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(54) NON-TRANSPARENT SMALL DELAY CYCLIC DELAY DIVERSITY

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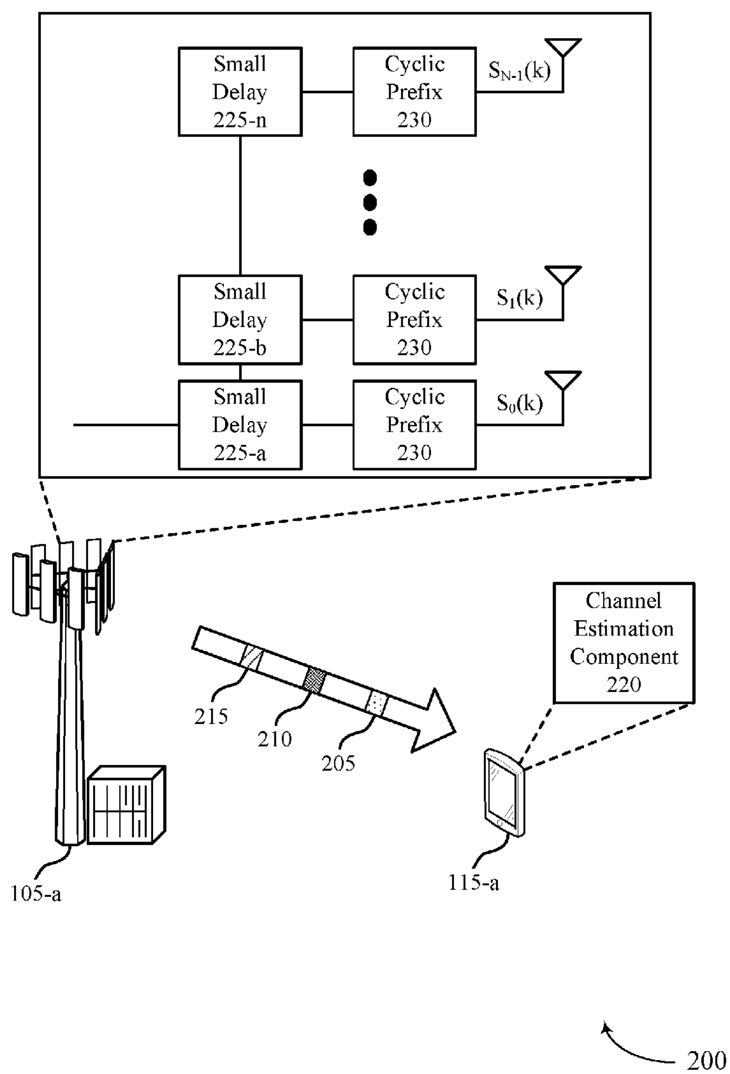
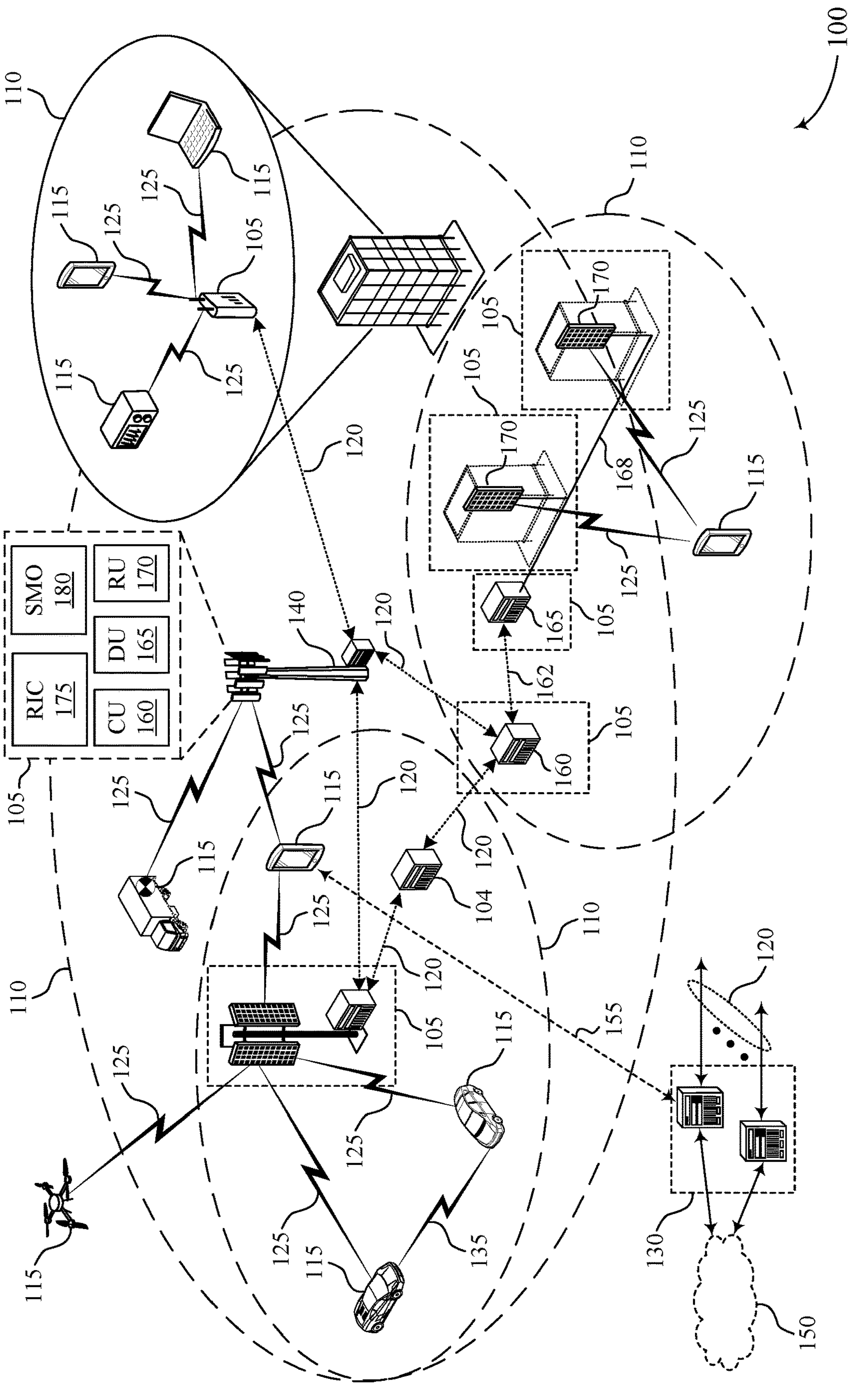
(57) **ABSTRACT**

Methods, systems, and devices for wireless communications are described. A user equipment (UE) may receive a first control signal that indicates a set of delay values corresponding to a set of antenna ports. The UE may receive a first reference signal that has a first delay profile. The first reference signal may be a multi-port reference signal or associated with the multi-port reference signal. The UE may determine a second delay profile for a demodulation reference signal (DMRS) based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRS. The UE may perform a channel estimation on the DMRS based on the set of delay values and the second delay profile.




100
RIC
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CU
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104

FIG. 1

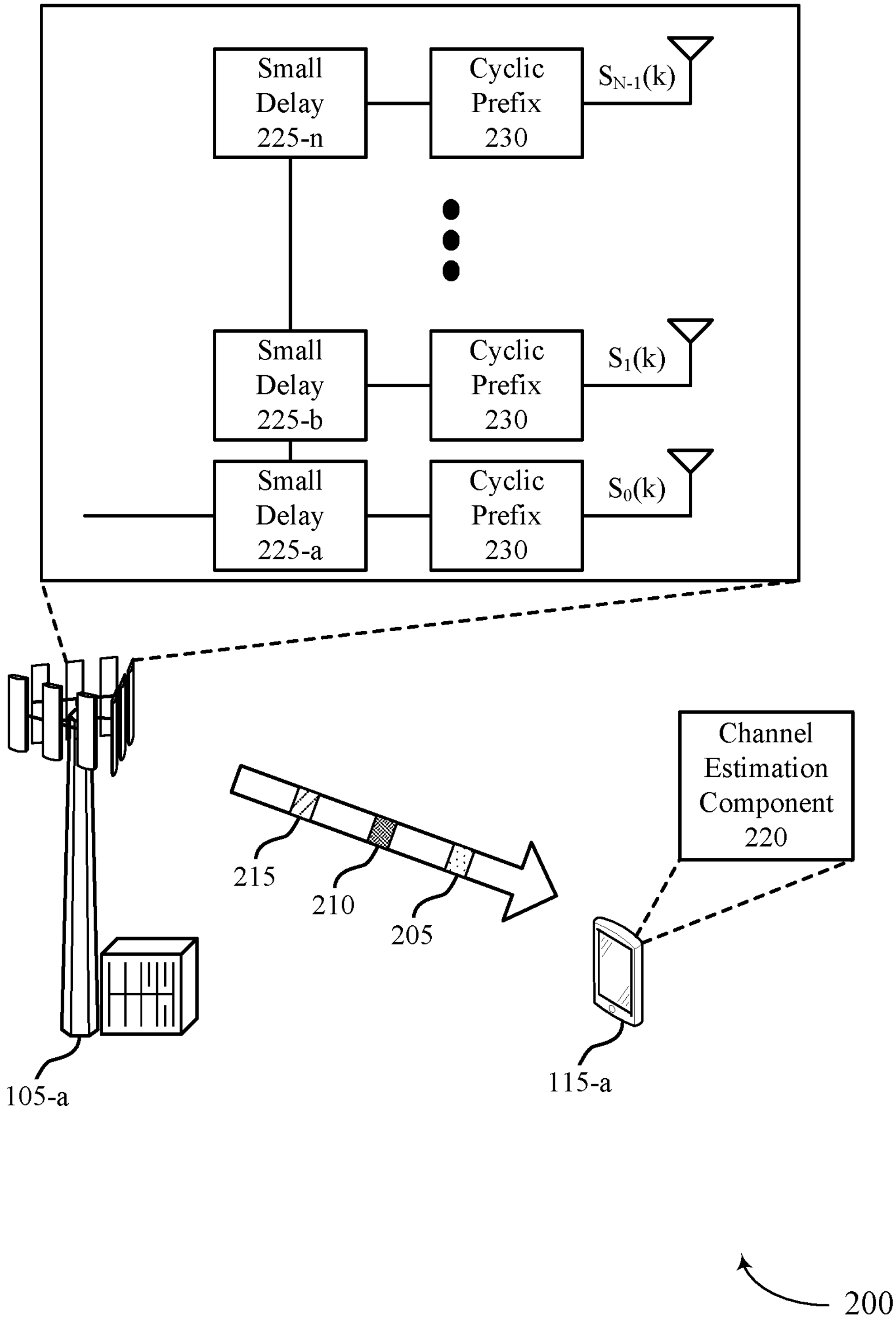

Small
Delay
225-n
Cyclic
Prefix
230
$S_{N-1}(k)$
Small
Delay
225-b
Cyclic
Prefix
230
$S_1(k)$
Small
Delay
225-a
Cyclic
Prefix
230
$S_0(k)$
Channel
Estimation
Component
220
215
210
205
105-a
115-a
200

FIG. 2

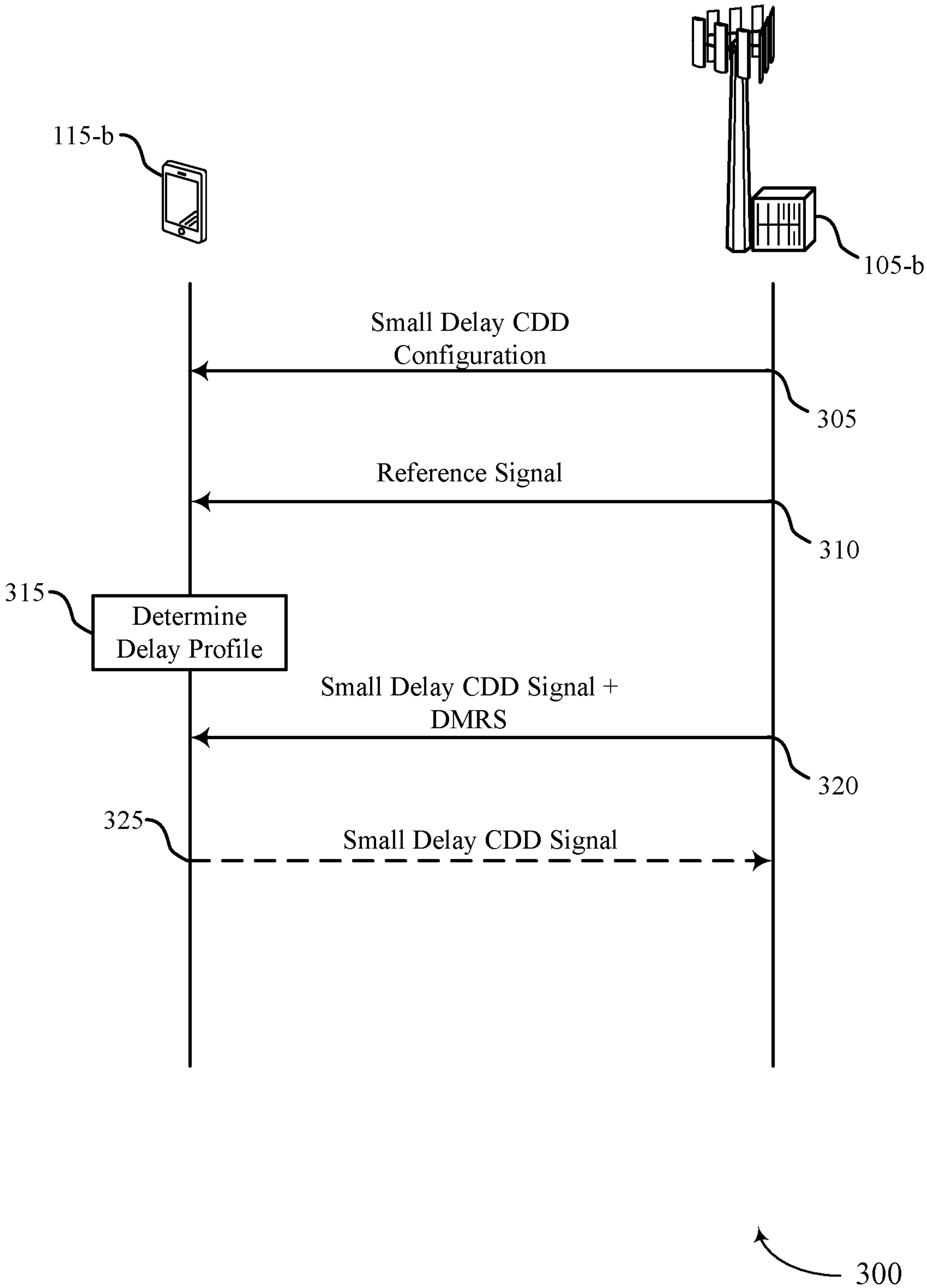

115-b
105-b
Small Delay CDD Configuration
305
Reference Signal
310
315
Determine Delay Profile
Small Delay CDD Signal + DMRS
320
325
Small Delay CDD Signal
300

