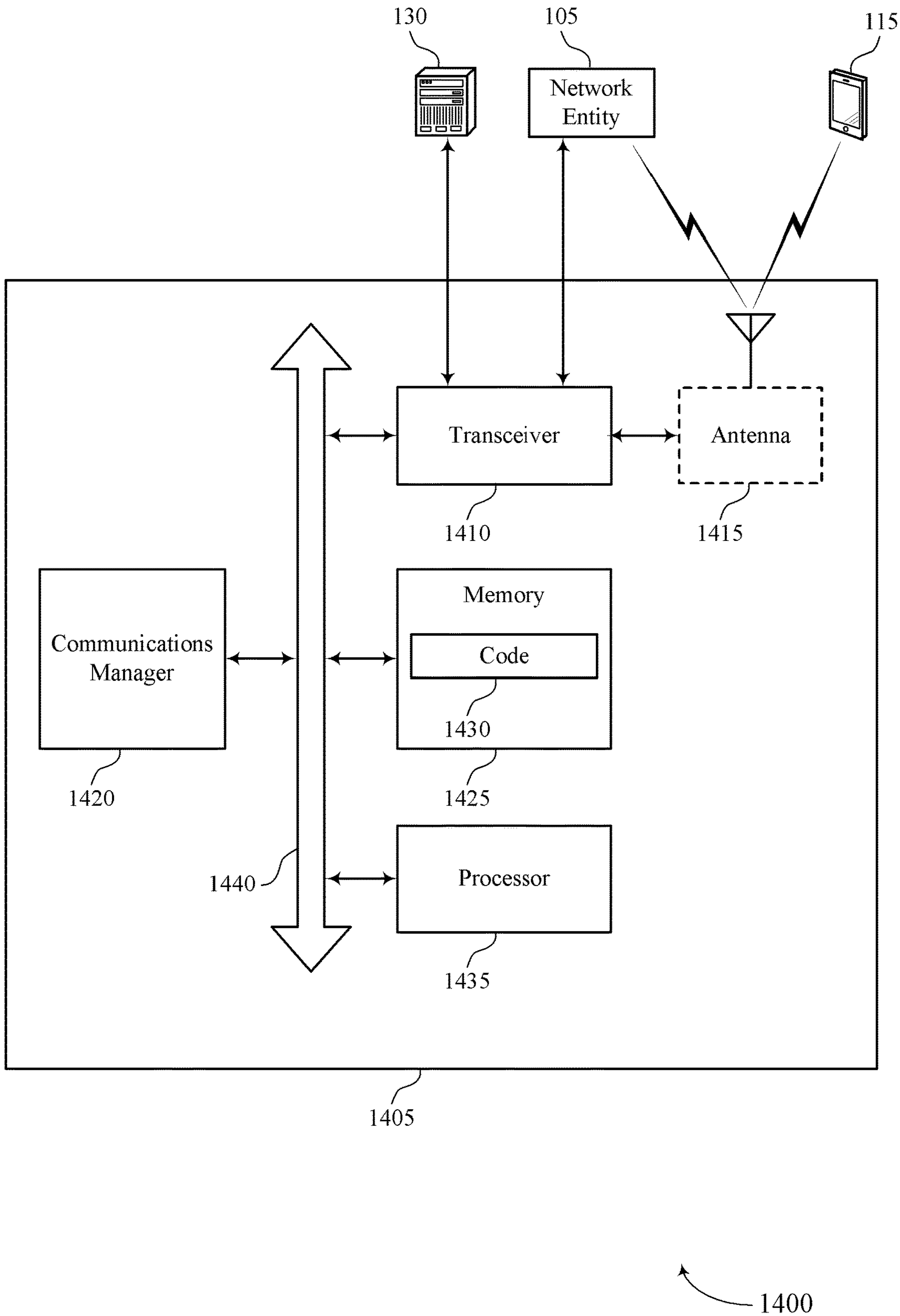

130
105
Network Entity
115
Transceiver
Antenna
1410
1415
Communications Manager
Memory
Code
1430
1425
1420
1440
Processor
1435
1405
1400

FIG. 14

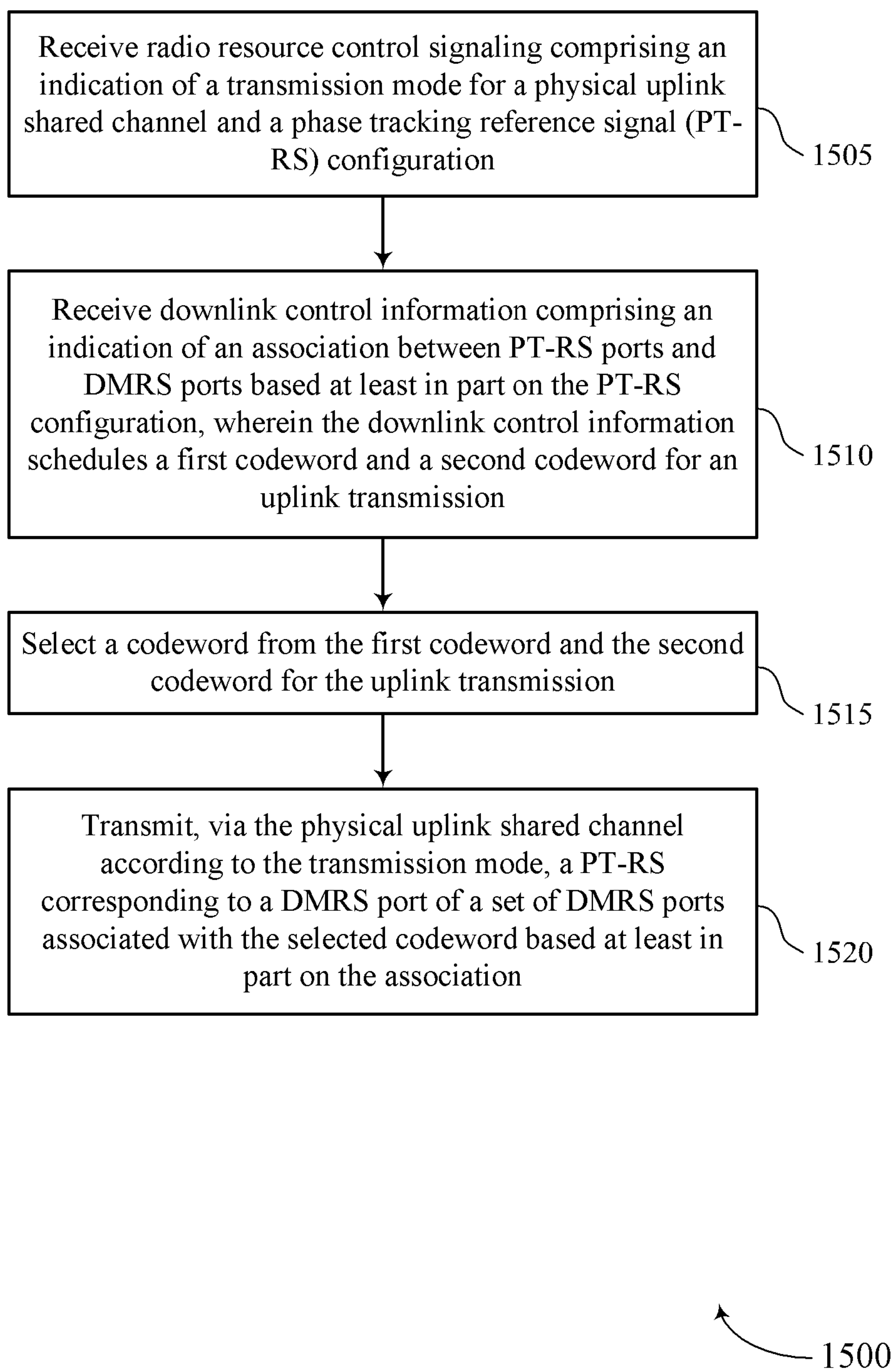

Receive radio resource control signaling comprising an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration
1505
Receive downlink control information comprising an indication of an association between PT-RS ports and DMRS ports based at least in part on the PT-RS configuration, wherein the downlink control information schedules a first codeword and a second codeword for an uplink transmission
1510
Select a codeword from the first codeword and the second codeword for the uplink transmission
1515
Transmit, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DMRS port of a set of DMRS ports associated with the selected codeword based at least in part on the association
1520
1500

FIG. 15

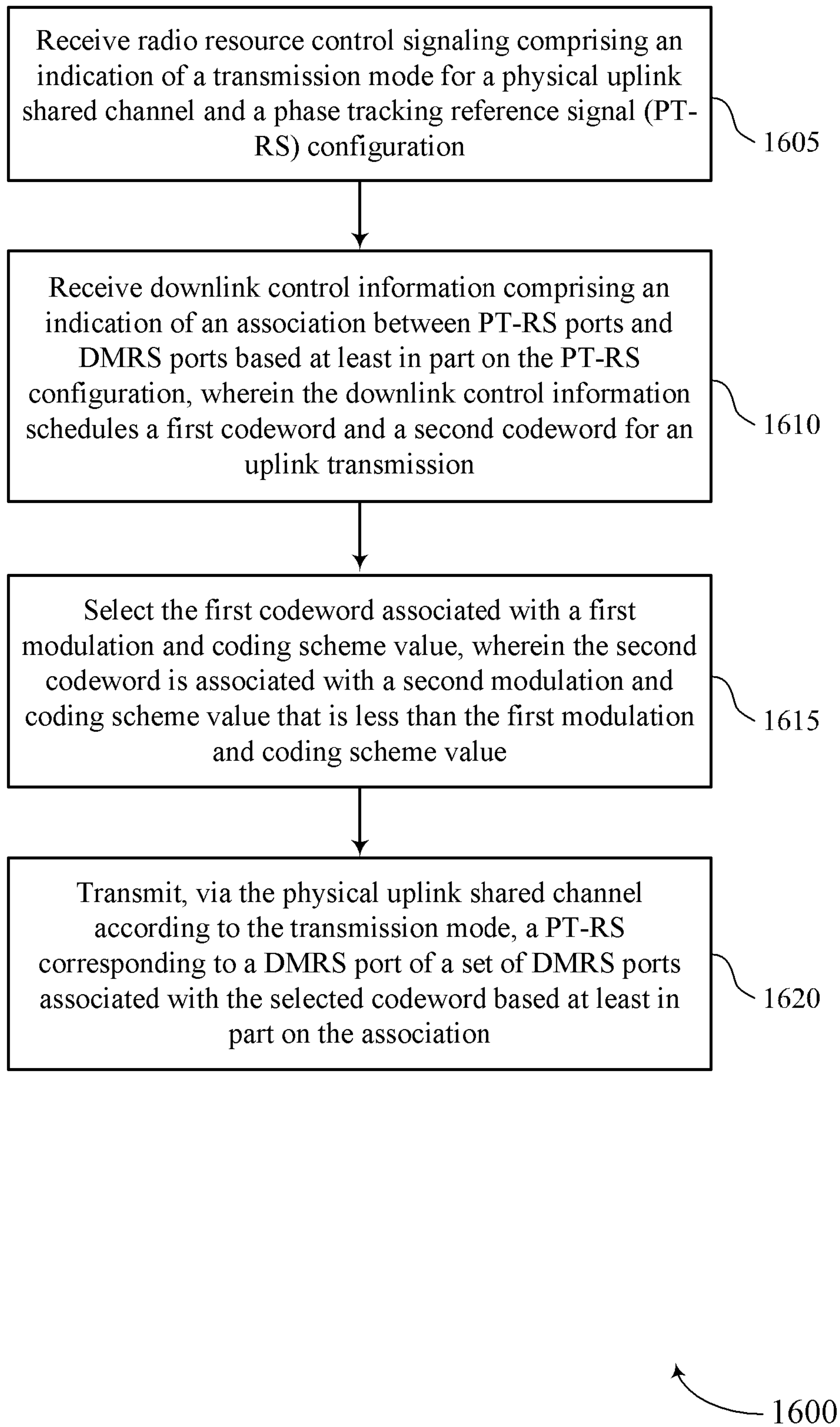

Receive radio resource control signaling comprising an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration
1605
Receive downlink control information comprising an indication of an association between PT-RS ports and DMRS ports based at least in part on the PT-RS configuration, wherein the downlink control information schedules a first codeword and a second codeword for an uplink transmission
1610
Select the first codeword associated with a first modulation and coding scheme value, wherein the second codeword is associated with a second modulation and coding scheme value that is less than the first modulation and coding scheme value
1615
Transmit, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DMRS port of a set of DMRS ports associated with the selected codeword based at least in part on the association
1620
1600

FIG. 16

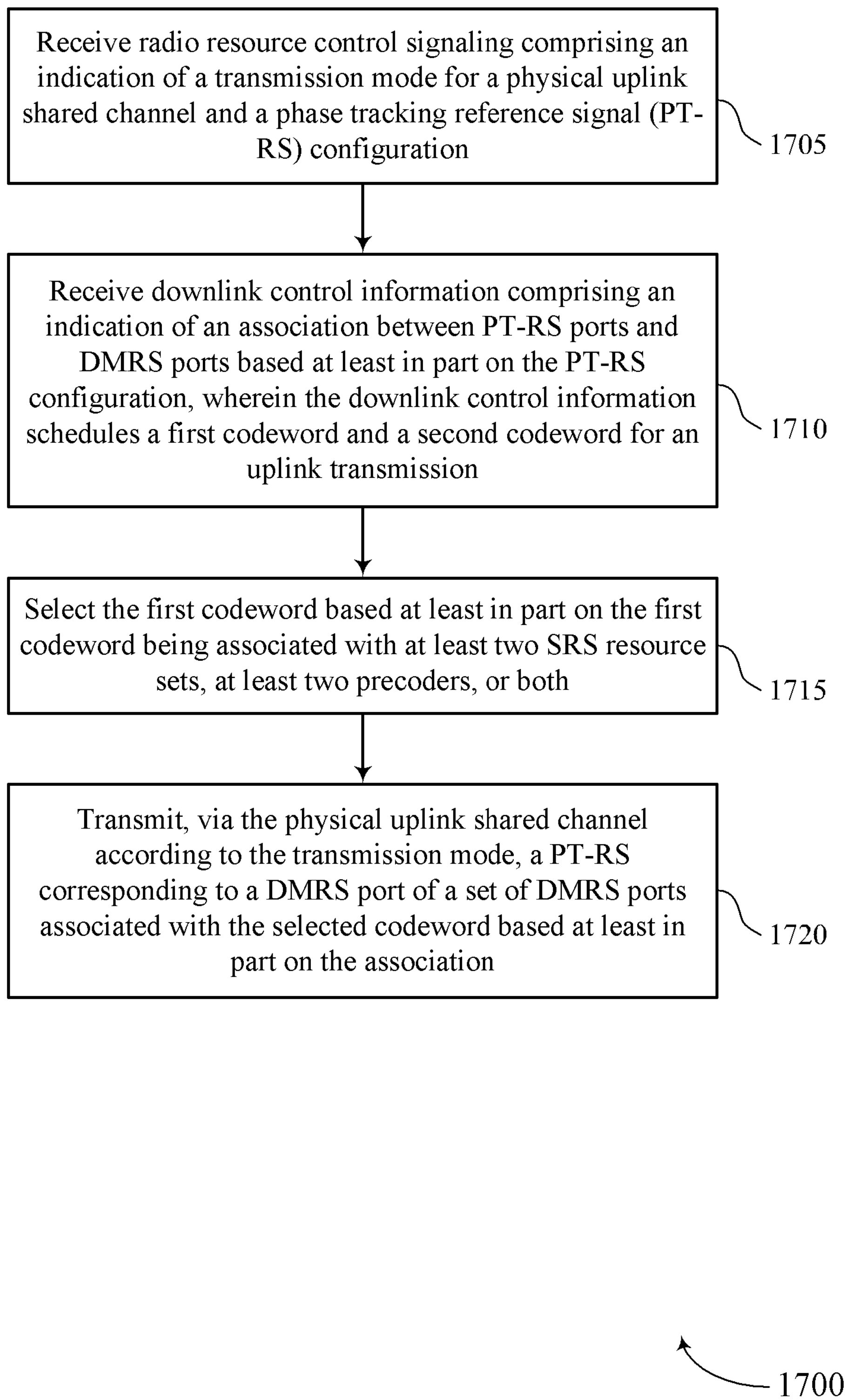

Receive radio resource control signaling comprising an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration
1705
Receive downlink control information comprising an indication of an association between PT-RS ports and DMRS ports based at least in part on the PT-RS configuration, wherein the downlink control information schedules a first codeword and a second codeword for an uplink transmission
1710
Select the first codeword based at least in part on the first codeword being associated with at least two SRS resource sets, at least two precoders, or both
1715
Transmit, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DMRS port of a set of DMRS ports associated with the selected codeword based at least in part on the association
1720
1700

FIG. 17

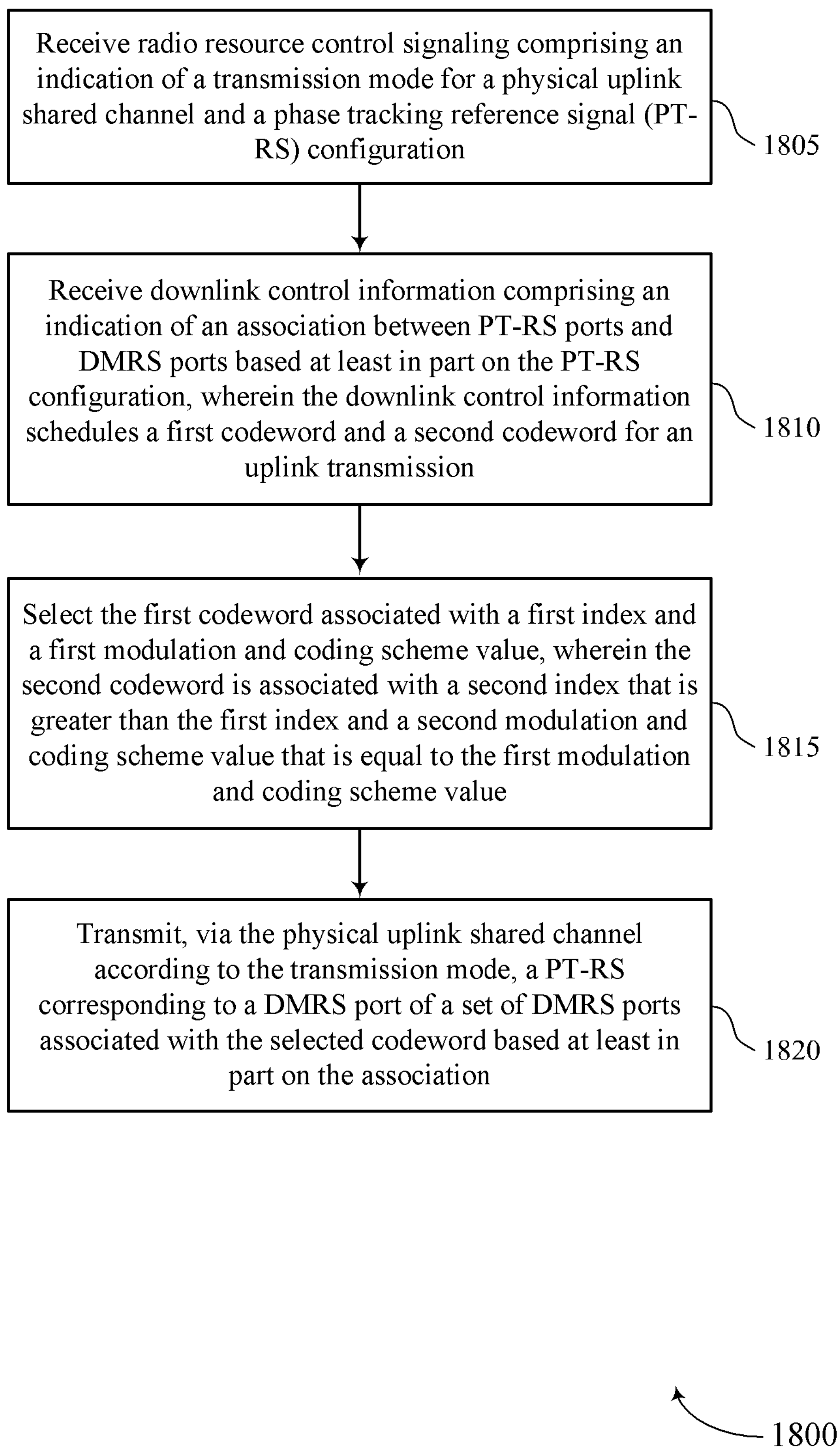

Receive radio resource control signaling comprising an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration
1805
Receive downlink control information comprising an indication of an association between PT-RS ports and DMRS ports based at least in part on the PT-RS configuration, wherein the downlink control information schedules a first codeword and a second codeword for an uplink transmission
1810
Select the first codeword associated with a first index and a first modulation and coding scheme value, wherein the second codeword is associated with a second index that is greater than the first index and a second modulation and coding scheme value that is equal to the first modulation and coding scheme value
1815
Transmit, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DMRS port of a set of DMRS ports associated with the selected codeword based at least in part on the association
1820
1800