FIG. 3

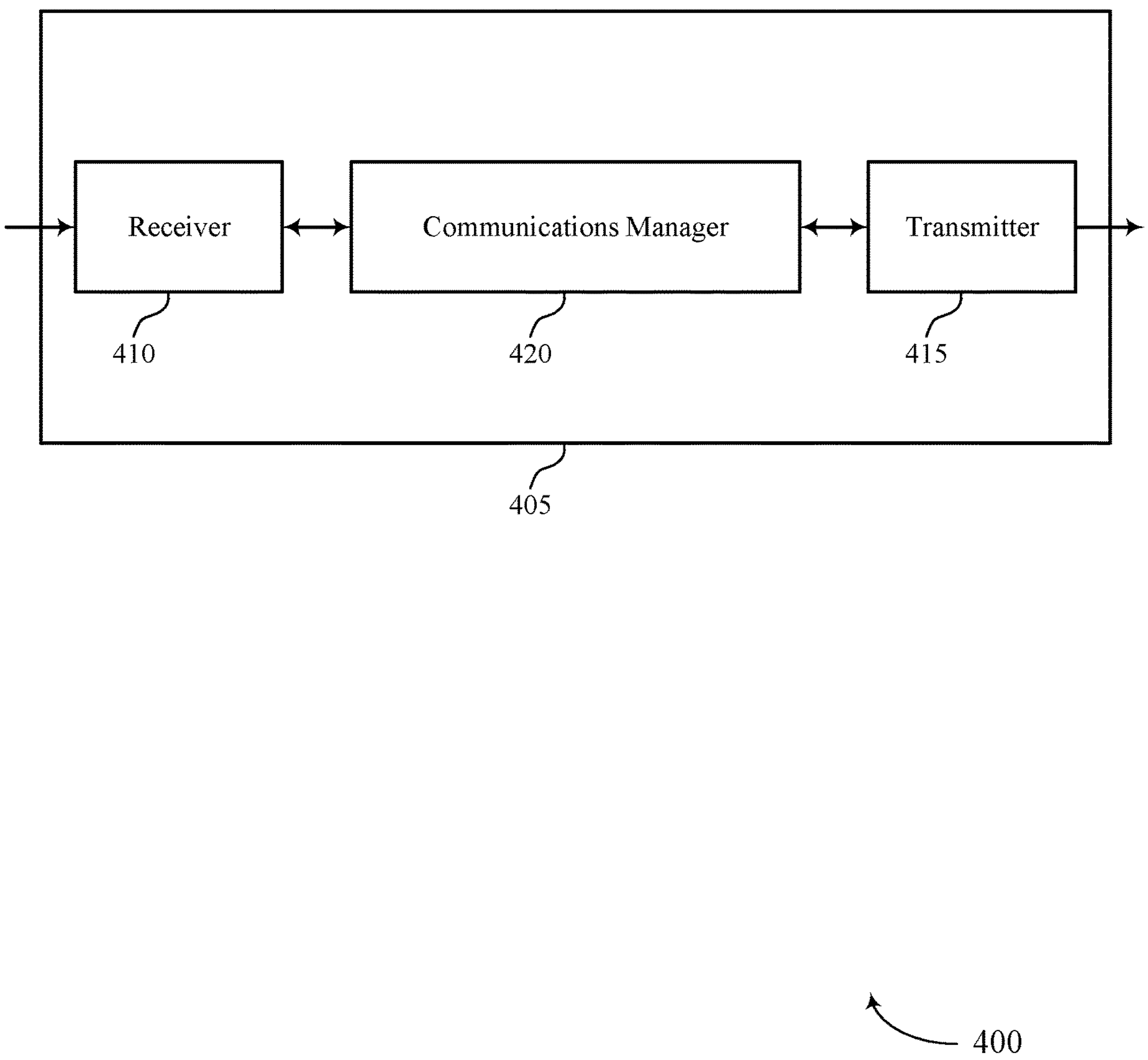

Receiver
Communications Manager
Transmitter
410
420
415
405
400

FIG. 4

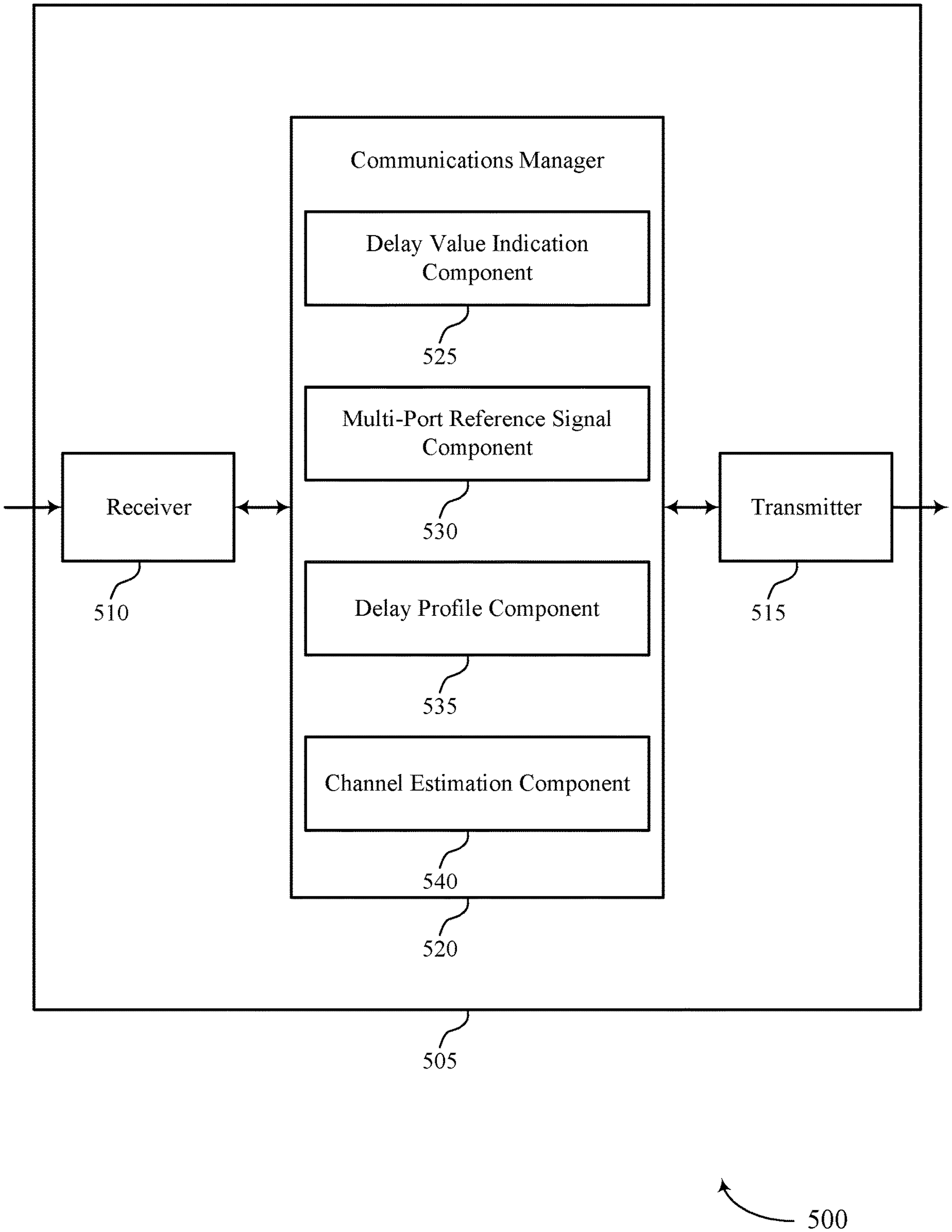

Communications Manager
Delay Value Indication Component
525
Multi-Port Reference Signal Component
530
Receiver
510
Transmitter
515
Delay Profile Component
535
Channel Estimation Component
540
520
505
500

FIG. 5

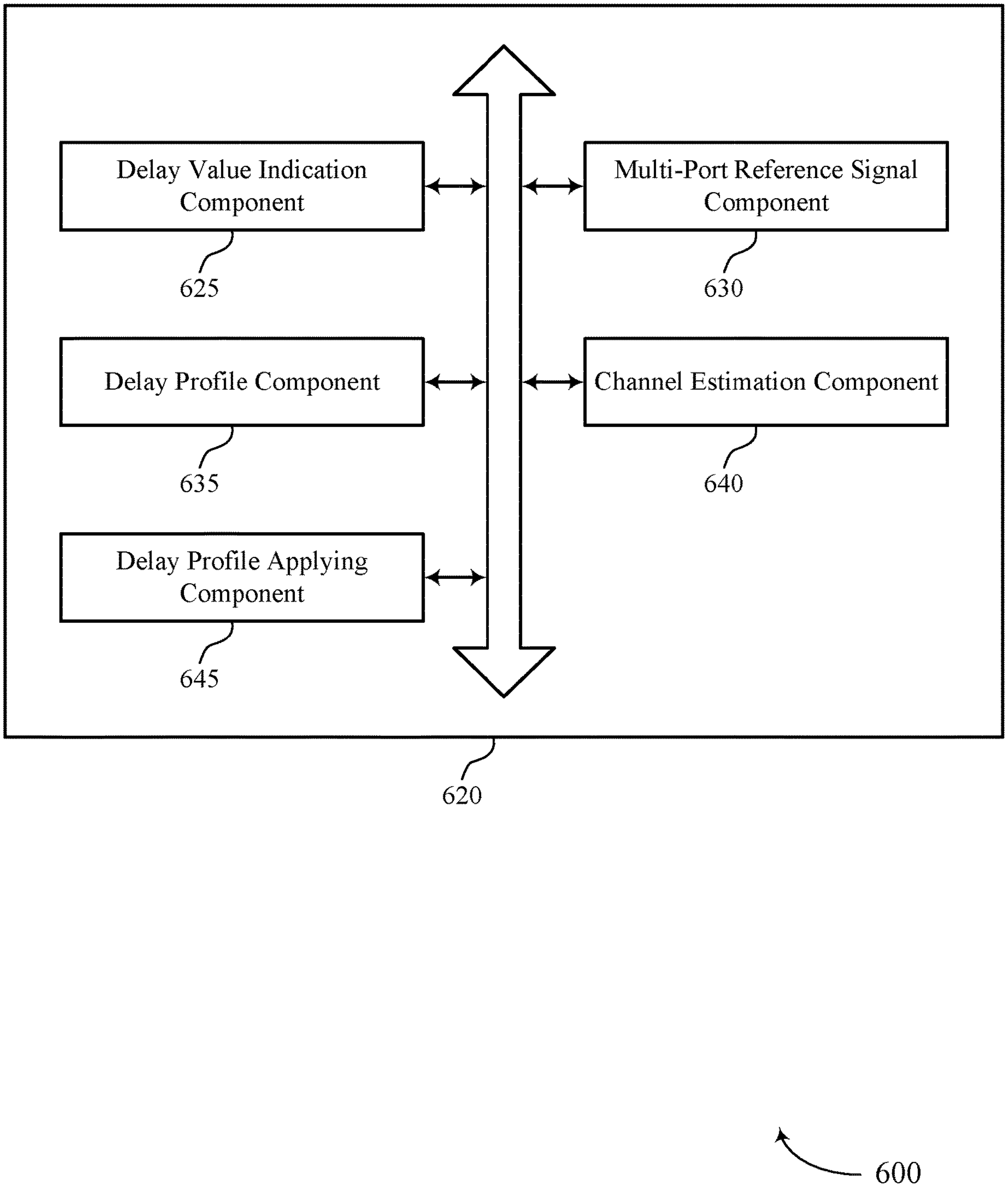

Delay Value Indication Component
625
Multi-Port Reference Signal Component
630
Delay Profile Component
635
Channel Estimation Component
640
Delay Profile Applying Component
645
620
600

FIG. 6

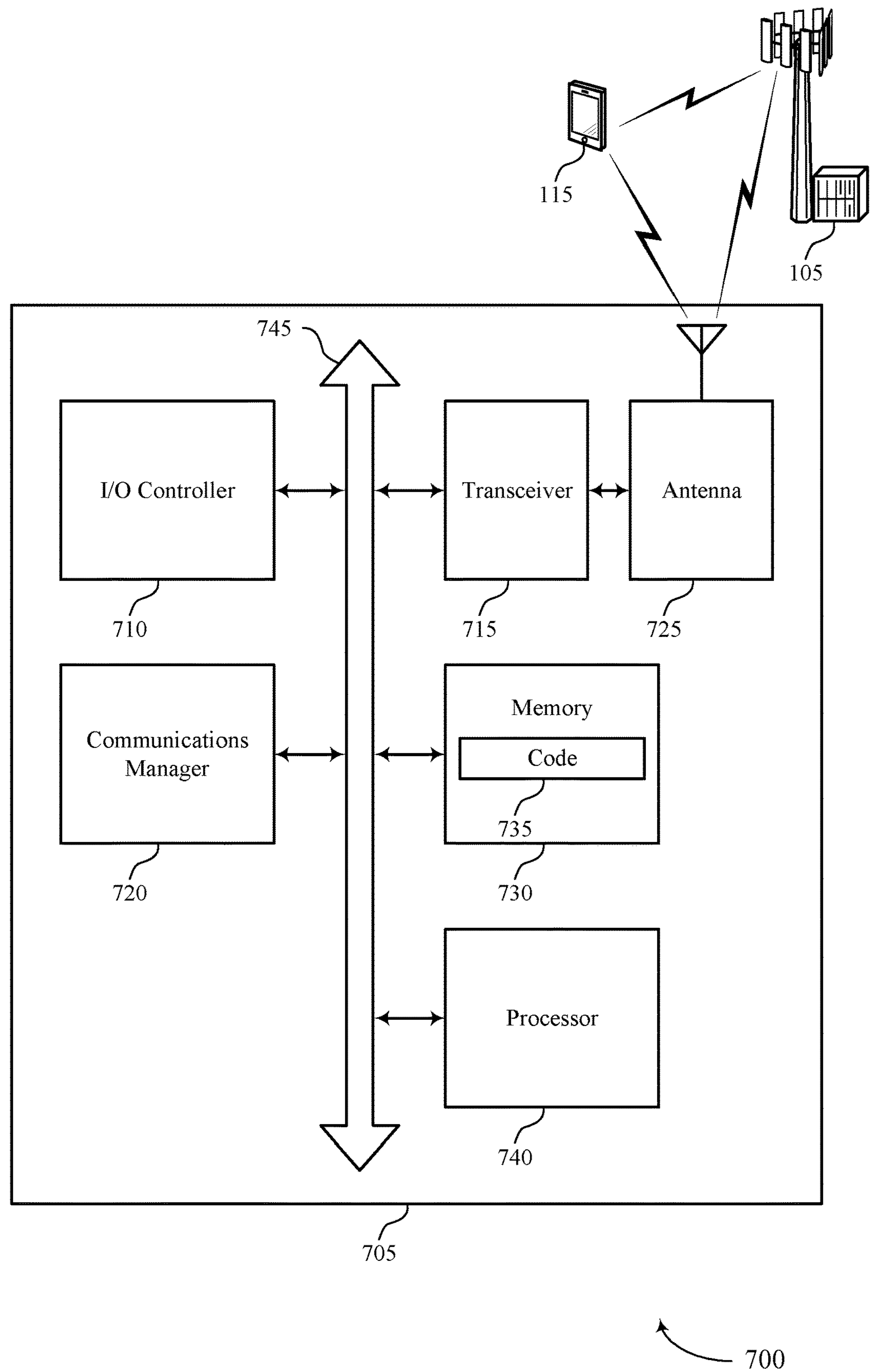

115
105
745
I/O Controller
Transceiver
Antenna
710
715
725
Communications Manager
Memory
Code
735
720
730
Processor
740
705
700

FIG. 7

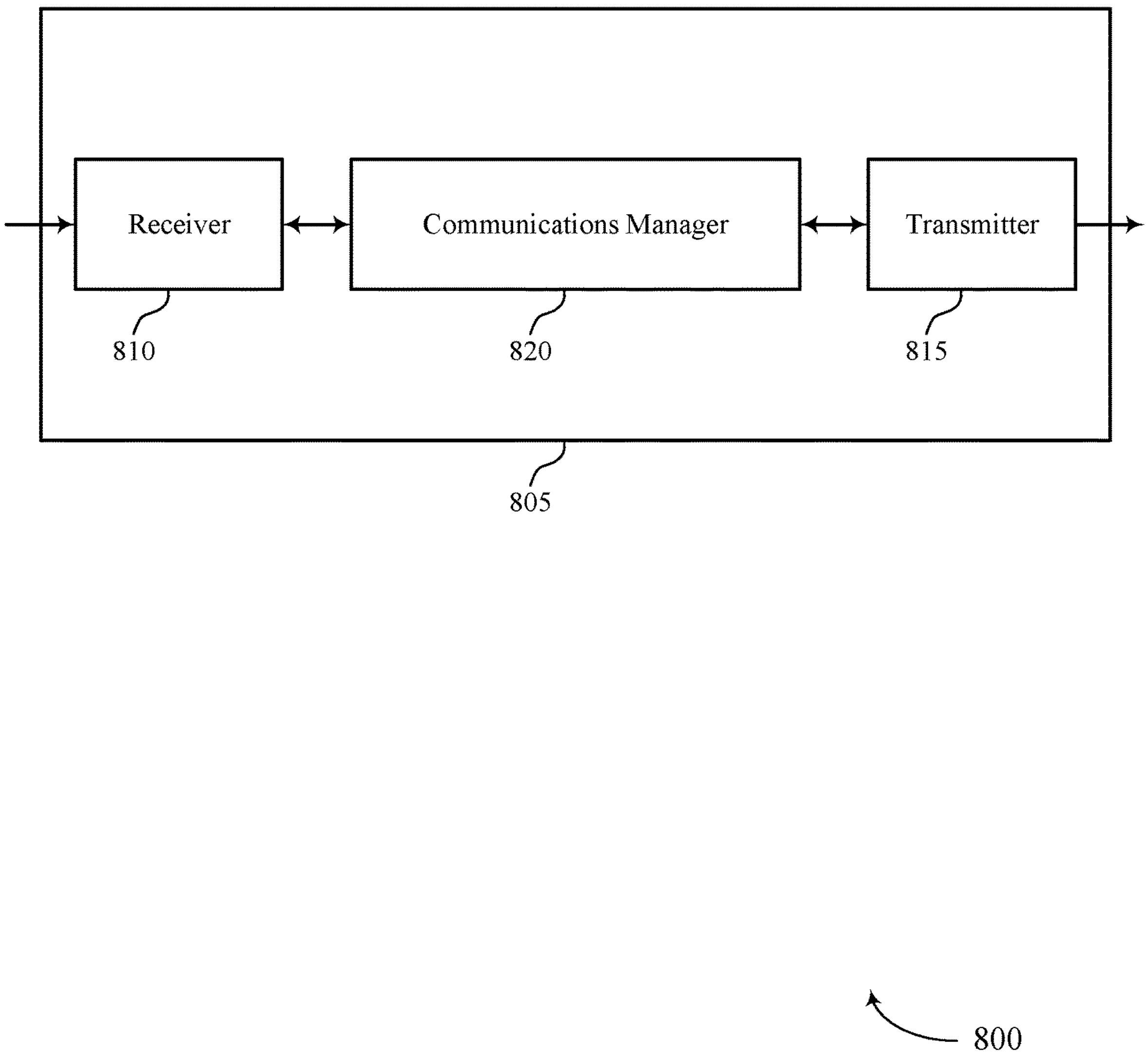

Receiver
Communications Manager
Transmitter
810
820
815
805
800

FIG. 8

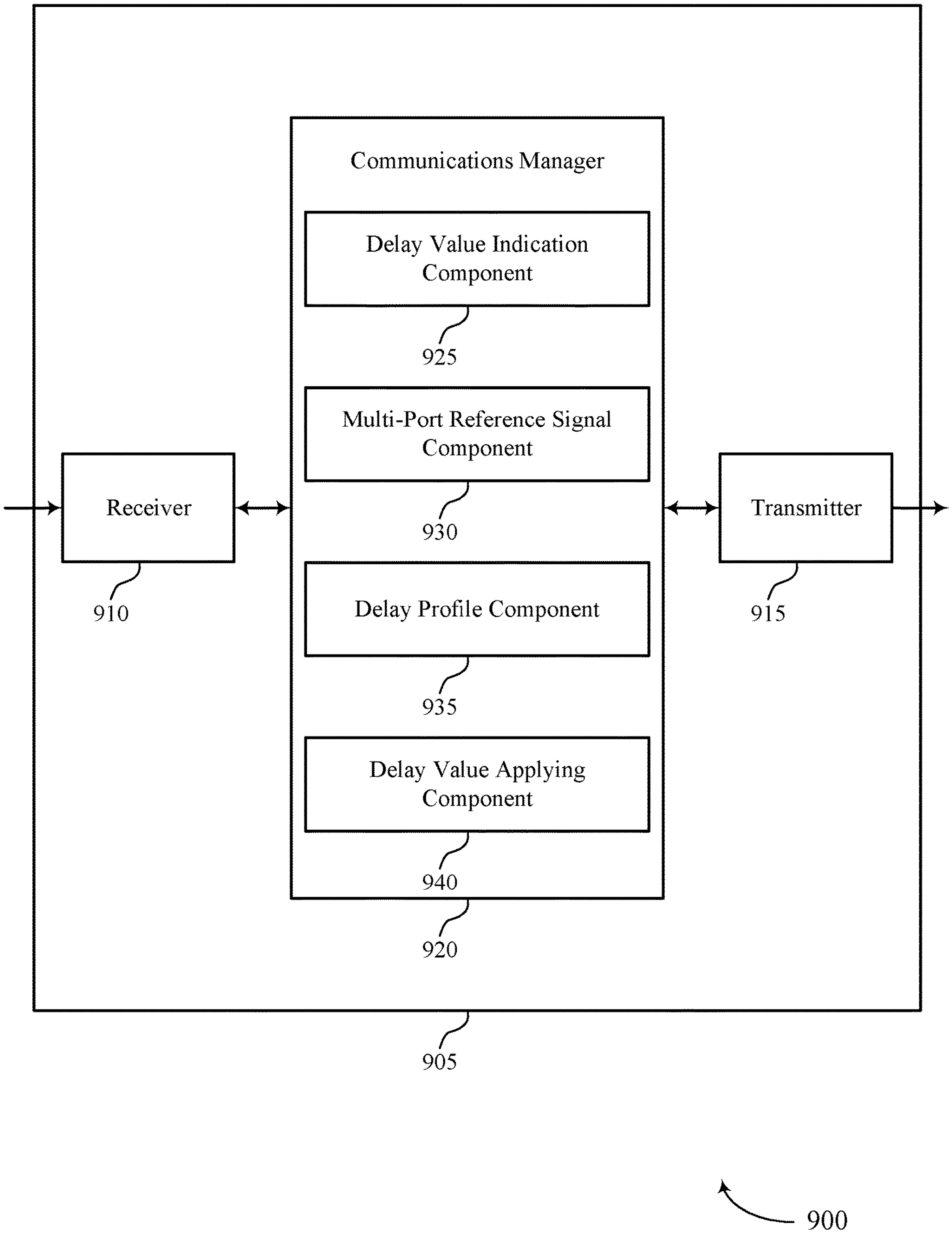
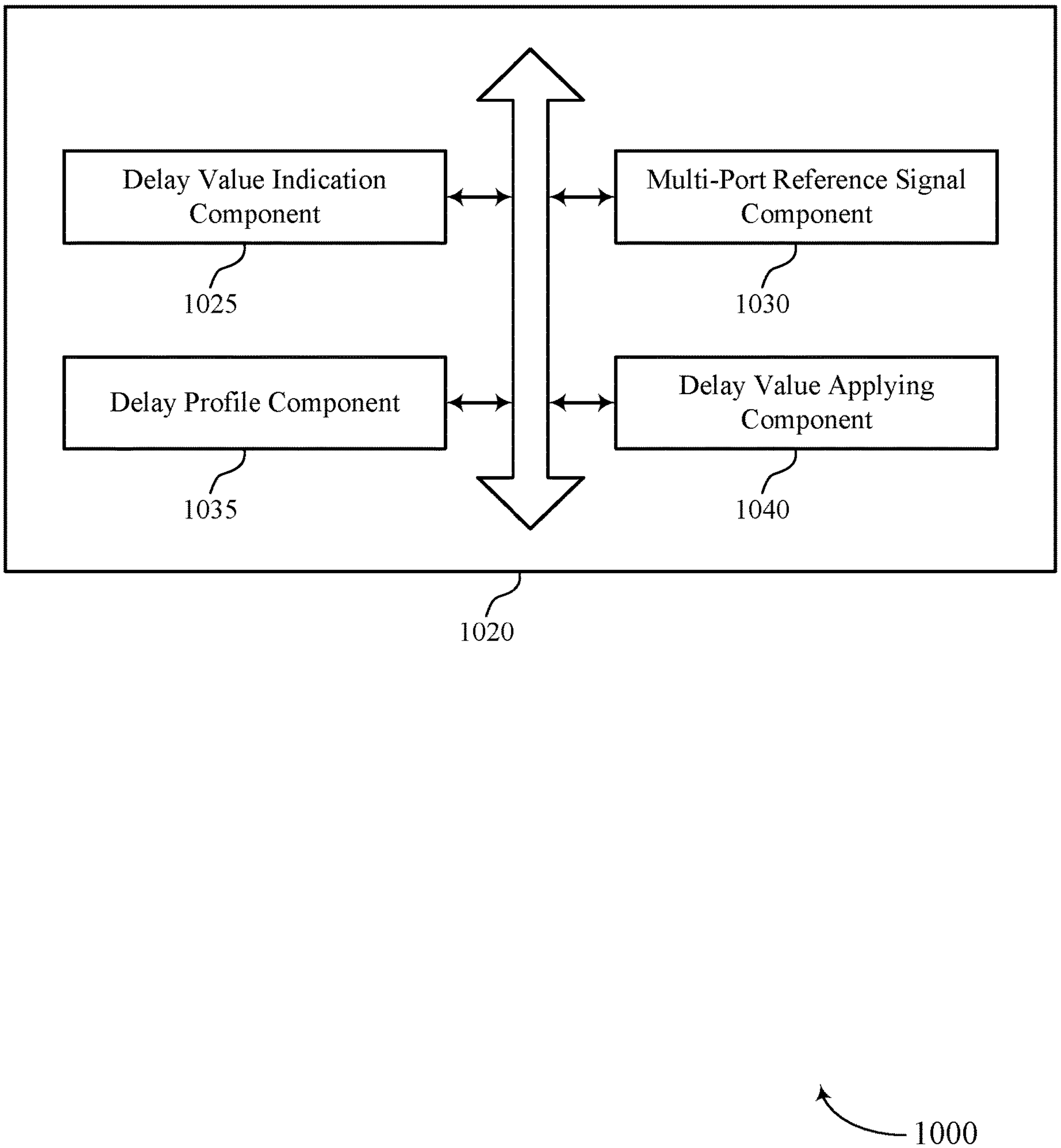

Communications Manager
Delay Value Indication Component
925
Multi-Port Reference Signal Component
930
Delay Profile Component
935
Delay Value Applying Component
940
920
Receiver
910
Transmitter
915
905
900

FIG. 9



Delay Value Indication Component
1025
Multi-Port Reference Signal Component
1030
Delay Profile Component
1035
Delay Value Applying Component
1040
1020
1000