FIG. 18

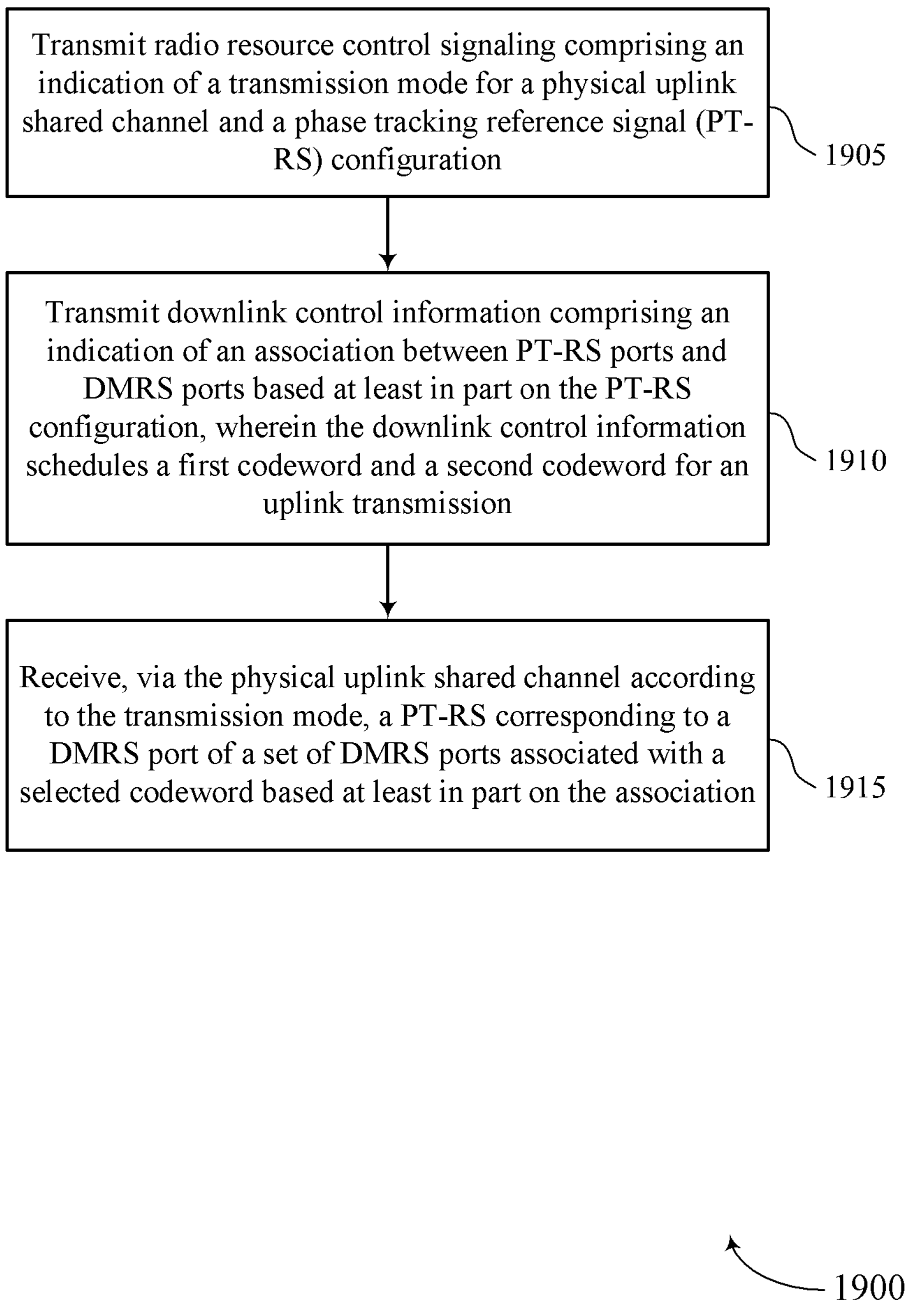

Transmit radio resource control signaling comprising an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration
1905
Transmit downlink control information comprising an indication of an association between PT-RS ports and DMRS ports based at least in part on the PT-RS configuration, wherein the downlink control information schedules a first codeword and a second codeword for an uplink transmission
1910
Receive, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DMRS port of a set of DMRS ports associated with a selected codeword based at least in part on the association
1915
1900

FIG. 19

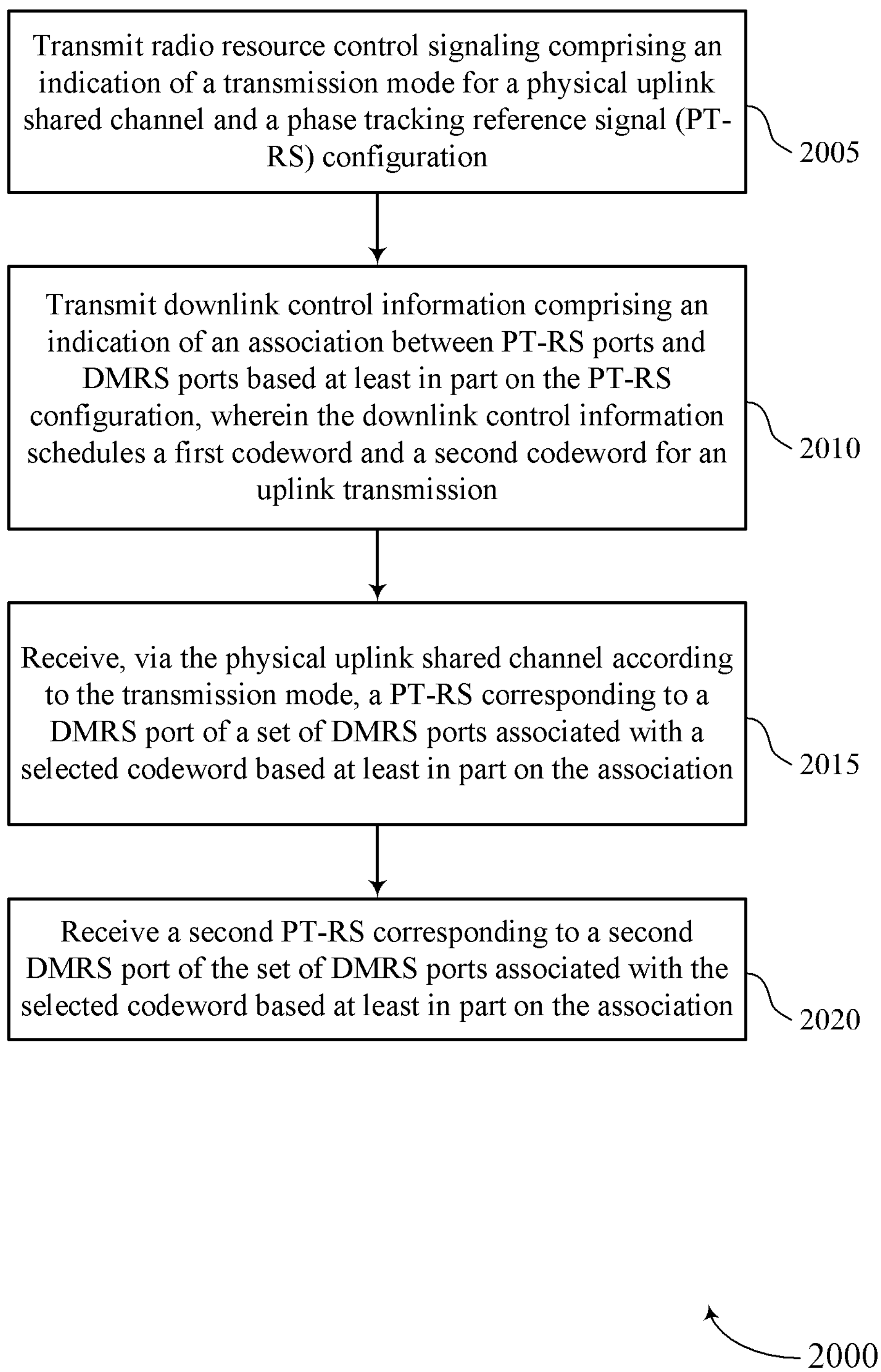

Transmit radio resource control signaling comprising an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration
2005
Transmit downlink control information comprising an indication of an association between PT-RS ports and DMRS ports based at least in part on the PT-RS configuration, wherein the downlink control information schedules a first codeword and a second codeword for an uplink transmission
2010
Receive, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DMRS port of a set of DMRS ports associated with a selected codeword based at least in part on the association
2015
Receive a second PT-RS corresponding to a second DMRS port of the set of DMRS ports associated with the selected codeword based at least in part on the association
2020
2000

FIG. 20

REFERENCE SIGNAL ASSOCIATION FOR MULTIPLE UPLINK CODEWORDS

CROSS REFERENCE

[0001] The present Application is a 371 national stage filing of International PCT Application No. PCT/CN2022/090487 by Guo et al. entitled "REFERENCE SIGNAL ASSOCIATION FOR MULTIPLE UPLINK CODEWORDS," filed Apr. 29, 2022, which is assigned to the assignee hereof, and which is expressly incorporated by reference in its entirety herein.

FIELD OF TECHNOLOGY

[0002] The present disclosure relates to wireless communications, including reference signal association for multiple uplink codewords.

BACKGROUND

[0003] Wireless communications systems are widely deployed to provide various types of communication content such as voice, video, packet data, messaging, broadcast, and so on. These systems may be capable of supporting communication with multiple users by sharing the available system resources (e.g., time, frequency, and power). Examples of such multiple-access systems include fourth generation (4G) systems such as Long Term Evolution (LTE) systems, LTE-Advanced (LTE-A) systems, or LTE-A Pro systems, and fifth generation (5G) systems which may be referred to as New Radio (NR) systems. These systems may employ technologies such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), or discrete Fourier transform spread orthogonal frequency division multiplexing (DFT-S-OFDM). A wireless multiple-access communications system may include one or more base stations, each supporting wireless communication for communication devices, which may be known as user equipment (UE).

[0004] In some wireless communications systems, a wireless device, such as a UE, may experience one or more types or sources of noise that may impact communications at the UE (e.g., from communications performed by the UE, from one or more other wireless devices such as another UE, a network entity, from one or more other sources, phase noise, thermal noise, or otherwise additive noise sources). Phase Tracking Reference Signals (PT-RSs) may be used to track the phase of a local oscillator at a transmitting device to reduce the effects of oscillator phase noise on communications. PT-RSs (e.g., PT-RS repetitions, occasions, instances) may be transmitted via one or more resources of a communications channel (e.g., physical uplink shared channel (PUSCH), physical downlink shared channel (PDSCH)). In some examples, the port used to transmit PT-RS occasions may be associated with one or more ports used to transmit other reference signals, for example, such as demodulation reference signals (DM-RSs) such that a PT-RS may be transmission over a set of resources (e.g., spatial resources, layers) associated with reliable communications (e.g., a strongest layer). The UE may transmit one or more PT-RS occasions in one or more resources of the communications channel according to the association.

SUMMARY

[0005] The described techniques relate to improved methods, systems, devices, and apparatuses that support reference signal association for multiple uplink codewords. For example, the described techniques provide for transmitting phase tracking reference signals (PT-RSs) according to an association between one or more PT-RS ports and one or more demodulation reference signal (DM-RS) ports when an uplink channel is scheduled with two or more codewords and multiple spatial resources (e.g., layers).

[0006] For example, a number of antenna ports for transmitting DM-RSs may be configured via control information (e.g., downlink control information (DCI)) which may indicate which resources or ports, or both over which to transmit DM-RSs. The control information or other control signaling (e.g., DCI, radio resource control (RRC) signaling) may indicate an association between one or more configured PT-RS ports and the one or more DM-RS ports. In some examples, more than one DM-RS port may be associated with each configured PT-RS port.

[0007] A network entity may schedule an uplink channel (e.g., a physical uplink shared channel (PUSCH)) transmission at the UE having a number of spatial layers (e.g., up to four), each layer may be associated with a port for transmitting a DM-RS. When the uplink physical channel transmissions is scheduled with 2 to 4 layers, the UE may support two codewords for transmission of the uplink channel, each having an associated set of DM-RS ports. As such, the UE may determine one or more PT-RS/DM-RS associations when two codewords are scheduled for multi-layer uplink data transmission by selecting a codeword out of the scheduled codewords based on one or more parameters associated with the uplink data transmission, control signaling, control information, or a combination thereof. The UE may determine which DM-RS ports are associated with the selected codeword and may determine the PT-RS/DM-RS association based on a PT-RS/DM-RS association indication via uplink DCI. As such, the PT-RS/DM-RS association for transmitting PT-RSs over multi-codeword configurations may be based on the selected codeword.

[0008] A method for wireless communication at a user equipment (UE) is described. The method may include receiving radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration, receiving downlink control information including an indication of an association between PT-RS ports and demodulation reference signal (DM-RS) ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission, selecting a codeword from the first codeword and the second codeword for the uplink transmission, and transmitting, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with the selected codeword based on the association.

[0009] An apparatus for wireless communication at a UE is described. The apparatus may include a processor, memory coupled with the processor, and instructions stored in the memory. The instructions may be executable by the processor to cause the apparatus to receive radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase

tracking reference signal (PT-RS) configuration, receive downlink control information including an indication of an association between PT-RS ports and demodulation reference signal (DM-RS) ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission, select a codeword from the first codeword and the second codeword for the uplink transmission, and transmit, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with the selected codeword based on the association.

[0010] Another apparatus for wireless communication at a UE is described. The apparatus may include means for receiving radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration, means for receiving downlink control information including an indication of an association between PT-RS ports and demodulation reference signal (DM-RS) ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission, means for selecting a codeword from the first codeword and the second codeword for the uplink transmission, and means for transmitting, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with the selected codeword based on the association.

[0011] A non-transitory computer-readable medium storing code for wireless communication at a UE is described. The code may include instructions executable by a processor to receive radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration, receive downlink control information including an indication of an association between PT-RS ports and demodulation reference signal (DM-RS) ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission, select a codeword from the first codeword and the second codeword for the uplink transmission, and transmit, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with the selected codeword based on the association.

[0012] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, selecting the codeword may include operations, features, means, or instructions for selecting the first codeword associated with a first modulation and coding scheme value, where the second codeword may be associated with a second modulation and coding scheme value that may be less than the first modulation and coding scheme value.

[0013] Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for determining that the first codeword associated with the first modulation and coding scheme value may be associated with at least two sounding reference signal (SRS) resource sets, at least two precoders, or both based on the PT-RS configuration indicating at least two available ports for transmitting one or more PT-RSs, where the physical uplink shared channel may be associated with a first set of transmission parameters and a second set of transmission parameters.

[0014] Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for transmitting a second PT-RS corresponding to a second DM-RS port of a second set of DM-RS ports associated with the selected codeword based on the association.

[0015] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, selecting the codeword may include operations, features, means, or instructions for selecting the first codeword based on the first codeword being associated with at least two SRS resource sets, at least two precoders, or both.

[0016] Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for determining that a second codeword may be associated with at least two SRS resource sets, at least two precoders, or both, where selecting the first codeword may be further based on a modulation and coding scheme value of the first codeword, an index of the first codeword, or both.

[0017] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, selecting the codeword may include operations, features, means, or instructions for selecting the first codeword associated with a first index and a first modulation and coding scheme value, where the second codeword may be associated with a second index that may be greater than the first index and a second modulation and coding scheme value that may be equal to the first modulation and coding scheme value.

[0018] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the radio resource control signaling, or the downlink control information, or both includes an indication of the first codeword or the second codeword, selecting the codeword includes, and selecting the indicated codeword.

[0019] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the PT-RS configuration indicates a single available port for transmitting a PT-RS and the transmission mode may be codebook-based or non-codebook-based.

[0020] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the indication of the association includes two bits indicating a DM-RS port of the set of DM-RS ports associated with the selected codeword.

[0021] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the PT-RS configuration indicates a set of multiple available ports for transmitting one or more PT-RSs.

[0022] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the indication of the association includes at least two bits and the method, apparatuses, and non-transitory computer-readable medium may include further operations, features, means, or instructions for transmitting a second PT-RS corresponding to the second DM-RS port of the second set of DM-RS ports associated with the selected codeword based on the association.

[0023] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, a rank of the physical uplink shared channel may be less than or equal to a threshold rank.

[0024] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the set of DM-RS ports may be associated with a first SRS resource set, a first precoder, or both and the second set of DM-RS ports may be associated with a second SRS resource set, a second precoder, or both.

[0025] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the indication of the association includes a set of multiple bits and the method, apparatuses, and non-transitory computer-readable medium may include further operations, features, means, or instructions for transmitting a second PT-RS corresponding to the second DM-RS port of the second set of DM-RS ports associated with the selected codeword based on the association.

[0026] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, a rank of the physical uplink shared channel may be greater than a threshold rank.

[0027] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the set of DM-RS ports may be associated with a first port for transmitting the PT-RS and a second set of ports may be associated with a second port for transmitting a second PT-RS.

[0028] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the transmission mode may be non-codebook-based.

[0029] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the downlink control information further includes an SRS resource indicator that indicates a set of multiple SRS resources and the method, apparatuses, and non-transitory computer-readable medium may include further operations, features, means, or instructions for determining which of the set of multiple available ports to use for transmitting the one or more PT-RSs based on the selected codeword and the SRS resource indicator, where each SRS resource may be associated with one of the set of multiple available ports for transmitting one or more PT-RSs.

[0030] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, determining which of the set of multiple available ports to use for transmitting the one or more PT-RSs may include operations, features, means, or instructions for determining to use one of the set of multiple available ports based on an PT-RS port index associated with each SRS resource of the SRS resources associated with the selected codeword being the same and determining to use two or more of the set of multiple available ports based on an PT-RS port index associated with multiple SRS resource associated with the selected codeword being different.

[0031] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the transmission mode may be codebook-based.

[0032] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the downlink control information further includes a transmit precoding matrix index and the method, apparatuses, and non-transitory computer-readable medium may include further operations, features, means, or instructions for determining which of the set of multiple available ports to use for transmitting the one or more PT-RSs based on the selected codeword and the transmit precoding matrix index, where the transmit precoding matrix index indicates a set of antenna ports for transmitting the physical uplink shared channel and a precoding matrix including an association between the set of DM-RS ports and the set of antenna ports.

[0033] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, determining which of the set of multiple available ports to use for transmitting the one or more PT-RSs may include operations, features, means, or instructions for determining to use one or more of the set of multiple available ports based on the association between the set of DM-RS ports and the set of antenna ports.

[0034] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the physical uplink shared channel may be associated with a first set of transmission parameters and a second set of transmission parameters.

[0035] A method for wireless communication is described. The method may include transmitting radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration, transmitting downlink control information including an indication of an association between PT-RS ports and demodulation reference signal (DM-RS) ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission, and receiving, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with a selected codeword based on the association.

[0036] An apparatus for wireless communication is described. The apparatus may include a processor, memory coupled with the processor, and instructions stored in the memory. The instructions may be executable by the processor to cause the apparatus to transmit radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration, transmit downlink control information including an indication of an association between PT-RS ports and demodulation reference signal (DM-RS) ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission, and receive, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with a selected codeword based on the association.

[0037] Another apparatus for wireless communication is described. The apparatus may include means for transmitting radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration, means for transmitting downlink control information including an indication of an association between PT-RS ports and demodulation reference signal (DM-RS) ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission, and means for receiving, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with a selected codeword based on the association.

[0038] A non-transitory computer-readable medium storing code for wireless communication is described. The code may include instructions executable by a processor to transmit radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration, transmit downlink control information including an indication of an association between PT-RS ports and demodulation reference signal (DM-RS) ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission, and receive, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with a selected codeword based on the association.

[0039] Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for receiving a second PT-RS corresponding to a second DM-RS port of the set of DM-RS ports associated with the selected codeword based on the association.

[0040] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the indication of the association includes at least two bits indicating the DM-RS port of the set of DM-RS ports associated with the selected codeword.

BRIEF DESCRIPTION OF THE DRAWINGS

[0041] FIG. **1** illustrates an example of a wireless communications system that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure.

[0042] FIG. **2** illustrates an example of a wireless communications system that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure.

[0043] FIG. **3** illustrates an example of a wireless communications that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure.

[0044] FIGS. **4**A, **4**B, & **4**C each illustrate an example of a spatial multiplexing configuration that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure.

[0045] FIGS. **5**A & **5**B illustrate examples of wireless communications systems that each support reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure.

[0046] FIG. **6** illustrates an example of a process flow that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure.

[0047] FIGS. **7** and **8** show block diagrams of devices that support reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure.

[0048] FIG. **9** shows a block diagram of a communications manager that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure.

[0049] FIG. **10** shows a diagram of a system including a device that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure.

[0050] FIGS. **11** and **12** show block diagrams of devices that support reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure.

[0051] FIG. **13** shows a block diagram of a communications manager that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure.

[0052] FIG. **14** shows a diagram of a system including a device that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure.

[0053] FIGS. **15** through **20** show flowcharts illustrating methods that support reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure.