FIG. 10

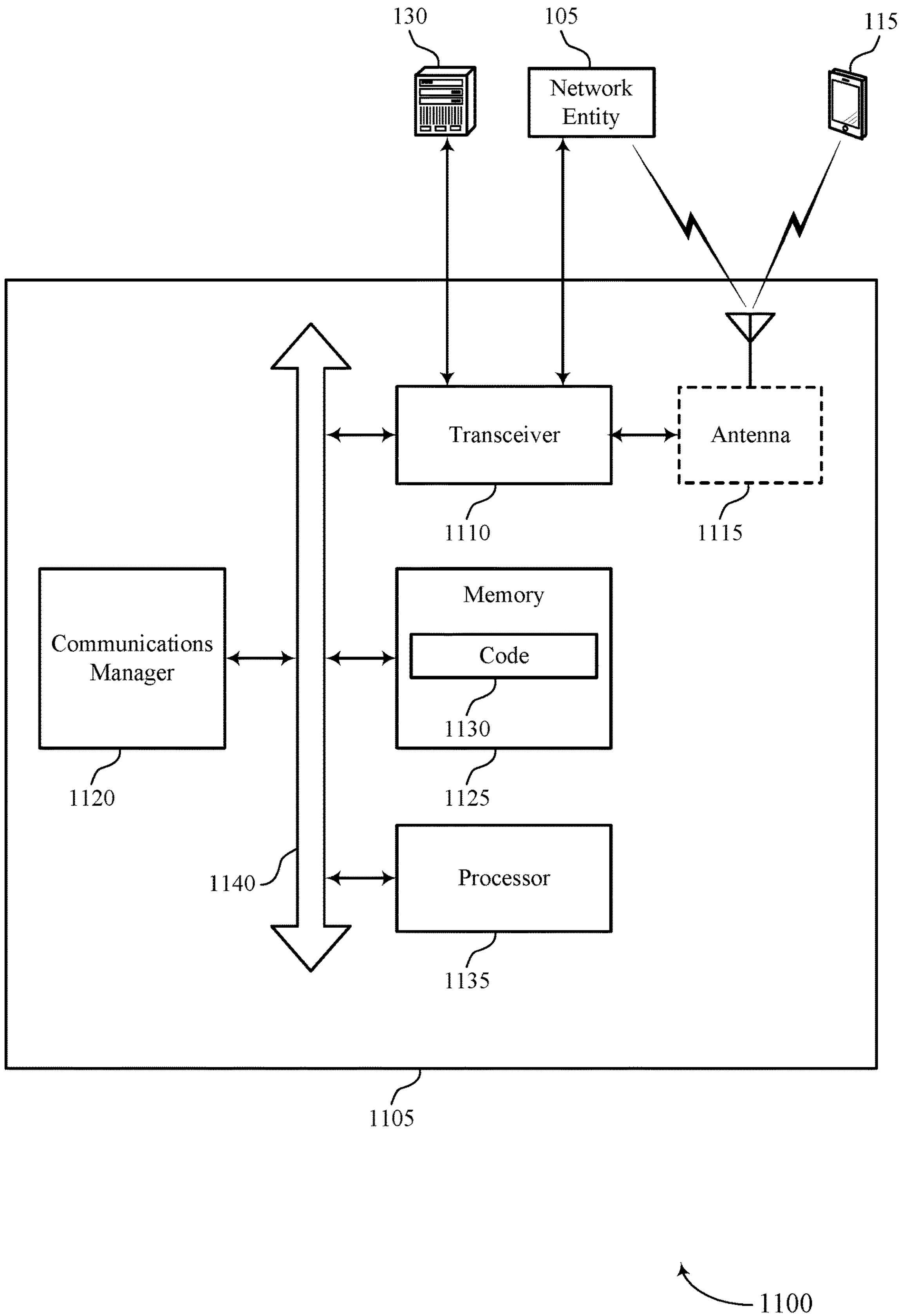

130
105
Network Entity
115
Transceiver
Antenna
1110
1115
Communications Manager
Memory
Code
1130
1120
1125
1140
Processor
1135
1105
1100

FIG. 11

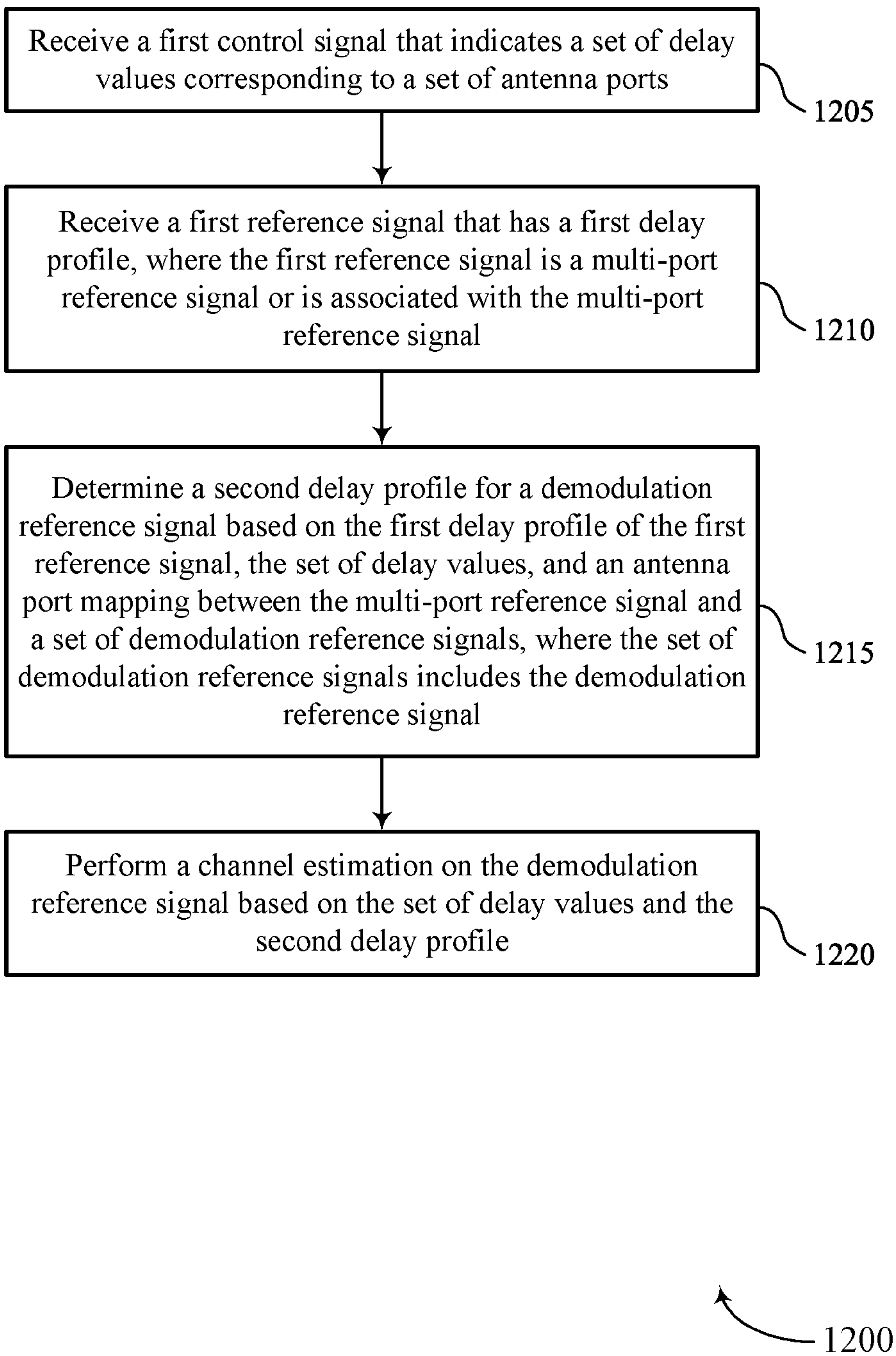

Receive a first control signal that indicates a set of delay values corresponding to a set of antenna ports
1205
Receive a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal
1210
Determine a second delay profile for a demodulation reference signal based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of demodulation reference signals, where the set of demodulation reference signals includes the demodulation reference signal
1215
Perform a channel estimation on the demodulation reference signal based on the set of delay values and the second delay profile
1220
1200

FIG. 12

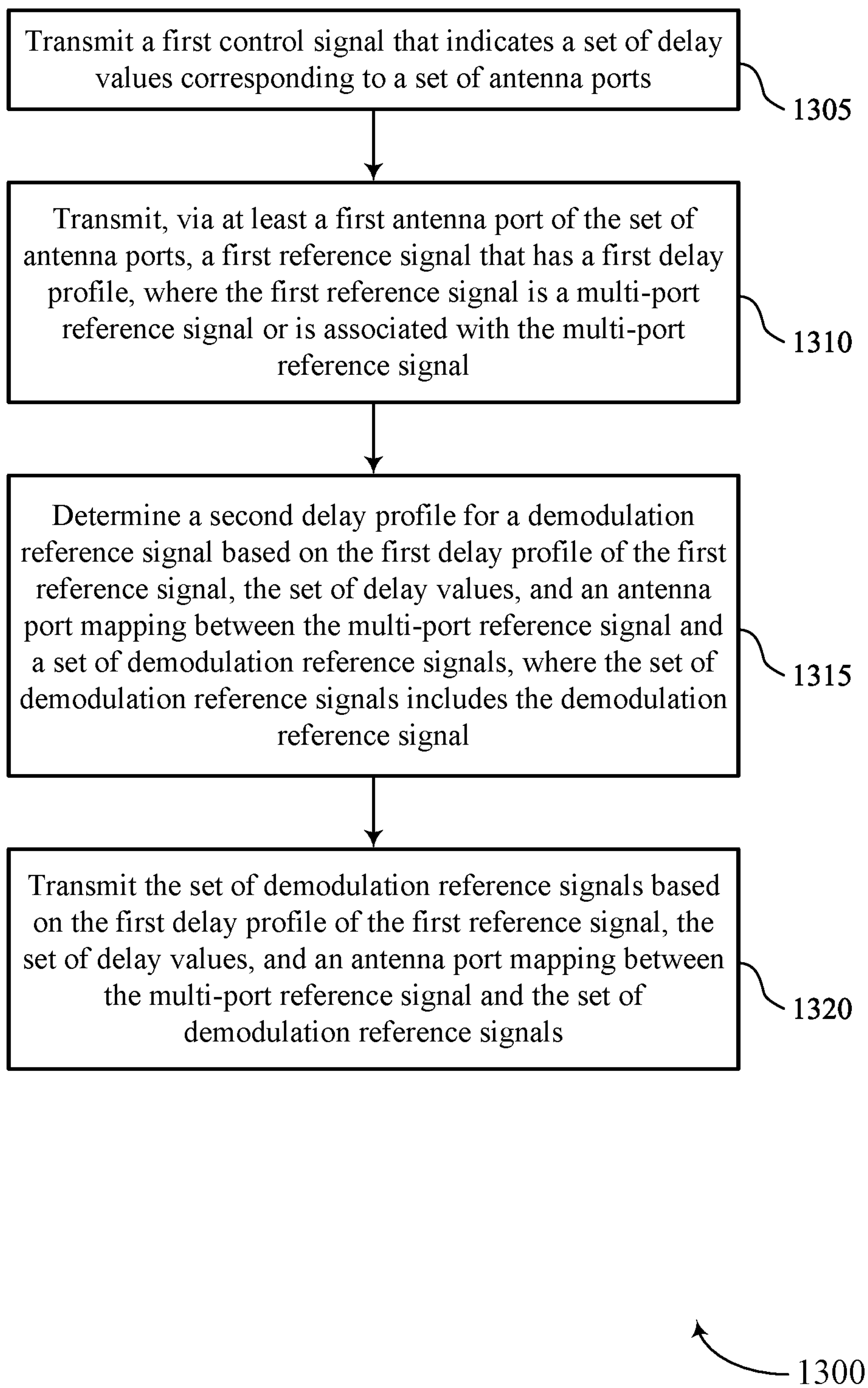

Transmit a first control signal that indicates a set of delay values corresponding to a set of antenna ports
1305
Transmit, via at least a first antenna port of the set of antenna ports, a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal
1310
Determine a second delay profile for a demodulation reference signal based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of demodulation reference signals, where the set of demodulation reference signals includes the demodulation reference signal
1315
Transmit the set of demodulation reference signals based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and the set of demodulation reference signals
1320
1300

FIG. 13

NON-TRANSPARENT SMALL DELAY CYCLIC DELAY DIVERSITY

FIELD OF TECHNOLOGY

[0001] The following relates to wireless communications, including non-transparent small delay cyclic delay diversity.

BACKGROUND

[0002] 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).

SUMMARY

[0003] The described techniques relate to improved methods, systems, devices, and apparatuses that support non-transparent small delay cyclic delay diversity (CDD). For example, the described techniques provide for a transmitter device, such as a network entity, to transmit a signal with a non-transparent small delay CDD to a receiver device, such as a user equipment (UE). The network entity may determine a set of small delay values for non-transparent small delay CDD, and the network entity may indicate the set of small delay values to the UE. The network entity may transmit a reference signal to the UE, and the UE may derive delay information for small delay CDD transmissions based on a first delay profile of the reference signal. The reference signal may be a multi-port reference signal or be associated (e.g., quasi co-located) with a virtual multi-port reference signal. For example, the UE may identify an antenna port mapping between the multi-port reference signal and a set of demodulation reference signals (DMRS). The UE may measure the first delay profile of the multi-port reference signal and use the antenna port mapping to determine a second delay profile for a DMRS. The network entity may transmit a data transmission which applies the small delay CDD over a downlink shared channel, and the network entity may transmit a DMRS over the downlink shared channel. The UE may perform channel estimation on the DMRS based on the second delay profile for the DMRS, and the UE may decode the data transmission based on performing channel estimation. For uplink signaling, the UE may apply the small delay values when transmitting uplink data on an uplink shared channel.

[0004] A method for wireless communications by a UE is described. The method may include receiving a first control signal that indicates a set of delay values corresponding to a set of antenna ports, receiving a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal, determining a second delay profile for a DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRSs, where the set of DMRSs includes the DMRS, and performing a channel estimation on the DMRS based on the set of delay values and the second delay profile.

[0005] A UE for wireless communications is described. The UE may include one or more memories storing processor executable code, and one or more processors coupled with the one or more memories. The one or more processors may individually or collectively be operable to execute the code to cause the UE to receive a first control signal that indicates a set of delay values corresponding to a set of antenna ports, receive a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal, determine a second delay profile for a DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRSs, where the set of DMRSs includes the DMRS, and perform a channel estimation on the DMRS based on the set of delay values and the second delay profile.

[0006] Another UE for wireless communications is described. The UE may include means for receiving a first control signal that indicates a set of delay values corresponding to a set of antenna ports, means for receiving a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal, means for determining a second delay profile for a DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRSs, where the set of DMRSs includes the DMRS, and means for performing a channel estimation on the DMRS based on the set of delay values and the second delay profile.

[0007] A non-transitory computer-readable medium storing code for wireless communications is described. The code may include instructions executable by one or more processors to receive a first control signal that indicates a set of delay values corresponding to a set of antenna ports, receive a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal, determine a second delay profile for a DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRSs, where the set of DMRSs includes the DMRS, and perform a channel estimation on the DMRS based on the set of delay values and the second delay profile.

[0008] In some examples of the method, UEs, and non-transitory computer-readable medium described herein, receiving the first reference signal may include operations, features, means, or instructions for receiving the multi-port reference signal via the set of antenna ports, where the first reference signal may be the multi-port reference signal.

[0009] In some examples of the method, UEs, and non-transitory computer-readable medium described herein, the multi-port reference signal may be a virtual reference signal corresponding to the first reference signal.

[0010] In some examples of the method, UEs, and non-transitory computer-readable medium described herein, a doppler profile of the DMRS corresponds to the first reference signal.

[0011] Some examples of the method, UEs, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for mapping the multi-port reference signal to the set of DMRSs based on the set of delay values.

[0012] In some examples of the method, UEs, and non-transitory computer-readable medium described herein, the first control signal indicates the set of delay values from a set of multiple sets of delay values.

[0013] Some examples of the method, UEs, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for receiving a second control signal indicating a set of multiple sets of delay values, where the first control signal indicates the set of delay values from the set of multiple sets of delay values.

[0014] Some examples of the method, UEs, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for receiving the DMRS via an antenna port of the set of antenna ports, where performing the channel estimation may be based on a delay value of the set of delay values corresponding to the antenna port and the second delay profile of the DMRS.