DETAILED DESCRIPTION

[0054] Some wireless communications systems may support communications in relatively higher frequency bands (e.g., FR2, FR4). Communications in these frequencies may be associated with higher levels of some types of noise, for example, such as phase noise. A wireless device, such as a user equipment UE may experience phase noise which may impact communications at the UE (e.g., from communications performed by the UE, from one or more other wireless devices such as another UE, a network entity, from one or more other sources). Phase Tracking Reference Signals (PT-RSs) may be used to track the phase of a local oscillator at a UE to reduce the effects of oscillator phase noise on communications.

[0055] For example, a UE may transmit one or more PT-RSs via one or more resources of a physical channel (e.g., physical uplink shared channel (PUSCH)). In some examples, the antenna port used for transmission of PT-RSs may be associated with one or more antenna ports used for transmission of other reference signals, for example, such as demodulation reference signals (DM-RS). The UE may transmit one or more PT-RSs via one or more resources of the physical uplink channel according to the association.

[0056] A number of antenna ports for transmitting DM-RS may be configured via control signaling (e.g., physical downlink control channel (PDCCH) signaling including downlink control information (DCI)). This control signaling or other control signaling (e.g., RRC signaling) may indicate an association between the one or more PT-RS ports and the one or more DM-RS ports based on a single codeword associated with the physical uplink channel. In some examples, more than one DM-RS port may be associated with each configured PT-RS port. A network entity may schedule an uplink transmission (e.g., PUSCH) for the UE having a number of spatial layers, each layer associated with a port for transmitting a DM-RS. When the uplink transmission is scheduled with 2 to 4 or more layers, the UE may support multiple codewords for transmission of the uplink physical channel, each having an associated set of DM-RS ports. Thus, the UE may determine a PT-RS/DM-RS association corresponding to one of the multiple codewords.

[0057] For example, the UE may determine PT-RS/DM-RS associations when multiple codewords are scheduled for multi-layer PUSCH by selecting a codeword out of the total number of scheduled codewords based on one or more parameters associated with the uplink transmission or based on control signaling or control information. The UE may determine which DM-RS ports are associated with the selected codeword and may determine the PT-RS/DM-RS association based on a PT-RS/DM-RS association indication received via uplink DCI from a network entity. As such, the PT-RS/DM-RS association for multi-codeword configurations may be based on the selected codeword of the number of scheduled codewords.

[0058] Aspects of the disclosure are initially described in the context of wireless communications systems. Aspects of the disclosure are further described in the context of spatial multiplexing configurations as well as a process flow. Aspects of the disclosure are further illustrated by and described with reference to apparatus diagrams, system diagrams, and flowcharts that relate to reference signal association for multiple uplink codewords.

[0059] FIG. **1** illustrates an example of a wireless communications system **100** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. The wireless communications system **100** may include one or more network entities **105**, one or more UEs **115**, and a core network **130**. In some examples, the wireless communications system **100** may be a Long Term Evolution (LTE) network, an LTE-Advanced (LTE-A) network, an LTE-A Pro network, a New Radio (NR) network, or a network operating in accordance with other systems and radio technologies, including future systems and radio technologies not explicitly mentioned herein.

[0060] The network entities **105** may be dispersed throughout a geographic area to form the wireless communications system **100** and may include devices in different forms or having different capabilities. In various examples, a network entity **105** may be referred to as a network element, a mobility element, a radio access network (RAN) node, or network equipment, among other nomenclature. In some examples, network entities **105** and UEs **115** may wirelessly communicate via one or more communication links **125** (e.g., a radio frequency (RF) access link). For example, a network entity **105** may support a coverage area **110** (e.g., a geographic coverage area) over which the UEs **115** and the network entity **105** may establish one or more communication links **125**. The coverage area **110** may be an example of a geographic area over which a network entity **105** and a UE **115** may support the communication of signals according to one or more radio access technologies (RATs).

[0061] The UEs **115** may be dispersed throughout a coverage area **110** of the wireless communications system **100**, and each UE **115** may be stationary, or mobile, or both at different times. The UEs **115** may be devices in different forms or having different capabilities. Some example UEs **115** are illustrated in FIG. **1**. The UEs **115** described herein may be able to communicate with various types of devices, such as other UEs **115** or network entities **105**, as shown in FIG. **1**.

[0062] As described herein, a node of the wireless communications system **100**, which may be referred to as a network node, or a wireless node, may be a network entity **105** (e.g., any network entity described herein), a UE **115** (e.g., any UE described herein), a network controller, an apparatus, a device, a computing system, one or more components, or another suitable processing entity configured to perform any of the techniques described herein. For example, a node may be a UE **115**. As another example, a node may be a network entity **105**. As another example, a first node may be configured to communicate with a second node or a third node. In one aspect of this example, the first node may be a UE **115**, the second node may be a network entity **105**, and the third node may be a UE **115**. In another aspect of this example, the first node may be a UE **115**, the second node may be a network entity **105**, and the third node may be a network entity **105**. In yet other aspects of this example, the first, second, and third nodes may be different relative to these examples. Similarly, reference to a UE **115**, network entity **105**, apparatus, device, computing system, or the like may include disclosure of the UE **115**, network entity **105**, apparatus, device, computing system, or the like being a node. For example, disclosure that a UE **115** is configured to receive information from a network entity **105** also discloses that a first node is configured to receive information from a second node.

[0063] In some examples, network entities **105** may communicate with the core network **130**, or with one another, or both. For example, network entities **105** may communicate with the core network **130** via one or more backhaul communication links **120** (e.g., in accordance with an S1, N2, N3, or other interface protocol). In some examples, network entities **105** may communicate with one another over a backhaul communication link **120** (e.g., in accordance with an X2, Xn, or other interface protocol) either directly (e.g., directly between network entities **105**) or indirectly (e.g., via a core network **130**). In some examples, network entities **105** may communicate with one another via a midhaul communication link **162** (e.g., in accordance with a midhaul interface protocol) or a fronthaul communication link **168** (e.g., in accordance with a fronthaul interface protocol), or any combination thereof. The backhaul communication links **120**, midhaul communication links **162**, or fronthaul communication links **168** may be or include one or more wired links (e.g., an electrical link, an optical fiber link), one or more wireless links (e.g., a radio link, a wireless optical link), among other examples or various combinations thereof. A UE **115** may communicate with the core network **130** through a communication link **155**.

[0064] One or more of the network entities **105** described herein may include or may be referred to as a base station **140** (e.g., a base transceiver station, a radio base station, an NR base station, an access point, a radio transceiver, a NodeB, an eNodeB (eNB), a next-generation NodeB or a giga-NodeB (either of which may be referred to as a gNB), a 5G NB, a next-generation eNB (ng-eNB), a Home NodeB, a Home eNodeB, or other suitable terminology). In some examples, a network entity **105** (e.g., a base station **140**) may be implemented in an aggregated (e.g., monolithic, standalone) base station architecture, which may be configured to utilize a protocol stack that is physically or logically integrated within a single network entity **105** (e.g., a single RAN node, such as a base station **140**).

[0065] In some examples, a network entity **105** may be implemented in a disaggregated architecture (e.g., a disaggregated base station architecture, a disaggregated RAN architecture), which may be configured to utilize a protocol stack that is physically or logically distributed among two or more network entities **105**, such as an integrated access backhaul (IAB) network, an open RAN (O-RAN) (e.g., a network configuration sponsored by the O-RAN Alliance), or a virtualized RAN (vRAN) (e.g., a cloud RAN (C-RAN)). For example, a network entity **105** may include one or more of a central unit (CU) **160**, a distributed unit (DU) **165**, a radio unit (RU) **170**, a RAN Intelligent Controller (RIC) **175** (e.g., a Near-Real Time RIC (Near-RT RIC), a Non-Real Time RIC (Non-RT RIC)), a Service Management and Orchestration (SMO) **180** system, or any combination thereof. An RU **170** may also be referred to as a radio head, a smart radio head, a remote radio head (RRH), a remote radio unit (RRU), or a transmission reception point (TRP). One or more components of the network entities **105** in a disaggregated RAN architecture may be co-located, or one or more components of the network entities **105** may be located in distributed locations (e.g., separate physical locations). In some examples, one or more network entities **105** of a disaggregated RAN architecture may be implemented as virtual units (e.g., a virtual CU (VCU), a virtual DU (VDU), a virtual RU (VRU)).

[0066] The split of functionality between a CU **160**, a DU **165**, and an RU **175** is flexible and may support different functionalities depending upon which functions (e.g., network layer functions, protocol layer functions, baseband functions, RF functions, and any combinations thereof) are performed at a CU **160**, a DU **165**, or an RU **175**. For example, a functional split of a protocol stack may be employed between a CU **160** and a DU **165** such that the CU **160** may support one or more layers of the protocol stack and the DU **165** may support one or more different layers of the protocol stack. In some examples, the CU **160** may host upper protocol layer (e.g., layer 3 (L3), layer 2 (L2)) functionality and signaling (e.g., Radio Resource Control (RRC), service data adaption protocol (SDAP), Packet Data Convergence Protocol (PDCP)). The CU **160** may be connected to one or more DUs **165** or RUs **170**, and the one or more DUs **165** or RUs **170** may host lower protocol layers, such as layer 1 (L1) (e.g., physical (PHY) layer) or L2 (e.g., radio link control (RLC) layer, medium access control (MAC) layer) functionality and signaling, and may each be at least partially controlled by the CU **160**. Additionally, or alternatively, a functional split of the protocol stack may be employed between a DU **165** and an RU **170** such that the DU **165** may support one or more layers of the protocol stack and the RU **170** may support one or more different layers of the protocol stack. The DU **165** may support one or multiple different cells (e.g., via one or more RUs **170**). In some cases, a functional split between a CU **160** and a DU **165**, or between a DU **165** and an RU **170** may be within a protocol layer (e.g., some functions for a protocol layer may be performed by one of a CU **160**, a DU **165**, or an RU **170**, while other functions of the protocol layer are performed by a different one of the CU **160**, the DU **165**, or the RU **170**). A CU **160** may be functionally split further into CU control plane (CU-CP) and CU user plane (CU-UP) functions. A CU **160** may be connected to one or more DUs **165** via a midhaul communication link **162** (e.g., F1, F1-c, F1-u), and a DU **165** may be connected to one or more RUs **170** via a fronthaul communication link **168** (e.g., open fronthaul (FH) interface). In some examples, a midhaul communication link **162** or a fronthaul communication link **168** may be implemented in accordance with an interface (e.g., a channel) between layers of a protocol stack supported by respective network entities **105** that are in communication over such communication links.

[0067] In wireless communications systems (e.g., wireless communications system **100**), infrastructure and spectral resources for radio access may support wireless backhaul link capabilities to supplement wired backhaul connections, providing an IAB network architecture (e.g., to a core network **130**). In some cases, in an IAB network, one or more network entities **105** (e.g., IAB nodes **104**) may be partially controlled by each other. One or more IAB nodes **104** may be referred to as a donor entity or an IAB donor. One or more DUs **165** or one or more RUs **170** may be partially controlled by one or more CUs **160** associated with a donor network entity **105** (e.g., a donor base station **140**). The one or more donor network entities **105** (e.g., IAB donors) may be in communication with one or more additional network entities **105** (e.g., IAB nodes **104**) via supported access and backhaul links (e.g., backhaul communication links **120**). IAB nodes **104** may include an IAB mobile termination (IAB-MT) controlled (e.g., scheduled) by DUs **165** of a coupled IAB donor. An IAB-MT may include an independent set of antennas for relay of communications with UEs **115**, or may share the same antennas (e.g., of an RU **170**) of an IAB node **104** used for access via the DU **165** of the IAB node **104** (e.g., referred to as virtual IAB-MT (vIAB-MT)). In some examples, the IAB nodes **104** may include DUs **165** that support communication links with additional entities (e.g., IAB nodes **104**, UEs **115**) within the relay chain or configuration of the access network (e.g., downstream). In such cases, one or more components of the disaggregated RAN architecture (e.g., one or more IAB nodes **104** or components of IAB nodes **104**) may be configured to operate according to the techniques described herein.

[0068] In the case of the techniques described herein applied in the context of a disaggregated RAN architecture, one or more components of the disaggregated RAN architecture may be configured to support reference signal association for multiple uplink codewords as described herein. For example, some operations described as being performed by a UE **115** or a network entity **105** (e.g., a base station **140**) may additionally, or alternatively, be performed by one or more components of the disaggregated RAN architecture (e.g., IAB nodes **104**, DUs **165**, CUs **160**, RUs **170**, RIC **175**, SMO **180**).

[0069] A UE **115** may include or may be referred to as a mobile device, a wireless device, a remote device, a handheld device, or a subscriber device, or some other suitable terminology, where the "device" may also be referred to as a unit, a station, a terminal, or a client, among other examples. A UE **115** may also include or may be referred to as a personal electronic device such as a cellular phone, a personal digital assistant (PDA), a tablet computer, a laptop computer, or a personal computer. In some examples, a UE **115** may include or be referred to as a wireless local loop (WLL) station, an Internet of Things (IoT) device, an Internet of Everything (IoE) device, or a machine type communications (MTC) device, among other examples, which may be implemented in various objects such as appliances, or vehicles, meters, among other examples.

[0070] The UEs **115** described herein may be able to communicate with various types of devices, such as other UEs **115** that may sometimes act as relays as well as the network entities **105** and the network equipment including macro eNBs or gNBs, small cell eNBs or gNBs, or relay base stations, among other examples, as shown in FIG. **1**.

[0071] The UEs **115** and the network entities **105** may wirelessly communicate with one another via one or more communication links **125** (e.g., an access link) over one or more carriers. The term "carrier" may refer to a set of RF spectrum resources having a defined physical layer structure for supporting the communication links **125**. For example, a carrier used for a communication link **125** may include a portion of a RF spectrum band (e.g., a bandwidth part (BWP)) that is operated according to one or more physical layer channels for a given radio access technology (e.g., LTE, LTE-A, LTE-A Pro, NR). Each physical layer channel may carry acquisition signaling (e.g., synchronization signals, system information), control signaling that coordinates operation for the carrier, user data, or other signaling. The wireless communications system **100** may support communication with a UE **115** using carrier aggregation or multi-carrier operation. A UE **115** may be configured with multiple downlink component carriers and one or more uplink component carriers according to a carrier aggregation configuration. Carrier aggregation may be used with both frequency division duplexing (FDD) and time division duplexing (TDD) component carriers. Communication between a network entity **105** and other devices may refer to communication between the devices and any portion (e.g., entity, sub-entity) of a network entity **105**. For example, the terms "transmitting," "receiving," or "communicating," when referring to a network entity **105**, may refer to any portion of a network entity **105** (e.g., a base station **140**, a CU **160**, a DU **165**, a RU **170**) of a RAN communicating with another device (e.g., directly or via one or more other network entities **105**).

[0072] Signal waveforms transmitted over a carrier may be made up of multiple subcarriers (e.g., using multi-carrier modulation (MCM) techniques such as orthogonal frequency division multiplexing (OFDM) or discrete Fourier transform spread OFDM (DFT-S-OFDM)). In a system employing MCM techniques, a resource element may refer to resources of one symbol period (e.g., a duration of one modulation symbol) and one subcarrier, in which case the symbol period and subcarrier spacing may be inversely related. The quantity of bits carried by each resource element may depend on the modulation scheme (e.g., the order of the modulation scheme, the coding rate of the modulation scheme, or both) such that the more resource elements that a device receives and the higher the order of the modulation scheme, the higher the data rate may be for the device. A wireless communications resource may refer to a combination of an RF spectrum resource, a time resource, and a spatial resource (e.g., a spatial layer, a beam), and the use of multiple spatial resources may increase the data rate or data integrity for communications with a UE **115**.

[0073] The time intervals for the network entities **105** or the UEs **115** may be expressed in multiples of a basic time unit which may, for example, refer to a sampling period of $T_s=1/(\Delta f_{max}\cdot N_f)$ seconds, where Δf_{max} may represent the maximum supported subcarrier spacing, and N_f may represent the maximum supported discrete Fourier transform (DFT) size. Time intervals of a communications resource may be organized according to radio frames each having a specified duration (e.g., 10 milliseconds (ms)). Each radio frame may be identified by a system frame number (SFN) (e.g., ranging from 0 to 1023).

[0074] Each frame may include multiple consecutively numbered subframes or slots, and each subframe or slot may have the same duration. In some examples, a frame may be divided (e.g., in the time domain) into subframes, and each subframe may be further divided into a quantity of slots. Alternatively, each frame may include a variable quantity of slots, and the quantity of slots may depend on subcarrier spacing. Each slot may include a quantity of symbol periods (e.g., depending on the length of the cyclic prefix prepended to each symbol period). In some wireless communications systems **100**, a slot may further be divided into multiple mini-slots containing one or more symbols. Excluding the cyclic prefix, each symbol period may contain one or more (e.g., N_f) sampling periods. The duration of a symbol period may depend on the subcarrier spacing or frequency band of operation.

[0075] A subframe, a slot, a mini-slot, or a symbol may be the smallest scheduling unit (e.g., in the time domain) of the wireless communications system **100** and may be referred to as a transmission time interval (TTI). In some examples, the TTI duration (e.g., a quantity of symbol periods in a TTI) may be variable. Additionally, or alternatively, the smallest scheduling unit of the wireless communications system **100** may be dynamically selected (e.g., in bursts of shortened TTIs (sTTIs)).

[0076] Physical channels may be multiplexed on a carrier according to various techniques. A physical control channel and a physical data channel may be multiplexed on a downlink carrier, for example, using one or more of time division multiplexing (TDM) techniques, frequency division multiplexing (FDM) techniques, or hybrid TDM-FDM techniques. A control region (e.g., a control resource set (CORESET)) for a physical control channel may be defined by a set of symbol periods and may extend across the system bandwidth or a subset of the system bandwidth of the carrier. One or more control regions (e.g., CORESETs) may be configured for a set of the UEs **115**. For example, one or more of the UEs **115** may monitor or search control regions for control information according to one or more search space sets, and each search space set may include one or multiple control channel candidates in one or more aggregation levels arranged in a cascaded manner. An aggregation level for a control channel candidate may refer to an amount of control channel resources (e.g., control channel elements (CCEs)) associated with encoded information for a control information format having a given payload size. Search space sets may include common search space sets configured for sending control information to multiple UEs **115** and UE-specific search space sets for sending control information to a specific UE **115**.

[0077] In some examples, a network entity **105** (e.g., a base station **140**, an RU **170**) may be movable and therefore provide communication coverage for a moving coverage area **110**. In some examples, different coverage areas **110** associated with different technologies may overlap, but the different coverage areas **110** may be supported by the same network entity **105**. In some other examples, the overlapping coverage areas **110** associated with different technologies may be supported by different network entities **105**. The wireless communications system **100** may include, for example, a heterogeneous network in which different types of the network entities **105** provide coverage for various coverage areas **110** using the same or different radio access technologies.

[0078] The wireless communications system **100** may be configured to support ultra-reliable communications or low-latency communications, or various combinations thereof. For example, the wireless communications system **100** may be configured to support ultra-reliable low-latency communications (URLLC). The UEs **115** may be designed to support ultra-reliable, low-latency, or critical functions. Ultra-reliable communications may include private communication or group communication and may be supported by one or more services such as push-to-talk, video, or data. Support for ultra-reliable, low-latency functions may include prioritization of services, and such services may be used for public safety or general commercial applications. The terms ultra-reliable, low-latency, and ultra-reliable low-latency may be used interchangeably herein.

[0079] In some examples, a UE **115** may be able to communicate directly with other UEs **115** over a device-to-device (D2D) communication link **135** (e.g., in accordance with a peer-to-peer (P2P), D2D, or sidelink protocol). In some examples, one or more UEs **115** of a group that are performing D2D communications may be within the coverage area **110** of a network entity **105** (e.g., a base station **140**, an RU **170**), which may support aspects of such D2D communications being configured by or scheduled by the network entity **105**. In some examples, one or more UEs **115** in such a group may be outside the coverage area **110** of a network entity **105** or may be otherwise unable to or not configured to receive transmissions from a network entity **105**. In some examples, groups of the UEs **115** communicating via D2D communications may support a one-to-many (1:M) system in which each UE **115** transmits to each of the other UEs **115** in the group. In some examples, a network entity **105** may facilitate the scheduling of resources for D2D communications. In some other examples, D2D communications may be carried out between the UEs **115** without the involvement of a network entity **105**.

[0080] In some systems, a D2D communication link **135** may be an example of a communication channel, such as a sidelink communication channel, between vehicles (e.g., UEs **115**). In some examples, vehicles may communicate using vehicle-to-everything (V2X) communications, vehicle-to-vehicle (V2V) communications, or some combination of these. A vehicle may signal information related to traffic conditions, signal scheduling, weather, safety, emergencies, or any other information relevant to a V2X system. In some examples, vehicles in a V2X system may communicate with roadside infrastructure, such as roadside units, or with the network via one or more network nodes (e.g., network entities **105**, base stations **140**, RUs **170**) using vehicle-to-network (V2N) communications, or with both.

[0081] The core network **130** may provide user authentication, access authorization, tracking, Internet Protocol (IP) connectivity, and other access, routing, or mobility functions. The core network **130** may be an evolved packet core (EPC) or 5G core (5GC), which may include at least one control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management function (AMF)) and at least one 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)). The control plane entity may manage non-access stratum (NAS) functions such as mobility, authentication, and bearer management for the UEs **115** served by the network entities **105** (e.g., base stations **140**) associated with the core network **130**. User IP packets may be transferred through the user plane entity, which may provide IP address allocation as well as other functions. The user plane entity may be connected to IP services **150** for one or more network operators. The IP services **150** may include access to the Internet, Intranet(s), an IP Multimedia Subsystem (IMS), or a Packet-Switched Streaming Service.