[0015] Some examples of the method, UEs, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for transmitting an uplink data message applying the set of delay values.

[0016] Some examples of the method, UEs, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for receiving data signaling via the set of antenna ports and decoding the data signaling based on performing the channel estimation on the DMRS.

[0017] Some examples of the method, UEs, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for receiving the DMRS based on the set of delay values and a quantity of layers of the DMRS.

[0018] In some examples of the method, UEs, and non-transitory computer-readable medium described herein, the first control signal indicates that the set of delay values may be applied for a data signal associated with the DMRS.

[0019] In some examples of the method, UEs, and non-transitory computer-readable medium described herein, a first quantity of the set of antenna ports, a second quantity of antenna ports associated with the multi-port reference signal, and a third quantity of DMRSs in the set of DMRSs may be the same.

[0020] In some examples of the method, UEs, and non-transitory computer-readable medium described herein, the first control signal indicates a mapping between the set of delay values and the set of antenna ports.

[0021] In some examples of the method, UEs, and non-transitory computer-readable medium described herein, a maximum delay for the set of delay values corresponds to a difference between cyclic prefix length and a maximum quantity of sample delays.

[0022] A method for wireless communications by a network entity is described. The method may include transmitting a first control signal that indicates a set of delay values corresponding to a set of antenna ports, transmitting, via at least a first antenna port of the set of antenna ports, a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal, determining a second delay profile for a DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRSs, where the set of DMRSs includes the DMRS, and transmitting the set of DMRSs based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and the set of DMRSs.

[0023] A network entity for wireless communications is described. The network entity may include one or more memories storing processor executable code, and one or more processors coupled with the one or more memories. The one or more processors may individually or collectively be operable to execute the code to cause the network entity to transmit a first control signal that indicates a set of delay values corresponding to a set of antenna ports, transmit, via at least a first antenna port of the set of antenna ports, a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal, determine a second delay profile for a DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRSs, where the set of DMRSs includes the DMRS, and transmit the set of DMRSs based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and the set of DMRSs.

[0024] Another network entity for wireless communications is described. The network entity may include means for transmitting a first control signal that indicates a set of delay values corresponding to a set of antenna ports, means for transmitting, via at least a first antenna port of the set of antenna ports, a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal, means for determining a second delay profile for a DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRSs, where the set of DMRSs includes the DMRS, and means for transmitting the set of DMRSs based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and the set of DMRSs.

[0025] A non-transitory computer-readable medium storing code for wireless communications is described. The code may include instructions executable by one or more processors to transmit a first control signal that indicates a set of delay values corresponding to a set of antenna ports, transmit, via at least a first antenna port of the set of antenna ports, a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal, determine a second delay profile for a DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRSs, where the set of DMRSs includes the DMRS, and transmit the set of DMRSs based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and the set of DMRSs.

[0026] In some examples of the method, network entities, and non-transitory computer-readable medium described herein, transmitting the first reference signal may include operations, features, means, or instructions for transmitting the multi-port reference signal via the set of antenna ports, where the first reference signal may be the multi-port reference signal.

[0027] In some examples of the method, network entities, and non-transitory computer-readable medium described herein, the multi-port reference signal may be a virtual reference signal corresponding to the first reference signal.

[0028] In some examples of the method, network entities, and non-transitory computer-readable medium described herein, a doppler profile of the DMRS corresponds to the first reference signal.

[0029] In some examples of the method, network entities, and non-transitory computer-readable medium described herein, the first control signal indicates the set of delay values from a set of multiple sets of delay values.

[0030] Some examples of the method, network entities, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for transmitting a second control signal indicating a set of multiple sets of delay values, where the first control signal indicates the set of delay values from the set of multiple sets of delay values.

[0031] Some examples of the method, network entities, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for transmitting the DMRS via the first antenna port using a delay value of the set of delay values corresponding to the first antenna port.

[0032] Some examples of the method, network entities, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for receiving an uplink data message, where the set of delay values may be applied to the uplink data message.

[0033] Some examples of the method, network entities, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for transmitting data signaling via the set of antenna ports applying the set of delay values.

[0034] Some examples of the method, network entities, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for transmitting the DMRS based on the set of delay values and a quantity of layers of the DMRS.

[0035] In some examples of the method, network entities, and non-transitory computer-readable medium described herein, the first control signal indicates that the set of delay values may be applied for a data signal associated with the DMRS.

[0036] In some examples of the method, network entities, and non-transitory computer-readable medium described herein, a first quantity of the set of antenna ports, a second quantity of antenna ports associated with the multi-port reference signal, and a third quantity of DMRSs in the set of DMRSs may be the same.

[0037] In some examples of the method, network entities, and non-transitory computer-readable medium described herein, a maximum delay for the set of delay values corresponds to a difference between cyclic prefix length and a maximum quantity of sample delays.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] FIG. **1** shows an example of a wireless communications system that supports non-transparent small delay cyclic delay diversity (CDD) in accordance with one or more aspects of the present disclosure.

[0039] FIG. **2** shows an example of a wireless communications system that supports non-transparent small delay CDD in accordance with one or more aspects of the present disclosure.

[0040] FIG. **3** shows an example of a process flow that supports non-transparent small delay CDD in accordance with one or more aspects of the present disclosure.

[0041] FIGS. **4** and **5** show block diagrams of devices that support non-transparent small delay CDD in accordance with one or more aspects of the present disclosure.

[0042] FIG. **6** shows a block diagram of a communications manager that supports non-transparent small delay CDD in accordance with one or more aspects of the present disclosure.

[0043] FIG. **7** shows a diagram of a system including a device that supports non-transparent small delay CDD in accordance with one or more aspects of the present disclosure.

[0044] FIGS. **8** and **9** show block diagrams of devices that support non-transparent small delay CDD in accordance with one or more aspects of the present disclosure.

[0045] FIG. **10** shows a block diagram of a communications manager that supports non-transparent small delay CDD in accordance with one or more aspects of the present disclosure.

[0046] FIG. **11** shows a diagram of a system including a device that supports non-transparent small delay CDD in accordance with one or more aspects of the present disclosure.

[0047] FIGS. **12** and **13** show flowcharts illustrating methods that support non-transparent small delay CDD in accordance with one or more aspects of the present disclosure.

DETAILED DESCRIPTION

[0048] A wireless communications system may implement techniques such as space frequency block coding or large cyclic delay diversity (CDD) to improve communications diversity. In CDD, a transmitter may apply a different delay for each transmit antenna. Some wireless communications systems may support large delay CDD. However, large delay CDD techniques may be inconsistent with demodulation reference signal (DMRS) transmission. For example, the same data may be transmitted via multiple antenna ports using the delay values, but different DMRS may be transmitted via different antenna ports, which may reduce channel estimation performance. A wireless communications system may support transparent small delay CDD. For transparent small delay CDD, a receiving wireless communications device may measure the delay spread, such as by combining the channel delay and cyclic delay, and perform channel estimation based on the measured delay spread. However, transparent small delay CDD may be performed without accurate delay spread estimation, which may reduce channel estimation performance.

[0049] A wireless communications system described herein may support techniques for non-transparent small delay CDD. A network entity may determine a set of small delay values for non-transparent small delay CDD, and the network entity may indicate the set of small delay values to a user equipment (UE). The network entity may transmit a reference signal to the UE, and the UE may derive delay information for small delay CDD transmissions based on a first delay profile of the reference signal. The reference signal may be a multi-port reference signal or be associated (e.g., quasi co-located) with a virtual multi-port reference signal. For example, the UE may identify an antenna port mapping between the multi-port reference signal and a set of DMRS. The UE may measure the first delay profile of the multi-port reference signal and use the antenna port mapping to determine a second delay profile for a DMRS. The network entity may transmit a data transmission which applies the small delay CDD over a downlink shared channel, and the network entity may transmit a DMRS over the downlink shared channel. The UE may perform channel estimation on the DMRS based on the second delay profile for the DMRS, and the UE may decode the data transmission based on performing channel estimation. For uplink signaling, the UE may apply the small delay values when transmitting uplink data on an uplink shared channel.

[0050] Aspects of the disclosure are initially described in the context of wireless communications systems. Aspects of the disclosure are further illustrated by and described with reference to apparatus diagrams, system diagrams, and flowcharts that relate to non-transparent small delay CDD.

[0051] FIG. **1** shows an example of a wireless communications system **100** that supports non-transparent small delay CDD 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.

[0052] 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).

[0053] 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 capable of supporting communications with various types of devices, such as other UEs **115** or network entities **105**, as shown in FIG. **1**.

[0054] 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.

[0055] 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 via 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** via a communication link **155**.

[0056] 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**).

[0057] 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)).

[0058] The split of functionality between a CU **160**, a DU **165**, and an RU **170** is flexible and may support different functionalities depending on 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 **170**. 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 via such communication links.

[0059] 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.

[0060] For instance, an access network (AN) or RAN may include communications between access nodes (e.g., an IAB donor), IAB nodes **104**, and one or more UEs **115**. The IAB donor may facilitate connection between the core network **130** and the AN (e.g., via a wired or wireless connection to the core network **130**). That is, an IAB donor may refer to a RAN node with a wired or wireless connection to core network **130**. The IAB donor may include a CU **160** and at least one DU **165** (e.g., and RU **170**), in which case the CU **160** may communicate with the core network **130** via an interface (e.g., a backhaul link). IAB donor and IAB nodes **104** may communicate via an F1 interface according to a protocol that defines signaling messages (e.g., an F1 AP protocol). Additionally, or alternatively, the CU **160** may communicate with the core network via an interface, which may be an example of a portion of backhaul link, and may communicate with other CUs **160** (e.g., a CU **160** associated with an alternative IAB donor) via an Xn-C interface, which may be an example of a portion of a backhaul link.

[0061] An IAB node **104** may refer to a RAN node that provides IAB functionality (e.g., access for UEs **115**, wireless self-backhauling capabilities). A DU **165** may act as a distributed scheduling node towards child nodes associated with the IAB node **104**, and the IAB-MT may act as a scheduled node towards parent nodes associated with the IAB node **104**. That is, an IAB donor may be referred to as a parent node in communication with one or more child nodes (e.g., an IAB donor may relay transmissions for UEs through one or more other IAB nodes **104**). Additionally, or alternatively, an IAB node **104** may also be referred to as a parent node or a child node to other IAB nodes **104**, depending on the relay chain or configuration of the AN. Therefore, the IAB-MT entity of IAB nodes **104** may provide a Uu interface for a child IAB node **104** to receive signaling from a parent IAB node **104**, and the DU interface (e.g., DUs **165**) may provide a Uu interface for a parent IAB node **104** to signal to a child IAB node **104** or UE **115**.

[0062] For example, IAB node **104** may be referred to as a parent node that supports communications for a child IAB node, or referred to as a child IAB node associated with an IAB donor, or both. The IAB donor may include a CU **160** with a wired or wireless connection (e.g., a backhaul communication link **120**) to the core network **130** and may act as parent node to IAB nodes **104**. For example, the DU **165** of IAB donor may relay transmissions to UEs **115** through IAB nodes **104**, or may directly signal transmissions to a UE **115**, or both. The CU **160** of IAB donor may signal communication link establishment via an F1 interface to IAB nodes **104**, and the IAB nodes **104** may schedule transmissions (e.g., transmissions to the UEs **115** relayed from the IAB donor) through the DUs **165**. That is, data may be relayed to and from IAB nodes **104** via signaling via an NR Uu interface to MT of the IAB node **104**. Communications with IAB node **104** may be scheduled by a DU **165** of IAB donor and communications with IAB node **104** may be scheduled by DU **165** of IAB node **104**.

[0063] 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 non-transparent small delay CDD 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**).

[0064] 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.

[0065] 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**.

[0066] 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) using resources associated with 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**).

[0067] In some examples, such as in a carrier aggregation configuration, a carrier may also have acquisition signaling or control signaling that coordinates operations for other carriers. A carrier may be associated with a frequency channel (e.g., an evolved universal mobile telecommunication system terrestrial radio access (E-UTRA) absolute RF channel number (EARFCN)) and may be identified according to a channel raster for discovery by the UEs **115**. A carrier may be operated in a standalone mode, in which case initial acquisition and connection may be conducted by the UEs **115** via the carrier, or the carrier may be operated in a non-standalone mode, in which case a connection is anchored using a different carrier (e.g., of the same or a different radio access technology).

[0068] The communication links **125** shown in the wireless communications system **100** may include downlink transmissions (e.g., forward link transmissions) from a network entity **105** to a UE **115**, uplink transmissions (e.g., return link transmissions) from a UE **115** to a network entity **105**, or both, among other configurations of transmissions. Carriers may carry downlink or uplink communications (e.g., in an FDD mode) or may be configured to carry downlink and uplink communications (e.g., in a TDD mode).

[0069] A carrier may be associated with a particular bandwidth of the RF spectrum and, in some examples, the carrier bandwidth may be referred to as a "system bandwidth" of the carrier or the wireless communications system **100**. For example, the carrier bandwidth may be one of a set of bandwidths for carriers of a particular radio access technology (e.g., 1.4, 3, 5, 10, 15, 20, 40, or 80 megahertz (MHz)). Devices of the wireless communications system **100** (e.g., the network entities **105**, the UEs **115**, or both) may have hardware configurations that support communications using a particular carrier bandwidth or may be configurable to support communications using one of a set of carrier bandwidths. In some examples, the wireless communications system **100** may include network entities **105** or UEs **115** that support concurrent communications using carriers associated with multiple carrier bandwidths. In some examples, each served UE **115** may be configured for operating using portions (e.g., a sub-band, a BWP) or all of a carrier bandwidth.

[0070] Signal waveforms transmitted via 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 a relatively higher quantity of resource elements (e.g., in a transmission duration) and a relatively higher order of a modulation scheme may correspond to a relatively higher rate of communication. 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**.

[0071] One or more numerologies for a carrier may be supported, and a numerology may include a subcarrier spacing (Δf) and a cyclic prefix. A carrier may be divided into one or more BWPs having the same or different numerologies. In some examples, a UE **115** may be configured with multiple BWPs. In some examples, a single BWP for a carrier may be active at a given time and communications for the UE **115** may be restricted to one or more active BWPs.

[0072] 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, for which Δf_{max} may represent a supported subcarrier spacing, and N_f may represent a 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).

[0073] 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 associated with one or more symbols. Excluding the cyclic prefix, each symbol period may be associated with 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.

[0074] 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)).

[0075] Physical channels may be multiplexed for communication using a carrier according to various techniques. A physical control channel and a physical data channel may be multiplexed for signaling via 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**.