[0082] The wireless communications system **100** may operate using one or more frequency bands, which may be in the range of 300 megahertz (MHz) to 300 gigahertz (GHz). Generally, the region from 300 MHz to 3 GHz is known as the ultra-high frequency (UHF) region or decimeter band because the wavelengths range from approximately one decimeter to one meter in length. The UHF waves may be blocked or redirected by buildings and environmental features, which may be referred to as clusters, but the waves may penetrate structures sufficiently for a macro cell to provide service to the UEs **115** located indoors. The transmission of UHF waves may be associated with smaller antennas and shorter ranges (e.g., less than 100 kilometers) compared to transmission using the smaller frequencies and longer waves of the high frequency (HF) or very high frequency (VHF) portion of the spectrum below 300 MHz.

[0083] The wireless communications system **100** may utilize both licensed and unlicensed RF spectrum bands. For example, the wireless communications system **100** may employ License Assisted Access (LAA), LTE-Unlicensed (LTE-U) radio access technology, or NR technology in an unlicensed band such as the 5 GHz industrial, scientific, and medical (ISM) band. While operating in unlicensed RF spectrum bands, devices such as the network entities **105** and the UEs **115** may employ carrier sensing for collision detection and avoidance. In some examples, operations in unlicensed bands may be based on a carrier aggregation configuration in conjunction with component carriers operating in a licensed band (e.g., LAA). Operations in unlicensed spectrum may include downlink transmissions, uplink transmissions, P2P transmissions, or D2D transmissions, among other examples.

[0084] A network entity **105** (e.g., a base station **140**, an RU **170**) or a UE **115** may be equipped with multiple antennas, which may be used to employ techniques such as transmit diversity, receive diversity, multiple-input multiple-output (MIMO) communications, or beamforming. The antennas of a network entity **105** or a UE **115** may be located within one or more antenna arrays or antenna panels, which may support MIMO operations or transmit or receive beamforming. For example, one or more base station antennas or antenna arrays may be co-located at an antenna assembly, such as an antenna tower. In some examples, antennas or antenna arrays associated with a network entity **105** may be located in diverse geographic locations. A network entity **105** may have an antenna array with a set of rows and columns of antenna ports that the network entity **105** may use to support beamforming of communications with a UE **115**. Likewise, a UE **115** may have one or more antenna arrays that may support various MIMO or beamforming operations. Additionally, or alternatively, an antenna panel may support RF beamforming for a signal transmitted via an antenna port.

[0085] The network entities **105** or the UEs **115** may use MIMO communications to exploit multipath signal propagation and increase the spectral efficiency by transmitting or receiving multiple signals via different spatial layers. Such techniques may be referred to as spatial multiplexing. The multiple signals may, for example, be transmitted by the transmitting device via different antennas or different combinations of antennas. Likewise, the multiple signals may be received by the receiving device via different antennas or different combinations of antennas. Each of the multiple signals may be referred to as a separate spatial stream and may carry information associated with the same data stream (e.g., the same codeword) or different data streams (e.g., different codewords). Different spatial layers may be associated with different antenna ports used for channel measurement and reporting. MIMO techniques include single-user MIMO (SU-MIMO), where multiple spatial layers are transmitted to the same receiving device, and multiple-user MIMO (MU-MIMO), where multiple spatial layers are transmitted to multiple devices.

[0086] Beamforming, which may also be referred to as spatial filtering, directional transmission, or directional reception, is a signal processing technique that may be used at a transmitting device or a receiving device (e.g., a network entity **105**, a UE **115**) to shape or steer an antenna beam (e.g., a transmit beam, a receive beam) along a spatial path between the transmitting device and the receiving device. Beamforming may be achieved by combining the signals communicated via antenna elements of an antenna array such that some signals propagating at particular orientations with respect to an antenna array experience constructive interference while others experience destructive interference. The adjustment of signals communicated via the antenna elements may include a transmitting device or a receiving device applying amplitude offsets, phase offsets, or both to signals carried via the antenna elements associated with the device. The adjustments associated with each of the antenna elements may be defined by a beamforming weight set associated with a particular orientation (e.g., with respect to the antenna array of the transmitting device or receiving device, or with respect to some other orientation).

[0087] A network entity **105** or a UE **115** may use beam sweeping techniques as part of beamforming operations. For example, a network entity **105** (e.g., a base station **140**, an RU **170**) may use multiple antennas or antenna arrays (e.g., antenna panels) to conduct beamforming operations for directional communications with a UE **115**. Some signals (e.g., synchronization signals, reference signals, beam selection signals, or other control signals) may be transmitted by a network entity **105** multiple times along different directions. For example, the network entity **105** may transmit a signal according to different beamforming weight sets associated with different directions of transmission. Transmissions along different beam directions may be used to identify (e.g., by a transmitting device, such as a network entity **105**, or by a receiving device, such as a UE **115**) a beam direction for later transmission or reception by the network entity **105**.

[0088] Some signals, such as data signals associated with a particular receiving device, may be transmitted by transmitting device (e.g., a transmitting network entity **105**, a transmitting UE **115**) along a single beam direction (e.g., a direction associated with the receiving device, such as a receiving network entity **105** or a receiving UE **115**). In some examples, the beam direction associated with transmissions along a single beam direction may be determined based on a signal that was transmitted along one or more beam directions. For example, a UE **115** may receive one or more of the signals transmitted by the network entity **105** along different directions and may report to the network entity **105** an indication of the signal that the UE **115** received with a highest signal quality or an otherwise acceptable signal quality.

[0089] In some examples, transmissions by a device (e.g., by a network entity **105** or a UE **115**) may be performed using multiple beam directions, and the device may use a combination of digital precoding or beamforming to generate a combined beam for transmission (e.g., from a network entity **105** to a UE **115**). The UE **115** may report feedback that indicates precoding weights for one or more beam directions, and the feedback may correspond to a configured set of beams across a system bandwidth or one or more sub-bands. The network entity **105** may transmit a reference signal (e.g., a cell-specific reference signal (CRS), a channel state information reference signal (CSI-RS)), which may be precoded or unprecoded. The UE **115** may provide feedback for beam selection, which may be a precoding matrix indicator (PMI) or codebook-based feedback (e.g., a multi-panel type codebook, a linear combination type codebook, a port selection type codebook). Although these techniques are described with reference to signals transmitted along one or more directions by a network entity **105** (e.g., a base station **140**, an RU **170**), a UE **115** may employ similar techniques for transmitting signals multiple times along different directions (e.g., for identifying a beam direction for subsequent transmission or reception by the UE **115**) or for transmitting a signal along a single direction (e.g., for transmitting data to a receiving device).

[0090] A receiving device (e.g., a UE **115**) may perform reception operations in accordance with multiple receive configurations (e.g., directional listening) when receiving various signals from a receiving device (e.g., a network entity **105**), such as synchronization signals, reference signals, beam selection signals, or other control signals. For example, a receiving device may perform reception in accordance with multiple receive directions by receiving via different antenna subarrays, by processing received signals according to different antenna subarrays, by receiving according to different receive beamforming weight sets (e.g., different directional listening weight sets) applied to signals received at multiple antenna elements of an antenna array, or by processing received signals according to different receive beamforming weight sets applied to signals received at multiple antenna elements of an antenna array, any of which may be referred to as "listening" according to different receive configurations or receive directions. In some examples, a receiving device may use a single receive configuration to receive along a single beam direction (e.g., when receiving a data signal). The single receive configuration may be aligned along a beam direction determined based on listening according to different receive configuration directions (e.g., a beam direction determined to have a highest signal strength, highest signal-to-noise ratio (SNR), or otherwise acceptable signal quality based on listening according to multiple beam directions).

[0091] The wireless communications system **100** may be a packet-based network that operates according to a layered protocol stack. In the user plane, communications at the bearer or PDCP layer may be IP-based. An RLC layer may perform packet segmentation and reassembly to communicate over logical channels. A MAC layer may perform priority handling and multiplexing of logical channels into transport channels. The MAC layer may also use error detection techniques, error correction techniques, or both to support retransmissions at the MAC layer to improve link efficiency. In the control plane, the RRC protocol layer may provide establishment, configuration, and maintenance of an RRC connection between a UE **115** and a network entity **105** or a core network **130** supporting radio bearers for user plane data. At the PHY layer, transport channels may be mapped to physical channels.

[0092] The UEs **115** and the network entities **105** may support retransmissions of data to increase the likelihood that data is received successfully. Hybrid automatic repeat request (HARQ) feedback is one technique for increasing the likelihood that data is received correctly over a communication link (e.g., a communication link **125**, a D2D communication link **135**). HARQ may include a combination of error detection (e.g., using a cyclic redundancy check (CRC)), forward error correction (FEC), and retransmission (e.g., automatic repeat request (ARQ)). HARQ may improve throughput at the MAC layer in poor radio conditions (e.g., low signal-to-noise conditions). In some examples, a device may support same-slot HARQ feedback, where the device may provide HARQ feedback in a specific slot for data received in a previous symbol in the slot. In some other examples, the device may provide HARQ feedback in a subsequent slot, or according to some other time interval.

[0093] The UEs **115** may be configured for uplink data transmission via PUSCH. For example, a UE **115** may receive DCI scheduling resources for PUSCH including a number of resources allocated to reference signals including DM-RS. Additionally, the UE **115** may be configured with one or more sets of sounding reference signal resources via RRC signaling. In some examples, the wireless communications system **100** may support more than one mode of PUSCH transmission. For example, the wireless communications system **100** may support codebook-based PUSCH transmission or non-codebook-based PUSCH transmission, or both. For example, a UE **115** configured for codebook-based transmissions may be configured or scheduled with a single SRS resource set with a usage indicator set to "codebook." In some examples, the UE **115** may receive a configuration for up to 4 SRS resources within the set. Each SRS resource may be RRC-configured with a number of ports (e.g., SRS ports, nrofSRS-Ports). In some examples, the UE **115** may receive, via uplink DCI, an SRS resource indicator (SRI) that indicates a single SRS resource of the set. The UE **115** may transmit the PUSCH with a same spatial domain filter (e.g., uplink transmission beam) as the indicated SRS resources. The number of layers (e.g., rank) and a transmitted precoding matrix indicator (TPMI) (e.g., precoder) for the scheduled PUSCH may be indicated by a DCI field associated with precoding information (e.g., a "precoding information and number of layers" field).

[0094] A UE **115** configured for non-codebook-based transmissions may be configured with a single SRS resource set with an associated SRS usage indicator set to "non-codebook." The UE **115** may receive a configuration for up to 4 SRS resources within the set. Each SRS resource may be RRC-configured with a single port (e.g., SRS ports, nrofSRS-Ports). The SRI field in the uplink DCI (e.g., scheduling the PUSCH) may indicate one or more SRS resources of the set, where the number of indicated SRS resources may determine a rank (e.g., number of layers) for the scheduled PUSCH. In some examples, the UE **115** may transmit the PUSCH with a same spatial domain filter (e.g., uplink transmission beam) as well as a same precoder as the indicated SRS resources.

[0095] In some examples, a PT-RS for phase noise correction may be transmitted within a number of allocated resources blocks via one or more resource elements of the scheduled PUSCH. Phase noise may be especially prevalent in some frequency ranges and thus the use of PT-RS may particularly improve communications in those ranges. PT-RS may be transmitted via PUSCH OFDM symbols that are not allocated for DM-RS. In some examples, a DM-RS may obviate the use of PT-RS and thus resource blocks allocated for DM-RS may not additionally include PT-RS. In some examples, PT-RS may be transmitted relatively infrequently in the frequency domain (e.g., one time per port per 2 to 4 resource blocks) and may be transmitted relatively frequently in the time domain (e.g., per 1/2/4 OFDM symbols).

[0096] The UE **115** may receive RRC signaling including an RRC parameter (e.g., "PTRS-UplinkConfig") configuring the occurrence of PT-RSs in the frequency and time domains. PT-RS may be transmitted via a number of ports (e.g., PT-RS ports indicated or configured by via RRC signaling (e.g., "maxNrofPorts"). In some examples, the number of ports may be one or two. For example, two PT-RS ports may be configured for CP-OFDM waveforms and one port may be configured for some types of UEs **115** (e.g., full-coherent UEs **115**).

[0097] For non-codebook-based uplink communications, an actual number of PT-RS ports used for transmitting PT-RS out of the number of indicated ports (e.g., max number of ports) may be indicated by SRI. The SRI may indicate one or more SRS resources where each SRS resource may be configured with a PT-RS port index. If the indicated SRS resources (e.g., indicated by the SRI) have a same PT-RS port index, then the actual number of PT-RS ports may be one PT-RS port; Otherwise, the actual number of PT-RS ports may be two PT-RS ports.

[0098] For codebook-based uplink communications, if the UE is a partial-coherent or non-coherent UE, the actual number of PT-RS ports used for transmitting PT-RS out of the number of indicated ports (e.g., max number of ports) is determined based on TMPI (e.g., via the "Precoding information and number of layers" field).

[0099] In some examples (e.g., when PUSCH is scheduled with more than one spatial layer), a PT-RS port may be associated with a DM-RS port such that PT-RSs may be transmitted on a strongest layer (e.g., most reliable, least subject to noise, or otherwise most suitable) associated with the DM-RS port as determined by transmitting one or more DM-RSs. Some uplink DCI formats (e.g., formats 0_1; 0_2) may include a PT-RS/DM-RS association indication (e.g., field). In some examples, the PT-RS/DM-RS association indication may include two bits based on the following conditions being met: when the scheduled PUSCH is configured to include PT-RS, CP-OFDM is used (e.g., transform precoder is disabled), and a maximum rank of the scheduled PUSCH is greater than one, or any combination thereof. Otherwise, the DCI may be transmitted without an association indication.

[0100] In some examples, the control signaling may configure a single PT-RS port (e.g., PT-RS port 0). In such examples, the value of the association indication may indicate with which DM-RS port the single PT-RS port is associated. For example, a first value may indicate a first scheduled DM-RS port, a second value may indicate a second scheduled DM-RS port, and so on.

[0101] In some examples, the control signaling may configure two or more PT-RS ports (e.g., PT-RS port 0 and PT-RS port 1). In such examples, a first bit of the association indication may indicate which DM-RS port (e.g., out of the DM-RS ports that share or may be associated with the first PT-RS port) is associated with the first PT-RS port and a second bit of the association indication may indicate which DM-RS port (e.g., out of the DM-RS ports that share or may be associated with the second PT-RS port) is associated with the second PT-RS port.

[0102] In some examples, the DM-RS ports that share a PT-RS port may be determined according to a PUSCH transmission mode (e.g., codebook-based or non-codebook-based). For example, for non-codebook-based PUSCH, an SRI field may indicate one or multiple SRS resources. For example, there may be a one-to-one mapping between indicated SRS resources and indicated DM-RS ports (e.g., indicated by antenna ports field). Each SRS resource may be configured with a PT-RS port index.

[0103] As an example, SRS resources 0, 1 may be RRC-configured with PT-RS port 0 and SRS resources 2, 3 may be RRC configured with PT-RS port 1. In this example, the SRI may indicate 4 SRS resources, an "antenna ports" field may indicate DM-RS ports 0 through 3 where DM-RS ports 0 and 1 share PT-RS port 0 and DM-RS ports 2- and 3 share PT-RS port 1 as indicated by the PT-RS/DM-RS association indication.

[0104] For codebook-based PUSCH, in the case of some types of UEs **115** (e.g., coherent, non-coherent), the TPMI may indicate which DM-RS ports share a PTRS port based on one or more conditions or rules. For example, TPMI may indicate a first PUSCH antenna port **1000** and a third PUSCH antenna port **1002** share PT-RS port 0, and a second PUSCH antenna port **1001** and a fourth PUSCH antenna **1003** share PT-RS port 1. In such examples, DM-RS ports corresponding to the layers which are transmitted with PUSCH antenna port **1000** and PUSCH antenna port **1002** as indicated by the TPMI share PTRS port 0 and the DM-RS ports corresponding to the layers which are transmitted with PUSCH antenna port **1001** and PUSCH antenna port **1003** as indicated by the TPMI share PTRS port 1.

[0105] As an example, the precoding information and number of layers field in the DCI may indicate three layers and a TPMI index. The "Antenna ports" field may indicate that DM-RS ports 0-2 correspond to the three layers where the first layer is transmitted with PUSCH antenna ports **1000** and **1002** and DM-RS port 0 shares PTRS port 0, the second layer is transmitted with PUSCH antenna port **1001**, and the third layer is transmitted with PUSCH antenna port **1003** where DM-RS port 1 and 2 share PTRS port 1. Note that in this example, the first bit of PTRS/DM-RS association indication may be irrelevant useless because a single DM-RS port "shares" PTRS port 0, but the second bit selects which DM-RS port (e.g., out DM-RS ports 1 and 2 that share PTRS port 1) is associated with PTRS port 1.

[0106] In some wireless communication systems, a single DCI may schedule a first set of PUSCH repetitions or layers and a second set of PUSCH repetitions or layers for transmission to at least two transmission/reception points (TRPs), which may be an example of a network entity **105**. In some examples, each set may be associated with a beam configuration, power control parameters, or other transmission parameters and may be transmitted according to a time division duplexing configuration. In such examples, each set may correspond to a respective SRS resource set. For example, DCI may indicate two beams or two sets of power control parameters via corresponding SRI fields for both codebook-based and non-codebook-based PUSCH.

[0107] The DCI, in some examples, may include an indication field for dynamic switching between single TRP (sTRP) configurations and multi-TRP (mTRP) configurations (e.g., one set versus two sets of transmission parameters for PUSCH repetitions or layers). The indication may include two bits and may indicate one of: {use first set of parameters only (TRP1); use second set of parameters only (TRP2); use both sets of parameters for two sets of repetitions with a first order (TRP1,TRP2); use both sets of parameters for two sets of repetitions with a second order (TRP2,TRP1)} mapped to {00,01,10,11}.

[0108] Some DCI configurations may include an indication for dynamic switching between sTRP communications and mTRP communications. In some examples, the dynamic switching indication may include 2 bits according to Table 1, below.

TABLE 1

DCI for Dynamic Switching

Codepoint	SRS resource set(s)	SRI (for codebook-based and non-codebook based PUSCH)/TPMI (for codebook) field(s)
00	sTRP with 1st SRS resource set (TRP1)	1st SRI/TPMI field (2nd field is unused)
01	sTRP with 2nd SRS resource set (TRP2)	1st SRI/TPMI field (2nd field is unused)
10	mTRP with (TRP1, TRP2) 1st SRI/TPMI field: 1st SRS resource set 2nd SRI/TPMI field: 2nd SRS resource set	Both 1st and 2nd SRI/TPMI fields
11	mTRP with (TRP2, TRP1) 1st SRI/TPMI field: 1st SRS resource set 2nd SRI/TPMI field: 2nd SRS resource set	Both 1st and 2nd SRI/TPMI fields

[0109] In some examples, the SRS resource set with a lower ID index may be a first SRS resource set, and the remaining SRS resource set may be a second SRS resource set for both codebook-based and non-codebook-based usage.

[0110] For codepoint "11," as shown in Table 1, the first repetition in time may be associated with the second SRS resource set, and the remaining repetitions may follow a configured mapping pattern (e.g., cyclic or sequential mapping pattern). For codepoint "10," the first repetition in time may be associated with a first SRS resource set, and the remaining repetitions may follow the configured mapping pattern (cyclic or sequential).

[0111] In some example PUSCH configurations, a total number of spatial layers may be four or more and a total number of supported codewords may be up to two across the panels of a transmitting device (e.g., a UE **115**).

[0112] In some examples, a PUSCH transmission may be scheduled for transmission over a number of spatial layers (e.g., two to four spatial layers) according to a spatial division multiplexing scheme (SDM) where different spatial layers are associated with a corresponding set of transmission parameters (e.g., beam configurations, power control parameters, TPMI values). In some such examples, the PUSCH transmission may include two codewords. As such, mechanisms for determining a PT-RS/DM-RS association when two codewords are scheduled for multi-layer PUSCH (e.g., sTRP PUSCH configurations or PUSCH configurations having a single set of transmission parameters) or SDM PUSCH with different set of transmission parameters (e.g., mTRP SDM PUSCH) may differ from mechanisms for determining PT-RS/DM-RS when a single codeword is scheduled.

[0113] For example, a UE **115** may receive RRC signaling including an indication of a transmission mode (e.g., codebook-based, non-codebook-based) for a PUSCH and a PT-RS configuration (e.g., nrofSRS-Ports). The UE **115** may receive DCI, for example, form a network entity, including an indication of an association between PT-RS ports and DM-RS ports based on the PT-RS configuration. That is, an indication of an association between PT-RS ports and DM-RS ports may be based on a number of PT-RS ports indicated by the PT-RS port configuration. In some examples, the DCI may schedule a first codeword and a second codeword for transmitting the PUSCH over one or more spatial layers. The UE **115** may select a codeword from the first codeword and the second codeword for the uplink transmission, and may transmit, via the PUSCH and according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with the selected codeword based on the association.