[0076] A network entity **105** may provide communication coverage via one or more cells, for example a macro cell, a small cell, a hot spot, or other types of cells, or any combination thereof. The term "cell" may refer to a logical communication entity used for communication with a network entity **105** (e.g., using a carrier) and may be associated with an identifier for distinguishing neighboring cells (e.g., a physical cell identifier (PCID), a virtual cell identifier (VCID), or others). In some examples, a cell also may refer to a coverage area **110** or a portion of a coverage area **110** (e.g., a sector) over which the logical communication entity operates. Such cells may range from smaller areas (e.g., a structure, a subset of structure) to larger areas depending on various factors such as the capabilities of the network entity **105**. For example, a cell may be or include a building, a subset of a building, or exterior spaces between or overlapping with coverage areas **110**, among other examples.

[0077] A macro cell generally covers a relatively large geographic area (e.g., several kilometers in radius) and may allow unrestricted access by the UEs **115** with service subscriptions with the network provider supporting the macro cell. A small cell may be associated with a lower-powered network entity **105** (e.g., a lower-powered base station **140**), as compared with a macro cell, and a small cell may operate using the same or different (e.g., licensed, unlicensed) frequency bands as macro cells. Small cells may provide unrestricted access to the UEs **115** with service subscriptions with the network provider or may provide restricted access to the UEs **115** having an association with the small cell (e.g., the UEs **115** in a closed subscriber group (CSG), the UEs **115** associated with users in a home or office). A network entity **105** may support one or multiple cells and may also support communications via the one or more cells using one or multiple component carriers.

[0078] In some examples, a carrier may support multiple cells, and different cells may be configured according to different protocol types (e.g., MTC, narrowband IoT (NB-IoT), enhanced mobile broadband (eMBB)) that may provide access for different types of devices.

[0079] 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.

[0080] The wireless communications system **100** may support synchronous or asynchronous operation. For synchronous operation, network entities **105** (e.g., base stations **140**) may have similar frame timings, and transmissions from different network entities **105** may be approximately aligned in time. For asynchronous operation, network entities **105** may have different frame timings, and transmissions from different network entities **105** may, in some examples, not be aligned in time. The techniques described herein may be used for either synchronous or asynchronous operations.

[0081] Some UEs **115**, such as MTC or IoT devices, may be low cost or low complexity devices and may provide for automated communication between machines (e.g., via Machine-to-Machine (M2M) communication). M2M communication or MTC may refer to data communication technologies that allow devices to communicate with one another or a network entity **105** (e.g., a base station **140**) without human intervention. In some examples, M2M communication or MTC may include communications from devices that integrate sensors or meters to measure or capture information and relay such information to a central server or application program that uses the information or presents the information to humans interacting with the application program. Some UEs **115** may be designed to collect information or enable automated behavior of machines or other devices. Examples of applications for MTC devices include smart metering, inventory monitoring, water level monitoring, equipment monitoring, healthcare monitoring, wildlife monitoring, weather and geological event monitoring, fleet management and tracking, remote security sensing, physical access control, and transaction-based business charging.

[0082] Some UEs **115** may be configured to employ operating modes that reduce power consumption, such as half-duplex communications (e.g., a mode that supports one-way communication via transmission or reception, but not transmission and reception concurrently). In some examples, half-duplex communications may be performed at a reduced peak rate. Other power conservation techniques for the UEs **115** include entering a power saving deep sleep mode when not engaging in active communications, operating using a limited bandwidth (e.g., according to narrowband communications), or a combination of these techniques. For example, some UEs **115** may be configured for operation using a narrowband protocol type that is associated with a defined portion or range (e.g., set of subcarriers or resource blocks (RBs)) within a carrier, within a guard-band of a carrier, or outside of a carrier.

[0083] 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.

[0084] In some examples, a UE **115** may be configured to support communicating directly with other UEs **115** via 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 (e.g., scheduled by) the network entity **105**. In some examples, one or more UEs **115** of 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 an involvement of a network entity **105**.

[0085] 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.

[0086] 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.

[0087] 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. 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. Communications using UHF waves may be associated with smaller antennas and shorter ranges (e.g., less than 100 kilometers) compared to communications using the smaller frequencies and longer waves of the high frequency (HF) or very high frequency (VHF) portion of the spectrum below 300 MHz.

[0088] The wireless communications system **100** may also operate using a super high frequency (SHF) region, which may be in the range of 3 GHz to 30 GHz, also known as the centimeter band, or using an extremely high frequency (EHF) region of the spectrum (e.g., from 30 GHz to 300 GHz), also known as the millimeter band. In some examples, the wireless communications system **100** may support millimeter wave (mmW) communications between the UEs **115** and the network entities **105** (e.g., base stations **140**, RUs **170**), and EHF antennas of the respective devices may be smaller and more closely spaced than UHF antennas. In some examples, such techniques may facilitate using antenna arrays within a device. The propagation of EHF transmissions, however, may be subject to even greater attenuation and shorter range than SHF or UHF transmissions. The techniques disclosed herein may be employed across transmissions that use one or more different frequency regions, and designated use of bands across these frequency regions may differ by country or regulating body.

[0089] 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 using an unlicensed band such as the 5 GHz industrial, scientific, and medical (ISM) band. While operating using 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 using unlicensed bands may be based on a carrier aggregation configuration in conjunction with component carriers operating using a licensed band (e.g., LAA). Operations using unlicensed spectrum may include downlink transmissions, uplink transmissions, P2P transmissions, or D2D transmissions, among other examples.

[0090] 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 at diverse geographic locations. A network entity **105** may include 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 include 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.

[0091] The network entities **105** or the UEs **115** may use MIMO communications to exploit multipath signal propagation and increase 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), for which multiple spatial layers are transmitted to the same receiving device, and multiple-user MIMO (MU-MIMO), for which multiple spatial layers are transmitted to multiple devices.

[0092] 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 along 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).

[0093] 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**.

[0094] 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.

[0095] 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).

[0096] 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 transmitting 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).

[0097] 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 via logical channels. A MAC layer may perform priority handling and multiplexing of logical channels into transport channels. The MAC layer also may implement error detection techniques, error correction techniques, or both to support retransmissions to improve link efficiency. In the control plane, an RRC 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. A PHY layer may map transport channels to physical channels.

[0098] 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 via 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, in which case the device may provide HARQ feedback in a specific slot for data received via 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.

[0099] Some wireless communications systems may implement techniques to provide transmission diversity. For example, some wireless communications systems may use space frequency block coding (SFBC) for two-port MIMO communications using two-port DMRS. The two ports may apply to two different polarities, panels, or beams for massive MIMO. Some systems, such as NR, may not support SFBC for data channels based on using two antenna ports to transmit a single layer. For example, to achieve a high spectral efficiency, NR devices may use a multi-layer spatially multiplexed transmission. Multiple transmission schemes for the same channel may complicate UE implementation complexity while limiting the application of an interference-aware advanced receiver.

[0100] Some wireless communications systems may use precoder cycling for transmission diversity. For example, some wireless communications systems may support resource block group (RBG)-level precoder cycling for downlink shared channel open-loop MIMO. In some cases, these systems may not support precoder cycling for broadcast or control channels. However, a large quantity of RBGs may be needed to achieve full cycling of the precoders. In some examples, a large bundling size may require a large quantity of RBs for the cycling while a small bundling size may degrade channel estimation performance. For example, there may be a tradeoff between diversity gain and channel estimation performance.

[0101] Some wireless communications systems may provide transmission diversity through CDD. For CDD, a transmitter may apply a different cyclic delay value to each antenna port used for a MIMO transmission. Some wireless communications systems may support large delay CDD, using large delay values. Small delay CDD may be supported in a transparent matter in some wireless communications systems. However, in a transparent case, a receiver device may perform channel estimation without accurate delay spread information.

[0102] For example, a transmitter may have N data symbols to transmit using N antenna ports after performing a Fast Fourier Transform (FFT). The transmitter may perform an IFFT, apply a set of N CDD delay values (δ_0 through δ_{N-1}) to the N data symbols, and add a cyclic prefix before transmitting the N data symbols using N antenna ports in a MIMO transmission. A maximum delay after applying the CDD may be equal to $[(\delta_{max}^{cyc}+N_{max})\mathrm{mod}(N_{FFT})]\times\tau_s$, where

$$\delta_{max}^{cyc} = \max_i \delta_i^{cyc},$$

N_{max} is the maximum delay in terms of samples, and τ_s is the sampling rate. A receiver may receive the N data symbols, remove the cyclic prefix, perform an FFT, and decode the data symbols.

[0103] In a wireless communications system using 30 kHz subcarrier spacing, a cyclic prefix length may be 288 samples, and each sample may be 2.34 microseconds long. For small delay CDD, δ_{max}^{cyc} may be smaller than a cyclic prefix length minus a maximum channel delay, N_{max}. The delay spread, or maximum delay, may combine the channel delay and cyclic delay and may be transparently measured at the receiver. The receiver may perform channel estimation based on the delay spread, or maximum delay, measured in a transparent matter, and the receiver may perform demodulation based on the channel estimation. However, for this situation, the receiver may perform a sub-optimal channel estimation. For example, a root mean square (RMS) delay may be measured as 300 milliseconds. The receiver may apply a minimum mean square error (MMSE) channel estimation based on frequency domain correlation assuming a uniform delay profile with a maximum of 600 nanoseconds, regardless of whether the transmitter is using small delay CDD. To obtain more accurate delay information, the transmitter would have to apply small delay CDD to a tracking reference signal (TRS). If TRS is not applying small delay CDD, a value for δ_{max}^{cyc} may be restricted to a very small value, which may limit transmit diversity gain.

[0104] An efficient diversity scheme may be used for broadcast data and control channels and signaling before an RRC connection is established. In some examples, an efficient diversity scheme may be used for fallback in case of unreliable CSI feedback, such as in high speed scenarios. An efficient diversity scheme may be a diversity scheme which provides high transmission diversity, has small DMRS overhead, and is consistent with DMRS transmission to simplify interference estimation.

[0105] The wireless communications system **100**, and wireless communications systems described herein, may support techniques for non-transparent small delay CDD. For example, the wireless communications system **100** may support a non-transparent small delay CDD scheme which provides improved DMRS channel estimation performance than transparent schemes while being consistent with DMRS transmission, providing high transmit diversity performance, and having small DMRS overhead.

[0106] For example, a network entity **105** may determine a small delay value to apply and indicate the small delay value to a UE **115**. For downlink signaling, the UE **115** may use the small delay value to derive a delay profile for channel estimation. For example, the UE **115** may measure a first delay profile of a multi-port reference signal and determine a second delay profile for a DMRS based on the first delay profile, the small delay value, and an antenna port mapping between the multi-port reference signal and the DMRS. The UE **115** may perform channel estimation based on the second delay profile for the DMRS. For uplink signaling, the UE **115** may apply the small delay value to transmit data. Candidate delay values may be identified by the UE **115** and the network entity **105**. In some examples, the network entity **105** may configure the candidate delay values at the UE **115** via a control signal. In some examples, the candidate delay values may be preconfigured for the wireless communications system **100**.

[0107] FIG. **2** shows an example of a wireless communications system **200** that supports non-transparent small delay CDD in accordance with one or more aspects of the present disclosure. The wireless communications system **200** may implement aspects of a wireless communications system **100**. For example, the wireless communications system may include a UE **115**-*a* and a network entity **105**-*a*, which may be respective examples of a UE **115** and a network entity **105** described herein.

[0108] The UE **115**-*a* and the network entity **105**-*a* may implement techniques which provide transmit diversity for data signaling. For example, the network entity **105**-*a* may transmit downlink signaling to the UE **115**-*a* using a non-transparent small delay CDD scheme. The network entity **105**-*a* may apply a small delay CDD value when transmitting downlink data to the UE **115**-*a* using MIMO communications. In a small delay CDD scheme, the network entity **105**-*a* may apply a different small delay to each antenna port of the network entity **105**-*a*. In a non-transparent small delay CDD scheme, the UE **115**-*a* may be configured with the small delay values, and the UE **115**-*a* may use the small delay values to derive a delay profile for a DMRS transmitted with the downlink data and perform channel estimation.

[0109] The network entity **105**-*a* may transmit a control signal **205** indicating parameters for the small delay CDD scheme to the UE **115**-*a*. For example, the network entity **105**-*a* may determine a small delay value to apply and indicate the small delay value to the UE **115**-*a*. Candidate delay values may be known to or configured at both the network entity **105**-*a* and the UE **115**-*a*. In some examples, the control signal **205** may indicate the small delay value from a set of candidate delay values.

[0110] In some examples, small delay values may be associated with a cyclic prefix length. For example, in a two-port CDD scheme, δ_0^{cyc} may represent a small delay value applied to a first antenna port, and δ_1^{cyc} may represent a small delay value applied to a second antenna port. Similar techniques or representations may be used for other quantities of antenna ports. Table 1 shows examples of different sets of candidate delay values for different port configurations in terms of samples of a cyclic prefix.

TABLE 1

	2-port CDD	4-port CDD
Candidate Delay Values in unit of samples	$[\delta_0^{cyc}\,\delta_1^{cyc}] = \left[0, \frac{CP}{2}\right]$	$[\delta_0^{cyc}\,\delta_1^{cyc}\,\delta_2^{cyc}\,\delta_3^{cyc}] = \left[0, \frac{CP}{4}, \frac{2CP}{4}, \frac{3CP}{4}\right]$
	$[\delta_0^{cyc}\,\delta_1^{cyc}] = \left[0, \frac{CP}{3}\right]$	$[\delta_0^{cyc}\,\delta_1^{cyc}\,\delta_2^{cyc}\,\delta_3^{cyc}] = \left[0, \frac{CP}{6}, \frac{2CP}{6}, \frac{3CP}{6}\right]$
	$[\delta_0^{cyc}\,\delta_1^{cyc}] = \left[0, \frac{CP}{4}\right]$	$[\delta_0^{cyc}\,\delta_1^{cyc}\,\delta_2^{cyc}\,\delta_3^{cyc}] = \left[0, \frac{CP}{8}, \frac{2CP}{8}, \frac{3CP}{8}\right]$
	$[\delta_0^{cyc}\,\delta_1^{cyc}] = \left[0, \frac{CP}{6}\right]$	$[\delta_0^{cyc}\,\delta_1^{cyc}\,\delta_2^{cyc}\,\delta_3^{cyc}] = \left[0, \frac{CP}{12}, \frac{2CP}{12}, \frac{3CP}{12}\right]$
	$[\delta_0^{cyc}\,\delta_1^{cyc}] = \left[0, \frac{CP}{8}\right]$	
	$[\delta_0^{cyc}\,\delta_1^{cyc}] = \left[0, \frac{CP}{12}\right]$	

[0111] For example, a first candidate delay value for a four-port small delay CDD scheme may be one fourth of a cyclic prefix. A first small delay value for a first antenna port, δ_0^{cyc}, may be 0, or the network entity **105**-*a* may not apply any delay value to the first antenna port. A second small delay value for a second antenna port, δ_1^{cyc}, may be one fourth of the cyclic prefix (e.g., CP/4), and a third small delay value for a third antenna port, δ_2^{cyc}, may be two fourths of the cyclic prefix (e.g., CP/2). For example, small delay **225**-*a* may correspond to δ_0^{cyc}, which may be 0 or no delay. Small delay **225**-*b* may correspond to δ_1^{cyc}, which, in the above example, may be CP/4. Small delay **225**-*n* may correspond to δ_{n-1}^{cyc}, which, in the above example, may be

$$(N-1)*\frac{CP}{4}, \text{ or } \frac{3*CP}{4}$$

in a four-port small delay CDD configuration. In some examples, the network entity **105**-*a* may add a cyclic prefix **230** to the signal component for each antenna port after applying the small delay value to the small delay CDD signal **215**. The network entity **105**-*a* may transmit the small delay CDD signal **215** using the N antenna ports, transmitting signal components $S_0(k)$ through $S_{N-1}(k)$.

[0112] In some examples, the network entity **105**-*a* may indicate each small delay value for each port. For example, the network entity **105**-*a* may indicate the small delay values δ_0^{cyc} through δ_3^{cyc} for a four-port small delay CDD scheme. In some other examples, the network entity **105**-*a* may indicate a single small delay value. For example, the network entity **105**-*a* may indicate a small delay value of CP/4, and the UE **115**-*a* may identify the small delay values for δ_0^{cyc} through δ_3^{cyc} based on the indication of CP/4.

[0113] In some examples, the small delay values may be associated with or defined with reference to a resource allocation for signaling that applies the small delay values. For example, the small delay values may be defined with respect to a quantity of data tones. For a two-port small delay CDD scheme, $[\delta_0^{cyc}, \delta_1^{cyc}]$ may correspond to

$$\left[0, \frac{N_{FFT}}{\#\text{ Data Tones}}\right],$$

where δ_1^{cyc} corresponds to N_{FFT}, the quantity of data symbols, divided by a quantity of data tones of the resource allocation.

[0114] The network entity **105**-*a* may indicate whether a small delay CDD scheme is applied for a data transmission. For example, the network entity **105**-*a* may transmit a higher layer control signaling to indicate that small delay CDD is configured. In some examples, the network entity **105**-*a* may transmit a downlink control information message that indicates whether small delay CDD is applied for an associated downlink data message. In some examples, one codepoint of a downlink control information message may indicate whether small delay CDD is applied.

[0115] The network entity **105**-*a* may transmit a reference signal **210** to the UE **115**-*a*, and the UE **115**-*a* may derive delay information for a small delay CDD signal **215** based on the reference signal **210**. In some examples, the reference signal **210** may be a multi-port reference signal (XRS). In some examples, a multi-port TRS may be an example of the XRS. The multi-port reference signal may be transmitted via N ports of the network entity **105**-*a*, where N is a quantity of antenna ports used for transmission of the small delay CDD signal **215**. The small delay CDD signal **215** may be transmitted together with DMRS applying the same small delay CDD precoding in the same slot.

[0116] Antenna ports of the XRS may be mapped to antenna ports of the DMRS. For example, when delay values $[\delta_0^{cyc}, \ldots, \delta_{N-1}^{cyc}]$ are used, a port mapping between DMRS of the small delay CDD signal **215** and the XRS may correspond to Equation (1), which may be rewritten as Equation (2). In Equation (1) and Equation (2), $a_{DMRS}^{(\tilde{p}_n)}$ and $a_{XRS}^{(p_n)}$ may correspond to the DMRS and the XRS that are transmitted on the port indexed with $\tilde{p}_n$ and p_n, respectively, and β_{DMRS} and β_{TRS} may be power offset values for DMRS and TRS provided by the network entity **105**-*a* via higher layer signaling, respectively.

$$\beta_{DMRS} a_{DMRS}^{(\tilde{p}_0)}(l) = \beta_{TRS} \begin{bmatrix} e^{j2\pi\frac{\delta_0^{cyc}}{N_{fft}}l} & e^{j2\pi\frac{\delta_1^{cyc}}{N_{fft}}l} & \ldots & e^{j2\pi\frac{\delta_{N-1}^{cyc}}{N_{fft}}l} \end{bmatrix} \begin{bmatrix} a_{XRS}^{(p_0)}(l) \\ a_{XRS}^{(p_1)}(l) \\ \vdots \\ a_{XRS}^{(p_{N-1})}(l) \end{bmatrix} \tag{1}$$

$$\beta_{DMRS} a_{DMRS}^{(\tilde{p}_0)}(l) \begin{bmatrix} e^{-j2\pi\frac{\delta_0^{cyc}}{N_{fft}}l} \\ e^{-j2\pi\frac{\delta_1^{cyc}}{N_{fft}}l} \\ \vdots \\ e^{-j2\pi\frac{\delta_{N-1}^{cyc}}{N_{fft}}l} \end{bmatrix} = \beta_{XRS} \begin{bmatrix} a_{XRS}^{(p_0)}(l) \\ a_{XRS}^{(p_1)}(l) \\ \vdots \\ a_{XRS}^{(p_{N-1})}(l) \end{bmatrix} \tag{2}$$

[0117] The UE **115**-*a* may perform channel estimation on the DMRS transmitted with the small delay CDD signal **215** with the assistance of the reference signal **210** or XRS. For example, the UE **115**-*a* may receive the XRS, and the XRS may have a first delay profile. The UE **115**-*a* may determine a second delay profile for a DMRS based on the first delay profile for the XRS. For example, the XRS may be mapped to antenna ports $(\tilde{p}_0, \ldots, \tilde{p}_{N-1})$, and DMRS may be mapped to other antenna ports $(\tilde{p}_0, \ldots, \tilde{p}_{R-1})$. The UE **115**-*a* may determine a second delay profile for a DMRS mapped to antenna ports $(\tilde{p}_0, \ldots, \tilde{p}_{R-1})$ based on the first delay profile for the XRS and the small delay value. A channel estimation component **220** of the UE **115**-*a* may perform channel estimation for the DMRS based on the second delay profile for the DMRS.

[0118] In some examples, a virtual multi-port reference signal, such as a virtual XRS, may be quasi co-located with the reference signal **210** with respect to delay information. For example, the reference signal **210** may be a TRS, and the XRS may not be a physical reference signal which the UE **115**-*a* measures. XRS may be a virtual reference signal to device a transmission scheme or port mapping according to Equation (1) or Equation (2). The virtual reference signal may correspond to any antenna virtualization which experiences the same channel delay as the reference signal **210**. For example, the reference signal **210** may be a TRS which has a single antenna port, and the XRS may have the same channel delay as the reference signal **210**. The UE **115**-*a* may use the reference signal **210** and small delay CDD configuration (e.g., the small delay CDD values) to derive a delay profile used for DMRS channel estimation. For example, DMRS may be quasi co-located with the small delay CDD-precoded reference signal (e.g., XRS) with respect to delay information. DMRS may be quasi co-located with the reference signal **210** with respect to doppler information.

[0119] The UE **115**-*a* may acquire an accurate delay profile using the reference signal **210** and the small delay CDD configuration and perform DMRS channel estimation to demodulate the small delay CDD signal **215**. In some examples, the UE **115**-*a* may assume that the cyclic delay for the small delay CDD is not applied to the reference signal **210**. For example, an RMS delay may be measured as 50 nanoseconds for the reference signal **210**. The max delay of the channel may be twice as much, or 100 nanoseconds. Based on the small delay CDD configuration, the receiver may determine that $[\delta_0^{cyc}, \ldots, \delta_{N-1}^{cyc}]$ are applied. For example, the UE **115**-*a* may identify that δ_0^{cyc} is 0 and δ_1^{cyc} is CP/4 for a two-port small delay CDD configuration. The receiver may identify two separate delays with a CP/4 gap, where a first delay spans from 0 to the max delay (e.g., 100 nanoseconds), and the second delay spans from

$$\frac{CP}{4} \text{ to } \frac{CP}{4} + 100$$

nanoseconds. The UE **115**-*a* may apply MMSE channel estimation based on a frequency domain correlation.

[0120] The small delay CDD signal **215** may be transmitted using MIMO communications or a multi-port transmission scheme. In some examples, a multi-port small delay CDD transmission may be supported by a port mapping between DMRS (e.g., and the small delay CDD signal **215**) and XRS when delay values $[\delta_0^{cyc}, \ldots, \delta_{N-1}^{cyc}]$ are used according to Equation (3). In Equation (3), $U_{N\times R}$ may correspond to a quantity of DMRS layers. XRS may be a physical multi-port reference signal (e.g., N-port reference signal) or a virtual multi-port reference signal.

$$\beta_{DMRS} \begin{bmatrix} e^{-j2\pi\frac{\delta_0^{cyc}}{N_{fft}}} & 0 & \ldots & 0 \\ 0 & e^{-j2\pi\frac{\delta_1^{cyc}}{N_{fft}}} & \ldots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \ldots & e^{-j2\pi\frac{\delta_{N-1}^{cyc}}{N_{fft}}} \end{bmatrix} [U_{N\times R}] \begin{bmatrix} a_{DMRS}^{(\tilde{p}_0)}(l) \\ a_{DMRS}^{(\tilde{p}_1)}(l) \\ \vdots \\ a_{DMRS}^{(\tilde{p}_{R-1})}(l) \end{bmatrix} = \beta_{XRS} \begin{bmatrix} a_{XRS}^{(p_0)}(l) \\ a_{XRS}^{(p_1)}(l) \\ \vdots \\ a_{XRS}^{(p_{N-1})}(l) \end{bmatrix} \tag{3}$$

[0121] While the examples described herein generally correspond to the network entity **105**-*a* transmitting the small delay CDD signal **215** and the UE **115**-*a* receiving the small delay CDD signal **215**, the UE **115**-*a* may support transmitting a signal using the small delay CDD scheme. For example, the UE **115**-*a* may apply small delay values for an uplink transmission. In some examples, the UE **115**-*a* may similarly transmit a multi-port reference signal or a reference signal that is quasi co-located with a multi-port reference signal with respect to delay information.

[0122] FIG. **3** shows an example of a process flow **300** that supports non-transparent small delay CDD in accordance with one or more aspects of the present disclosure. The process flow **300** may implement aspects of wireless communications system **100** or a wireless communications system **200**. For instance, the process flow **300** may illustrate operations between a UE **115**-*b* and a network entity **105**-*b*, which may be respective examples of a UE **115** and a network entity **105** described herein. In the following description of the process flow **300**, the operations between the UE **115**-*b* and the network entity **105**-*b* may be transmitted in a different order than the example order shown, or the operations performed by the UE **115**-*b* and the network entity **105**-*b* may be performed in different orders or at different times. Some operations also may be omitted from the process flow **300**, and other operations may be added to the process flow **300**.

[0123] At **305**, the network entity **105**-*b* may transmit an indication of parameters for a small delay CDD configuration to the UE **115**-*b*. For example, the UE **115**-*b* may receive a first control signal that indicates a set of delay values corresponding to a set of antenna ports. In some examples, the set of delay values may include a small delay value for each antenna port used for a small delay CDD transmission. For example, the network entity **105**-*b* may indicate δ_0^{cyc} through δ_{N-1}^{cyc}, where N antenna ports are used for the small delay CDD transmission. The control signal may indicate the set of delay values from multiple sets of candidate small delay values. In some examples, the network entity **105**-*b* may transmit an indication of the multiple sets of candidate small delay values to the UE **115**-*b*. In some examples, the multiple sets of candidate small delay values may be indicated via separate signaling from the small delay CDD configuration.

[0124] At **310**, the network entity **105**-*b* may transmit a reference signal that has a first delay profile to the UE **115**-*b*. For example, the UE **115**-*b* may receive a first reference signal that has a first delay profile. In some examples, the first reference signal may be a multi-port reference signal, such as a physical XRS. For example, the UE **115**-*b* may receive the multi-port reference signal via the set of antenna ports.

[0125] In some examples, the first reference signal may be associated with a multi-port reference signal. For example, the multi-port reference signal may be a virtual reference signal corresponding to the first reference signal. For example, the multi-port reference signal may not be a physical reference signal which the UE **115**-*b* measures but a virtual reference signal which defines a transmission scheme or port mapping. Each virtual reference signal port may be an antenna virtualization which experiences the same channel delay as the first reference signal.

[0126] At **315**, the UE **115**-*b* may determine a second delay profile for a DMRS. For example, the UE **115**-*b* may determine the second delay profile for the DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRS. In some examples, the UE **115**-*b* may map the multi-port reference signal to the set of DMRS based on the set of delay values. In some examples, the first control signal may indicate the antenna port mapping between the multi-port reference signal and the set of DMRS. In some examples, the antenna port mapping may be preconfigured at the UE **115**-*b*.

[0127] At **320**, the UE **115**-*b* may receive a small delay CDD signal from the network entity **105**-*b*. For example, the network entity **105**-*b* may transmit the small delay CDD signal via a downlink shared channel. The network entity **105**-*b* may transmit DMRS via the downlink shared channel. For example, the network entity **105**-*b* may transmit the DMRS for which the UE **115**-*b* determined the second delay profile. The network entity **105**-*b* may apply the set of delay values to the small delay CDD signal and the DMRS.

[0128] The UE **115**-*b* may perform a channel estimation on the DMRS based on the set of delay values and the second delay profile. The UE **115**-*b* may receive data signaling via the set of antenna ports, and the UE **115**-*b* may decode the data signaling based on performing the channel estimation on the DMRS.

[0129] In some examples, the UE **115**-*b* may use the set of delay values for uplink signaling. For example, the UE **115**-*b* may transmit an uplink data message applying the set of delay values at **325**. In some examples, the UE **115**-*b* may transmit the uplink data message using multiple antenna ports, and the UE **115**-*b* may apply the set of delay values associated with the multiple antenna ports.

[0130] FIG. **4** shows a block diagram **400** of a device **405** that supports non-transparent small delay CDD in accordance with one or more aspects of the present disclosure. The device **405** may be an example of aspects of a UE **115** as described herein. The device **405** may include a receiver **410**, a transmitter **415**, and a communications manager **420**. The device **405**, or one or more components of the device **405** (e.g., the receiver **410**, the transmitter **415**, and the communications manager **420**), may include at least one processor, which may be coupled with at least one memory, to, individually or collectively, support or enable the described techniques. Each of these components may be in communication with one another (e.g., via one or more buses).

[0131] The receiver **410** 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 non-transparent small delay CDD). Information may be passed on to other components of the device **405**. The receiver **410** may utilize a single antenna or a set of multiple antennas.

[0132] The transmitter **415** may provide a means for transmitting signals generated by other components of the device **405**. For example, the transmitter **415** 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 non-transparent small delay CDD). In some examples, the transmitter **415** may be co-located with a receiver **410** in a transceiver module. The transmitter **415** may utilize a single antenna or a set of multiple antennas.