[0114] FIG. **2** illustrates an example of a wireless communications system **200** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. In some examples, wireless communications system **200** may implement aspects of wireless communications system **100**. The wireless communications system **200** may include a UE **115**-*a* and a network entity **105**-*a*, each of which may be examples of the corresponding devices as described with reference to FIG. **1**. In some examples, the wireless communications system **200** may support sTRP configurations or PUSCH configurations associated with a single set of transmission parameters.

[0115] The wireless communications system **200** may support communications in relatively higher frequency bands (e.g., FR2, FR2x, FR4). In some examples, noise (e.g., phase noise) at these operating frequencies may be associated with higher levels than at other operating frequencies. To mitigate the effects of phase noise, the UE **115**-*a* may transmit one or more PT-RSs via an uplink **205**-*b* to track the phase of a local oscillator to reduce the effects of oscillator phase noise on communications between the UE **115**-*a* and the network entity **105**-*a*.

[0116] For example, the network entity **105**-*b* may transmit RRC signaling **210** to the UE **115**-*a* via downlink **205**-*a*. In some examples, the RRC signaling **210** may configure a set of SRS resources as well as a number of ports associated with each SRS resource. In some examples, the UE **115**-*a* may receive DCI **215** (e.g., scheduling PUSCH **220** for the UE **115**-*a*) including an SRS resource indicator (SRI) that indicates one or more SRS resources of the set depending on the PUSCH transmission mode (e.g., codebook-based or non-codebook-based).

[0117] To transmit the one or more PT-RSs, the UE **115**-*a* may determine an association between one or more ports used for other reference signals (e.g., DM-RS) and may transmit the one or more PT-RSs via one or more resource blocks **225** of a PUSCH **220** according to the association.

[0118] For example, for spatial division multiplexed PUSCH with a single set of transmission parameters, when the UE **115**-*a* is scheduled with two or more codewords, the DM-RS ports from one of the codewords may be used for the PT-RS/DM-RS association. The UE **115**-*a* may determine which codeword based on an MCS value of the scheduled codewords, an index of the scheduled codeword, an RRC configuration, or based on a DCI indication. For example, the UE **115**-*a* may select the codeword with the higher MCS value or if the MCS values of the two scheduled codewords are the same, the UE **115**-*a* may select the codeword with the smaller codeword index (e.g., codeword 0). In some examples, the UE **115**-*a* may receive RRC signaling **210** or DCI **215** including an indication of the codeword to select.

[0119] The UE **115**-*a* may determine PT-RS port(s) is associated with which DM-RS ports of the selected codeword based on the PT-RS/DM-RS association indication and the number of ports configured by the PTRS configuration. In some examples, the DCI **215** may include a PT-RS/DM-RS association indication based on the number of PT-RS ports configured by maxNrofPorts in "PTRS-UplinkConfig". When one PT-RS port is configured, the PT-RS/DM-RS association indication may include two bits and the value of the field (e.g., 0, 1, 2, 3) may indicate with which DM-RS port of the selected codeword that the PT-RS port is associated, as shown in Table 2, below.

TABLE 2

PT-RS/DM-RS association for UL PT-RS port 0	
Value	DM-RS port of the selected CW
0	1st scheduled DM-RS port
1	2nd scheduled DM-RS port
2	3rd scheduled DM-RS port
3	4th scheduled DM-RS port

[0120] When two PT-RS ports are configured and a maximum rank of the scheduled PUSCH is less than or equal to four, the PT-RS/DM-RS association indication may include two bits, as shown in Table 3, below. In some such examples, the first bit (e.g., the most significant bit (MSB) may indicate with which DM-RS port a first PT-RS port is associated out of all the DM-RS ports that share (e.g., are eligible to be associated with) the first PT-RS port and that correspond to the selected codeword. The second bit (e.g., the least significant bit (LSB) may indicate with which DM-RS port a second PT-RS port is associated with out of all the DM-RS ports that share (e.g., are eligible to be associated with) the second PT-RS port and that correspond to the selected codeword.

TABLE 3

PT-RS/DM-RS association for UL PT-RS ports 0 and 1

Value of MSB	DM-RS port of the selected CW	Value of LSB	DM-RS port of the selected CW
0	1st DM-RS port which shares PT-RS port 0	0	1st DM-RS port which shares PT-RS port 1
1	2nd DM-RS port which shares PT-RS port 0	1	2nd DM-RS port which shares PT-RS port 1

[0121] When two PT-RS ports are configured and a maximum rank of the scheduled PUSCH is greater than four, the PT-RS/DM-RS association indication may include four bits, as shown in Table 4, below. In some such examples, a value (e.g., 0, 1, 2, 3) of a first subset of bits (e.g., the first two MSBs) may indicate with which DM-RS port a first PT-RS port is associated out of all the DM-RS ports that share (e.g., are eligible to be associated with) the first PT-RS port and that correspond to the selected codeword. A value of a second subset of bits (e.g., the second two LSBs) may indicate with which DM-RS port a second PT-RS port is associated with out of all the DM-RS ports that share (e.g., are eligible to be associated with) the second PT-RS port and that correspond to the selected codeword.

TABLE 4

PT-RS/DM-RS association for UL PT-RS ports 0 and 1

Value of MSB	DM-RS port of the selected CW	Value of LSB	DM-RS port of the selected CW
0	1st DM-RS port which shares PT-RS port 0	0	1st DM-RS port which shares PT-RS port 1
1	2nd DM-RS port which shares PT-RS port 0	1	2nd DM-RS port which shares PT-RS port 1
2	3rd DM-RS port which shares PT-RS port 0	2	3rd DM-RS port which shares PT-RS port 1
3	4th DM-RS port which shares PT-RS port 0	3	4th DM-RS port which shares PT-RS port 1

[0122] For non-codebook-based PUSCH transmission, an actual number of PT-RS ports (if maxNrofPorts=2) depends on the SRI field of the DCI and the selected codeword. An "actual" number of ports may correspond to a number of ports that are scheduled for transmitting PT-RS when two PT-RS ports are available. For example, a maximum number of ports may equal two, but an actual number of ports may be one or two. The SRI may indicates one or multiple SRS resources, where each SRS resource is configures with a PT-RS port index. When the indicated SRS resource (e.g., as indicated by SRI) for the selected codeword have a same PT-RS port index then an actual number of ports may equal one, otherwise an actual number of ports may equal two.

[0123] For codebook-based UL in examples where the UE **115**-*a* is a partial-coherent UE or a non-coherent UE, the actual number of PT-RS ports may be determined based on TPMI (e.g., via a "precoding information and number of layers" field) and the selected codeword. For example, the TMPI may indicate the precoding matrix and the number of layers. The precoding matrix may indicate the association between antenna ports and each layer while the actual number of PT-RS ports may be determined based on the layers corresponding to the selected codeword.

[0124] In the example of PUSCH **220**, a single PTRS port (e.g., PTRS port 0) is configured and is associated with DM-RS port 0. The UE **115**-*a* may transmit one or more DM-RS instances and PT-RS instances via resource block **225**-*a* and may transmit one or more DM-RS instances via resource block **225**-*b*.

[0125] FIG. **3** illustrates an example of a wireless communications system **300** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. In some examples, wireless communications system **300** may implement aspects of wireless communications system **100**, or **200**, or both. The wireless communications system **300** may include a TRP **305**-*a* and a TRP **305**-*b*, each of which may be examples of the corresponding devices as described with reference to FIG. **1**. In some examples, the wireless communications system **300** may support mTRP configurations or PUSCH configurations associated with two or more sets of transmission parameters.

[0126] In the example of wireless communications system **300**, a single DCI may schedule a first set of PUSCH layers for transmission to the first TRP **305**-*a* and may schedule a second set of PUSCH layers for transmission to the second TRP **305**-*b*. Each set of layers may be associated with a corresponding set of transmission parameters (e.g., beam/spatial relation, power control, precoding) In some examples, each set may be transmitted according to a spatial division duplexing configuration. In such examples, each set of PUSCH layers may correspond to one or more respective SRS resources with a respective SRS resource set. In some examples, each set of PUSCH layers may be mapped to one or more codewords. For example, a first codeword may be mapped to layers **310**-*a*, **310**-*b*, and **310**-*c*, a second codeword may be mapped to layers **310**-*d*, **310**-*e*, and **310**-*f*. Thus, the first set of PUSCH layers (e.g., transmitted to TRP **305**-*a*) may include layers **310**-*a*, **310**-*b*, and **310**-*d*, and the second set of PUSCH layers (transmitted to second TRP **305**-*b*) may include layers **310**-*c*, **310**-*e*, and **310**-*f*. The single DCI may indicate two beams or two sets of power control parameters, or both via two corresponding SRI fields for both codebook-based and non-codebook-based PUSCH.

[0127] In some examples, the first set of PUSCH layers may be associated with one or more SRS resources of a first SRS resource set and a first uplink transmission beam, or a first set of power control parameters, or a combination thereof may be used for communications with the TRP **305**-*a*. The second set of PUSCH layers **310** may be associated with one or more SRS resources of a second SRS resource set and a second uplink transmission beam, or a second set of power control parameters, or a combination thereof may be used for communications with the TRP **305**-*b*.

[0128] In some such examples, when a UE is scheduled with multiple codewords, DM-RS ports from one of the scheduled codewords may be used to determine the PT-RS/DM-RS association for each set of PUSCH layers. The UE may select a codeword based on an MCS value associated with each codeword or based on how many SRS resource sets with which each codeword is associated, or both.

[0129] FIGS. **4**A, **4**B, and **4**C illustrate examples of a spatial multiplexing configuration **400**-*a*, **400**-*b*, and **400**-*c* that each supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. FIG. **4**A may include a first set of transmission parameters **410**-*a* and a second set of transmission parameters **410**-*b*. FIGS. **4**B and **4**C may each include a first codeword **415** and a second codeword **420**.

[0130] In the example, of FIG. **4**A, a PUSCH transmission may be scheduled for transmission over a number of spatial layers (e.g., layers **0**-**3**) according to an SDM scheme where different spatial layer are associated with a corresponding set of transmission parameters **410**-*a* or **410**-*b* (e.g., beam configurations, power control parameters, TPMI values). In some such examples, the PUSCH transmission may include two codewords. As such, mechanisms for determining a PT-RS/DM-RS association when two CWs are scheduled for multi-layer PUSCH (i.e., sTRP PUSCH or PUSCH with single set of transmission parameters) or SDM PUSCH with different set of transmission parameters (i.e., multi-TRP SDM PUSCH) may differ from mechanisms for determining PT-RS/DM-RS when a single codeword is scheduled.

[0131] FIG. **4**B illustrates an example of PT-RS/DM-RS association determination for non-codebook-based PUSCH with a single set of transmission parameters and may correspond to aspects as described with reference to FIG. **2**. In some examples, a UE (e.g., a UE **115**) may receive control signaling (e.g., RRC signaling) indicating a set of SRS resources. The UE may be configured with a single PT-RS port and may receive an SRI in DCI indicating that a first codeword **415**-*a* includes or is associated with SRS resources **401**-*a*, **402**-*a*, and **403**-*a* (e.g., corresponding to layers 0-2) and a second codeword **420**-*a* includes or is associated with SRS resources **404**-*a*, **405**-*a*, and **406**-*a* (e.g., corresponding to layers 3-5). In a first example of FIG. **4**B, the first codeword **415**-*a* may be associated with a higher MCS value and the UE may select first codeword **415**-*a* for determining the PT-RS/DM-RS association according to Table 5, below.

TABLE 5

PT-RS/DM-RS association for UL PT-RS port 0

Value	DM-RS port of the selected CW (e.g., CW0)
0	1st scheduled DM-RS port → Layer 0 of CW0
1	2nd scheduled DM-RS port → Layer 1 of CW0
2	3rd scheduled DM-RS port → Layer 2 of CW0
3	4th scheduled DM-RS port → unused.

[0132] In a second example of FIG. **4**B, the UE may be configured with two PT-RS ports and may determine that an actual number of PT-RS ports is one because the DM-RS ports (e.g., corresponding to layers 0-2) associated with the first codeword **415**-*a* are associated with SRS resources that are configured with a single PT-RS port (e.g., PT-RS port 0). That is, the received SRI indicated that SRS resources **401**-*a*, **402**-*a*, and **403**-*a* are configured for PT-RS port 0 and thus, the second two bits or the two LSBs of the four-bit PT-RS/DM-RS association indication (e.g., because the rank of spatial multiplexing configuration **400**-*b* equals six) may be irrelevant (e.g., unused) for indicating which DM-RS port of those associated with layers 0-3 to use for PT-RS transmission and only the first two bits or the two MSBs of the four-bits PT-RS/DM-RS association indication are used to indicate which DM-RS ports of those associated with layer 0-2 is associated with PT-RS port 0, as shown in Table 6, below.

TABLE 6

PT-RS/DM-RS association for UL PT-RS ports 0 and 1

Value of MSB	DM-RS port of the selected CW (e.g., CW0)	Value of LSB	DM-RS port of the selected CW (e.g., CW0)
0	1st DM-RS port which shares PT-RS port 0 → Layer 0 of CW0	0	unused
1	2nd DM-RS port which shares PT-RS port 0 → Layer 1 of CW0	1	
2	3rd DM-RS port which shares PT-RS port 0 → Layer 2 of CW0	2	
3	unused	3	

[0133] FIG. **4**C illustrates an example of PT-RS/DM-RS association determination for non-codebook-based PUSCH with two or more sets of transmission parameters and may correspond to aspects as described with reference to FIG. **3**.

[0134] In the example of FIG. **4**C, a UE may receive a PT-RS port configuration indicating that two PT-RS ports are configured (e.g., maxNrofPorts=**2**). Each SRS resource may be configured with a PT-RS port index. For example, SRS resource **401**-*b*, **402**-*b* and **403**-*b* in the first SRS resource set are configured with PT-RS port 0, and SRS resource **404**-*b*, **405**-*b*, and **406**-*b* in the second SRS resource set are configured with PT-RS port 1. A first SRI (e.g., associated with the first set of parameters) may indicate that SRS resources **401**-*b*, **402**-*b*, and **403**-*b* are associated with codeword **415**-*b* or codeword **420**-*b* and a second SRI (e.g., associated with the second set of parameters) may indicate that SRS resources **404**-*b*, **405**-*b*, and **406**-*b* are associated with codeword **415**-*b* or codeword **420**-*b*. The first codeword **415**-*b* may have or be associated with the higher MCS value in this example, and may be selected for the PT-RS/DM-RS association. As such, the PT-RS/DM-RS association indication of the DCI indicates the association for each set of DM-RS ports respectively for selected codeword 0, according to Table 7, below.

TABLE 7

PT-RS/DM-RS association for UL PT-RS port 0 and PT-RS port 1

Value of MSB	DM-RS port of the selected CW (e.g., CW0)	Value of LSB	DM-RS port of the selected CW (e.g., CW0)
0	1st DM-RS port which shares PT-RS port 0 → Layer 0 of CW0	0	unused
1	2nd DM-RS port which shares PT-RS port 0 → Layer 1 of CW0	1	

[0135] FIGS. **5**A & **5**B each illustrate an example of a wireless communications system **501** and **502** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. Wireless communications systems **501** and **502** may each support codebook-based PUSCH transmissions (e.g., single SRS resource configurations). In the example of FIG. **5**A, the wireless communications system **501** may include a network entity **105**-*b* and a UE **115**-*b*, each of which may be examples of the corresponding devices as described with reference to FIG. **1**. The UE **115**-*b* may be scheduled with layers **505**, a first codeword **515**-*a*, and a second codeword **520**-*a*.

[0136] The UE **115**-*b* may be configured with two PT-RS ports (e.g., "maxNrofPorts" may equal 2) including PT-RS port 0 and PT-RS port 1. A number of layers **505** indicated by a TPMI may be 6, where layers **505**-*a*, **505**-*b*, and **505**-*c* are associated with the first codeword **515**-*a* and layers **505**-*d*, **505**-*e*, and **505**-*f* are associated with the second codeword **520**-*a*. The UE **115**-*b* may be configured such that PUSCH antenna port **1000** and **1002** share the first PT-RS port (e.g., PT-RS port 0) and PUSCH antenna ports **1001** and **1003** share the second PT-RS port (e.g., PT-RS port 1). Based on the TPMI indication, Layer **505**-*a* may be associated with PUSCH antenna port **1000** and **1002**, layer **505**-*b* may be associated with PUSCH antenna port **1001**, layer **505**-*c* may be associated with PUSCH antenna port **1003**, and layers **505**-*d*, **505**-*e*, and **505**-*f* may be associated with PUSCH antenna ports **1001** and **1003**. In some such examples, layer **505**-*a* may be associated with the first PT-RS port (e.g., PT-RS port 0) and layers **505**-*b* through **505**-*f* may be associated with the second PT-RS port (e.g., PT-RS port 1).

[0137] In some such examples, when the first codeword **515**-*a* is selected, the actual number of PT-RS ports is two, then PT-RS port 0 may be associated with layer **505**-*a* and the first two bits (e.g., MSB) of the PT-RS/DM-RS association indication may be irrelevant because only one layer **505**-*a* is associated with the first PT-RS port (e.g., and thus no explicit indication of DM-RS port may be needed), while the second two bits (e.g., LSB) in the PT-RS/DM-RS association indication may indicate which layer out of layers **505**-*b* and **505**-*c* is associated with PT-RS port 1, as demonstrated with reference to Table 8, below.

TABLE 8

PT-RS/DM-RS association for UL PT-RS ports 0 and 1 if CW0 is selected

Value of MSB	DM-RS port of the selected codeword (e.g., CW0)	Value of LSB	DM-RS port of the selected codeword (e.g., CW0)
0	Indicated DM-RS port which shares PT-RS port 0 →Layer 505-a of CW0	0	1st DM-RS port which shares PT-RS port 1 →Layer 505-b of CW0
1		1	2nd DM-RS port which shares PT-RS port 1 →Layer 505-c of CW0
2		2	unused
3		3	unused

[0138] In some other such examples, when the second codeword **520**-*a* is selected and the actual number of PT-RS ports is one, then the first two bits (e.g., MSB) of the PT-RS/DM-RS association indication may be unused (because, in this example, no layers of the second codeword **520**-*a* are associated with PT-RS port 0), while the second two bits (e.g., LSB) in the PT-RS/DM-RS association indication may indicate which layer out of layers **505**-*d*, **505**-*e* and **505**-*f* is associated with PT-RS port 1, as demonstrated with reference to Table 9, below.

TABLE 9

PT-RS/DM-RS association for UL PT-RS ports 0 and 1 if CW1 is selected

Value of MSB	DM-RS port of the selected codeword (e.g., CW1)	Value of LSB	DM-RS port of the selected codeword (e.g., CW1)
0	Unused	0	1st DM-RS port which shares PT-RS port 1 →Layer 505-d of CW1
1		1	2nd DM-RS port which shares PT-RS port 1 →Layer 505-e of CW1
2		2	3rd DM-RS port which shares PT-RS port 1 →Layer 505-f of CW1
3		3	Unused

[0139] In the example of FIG. **5**B, the wireless communications system **502** may include a network entity **105**-*c* and a UE **115**-*c*, each of which may be examples of the corresponding devices as described with reference to FIG. **1**. The UE **115**-*c* may be scheduled with layers **505**, a first codeword **515**-*b* and a second codeword **520**-*b*, where layers **505**-*g*, **505**-*h*, and **505**-*j* are associated with the first codeword **515**-*b* and layers **505**-*k*, **505**-*m*, and **505**-*n* are associated with the second codeword **520**-*b*.

[0140] The UE **115**-*c* may be configured with two PT-RS ports (e.g., maxNrofPorts may equal 2) including a first PT-RS port (e.g., PT-RS port 0) and a second PT-RS port (e.g., PT-RS port 1). A number of layers **505** indicated by the TPMI may be six, where layers **505**-*g*, **505**-*h*, and **505**-*k* are associated with a first TPMI and layers **505**-*j*, **505**-*m*, and **505**-*n* are associated with a second TPMI. The DM-RS ports associated with the first TPMI may share the first PT-RS port (e.g., PT-RS port 0) and the DM-RS ports associated with the second TPMI may share the second PT-RS port (e.g., PT-RS port 1). In some such examples, layers **505**-*g*, **505**-*h*, and **505**-*k* may be associated with a first PT-RS port and layers **505**-*j*, **505**-*m*, and **505**-*n* may be associated with the second PT-RS port.

[0141] In some such examples, as shown in Table 10, below, when the UE **115**-*c* selects a first codeword **515**-*b* (e.g., codeword 0) out of the scheduled codewords, the actual number of PT-RS ports is two, then a first bit (MSB) in the PT-RS/DM-RS association indication may indicate which layer out of layers **505**-*g* and **505**-*h* are associated with the first PT-RS port and a second bit (e.g., LSB) may remain unused or may be irrelevant as the second PT-RS port is associated with a single layer **505**-*j* within the selected CW and thus does not need to be explicitly indicated (e.g., may be unused or irrelevant).

TABLE 10

PT-RS/DM-RS association for UL PT-RS ports 0 and 1 if CW0 is selected

Value of MSB	DM-RS port of the selected CW (e.g., CW0)	Value of LSB	DM-RS port of the selected CW (e.g., CW0)
0	1st DM-RS port which shares PT-RS port 0→Layer 505-g of CW0	0	unused

TABLE 10-continued

PT-RS/DM-RS association for UL PT-RS ports 0 and 1 if CW0 is selected			
Value of MSB	DM-RS port of the selected CW (e.g., CW0)	Value of LSB	DM-RS port of the selected CW (e.g., CW0)
1	2nd DM-RS port which shares PT-RS port 0→Layer 505-h of CW0	1	

[0142] In some such examples, as shown in Table 11 below, when the UE **115**-*c* selects a second codeword **520**-*b* (e.g., codeword 1) out of the scheduled codewords, the actual number of PT-RS ports is two, then a first bit (MSB) in the PT-RS/DM-RS association indication may be unused or irrelevant as the first PT-RS port (e.g., PT-RS port 0) is associated with single layer **505**-*k* (e.g., DM-RS port) within the selected second codeword **520**-*b* and a second bit (e.g., LSB) may indicate which layer out of layers **505**-*m* and **505**-*n* is associated with the second PT-RS port (e.g., PT-RS port 1).

TABLE 11

PT-RS/DM-RS association for UL PT-RS ports 0 and 1 if CW1 is selected			
Value of MSB	DM-RS port of the selected CW (e.g., CW0)	Value of LSB	DM-RS port of the selected CW (e.g., CW0)
0	Unused	0	1st DM-RS port which shares PT-RS port 1→Layer 505-m of CW1
1		1	2nd DM-RS port which shares PT-RS port 1→Layer 505-n of CW1

[0143] FIG. **6** illustrates an example of a process flow **600** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. The process flow **600** may implement or be implemented by aspects of wireless communications system **100**, **200**, **501**, or **502**. For example, the process flow **600** may illustrate operations between a UE **115**-*d* and a network entity **105**-*d*, which may be examples of a UE **115** and a network entity **105**, as described with reference to FIG. **1**. In the following description of the process flow **600**, the operations between the UE **115**-*d* and the network entity **105**-*d* may be transmitted in a different order than the example order shown, or the operations performed by the UE **115**-*d* and the network entity **105**-*d* may be performed in different orders or at different times or by different devices. Some operations may also be omitted from the process flow **600**, and other operations may be added to the process flow **600**.

[0144] At **605**, the network entity **105**-*d* may transmit RRC signaling to the UE **115**-*d*. In some examples, the RRC signaling may include an indication of a transmission mode (e.g., codebook-based PUSCH transmission or non-codebook-based transmission) for a PUSCH and a PT-RS configuration. In some examples, the PT-RS signal indication may indicate a number of configured PT-RS ports, or a density of PT-RS occasions in the frequency domain, or the time domain, or both. In some examples, the RRC signaling may include an indication of a first codeword or a second codeword which the UE is to select for determining a PT-RS/DM-RS association.

[0145] At **610**, the network entity **105**-*d* may transmit a downlink control channel (e.g., PDCCH) including DCI. The DCI may include an indication of a PT-RS/DM-RS association based on the PT-RS configuration (e.g., the number of available ports). In some examples, the DCI schedules resources for a PUSCH transmission as well as a first codeword and a second codeword for uplink data transmission. In some examples, the DCI may include an indication of the first codeword or the second codeword which the UE is to select for determining the PT-RS/DM-RS association. In some examples, the DCI may further include an SRS resource indicator that indicates a plurality of SRS resources, where each SRS resource of the plurality may be associated with one of the plurality of available PT-RS ports. In some examples, the DCI may include a TPMI, where the TPMI indicates a set of antenna ports for transmitting the PUSCH and indicates a precoding matrix comprising an association between the set of DM-RS ports and the set of antenna ports.

[0146] At **615**, the UE **115**-*d* may select a codeword from the plurality of scheduled codewords. For example, the UE **115**-*d* may select the first codeword associated with a first MCS value that is larger than a second MCS value associated with the second codeword. In some examples, the UE **115**-*d* may select the first codeword based on the first codeword being associated with at least two SRS resource sets, at least two precoders, or both. In some examples, the UE **115**-*d* may select the first codeword associated with a first index and a first MCS value when the second codeword is associated with a second index that is greater than the first index and a second MCS value that is equal to the first MCS value. In some examples, the UE **115**-*d* may select a codeword indicated by DCI or RRC signaling.

[0147] At **620**, the UE **115**-*d* may transmit a first PTRS instance. For example, the UE **115**-*d* may transmit a first PTRS instance, via one or more resources of the PUSCH according to the transmission mode, using a PTRS port corresponding to a DM-RS port of a set of DM-RS ports associated with the selected codeword based on the indicated association.

[0148] At **625**, the UE **115**-*d* may transmit a second PTRS instance. For example, the UE **115**-*d* may transmit a second PT-RS corresponding to a second DM-RS port of a second set of DM-RS ports associated with the selected codeword based on the association.

[0149] FIG. **7** shows a block diagram **700** of a device **705** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. The device **705** may be an example of aspects of a UE **115** as described herein. The device **705** may include a receiver **710**, a transmitter **715**, and a communications manager **720**. The device **705** may also include one or more processors, memory coupled with the one or more processors, and instructions stored in the memory that are executable by the one or more processors to enable the one or more processors to perform the codeword selection features discussed herein. Each of these components may be in communication with one another (e.g., via one or more buses).

[0150] The receiver **710** may provide a means for receiving information such as packets, user data, control information, or any combination thereof associated with various information channels (e.g., control channels, data channels, information channels related to reference signal association for multiple uplink codewords). Information may be passed on to other components of the device **705**. The receiver **710** may utilize a single antenna or a set of multiple antennas.

[0151] The transmitter **715** may provide a means for transmitting signals generated by other components of the device **705**. For example, the transmitter **715** may transmit information such as packets, user data, control information, or any combination thereof associated with various information channels (e.g., control channels, data channels, information channels related to reference signal association for multiple uplink codewords). In some examples, the transmitter **715** may be co-located with a receiver **710** in a transceiver module. The transmitter **715** may utilize a single antenna or a set of multiple antennas.

[0152] The communications manager **720**, the receiver **710**, the transmitter **715**, or various combinations thereof or various components thereof may be examples of means for performing various aspects of reference signal association for multiple uplink codewords as described herein. For example, the communications manager **720**, the receiver **710**, the transmitter **715**, or various combinations or components thereof may support a method for performing one or more of the functions described herein.

[0153] In some examples, the communications manager **720**, the receiver **710**, the transmitter **715**, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include a processor, a digital signal processor (DSP), a central processing unit (CPU), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA) or other programmable logic device, a microcontroller, discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure. In some examples, a processor and memory coupled with the processor may be configured to perform one or more of the functions described herein (e.g., by executing, by the processor, instructions stored in the memory).

[0154] Additionally, or alternatively, in some examples, the communications manager **720**, the receiver **710**, the transmitter **715**, or various combinations or components thereof may be implemented in code (e.g., as communications management software or firmware) executed by a processor. If implemented in code executed by a processor, the functions of the communications manager **720**, the receiver **710**, the transmitter **715**, or various combinations or components thereof may be performed by a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, a microcontroller, or any combination of these or other programmable logic devices (e.g., configured as or otherwise supporting a means for performing the functions described in the present disclosure).

[0155] In some examples, the communications manager **720** may be configured to perform various operations (e.g., receiving, obtaining, monitoring, outputting, transmitting) using or otherwise in cooperation with the receiver **710**, the transmitter **715**, or both. For example, the communications manager **720** may receive information from the receiver **710**, send information to the transmitter **715**, or be integrated in combination with the receiver **710**, the transmitter **715**, or both to obtain information, output information, or perform various other operations as described herein.

[0156] The communications manager **720** may support wireless communication at a UE in accordance with examples as disclosed herein. For example, the communications manager **720** may be configured as or otherwise support a means for receiving radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration. The communications manager **720** may be configured as or otherwise support a means for receiving downlink control information including an indication of an association between PT-RS ports and DM-RS ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission. The communications manager **720** may be configured as or otherwise support a means for selecting a codeword from the first codeword and the second codeword for the uplink transmission. The communications manager **720** may be configured as or otherwise support a means for transmitting, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with the selected codeword based on the association.

[0157] By including or configuring the communications manager **720** in accordance with examples as described herein, the device **705** (e.g., a processor controlling or otherwise coupled with the receiver **710**, the transmitter **715**, the communications manager **720**, or a combination thereof) may support techniques for increased data rates, increased capacity, higher reliability communications, and increased spectral efficiency among other examples.

[0158] FIG. **8** shows a block diagram **800** of a device **805** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. The device **805** may be an example of aspects of a device **705** or a UE **115** as described herein. The device **805** may include a receiver **810**, a transmitter **815**, and a communications manager **820**. The device **805** may also include a processor. Each of these components may be in communication with one another (e.g., via one or more buses).

[0159] The receiver **810** may provide a means for receiving information such as packets, user data, control information, or any combination thereof associated with various information channels (e.g., control channels, data channels, information channels related to reference signal association for multiple uplink codewords). Information may be passed on to other components of the device **805**. The receiver **810** may utilize a single antenna or a set of multiple antennas.

[0160] The transmitter **815** may provide a means for transmitting signals generated by other components of the device **805**. For example, the transmitter **815** may transmit information such as packets, user data, control information, or any combination thereof associated with various information channels (e.g., control channels, data channels, information channels related to reference signal association for multiple uplink codewords). In some examples, the transmitter **815** may be co-located with a receiver **810** in a transceiver module. The transmitter **815** may utilize a single antenna or a set of multiple antennas.

[0161] The device **805**, or various components thereof, may be an example of means for performing various aspects of reference signal association for multiple uplink codewords as described herein. For example, the communications manager **820** may include a control signaling component **825**, a reference signal association component **830**, a codeword selection component **835**, a reference signal component **840**, or any combination thereof. The communications manager **820** may be an example of aspects of a communications manager **720** as described herein. In some examples, the communications manager **820**, or various components thereof, may be configured to perform various operations (e.g., receiving, obtaining, monitoring, outputting, transmitting) using or otherwise in cooperation with the receiver **810**, the transmitter **815**, or both. For example, the communications manager **820** may receive information from the receiver **810**, send information to the transmitter **815**, or be integrated in combination with the receiver **810**, the transmitter **815**, or both to obtain information, output information, or perform various other operations as described herein.

[0162] The communications manager **820** may support wireless communication at a UE in accordance with examples as disclosed herein. The control signaling component **825** may be configured as or otherwise support a means for receiving radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration. The reference signal association component **830** may be configured as or otherwise support a means for receiving downlink control information including an indication of an association between PT-RS ports and DM-RS ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission. The codeword selection component **835** may be configured as or otherwise support a means for selecting a codeword from the first codeword and the second codeword for the uplink transmission. The reference signal component **840** may be configured as or otherwise support a means for transmitting, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with the selected codeword based on the association.

[0163] In some cases, the control signaling component **825**, the reference signal association component **830**, the codeword selection component **835**, and the reference signal component **840** may each be or be at least a part of a processor (e.g., a transceiver processor, or a radio processor, or a transmitter processor, or a receiver processor). The processor may be coupled with memory and execute instructions stored in the memory that enable the processor to perform or facilitate the features of the control signaling component **825**, the reference signal association component **830**, the codeword selection component **835**, and the reference signal component **840** discussed herein. A transceiver processor may be collocated with and/or communicate with (e.g., direct the operations of) a transceiver of the device. A radio processor may be collocated with and/or communicate with (e.g., direct the operations of) a radio (e.g., an NR radio, an LTE radio, a Wi-Fi radio) of the device. A transmitter processor may be collocated with and/or communicate with (e.g., direct the operations of) a transmitter of the device. A receiver processor may be collocated with and/or communicate with (e.g., direct the operations of) a receiver of the device.

[0164] FIG. **9** shows a block diagram **900** of a communications manager **920** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. The communications manager **920** may be an example of aspects of a communications manager **720**, a communications manager **820**, or both, as described herein. The communications manager **920**, or various components thereof, may be an example of means for performing various aspects of reference signal association for multiple uplink codewords as described herein. For example, the communications manager **920** may include a control signaling component **925**, a reference signal association component **930**, a codeword selection component **935**, a reference signal component **940**, a port selection component **945**, or any combination thereof. Each of these components may communicate, directly or indirectly, with one another (e.g., via one or more buses).

[0165] The communications manager **920** may support wireless communication at a UE in accordance with examples as disclosed herein. The control signaling component **925** may be configured as or otherwise support a means for receiving radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration. The reference signal association component **930** may be configured as or otherwise support a means for receiving downlink control information including an indication of an association between PT-RS ports and DM-RS ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission. The codeword selection component **935** may be configured as or otherwise support a means for selecting a codeword from the first codeword and the second codeword for the uplink transmission. The reference signal component **940** may be configured as or otherwise support a means for transmitting, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with the selected codeword based on the association.

[0166] In some examples, to support selecting the codeword, the codeword selection component **935** may be configured as or otherwise support a means for selecting the first codeword associated with a first modulation and coding scheme value, where the second codeword is associated with a second modulation and coding scheme value that is less than the first modulation and coding scheme value.

[0167] In some examples, the reference signal association component **930** may be configured as or otherwise support a means for determining that the first codeword associated with the first modulation and coding scheme value is associated with at least two SRS resource sets, at least two precoders, or both based on the PT-RS configuration indicating at least two available ports for transmitting one or more PT-RSs, where the physical uplink shared channel is associated with a first set of transmission parameters and a second set of transmission parameters.

[0168] In some examples, the reference signal component **940** may be configured as or otherwise support a means for transmitting a second PT-RS corresponding to a second DM-RS port of a second set of DM-RS ports associated with the selected codeword based on the association.

[0169] In some examples, to support selecting the codeword, the codeword selection component **935** may be configured as or otherwise support a means for selecting the first codeword based on the first codeword being associated with at least two SRS resource sets, at least two precoders, or both.

[0170] In some examples, the reference signal association component **930** may be configured as or otherwise support a means for determining that a second codeword is associated with at least two SRS resource sets, at least two precoders, or both, where selecting the first codeword is further based on a modulation and coding scheme value of the first codeword, an index of the first codeword, or both.

[0171] In some examples, to support selecting the codeword, the codeword selection component **935** may be configured as or otherwise support a means for selecting the first codeword associated with a first index and a first modulation and coding scheme value, where the second codeword is associated with a second index that is greater than the first index and a second modulation and coding scheme value that is equal to the first modulation and coding scheme value.

[0172] In some examples, the radio resource control signaling, or the downlink control information, or both includes an indication of the first codeword or the second codeword. In some examples, selecting the codeword includes. In some examples, selecting the indicated codeword.

[0173] In some examples, the PT-RS configuration indicates a single available port for transmitting a PT-RS and the transmission mode is codebook-based or non-codebook-based. In some examples, the indication of the association includes two bits indicating a DM-RS port of the set of DM-RS ports associated with the selected codeword. In some examples, the PT-RS configuration indicates a set of multiple available ports for transmitting one or more PT-RSs.

[0174] In some examples, the indication of the association includes at least two bits, and the reference signal component **940** may be configured as or otherwise support a means for transmitting a second PT-RS corresponding to the second DM-RS port of the second set of DM-RS ports associated with the selected codeword based on the association. In some examples, a rank of the physical uplink shared channel is less than or equal to a threshold rank.

[0175] In some examples, the set of DM-RS ports are associated with a first SRS resource set, a first precoder, or both and the second set of DM-RS ports are associated with a second SRS resource set, a second precoder, or both.

[0176] In some examples, the indication of the association includes a set of multiple bits, and the reference signal component **940** may be configured as or otherwise support a means for transmitting a second PT-RS corresponding to the second DM-RS port of the second set of DM-RS ports associated with the selected codeword based on the association.

[0177] In some examples, a rank of the physical uplink shared channel is greater than a threshold rank. In some examples, the set of DM-RS ports is associated with a first port for transmitting the PT-RS and a second set of ports is associated with a second port for transmitting a second PT-RS. In some examples, the transmission mode is non-codebook-based.

[0178] In some examples, the downlink control information further includes an SRS resource indicator that indicates a set of multiple SRS resources, and the port selection component **945** may be configured as or otherwise support a means for determining which of the set of multiple available ports to use for transmitting the one or more PT-RSs based on the selected codeword and the SRS resource indicator, where each SRS resource is associated with one of the set of multiple available ports for transmitting one or more PT-RSs.

[0179] In some examples, to support determining which of the set of multiple available ports to use for transmitting the one or more PT-RSs, the port selection component **945** may be configured as or otherwise support a means for determining to use one of the set of multiple available ports based on an PT-RS port index associated with each SRS resource of the SRS resources associated with the selected codeword being the same. In some examples, to support determining which of the set of multiple available ports to use for transmitting the one or more PT-RSs, the port selection component **945** may be configured as or otherwise support a means for determining to use two or more of the set of multiple available ports based on an PT-RS port index associated with multiple SRS resource associated with the selected codeword being different. In some examples, the transmission mode is codebook-based.

[0180] In some examples, the downlink control information further includes a transmit precoding matrix index, and the port selection component **945** may be configured as or otherwise support a means for determining which of the set of multiple available ports to use for transmitting the one or more PT-RSs based on the selected codeword and the transmit precoding matrix index, where the transmit precoding matrix index indicates a set of antenna ports for transmitting the physical uplink shared channel and a precoding matrix including an association between the set of DM-RS ports and the set of antenna ports.

[0181] In some examples, to support determining which of the set of multiple available ports to use for transmitting the one or more PT-RSs, the port selection component **945** may be configured as or otherwise support a means for determining to use one or more of the set of multiple available ports based on the association between the set of DM-RS ports and the set of antenna ports.

[0182] In some examples, the physical uplink shared channel is associated with a first set of transmission parameters and a second set of transmission parameters.

[0183] In some cases, the control signaling component **925**, the reference signal association component **930**, the codeword selection component **935**, the reference signal component **940**, and the port selection component **945** may each be or be at least a part of a processor (e.g., a transceiver processor, or a radio processor, or a transmitter processor, or a receiver processor). The processor may be coupled with memory and execute instructions stored in the memory that enable the processor to perform or facilitate the features of the control signaling component **925**, the reference signal association component **930**, the codeword selection component **935**, the reference signal component **940**, and the port selection component **945** discussed herein.

[0184] FIG. **10** shows a diagram of a system **1000** including a device **1005** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. The device **1005** may be an example of or include the components of a device **705**, a device **805**, or a UE **115** as described herein. The device **1005** may communicate (e.g., wirelessly) with one or more network entities **105**, one or more UEs **115**, or any combination thereof. The device **1005** may include components for bi-directional voice and data communications including components for transmitting and receiving communications, such as a communications manager **1020**, an input/output (I/O) controller **1010**, a transceiver **1015**, an antenna **1025**, a memory **1030**, code **1035**, and a processor **1040**. These components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more buses (e.g., a bus **1045**).

[0185] The I/O controller **1010** may manage input and output signals for the device **1005**. The I/O controller **1010** may also manage peripherals not integrated into the device **1005**. In some cases, the I/O controller **1010** may represent a physical connection or port to an external peripheral. In some cases, the I/O controller **1010** may utilize an operating system such as iOS®, ANDROID®, MS-DOS®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. Additionally, or alternatively, the I/O controller **1010** may represent or interact with a modem, a keyboard, a mouse, a touchscreen, or a similar device. In some cases, the I/O controller **1010** may be implemented as part of a processor, such as the processor **1040**. In some cases, a user may interact with the device **1005** via the I/O controller **1010** or via hardware components controlled by the I/O controller **1010**.

[0186] In some cases, the device **1005** may include a single antenna **1025**. However, in some other cases, the device **1005** may have more than one antenna **1025**, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver **1015** may communicate bi-directionally, via the one or more antennas **1025**, wired, or wireless links as described herein. For example, the transceiver **1015** may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver **1015** may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas **1025** for transmission, and to demodulate packets received from the one or more antennas **1025**. The transceiver **1015**, or the transceiver **1015** and one or more antennas **1025**, may be an example of a transmitter **715**, a transmitter **815**, a receiver **710**, a receiver **810**, or any combination thereof or component thereof, as described herein.

[0187] The memory **1030** may include random access memory (RAM) and read-only memory (ROM). The memory **1030** may store computer-readable, computer-executable code **1035** including instructions that, when executed by the processor **1040**, cause the device **1005** to perform various functions described herein. The code **1035** may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some cases, the code **1035** may not be directly executable by the processor **1040** but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some cases, the memory **1030** may contain, among other things, a basic I/O system (BIOS) which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[0188] The processor **1040** may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some cases, the processor **1040** may be configured to operate a memory array using a memory controller. In some other cases, a memory controller may be integrated into the processor **1040**. The processor **1040** may be configured to execute computer-readable instructions stored in a memory (e.g., the memory **1030**) to cause the device **1005** to perform various functions (e.g., functions or tasks supporting reference signal association for multiple uplink codewords). For example, the device **1005** or a component of the device **1005** may include a processor **1040** and memory **1030** coupled with or to the processor **1040**, the processor **1040** and memory **1030** configured to perform various functions described herein.

[0189] The communications manager **1020** may support wireless communication at a UE in accordance with examples as disclosed herein. For example, the communications manager **1020** may be configured as or otherwise support a means for receiving radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration. The communications manager **1020** may be configured as or otherwise support a means for receiving downlink control information including an indication of an association between PT-RS ports and DM-RS ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission. The communications manager **1020** may be configured as or otherwise support a means for selecting a codeword from the first codeword and the second codeword for the uplink transmission. The communications manager **1020** may be configured as or otherwise support a means for transmitting, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with the selected codeword based on the association.

[0190] By including or configuring the communications manager **1020** in accordance with examples as described herein, the device **1005** may support techniques for improved communication reliability, improved user experience, more efficient utilization of communication resources, improved coordination between devices, and improved utilization of processing capability, among other examples.

[0191] In some examples, the communications manager **1020** may be configured to perform various operations (e.g., receiving, monitoring, transmitting) using or otherwise in cooperation with the transceiver **1015**, the one or more antennas **1025**, or any combination thereof. Although the communications manager **1020** is illustrated as a separate component, in some examples, one or more functions described with reference to the communications manager **1020** may be supported by or performed by the processor **1040**, the memory **1030**, the code **1035**, or any combination thereof. For example, the code **1035** may include instructions executable by the processor **1040** to cause the device **1005** to perform various aspects of reference signal association for multiple uplink codewords as described herein, or the processor **1040** and the memory **1030** may be otherwise configured to perform or support such operations.

[0192] FIG. **11** shows a block diagram **1100** of a device **1105** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. The device **1105** may be an example of aspects of a network entity **105** as described herein. The device **1105** may include a receiver **1110**, a transmitter **1115**, and a communications manager **1120**. The device **1105** may also include one or more processors, memory coupled with the one or more processors, and instructions stored in the memory that are executable by the one or more processors to enable the one or more processors to perform the codeword selection features discussed herein. Each of these components may be in communication with one another (e.g., via one or more buses).

[0193] The receiver **1110** may provide a means for obtaining (e.g., receiving, determining, identifying) information such as user data, control information, or any combination thereof (e.g., I/Q samples, symbols, packets, protocol data units, service data units) associated with various channels (e.g., control channels, data channels, information channels, channels associated with a protocol stack). Information may be passed on to other components of the device **1105**. In some examples, the receiver **1110** may support obtaining information by receiving signals via one or more antennas. Additionally, or alternatively, the receiver **1110** may support obtaining information by receiving signals via one or more wired (e.g., electrical, fiber optic) interfaces, wireless interfaces, or any combination thereof.

[0194] The transmitter **1115** may provide a means for outputting (e.g., transmitting, providing, conveying, sending) information generated by other components of the device **1105**. For example, the transmitter **1115** may output information such as user data, control information, or any combination thereof (e.g., I/Q samples, symbols, packets, protocol data units, service data units) associated with various channels (e.g., control channels, data channels, information channels, channels associated with a protocol stack). In some examples, the transmitter **1115** may support outputting information by transmitting signals via one or more antennas. Additionally, or alternatively, the transmitter **1115** may support outputting information by transmitting signals via one or more wired (e.g., electrical, fiber optic) interfaces, wireless interfaces, or any combination thereof. In some examples, the transmitter **1115** and the receiver **1110** may be co-located in a transceiver, which may include or be coupled with a modem.

[0195] The communications manager **1120**, the receiver **1110**, the transmitter **1115**, or various combinations thereof or various components thereof may be examples of means for performing various aspects of reference signal association for multiple uplink codewords as described herein. For example, the communications manager **1120**, the receiver **1110**, the transmitter **1115**, or various combinations or components thereof may support a method for performing one or more of the functions described herein.

[0196] In some examples, the communications manager **1120**, the receiver **1110**, the transmitter **1115**, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include a processor, a DSP, a CPU, an ASIC, an FPGA or other programmable logic device, a microcontroller, discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure. In some examples, a processor and memory coupled with the processor may be configured to perform one or more of the functions described herein (e.g., by executing, by the processor, instructions stored in the memory).

[0197] Additionally, or alternatively, in some examples, the communications manager **1120**, the receiver **1110**, the transmitter **1115**, or various combinations or components thereof may be implemented in code (e.g., as communications management software or firmware) executed by a processor. If implemented in code executed by a processor, the functions of the communications manager **1120**, the receiver **1110**, the transmitter **1115**, or various combinations or components thereof may be performed by a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, a microcontroller, or any combination of these or other programmable logic devices (e.g., configured as or otherwise supporting a means for performing the functions described in the present disclosure).

[0198] In some examples, the communications manager **1120** may be configured to perform various operations (e.g., receiving, obtaining, monitoring, outputting, transmitting) using or otherwise in cooperation with the receiver **1110**, the transmitter **1115**, or both. For example, the communications manager **1120** may receive information from the receiver **1110**, send information to the transmitter **1115**, or be integrated in combination with the receiver **1110**, the transmitter **1115**, or both to obtain information, output information, or perform various other operations as described herein.

[0199] The communications manager **1120** may support wireless communication in accordance with examples as disclosed herein. For example, the communications manager **1120** may be configured as or otherwise support a means for transmitting radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration. The communications manager **1120** may be configured as or otherwise support a means for transmitting downlink control information including an indication of an association between PT-RS ports and DM-RS ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission. The communications manager **1120** may be configured as or otherwise support a means for receiving, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with a selected codeword based on the association.

[0200] By including or configuring the communications manager **1120** in accordance with examples as described herein, the device **1105** (e.g., a processor controlling or otherwise coupled with the receiver **1110**, the transmitter **1115**, the communications manager **1120**, or a combination thereof) may support techniques for increased data rates, increased capacity, higher reliability communications, and increased spectral efficiency among other examples.

[0201] FIG. **12** shows a block diagram **1200** of a device **1205** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. The device **1205** may be an example of aspects of a device **1105** or a network entity **105** as described herein. The device **1205** may include a receiver **1210**, a transmitter **1215**, and a communications manager **1220**. The device **1205** may also include a processor. Each of these components may be in communication with one another (e.g., via one or more buses).

[0202] The receiver **1210** may provide a means for obtaining (e.g., receiving, determining, identifying) information such as user data, control information, or any combination thereof (e.g., I/Q samples, symbols, packets, protocol data units, service data units) associated with various channels (e.g., control channels, data channels, information channels, channels associated with a protocol stack). Information may be passed on to other components of the device **1205**. In some examples, the receiver **1210** may support obtaining information by receiving signals via one or more antennas. Additionally, or alternatively, the receiver **1210** may support obtaining information by receiving signals via one or more wired (e.g., electrical, fiber optic) interfaces, wireless interfaces, or any combination thereof.

[0203] The transmitter **1215** may provide a means for outputting (e.g., transmitting, providing, conveying, sending) information generated by other components of the device **1205**. For example, the transmitter **1215** may output information such as user data, control information, or any combination thereof (e.g., I/Q samples, symbols, packets, protocol data units, service data units) associated with various channels (e.g., control channels, data channels, information channels, channels associated with a protocol stack). In some examples, the transmitter **1215** may support outputting information by transmitting signals via one or more antennas. Additionally, or alternatively, the transmitter **1215** may support outputting information by transmitting signals via one or more wired (e.g., electrical, fiber optic) interfaces, wireless interfaces, or any combination thereof. In some examples, the transmitter **1215** and the receiver **1210** may be co-located in a transceiver, which may include or be coupled with a modem.

[0204] The device **1205**, or various components thereof, may be an example of means for performing various aspects of reference signal association for multiple uplink codewords as described herein. For example, the communications manager **1220** may include a control signaling component **1225**, a reference signal association component **1230**, a reference signal manager **1235**, or any combination thereof. The communications manager **1220** may be an example of aspects of a communications manager **1120** as described herein. In some examples, the communications manager **1220**, or various components thereof, may be configured to perform various operations (e.g., receiving, obtaining, monitoring, outputting, transmitting) using or otherwise in cooperation with the receiver **1210**, the transmitter **1215**, or both. For example, the communications manager **1220** may receive information from the receiver **1210**, send information to the transmitter **1215**, or be integrated in combination with the receiver **1210**, the transmitter **1215**, or both to obtain information, output information, or perform various other operations as described herein.

[0205] The communications manager **1220** may support wireless communication in accordance with examples as disclosed herein. The control signaling component **1225** may be configured as or otherwise support a means for transmitting radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration. The reference signal association component **1230** may be configured as or otherwise support a means for transmitting downlink control information including an indication of an association between PT-RS ports and DM-RS ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission. The reference signal manager **1235** may be configured as or otherwise support a means for receiving, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with a selected codeword based on the association.

[0206] In some cases, the control signaling component **1225**, the reference signal association component **1230**, and the reference signal manager **1235** may each be or be at least a part of a processor (e.g., a transceiver processor, or a radio processor, or a transmitter processor, or a receiver processor). The processor may be coupled with memory and execute instructions stored in the memory that enable the processor to perform or facilitate the features of the control signaling component **1225**, the reference signal association component **1230**, and the reference signal manager **1235** discussed herein. A transceiver processor may be collocated with and/or communicate with (e.g., direct the operations of) a transceiver of the device. A radio processor may be collocated with and/or communicate with (e.g., direct the operations of) a radio (e.g., an NR radio, an LTE radio, a Wi-Fi radio) of the device. A transmitter processor may be collocated with and/or communicate with (e.g., direct the operations of) a transmitter of the device. A receiver processor may be collocated with and/or communicate with (e.g., direct the operations of) a receiver of the device.

[0207] FIG. **13** shows a block diagram **1300** of a communications manager **1320** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. The communications manager **1320** may be an example of aspects of a communications manager **1120**, a communications manager **1220**, or both, as described herein. The communications manager **1320**, or various components thereof, may be an example of means for performing various aspects of reference signal association for multiple uplink codewords as described herein. For example, the communications manager **1320** may include a control signaling component **1325**, a reference signal association component **1330**, a reference signal manager **1335**, or any combination thereof. Each of these components may communicate, directly or indirectly, with one another (e.g., via one or more buses) which may include communications within a protocol layer of a protocol stack, communications associated with a logical channel of a protocol stack (e.g., between protocol layers of a protocol stack, within a device, component, or virtualized component associated with a network entity **105**, between devices, components, or virtualized components associated with a network entity **105**), or any combination thereof.

[0208] The communications manager **1320** may support wireless communication in accordance with examples as disclosed herein. The control signaling component **1325** may be configured as or otherwise support a means for transmitting radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration. The reference signal association component **1330** may be configured as or otherwise support a means for transmitting downlink control information including an indication of an association between PT-RS ports and DM-RS ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission. The reference signal manager **1335** may be configured as or otherwise support a means for receiving, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with a selected codeword based on the association.

[0209] In some examples, the reference signal manager **1335** may be configured as or otherwise support a means for receiving a second PT-RS corresponding to a second DM-RS port of the set of DM-RS ports associated with the selected codeword based on the association.

[0210] In some examples, the indication of the association includes at least two bits indicating the DM-RS port of the set of DM-RS ports associated with the selected codeword.

[0211] In some cases, the control signaling component **1325**, the reference signal association component **1330**, and the reference signal manager **1335** may each be or be at least a part of a processor (e.g., a transceiver processor, or a radio processor, or a transmitter processor, or a receiver processor). The processor may be coupled with memory and execute instructions stored in the memory that enable the processor to perform or facilitate the features of the control signaling component **1325**, the reference signal association component **1330**, and the reference signal manager **1335** discussed herein.

[0212] FIG. **14** shows a diagram of a system **1400** including a device **1405** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. The device **1405** may be an example of or include the components of a device **1105**, a device **1205**, or a network entity **105** as described herein. The device **1405** may communicate with one or more network entities **105**, one or more UEs **115**, or any combination thereof, which may include communications over one or more wired interfaces, over one or more wireless interfaces, or any combination thereof. The device **1405** may include components that support outputting and obtaining communications, such as a communications manager **1420**, a transceiver **1410**, an antenna **1415**, a memory **1425**, code **1430**, and a processor **1435**. These components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more buses (e.g., a bus **1440**).

[0213] The transceiver **1410** may support bi-directional communications via wired links, wireless links, or both as described herein. In some examples, the transceiver **1410** may include a wired transceiver and may communicate bi-directionally with another wired transceiver. Additionally, or alternatively, in some examples, the transceiver **1410** may include a wireless transceiver and may communicate bi-directionally with another wireless transceiver. In some examples, the device **1405** may include one or more antennas **1415**, which may be capable of transmitting or receiving wireless transmissions (e.g., concurrently). The transceiver **1410** may also include a modem to modulate signals, to provide the modulated signals for transmission (e.g., by one or more antennas **1415**, by a wired transmitter), to receive modulated signals (e.g., from one or more antennas **1415**, from a wired receiver), and to demodulate signals. The transceiver **1410**, or the transceiver **1410** and one or more antennas **1415** or wired interfaces, where applicable, may be an example of a transmitter **1115**, a transmitter **1215**, a receiver **1110**, a receiver **1210**, or any combination thereof or component thereof, as described herein. In some examples, the transceiver may be operable to support communications via one or more communications links (e.g., a communication link **125**, a backhaul communication link **120**, a midhaul communication link **162**, a fronthaul communication link **168**).

[0214] The memory **1425** may include RAM and ROM. The memory **1425** may store computer-readable, computer-executable code **1430** including instructions that, when executed by the processor **1435**, cause the device **1405** to perform various functions described herein. The code **1430** may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some cases, the code **1430** may not be directly executable by the processor **1435** but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some cases, the memory **1425** may contain, among other things, a BIOS which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[0215] The processor **1435** may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, an ASIC, a CPU, an FPGA, a microcontroller, a programmable logic device, discrete gate or transistor logic, a discrete hardware component, or any combination thereof). In some cases, the processor **1435** may be configured to operate a memory array using a memory controller. In some other cases, a memory controller may be integrated into the processor **1435**. The processor **1435** may be configured to execute computer-readable instructions stored in a memory (e.g., the memory **1425**) to cause the device **1405** to perform various functions (e.g., functions or tasks supporting reference signal association for multiple uplink codewords). For example, the device **1405** or a component of the device **1405** may include a processor **1435** and memory **1425** coupled with the processor **1435**, the processor **1435** and memory **1425** configured to perform various functions described herein. The processor **1435** may be an example of a cloud-computing platform (e.g., one or more physical nodes and supporting software such as operating systems, virtual machines, or container instances) that may host the functions (e.g., by executing code **1430**) to perform the functions of the device **1405**.

[0216] In some examples, a bus **1440** may support communications of (e.g., within) a protocol layer of a protocol stack. In some examples, a bus **1440** may support communications associated with a logical channel of a protocol stack (e.g., between protocol layers of a protocol stack), which may include communications performed within a component of the device **1405**, or between different components of the device **1405** that may be co-located or located in different locations (e.g., where the device **1405** may refer to a system in which one or more of the communications manager **1420**, the transceiver **1410**, the memory **1425**, the code **1430**, and the processor **1435** may be located in one of the different components or divided between different components).

[0217] In some examples, the communications manager **1420** may manage aspects of communications with a core network **130** (e.g., via one or more wired or wireless backhaul links). For example, the communications manager **1420** may manage the transfer of data communications for client devices, such as one or more UEs **115**. In some examples, the communications manager **1420** may manage communications with other network entities **105**, and may include a controller or scheduler for controlling communications with UEs **115** in cooperation with other network entities **105**. In some examples, the communications manager **1420** may support an X2 interface within an LTE/LTE-A wireless communications network technology to provide communication between network entities **105**.

[0218] The communications manager **1420** may support wireless communication in accordance with examples as disclosed herein. For example, the communications manager **1420** may be configured as or otherwise support a means for transmitting radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration. The communications manager **1420** may be configured as or otherwise support a means for transmitting downlink control information including an indication of an association between PT-RS ports and DM-RS ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission. The communications manager **1420** may be configured as or otherwise support a means for receiving, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with a selected codeword based on the association.

[0219] By including or configuring the communications manager **1420** in accordance with examples as described herein, the device **1405** may support techniques for improved communication reliability, improved user experience, more efficient utilization of communication resources, improved coordination between devices, and improved utilization of processing capability, among other examples.

[0220] In some examples, the communications manager **1420** may be configured to perform various operations (e.g., receiving, obtaining, monitoring, outputting, transmitting) using or otherwise in cooperation with the transceiver **1410**, the one or more antennas **1415** (e.g., where applicable), or any combination thereof. Although the communications manager **1420** is illustrated as a separate component, in some examples, one or more functions described with reference to the communications manager **1420** may be supported by or performed by the processor **1435**, the memory **1425**, the code **1430**, the transceiver **1410**, or any combination thereof. For example, the code **1430** may include instructions executable by the processor **1435** to cause the device **1405** to perform various aspects of reference signal association for multiple uplink codewords as described herein, or the processor **1435** and the memory **1425** may be otherwise configured to perform or support such operations.

[0221] FIG. **15** shows a flowchart illustrating a method **1500** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. The operations of the method **1500** may be implemented by a UE or its components as described herein. For example, the operations of the method **1500** may be performed by a UE **115** as described with reference to FIGS. **1** through **10**. In some examples, a UE may execute a set of instructions to control the functional elements of the UE to perform the described functions. Additionally, or alternatively, the UE may perform aspects of the described functions using special-purpose hardware.

[0222] At **1505**, the method may include receiving radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration. The operations of **1505** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1505** may be performed by a control signaling component **925** as described with reference to FIG. **9**.

[0223] At **1510**, the method may include receiving downlink control information including an indication of an association between PT-RS ports and DM-RS ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission. The operations of **1510** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1510** may be performed by a reference signal association component **930** as described with reference to FIG. **9**.

[0224] At **1515**, the method may include selecting a codeword from the first codeword and the second codeword for the uplink transmission. The operations of **1515** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1515** may be performed by a codeword selection component **935** as described with reference to FIG. **9**.

[0225] At **1520**, the method may include transmitting, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with the selected codeword based on the association. The operations of **1520** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1520** may be performed by a reference signal component **940** as described with reference to FIG. **9**.

[0226] FIG. **16** shows a flowchart illustrating a method **1600** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. The operations of the method **1600** may be implemented by a UE or its components as described herein. For example, the operations of the method **1600** may be performed by a UE **115** as described with reference to FIGS. **1** through **10**. In some examples, a UE may execute a set of instructions to control the functional elements of the UE to perform the described functions. Additionally, or alternatively, the UE may perform aspects of the described functions using special-purpose hardware.

[0227] At **1605**, the method may include receiving radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration. The operations of **1605** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1605** may be performed by a control signaling component **925** as described with reference to FIG. **9**.

[0228] At **1610**, the method may include receiving downlink control information including an indication of an association between PT-RS ports and DM-RS ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission. The operations of **1610** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1610** may be performed by a reference signal association component **930** as described with reference to FIG. **9**.

[0229] At **1615**, the method may include selecting the first codeword associated with a first modulation and coding scheme value, where the second codeword is associated with a second modulation and coding scheme value that is less than the first modulation and coding scheme value. The operations of **1615** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1615** may be performed by a codeword selection component **935** as described with reference to FIG. **9**.

[0230] At **1620**, the method may include transmitting, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with the selected codeword based on the association. The operations of **1620** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1620** may be performed by a reference signal component **940** as described with reference to FIG. **9**.

[0231] FIG. **17** shows a flowchart illustrating a method **1700** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. The operations of the method **1700** may be implemented by a UE or its components as described herein. For example, the operations of the method **1700** may be performed by a UE **115** as described with reference to FIGS. **1** through **10**. In some examples, a UE may execute a set of instructions to control the functional elements of the UE to perform the described functions. Additionally, or alternatively, the UE may perform aspects of the described functions using special-purpose hardware.

[0232] At **1705**, the method may include receiving radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration. The operations of **1705** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1705** may be performed by a control signaling component **925** as described with reference to FIG. **9**.

[0233] At **1710**, the method may include receiving downlink control information including an indication of an association between PT-RS ports and DM-RS ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission. The operations of **1710** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1710** may be performed by a reference signal association component **930** as described with reference to FIG. **9**.

[0234] At **1715**, the method may include selecting the first codeword based on the first codeword being associated with at least two SRS resource sets, at least two precoders, or both. The operations of **1715** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1715** may be performed by a codeword selection component **935** as described with reference to FIG. **9**.

[0235] At **1720**, the method may include transmitting, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with the selected codeword based on the association. The operations of **1720** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1720** may be performed by a reference signal component **940** as described with reference to FIG. **9**.

[0236] FIG. **18** shows a flowchart illustrating a method **1800** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. The operations of the method **1800** may be implemented by a UE or its components as described herein. For example, the operations of the method **1800** may be performed by a UE **115** as described with reference to FIGS. **1** through **10**. In some examples, a UE may execute a set of instructions to control the functional elements of the UE to perform the described functions. Additionally, or alternatively, the UE may perform aspects of the described functions using special-purpose hardware.

[0237] At **1805**, the method may include receiving radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration. The operations of **1805** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1805** may be performed by a control signaling component **925** as described with reference to FIG. **9**.

[0238] At **1810**, the method may include receiving downlink control information including an indication of an association between PT-RS ports and DM-RS ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission. The operations of **1810** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1810** may be performed by a reference signal association component **930** as described with reference to FIG. **9**.

[0239] At **1815**, the method may include selecting the first codeword associated with a first index and a first modulation and coding scheme value, where the second codeword is associated with a second index that is greater than the first index and a second modulation and coding scheme value that is equal to the first modulation and coding scheme value. The operations of **1815** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1815** may be performed by a codeword selection component **935** as described with reference to FIG. **9**.

[0240] At **1820**, the method may include transmitting, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with the selected codeword based on the association. The operations of **1820** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1820** may be performed by a reference signal component **940** as described with reference to FIG. **9**.

[0241] FIG. **19** shows a flowchart illustrating a method **1900** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. The operations of the method **1900** may be implemented by a network entity or its components as described herein. For example, the operations of the method **1900** may be performed by a network entity as described with reference to FIGS. **1** through **6** and **11** through **14**. In some examples, a network entity may execute a set of instructions to control the functional elements of the network entity to perform the described functions. Additionally, or alternatively, the network entity may perform aspects of the described functions using special-purpose hardware.

[0242] At **1905**, the method may include transmitting radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration. The operations of **1905** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1905** may be performed by a control signaling component **1325** as described with reference to FIG. **13**.

[0243] At **1910**, the method may include transmitting downlink control information including an indication of an association between PT-RS ports and DM-RS ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission. The operations of **1910** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1910** may be performed by a reference signal association component **1330** as described with reference to FIG. **13**.

[0244] At **1915**, the method may include receiving, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with a selected codeword based on the association. The operations of **1915** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1915** may be performed by a reference signal manager **1335** as described with reference to FIG. **13**.

[0245] FIG. **20** shows a flowchart illustrating a method **2000** that supports reference signal association for multiple uplink codewords in accordance with one or more aspects of the present disclosure. The operations of the method **2000** may be implemented by a network entity or its components as described herein. For example, the operations of the method **2000** may be performed by a network entity as described with reference to FIGS. **1** through **6** and **11** through **14**. In some examples, a network entity may execute a set of instructions to control the functional elements of the network entity to perform the described functions. Additionally, or alternatively, the network entity may perform aspects of the described functions using special-purpose hardware.

[0246] At **2005**, the method may include transmitting radio resource control signaling including an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration. The operations of **2005** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **2005** may be performed by a control signaling component **1325** as described with reference to FIG. **13**.

[0247] At **2010**, the method may include transmitting downlink control information including an indication of an association between PT-RS ports and DM-RS ports based on the PT-RS configuration, where the downlink control information schedules a first codeword and a second codeword for an uplink transmission. The operations of **2010** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **2010** may be performed by a reference signal association component **1330** as described with reference to FIG. **13**.

[0248] At **2015**, the method may include receiving, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with a selected codeword based on the association. The operations of **2015** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **2015** may be performed by a reference signal manager **1335** as described with reference to FIG. **13**.

[0249] At **2020**, the method may include receiving a second PT-RS corresponding to a second DM-RS port of the set of DM-RS ports associated with the selected codeword based on the association. The operations of **2020** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **2020** may be performed by a reference signal manager **1335** as described with reference to FIG. **13**.

[0250] The following provides an overview of aspects of the present disclosure:

[0251] Aspect 1: A method for wireless communication at a UE, comprising: receiving radio resource control signaling comprising an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration; receiving downlink control information comprising an indication of an association between PT-RS ports and demodulation reference signal (DM-RS) ports based at least in part on the PT-RS configuration, wherein the downlink control information schedules a first codeword and a second codeword for an uplink transmission; selecting a codeword from the first codeword and the second codeword for the uplink transmission; and transmitting, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with the selected codeword based at least in part on the association.

[0252] Aspect 2: The method of aspect 1, wherein selecting the codeword comprises: selecting the first codeword associated with a first modulation and coding scheme value, wherein the second codeword is associated with a second modulation and coding scheme value that is less than the first modulation and coding scheme value.

[0253] Aspect 3: The method of aspect 2, further comprising: determining that the first codeword associated with the first modulation and coding scheme value is associated with at least two SRS resource sets, at least two precoders, or both based at least in part on the PT-RS configuration indicating at least two available ports for transmitting one or more PT-RSs, wherein the physical uplink shared channel is associated with a first set of transmission parameters and a second set of transmission parameters.

[0254] Aspect 4: The method of aspect 3, further comprising: transmitting a second PT-RS corresponding to a second DM-RS port of a second set of DM-RS ports associated with the selected codeword based at least in part on the association.

[0255] Aspect 5: The method of any of aspect 1, wherein selecting the codeword comprises: selecting the first codeword based at least in part on the first codeword being associated with at least two SRS resource sets, at least two precoders, or both.

[0256] Aspect 6: The method of aspect 5, further comprising: determining that a second codeword is associated with at least two SRS resource sets, at least two precoders, or both, wherein selecting the first codeword is further based at least in part on a modulation and coding scheme value of the first codeword, an index of the first codeword, or both.

[0257] Aspect 7: The method of any of aspect 1, wherein selecting the codeword comprises: selecting the first codeword associated with a first index and a first modulation and coding scheme value, wherein the second codeword is associated with a second index that is greater than the first index and a second modulation and coding scheme value that is equal to the first modulation and coding scheme value.

[0258] Aspect 8: The method of any of aspect 1, wherein the radio resource control signaling, or the downlink control information, or both comprises an indication of the first codeword or the second codeword; and selecting the codeword comprises: selecting the indicated codeword.

[0259] Aspect 9: The method of any of aspects 1 through 8, wherein the PT-RS configuration indicates a single available port for transmitting a PT-RS and the transmission mode is codebook-based or non-codebook-based.

[0260] Aspect 10: The method of aspect 9, wherein the indication of the association comprises two bits indicating a DM-RS port of the set of DM-RS ports associated with the selected codeword.

[0261] Aspect 11: The method of any of aspects 1 through 10, wherein the PT-RS configuration indicates a plurality of available ports for transmitting one or more PT-RSs.

[0262] Aspect 12: The method of aspect 11, wherein the indication of the association comprises at least two bits, wherein a first bit indicates a DM-RS port of the set of DM-RS ports associated with the selected codeword and a second bit indicates a second DM-RS port of the second set of DM-RS ports associated with the selected codeword, the method further comprising: transmitting a second PT-RS corresponding to the second DM-RS port of the second set of DM-RS ports associated with the selected codeword based at least in part on the association.

[0263] Aspect 13: The method of aspect 12, wherein a rank of the physical uplink shared channel is less than or equal to a threshold rank.

[0264] Aspect 14: The method of any of aspects 12 through 13, wherein the set of DM-RS ports are associated with a first SRS resource set, a first precoder, or both and the second set of DM-RS ports are associated with a second SRS resource set, a second precoder, or both.

[0265] Aspect 15: The method of any of aspect 11, wherein the indication of the association comprises a plurality of bits, wherein a first subset of bits indicates a DM-RS port of the set of DM-RS ports associated with the selected codeword and a second subset of bits indicates a second DM-RS port of the set of DM-RS ports associated with the selected codeword, the method further comprising: transmitting a second PT-RS corresponding to the second DM-RS port of the second set of DM-RS ports associated with the selected codeword based at least in part on the association.

[0266] Aspect 16: The method of aspect 15, wherein a rank of the physical uplink shared channel is greater than a threshold rank.

[0267] Aspect 17: The method of any of aspect 11, wherein the set of DM-RS ports is associated with a first port for transmitting the PT-RS and a second set of ports is associated with a second port for transmitting a second PT-RS.

[0268] Aspect 18: The method of any of aspects 11 through 17, wherein the transmission mode is non-codebook-based.

[0269] Aspect 19: The method of aspect 18, wherein the downlink control information further comprises an SRS resource indicator that indicates a plurality of SRS resources, the method further comprising: determining which of the plurality of available ports to use for transmitting the one or more PT-RSs based at least in part on the selected codeword and the SRS resource indicator, wherein each SRS resource is associated with one of the plurality of available ports for transmitting one or more PT-RSs.

[0270] Aspect 20: The method of aspect 19, wherein determining which of the plurality of available ports to use for transmitting the one or more PT-RSs comprises: determining to use one of the plurality of available ports based at least in part on an PT-RS port index associated with each SRS resource of the SRS resources associated with the selected codeword being the same; or determining to use two or more of the plurality of available ports based at least in part on an PT-RS port index associated with multiple SRS resource associated with the selected codeword being different.

[0271] Aspect 21: The method of any of aspects 11 through 17, wherein the transmission mode is codebook-based.

[0272] Aspect 22: The method of aspect 21, wherein the downlink control information further comprises a transmit precoding matrix index, the method further comprising: determining which of the plurality of available ports to use for transmitting the one or more PT-RSs based at least in part on the selected codeword and the transmit precoding matrix index, wherein the transmit precoding matrix index indicates a set of antenna ports for transmitting the physical uplink shared channel and a precoding matrix comprising an association between the set of DM-RS ports and the set of antenna ports.

[0273] Aspect 23: The method of aspect 22, wherein determining which of the plurality of available ports to use for transmitting the one or more PT-RSs comprises: determining to use one or more of the plurality of available ports based at least in part on the association between the set of DM-RS ports and the set of antenna ports.

[0274] Aspect 24: The method of any of aspects 1 through 23, wherein the physical uplink shared channel is associated with a first set of transmission parameters and a second set of transmission parameters.

[0275] Aspect 25: A method for wireless communication, comprising: transmitting radio resource control signaling comprising an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration; transmitting downlink control information comprising an indication of an association between PT-RS ports and demodulation reference signal (DM-RS) ports based at least in part on the PT-RS configuration, wherein the downlink control information schedules a first codeword and a second codeword for an uplink transmission; and receiving, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with a selected codeword based at least in part on the association.

[0276] Aspect 26: The method of aspect 25, further comprising: receiving a second PT-RS corresponding to a second DM-RS port of the set of DM-RS ports associated with the selected codeword based at least in part on the association.

[0277] Aspect 27: The method of any of aspects 25 through 26, wherein the indication of the association comprises at least two bits indicating the DM-RS port of the set of DM-RS ports associated with the selected codeword.

[0278] Aspect 28: An apparatus for wireless communication at a UE, comprising a processor; memory coupled with the processor; and instructions stored in the memory and executable by the processor to cause the apparatus to perform a method of any of aspects 1 through 24.

[0279] Aspect 29: An apparatus for wireless communication at a UE, comprising at least one means for performing a method of any of aspects 1 through 24.

[0280] Aspect 30: A non-transitory computer-readable medium storing code for wireless communication at a UE, the code comprising instructions executable by a processor to perform a method of any of aspects 1 through 24.

[0281] Aspect 31: An apparatus for wireless communication, comprising a processor; memory coupled with the processor; and instructions stored in the memory and executable by the processor to cause the apparatus to perform a method of any of aspects 25 through 27.

[0282] Aspect 32: An apparatus for wireless communication, comprising at least one means for performing a method of any of aspects 25 through 27.

[0283] Aspect 33: A non-transitory computer-readable medium storing code for wireless communication, the code comprising instructions executable by a processor to perform a method of any of aspects 25 through 27.

[0284] It should be noted that the methods described herein describe possible implementations, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible. Further, aspects from two or more of the methods may be combined.

[0285] Although aspects of an LTE, LTE-A, LTE-A Pro, or NR system may be described for purposes of example, and LTE, LTE-A, LTE-A Pro, or NR terminology may be used in much of the description, the techniques described herein are applicable beyond LTE, LTE-A, LTE-A Pro, or NR networks. For example, the described techniques may be applicable to various other wireless communications systems such as Ultra Mobile Broadband (UMB), Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDM, as well as other systems and radio technologies not explicitly mentioned herein.

[0286] Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0287] The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, a CPU, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration).

[0288] The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software, functions described herein may be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

[0289] 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. By way of example, and not limitation, non-transitory computer-readable media may include RAM, ROM, electrically erasable programmable ROM (EEPROM), flash memory, compact disk (CD) ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium that may be used to carry or store desired program code means in the form of instructions or data structures and that may be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of computer-readable medium. Disk and disc, as used herein, include CD, laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of computer-readable media.

[0290] 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") 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."

[0291] The term "determine" or "determining" encompasses a variety of actions and, therefore, "determining" can include calculating, computing, processing, deriving, investigating, looking up (such as via looking up in a table, a database or another data structure), ascertaining and the like. Also, "determining" can include receiving (such as receiving information), accessing (such as accessing data in a memory) and the like. Also, "determining" can include resolving, obtaining, selecting, choosing, establishing and other such similar actions.

[0292] In the appended figures, similar components or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label by a dash and a second label that distinguishes among the similar components. If just the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label, or other subsequent reference label.

[0293] The description set forth herein, in connection with the appended drawings, describes example configurations and does not represent all the examples that may be implemented or that are within the scope of the claims. The term "example" used herein means "serving as an example, instance, or illustration," and not "preferred" or "advantageous over other examples." The detailed description includes specific details for the purpose of providing an understanding of the described techniques. These techniques, however, may be practiced without these specific details. In some instances, known structures and devices are shown in block diagram form in order to avoid obscuring the concepts of the described examples.

[0294] 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.

What is claimed is:

1. An apparatus for wireless communication at a user equipment (UE), comprising:

a processor;

memory coupled with the processor; and

instructions stored in the memory and executable by the processor to cause the apparatus to:

receive radio resource control signaling comprising an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration;

receive downlink control information comprising an indication of an association between PT-RS ports and demodulation reference signal (DM-RS) ports based at least in part on the PT-RS configuration, wherein the downlink control information schedules a first codeword and a second codeword for an uplink transmission;

select a codeword from the first codeword and the second codeword for the uplink transmission; and

transmit, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with the selected codeword based at least in part on the association.

2. The apparatus of claim **1**, wherein the instructions to select the codeword are executable by the processor to cause the apparatus to:

select the first codeword associated with a first modulation and coding scheme value, wherein the second codeword is associated with a second modulation and coding scheme value that is less than the first modulation and coding scheme value.

3. The apparatus of claim **2**, wherein the instructions are further executable by the processor to cause the apparatus to:

determine that the first codeword associated with the first modulation and coding scheme value is associated with at least two sounding reference signal (SRS) resource sets, at least two precoders, or both based at least in part on the PT-RS configuration indicating at least two available ports for transmitting one or more PT-RSs, wherein the physical uplink shared channel is associated with a first set of transmission parameters and a second set of transmission parameters.

4. The apparatus of claim **3**, wherein the instructions are further executable by the processor to cause the apparatus to:

transmit a second PT-RS corresponding to a second DM-RS port of a second set of DM-RS ports associated with the selected codeword based at least in part on the association.

5. The apparatus of claim **1**, wherein the instructions to select the codeword are executable by the processor to cause the apparatus to:

select the first codeword based at least in part on the first codeword being associated with at least two SRS resource sets, at least two precoders, or both.

6. The apparatus of claim **5**, wherein the instructions are further executable by the processor to cause the apparatus to:

determine that a second codeword is associated with at least two SRS resource sets, at least two precoders, or both, wherein selecting the first codeword is further based at least in part on a modulation and coding scheme value of the first codeword, an index of the first codeword, or both.

7. The apparatus of claim **1**, wherein the instructions to select the codeword are executable by the processor to cause the apparatus to:

select the first codeword associated with a first index and a first modulation and coding scheme value, wherein the second codeword is associated with a second index that is greater than the first index and a second modulation and coding scheme value that is equal to the first modulation and coding scheme value.

8. The apparatus of claim **1**, wherein:

the radio resource control signaling, or the downlink control information, or both comprises an indication of the first codeword or the second codeword; and

selecting the codeword comprises:

selecting the indicated codeword.

9. The apparatus of claim **1**, wherein the PT-RS configuration indicates a single available port for transmitting a PT-RS and the transmission mode is codebook-based or non-codebook-based.

10. The apparatus of claim **9**, wherein the indication of the association comprises two bits indicating a DM-RS port of the set of DM-RS ports associated with the selected codeword.

11. The apparatus of claim **1**, wherein the PT-RS configuration indicates a plurality of available ports for transmitting one or more PT-RSs.

12. The apparatus of claim **11**, wherein the indication of the association comprises at least two bits, and the instructions are further executable by the processor to cause the apparatus to:

transmit a second PT-RS corresponding to the second DM-RS port of the second set of DM-RS ports associated with the selected codeword based at least in part on the association.

13. The apparatus of claim **12**, wherein a rank of the physical uplink shared channel is less than or equal to a threshold rank.

14. The apparatus of claim **12**, wherein the set of DM-RS ports are associated with a first SRS resource set, a first precoder, or both and the second set of DM-RS ports are associated with a second SRS resource set, a second precoder, or both.

15. The apparatus of claim **11**, wherein the indication of the association comprises a plurality of bits, and the instructions are further executable by the processor to cause the apparatus to:

transmit a second PT-RS corresponding to the second DM-RS port of the second set of DM-RS ports associated with the selected codeword based at least in part on the association.

16. The apparatus of claim **15**, wherein a rank of the physical uplink shared channel is greater than a threshold rank.

17. The apparatus of claim **11**, wherein the set of DM-RS ports is associated with a first port for transmitting the PT-RS and a second set of ports is associated with a second port for transmitting a second PT-RS.

18. The apparatus of claim **11**, wherein:

the transmission mode is non-codebook-based.

19. The apparatus of claim **18**, wherein the downlink control information further comprises an SRS resource indicator that indicates a plurality of SRS resources, and the instructions are further executable by the processor to cause the apparatus to:

determine which of the plurality of available ports to use for transmitting the one or more PT-RSs based at least in part on the selected codeword and the SRS resource indicator, wherein each SRS resource is associated with one of the plurality of available ports for transmitting one or more PT-RSs.

20. The apparatus of claim **19**, wherein the instructions to determine which of the plurality of available ports to use for transmitting the one or more PT-RSs are executable by the processor to cause the apparatus to:

determine to use one of the plurality of available ports based at least in part on an PT-RS port index associated with each SRS resource of the SRS resources associated with the selected codeword being the same; or

determine to use two or more of the plurality of available ports based at least in part on an PT-RS port index associated with multiple SRS resource associated with the selected codeword being different.

21. The apparatus of claim **11**, wherein:

the transmission mode is codebook-based.

22. The apparatus of claim **21**, wherein the downlink control information further comprises a transmit precoding matrix index, and the instructions are further executable by the processor to cause the apparatus to:

determine which of the plurality of available ports to use for transmitting the one or more PT-RSs based at least in part on the selected codeword and the transmit precoding matrix index, wherein the transmit precoding matrix index indicates a set of antenna ports for transmitting the physical uplink shared channel and a precoding matrix comprising an association between the set of DM-RS ports and the set of antenna ports.

23. The apparatus of claim **22**, wherein the instructions to determine which of the plurality of available ports to use for transmitting the one or more PT-RSs are executable by the processor to cause the apparatus to:

determine to use one or more of the plurality of available ports based at least in part on the association between the set of DM-RS ports and the set of antenna ports.

24. The apparatus of claim **1**, wherein the physical uplink shared channel is associated with a first set of transmission parameters and a second set of transmission parameters.

25. An apparatus for wireless communication, comprising:

a processor;

memory coupled with the processor; and

instructions stored in the memory and executable by the processor to cause the apparatus to:

transmit radio resource control signaling comprising an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration;

transmit downlink control information comprising an indication of an association between PT-RS ports and demodulation reference signal (DM-RS) ports based at least in part on the PT-RS configuration, wherein the downlink control information schedules a first codeword and a second codeword for an uplink transmission; and

receive, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with a selected codeword based at least in part on the association.

26. The apparatus of claim **25**, wherein the instructions are further executable by the processor to cause the apparatus to:

receive a second PT-RS corresponding to a second DM-RS port of the set of DM-RS ports associated with the selected codeword based at least in part on the association.

27. The apparatus of claim **25**, wherein the indication of the association comprises at least two bits indicating the DM-RS port of the set of DM-RS ports associated with the selected codeword.

28. A method for wireless communication at a user equipment (UE), comprising:

receiving radio resource control signaling comprising an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration;

receiving downlink control information comprising an indication of an association between PT-RS ports and demodulation reference signal (DM-RS) ports based at least in part on the PT-RS configuration, wherein the downlink control information schedules a first codeword and a second codeword for an uplink transmission;

selecting a codeword from the first codeword and the second codeword for the uplink transmission; and transmitting, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with the selected codeword based at least in part on the association.

29. The method of claim **28**, wherein selecting the codeword comprises:

selecting the first codeword associated with a first modulation and coding scheme value, wherein the second codeword is associated with a second modulation and coding scheme value that is less than the first modulation and coding scheme value.

30. A method for wireless communication, comprising:

transmitting radio resource control signaling comprising an indication of a transmission mode for a physical uplink shared channel and a phase tracking reference signal (PT-RS) configuration;

transmitting downlink control information comprising an indication of an association between PT-RS ports and demodulation reference signal (DM-RS) ports based at least in part on the PT-RS configuration, wherein the downlink control information schedules a first codeword and a second codeword for an uplink transmission; and

receiving, via the physical uplink shared channel according to the transmission mode, a PT-RS corresponding to a DM-RS port of a set of DM-RS ports associated with a selected codeword based at least in part on the association.

* * * * *