[0133] The communications manager **420**, the receiver **410**, the transmitter **415**, or various combinations thereof or various components thereof may be examples of means for performing various aspects of non-transparent small delay CDD as described herein. For example, the communications manager **420**, the receiver **410**, the transmitter **415**, or various combinations or components thereof may be capable of performing one or more of the functions described herein.

[0134] In some examples, the communications manager **420**, the receiver **410**, the transmitter **415**, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include at least one of 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, individually or collectively, a means for performing the functions described in the present disclosure. In some examples, at least one processor and at least one memory coupled with the at least one processor may be configured to perform one or more of the functions described herein (e.g., by one or more processors, individually or collectively, executing instructions stored in the at least one memory).

[0135] Additionally, or alternatively, the communications manager **420**, the receiver **410**, the transmitter **415**, or various combinations or components thereof may be implemented in code (e.g., as communications management software or firmware) executed by at least one processor. If implemented in code executed by at least one processor, the functions of the communications manager **420**, the receiver **410**, the transmitter **415**, 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, individually or collectively, a means for performing the functions described in the present disclosure).

[0136] In some examples, the communications manager **420** may be configured to perform various operations (e.g., receiving, obtaining, monitoring, outputting, transmitting) using or otherwise in cooperation with the receiver **410**, the transmitter **415**, or both. For example, the communications manager **420** may receive information from the receiver **410**, send information to the transmitter **415**, or be integrated in combination with the receiver **410**, the transmitter **415**, or both to obtain information, output information, or perform various other operations as described herein.

[0137] The communications manager **420** may support wireless communications in accordance with examples as disclosed herein. For example, the communications manager **420** is capable of, configured to, or operable to support a means for receiving a first control signal that indicates a set of delay values corresponding to a set of antenna ports. The communications manager **420** is capable of, configured to, or operable to support a means for receiving a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal. The communications manager **420** is capable of, configured to, or operable to support a means for determining a second delay profile for a DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRS, where the set of DMRS includes the DMRS. The communications manager **420** is capable of, configured to, or operable to support a means for performing a channel estimation on the DMRS based on the set of delay values and the second delay profile.

[0138] By including or configuring the communications manager **420** in accordance with examples as described herein, the device **405** (e.g., at least one processor controlling or otherwise coupled with the receiver **410**, the transmitter **415**, the communications manager **420**, or a combination thereof) may support techniques for reduced processing and more efficient utilization of communication resources.

[0139] FIG. **5** shows a block diagram **500** of a device **505** that supports non-transparent small delay CDD in accordance with one or more aspects of the present disclosure. The device **505** may be an example of aspects of a device **405** or a UE **115** as described herein. The device **505** may include a receiver **510**, a transmitter **515**, and a communications manager **520**. The device **505**, or one or more components of the device **505** (e.g., the receiver **510**, the transmitter **515**, and the communications manager **520**), may include at least one processor, which may be coupled with at least one memory, to support the described techniques. Each of these components may be in communication with one another (e.g., via one or more buses).

[0140] The receiver **510** 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 non-transparent small delay CDD). Information may be passed on to other components of the device **505**. The receiver **510** may utilize a single antenna or a set of multiple antennas.

[0141] The transmitter **515** may provide a means for transmitting signals generated by other components of the device **505**. For example, the transmitter **515** 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 non-transparent small delay CDD). In some examples, the transmitter **515** may be co-located with a receiver **510** in a transceiver module. The transmitter **515** may utilize a single antenna or a set of multiple antennas.

[0142] The device **505**, or various components thereof, may be an example of means for performing various aspects of non-transparent small delay cyclic delay diversity as described herein. For example, the communications manager **520** may include a delay value indication component **525**, a multi-port reference signal component **530**, a delay profile component **535**, a channel estimation component **540**, or any combination thereof. The communications manager **520** may be an example of aspects of a communications manager **420** as described herein. In some examples, the communications manager **520**, 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

510, the transmitter **515**, or both. For example, the communications manager **520** may receive information from the receiver **510**, send information to the transmitter **515**, or be integrated in combination with the receiver **510**, the transmitter **515**, or both to obtain information, output information, or perform various other operations as described herein.

[0143] The communications manager **520** may support wireless communications in accordance with examples as disclosed herein. The delay value indication component **525** is capable of, configured to, or operable to support a means for receiving a first control signal that indicates a set of delay values corresponding to a set of antenna ports. The multi-port reference signal component **530** is capable of, configured to, or operable to support a means for receiving a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal. The delay profile component **535** is capable of, configured to, or operable to support a means for determining a second delay profile for a DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRS, where the set of DMRS includes the DMRS. The channel estimation component **540** is capable of, configured to, or operable to support a means for performing a channel estimation on the DMRS based on the set of delay values and the second delay profile.

[0144] FIG. **6** shows a block diagram **600** of a communications manager **620** that supports non-transparent small delay CDD in accordance with one or more aspects of the present disclosure. The communications manager **620** may be an example of aspects of a communications manager **420**, a communications manager **520**, or both, as described herein. The communications manager **620**, or various components thereof, may be an example of means for performing various aspects of non-transparent small delay CDD as described herein. For example, the communications manager **620** may include a delay value indication component **625**, a multi-port reference signal component **630**, a delay profile component **635**, a channel estimation component **640**, a delay profile applying component **645**, or any combination thereof. Each of these components, or components or subcomponents thereof (e.g., one or more processors, one or more memories), may communicate, directly or indirectly, with one another (e.g., via one or more buses).

[0145] The communications manager **620** may support wireless communications in accordance with examples as disclosed herein. The delay value indication component **625** is capable of, configured to, or operable to support a means for receiving a first control signal that indicates a set of delay values corresponding to a set of antenna ports. The multi-port reference signal component **630** is capable of, configured to, or operable to support a means for receiving a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal. The delay profile component **635** is capable of, configured to, or operable to support a means for determining a second delay profile for a DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRS, where the set of DMRS includes the DMRS. The channel estimation component **640** is capable of, configured to, or operable to support a means for performing a channel estimation on the DMRS based on the set of delay values and the second delay profile.

[0146] In some examples, to support receiving the first reference signal, the multi-port reference signal component **630** is capable of, configured to, or operable to support a means for receiving the multi-port reference signal via the set of antenna ports, where the first reference signal is the multi-port reference signal.

[0147] In some examples, the multi-port reference signal is a virtual reference signal corresponding to the first reference signal.

[0148] In some examples, a doppler profile of the DMRS corresponds to the first reference signal.

[0149] In some examples, the delay profile component **635** is capable of, configured to, or operable to support a means for mapping the multi-port reference signal to the set of DMRS based on the set of delay values.

[0150] In some examples, the first control signal indicates the set of delay values from a set of multiple sets of delay values.

[0151] In some examples, the delay value indication component **625** is capable of, configured to, or operable to support a means for receiving a second control signal indicating a set of multiple sets of delay values, where the first control signal indicates the set of delay values from the set of multiple sets of delay values.

[0152] In some examples, the channel estimation component **640** is capable of, configured to, or operable to support a means for receiving the DMRS via an antenna port of the set of antenna ports, where performing the channel estimation is based on a delay value of the set of delay values corresponding to the antenna port and the second delay profile of the DMRS.

[0153] In some examples, the delay profile applying component **645** is capable of, configured to, or operable to support a means for transmitting an uplink data message applying the set of delay values.

[0154] In some examples, the delay profile applying component **645** is capable of, configured to, or operable to support a means for receiving data signaling via the set of antenna ports. In some examples, the delay profile applying component **645** is capable of, configured to, or operable to support a means for decoding the data signaling based on performing the channel estimation on the DMRS.

[0155] In some examples, the channel estimation component **640** is capable of, configured to, or operable to support a means for receiving the DMRS based on the set of delay values and a quantity of layers of the DMRS.

[0156] In some examples, the first control signal indicates that the set of delay values are applied for a data signal associated with the DMRS.

[0157] In some examples, a first quantity of the set of antenna ports, a second quantity of antenna ports associated with the multi-port reference signal, and a third quantity of DMRS in the set of DMRS are the same.

[0158] In some examples, the first control signal indicates a mapping between the set of delay values and the set of antenna ports.

[0159] In some examples, a maximum delay for the set of delay values corresponds to a difference between cyclic prefix length and a maximum quantity of sample delays.

[0160] FIG. **7** shows a diagram of a system **700** including a device **705** that supports non-transparent small delay CDD in accordance with one or more aspects of the present disclosure. The device **705** may be an example of or include the components of a device **405**, a device **505**, or a UE **115** as described herein. The device **705** may communicate (e.g., wirelessly) with one or more network entities **105**, one or more UEs **115**, or any combination thereof. The device **705** may include components for bi-directional voice and data communications including components for transmitting and receiving communications, such as a communications manager **720**, an input/output (I/O) controller **710**, a transceiver **715**, an antenna **725**, at least one memory **730**, code **735**, and at least one processor **740**. 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 **745**).

[0161] The I/O controller **710** may manage input and output signals for the device **705**. The I/O controller **710** may also manage peripherals not integrated into the device **705**. In some cases, the I/O controller **710** may represent a physical connection or port to an external peripheral. In some cases, the I/O controller **710** 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 **710** may represent or interact with a modem, a keyboard, a mouse, a touchscreen, or a similar device. In some cases, the I/O controller **710** may be implemented as part of one or more processors, such as the at least one processor **740**. In some cases, a user may interact with the device **705** via the I/O controller **710** or via hardware components controlled by the I/O controller **710**.

[0162] In some cases, the device **705** may include a single antenna **725**. However, in some other cases, the device **705** may have more than one antenna **725**, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver **715** may communicate bi-directionally, via the one or more antennas **725**, wired, or wireless links as described herein. For example, the transceiver **715** may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver **715** may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas **725** for transmission, and to demodulate packets received from the one or more antennas **725**. The transceiver **715**, or the transceiver **715** and one or more antennas **725**, may be an example of a transmitter **415**, a transmitter **515**, a receiver **410**, a receiver **510**, or any combination thereof or component thereof, as described herein.

[0163] The at least one memory **730** may include random access memory (RAM) and read-only memory (ROM). The at least one memory **730** may store computer-readable, computer-executable code **735** including instructions that, when executed by the at least one processor **740**, cause the device **705** to perform various functions described herein. The code **735** may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some cases, the code **735** may not be directly executable by the at least one processor **740** but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some cases, the at least one memory **730** 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.

[0164] The at least one processor **740** 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 at least one processor **740** may be configured to operate a memory array using a memory controller. In some other cases, a memory controller may be integrated into the at least one processor **740**. The at least one processor **740** may be configured to execute computer-readable instructions stored in a memory (e.g., the at least one memory **730**) to cause the device **705** to perform various functions (e.g., functions or tasks supporting non-transparent small delay CDD). For example, the device **705** or a component of the device **705** may include at least one processor **740** and at least one memory **730** coupled with or to the at least one processor **740**, the at least one processor **740** and at least one memory **730** configured to perform various functions described herein. In some examples, the at least one processor **740** may include multiple processors and the at least one memory **730** may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein. In some examples, the at least one processor **740** may be a component of a processing system, which may refer to a system (such as a series) of machines, circuitry (including, for example, one or both of processor circuitry (which may include the at least one processor **740**) and memory circuitry (which may include the at least one memory **730**)), or components, that receives or obtains inputs and processes the inputs to produce, generate, or obtain a set of outputs. The processing system may be configured to perform one or more of the functions described herein. For example, the at least one processor **740** or a processing system including the at least one processor **740** may be configured to, configurable to, or operable to cause the device **705** to perform one or more of the functions described herein. Further, as described herein, being "configured to," being "configurable to," and being "operable to" may be used interchangeably and may be associated with a capability, when executing code stored in the at least one memory **730** or otherwise, to perform one or more of the functions described herein.

[0165] The communications manager **720** may support wireless communications in accordance with examples as disclosed herein. For example, the communications manager **720** is capable of, configured to, or operable to support a means for receiving a first control signal that indicates a set of delay values corresponding to a set of antenna ports. The communications manager **720** is capable of, configured to, or operable to support a means for receiving a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal. The communications manager **720** is capable of, configured to, or operable to support a means for determining a second delay profile for a DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRS, where the set of DMRS includes the DMRS. The communications manager **720** is capable of, configured to, or operable to support a means for performing a channel estimation on the DMRS based on the set of delay values and the second delay profile.

[0166] By including or configuring the communications manager **720** in accordance with examples as described herein, the device **705** may support techniques for improved communication reliability, more efficient utilization of communication resources, and improved transmit diversity.

[0167] In some examples, the communications manager **720** may be configured to perform various operations (e.g., receiving, monitoring, transmitting) using or otherwise in cooperation with the transceiver **715**, the one or more antennas **725**, or any combination thereof. Although the communications manager **720** is illustrated as a separate component, in some examples, one or more functions described with reference to the communications manager **720** may be supported by or performed by the at least one processor **740**, the at least one memory **730**, the code **735**, or any combination thereof. For example, the code **735** may include instructions executable by the at least one processor **740** to cause the device **705** to perform various aspects of non-transparent small delay CDD as described herein, or the at least one processor **740** and the at least one memory **730** may be otherwise configured to, individually or collectively, perform or support such operations.

[0168] FIG. **8** shows a block diagram **800** of a device **805** that supports non-transparent small delay CDD in accordance with one or more aspects of the present disclosure. The device **805** may be an example of aspects of a network entity **105** as described herein. The device **805** may include a receiver **810**, a transmitter **815**, and a communications manager **820**. The device **805**, or one or more components of the device **805** (e.g., the receiver **810**, the transmitter **815**, and the communications manager **820**), may include at least one processor, which may be coupled with at least one memory, to, individually or collectively, support or enable the described techniques. Each of these components may be in communication with one another (e.g., via one or more buses).

[0169] The receiver **810** 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 **805**. In some examples, the receiver **810** may support obtaining information by receiving signals via one or more antennas. Additionally, or alternatively, the receiver **810** may support obtaining information by receiving signals via one or more wired (e.g., electrical, fiber optic) interfaces, wireless interfaces, or any combination thereof.

[0170] The transmitter **815** may provide a means for outputting (e.g., transmitting, providing, conveying, sending) information generated by other components of the device **805**. For example, the transmitter **815** 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 **815** may support outputting information by transmitting signals via one or more antennas. Additionally, or alternatively, the transmitter **815** 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 **815** and the receiver **810** may be co-located in a transceiver, which may include or be coupled with a modem.

[0171] The communications manager **820**, the receiver **810**, the transmitter **815**, or various combinations thereof or various components thereof may be examples of means for performing various aspects of non-transparent small delay CDD as described herein. For example, the communications manager **820**, the receiver **810**, the transmitter **815**, or various combinations or components thereof may be capable of performing one or more of the functions described herein.

[0172] In some examples, the communications manager **820**, the receiver **810**, the transmitter **815**, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include at least one of 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, individually or collectively, a means for performing the functions described in the present disclosure. In some examples, at least one processor and at least one memory coupled with the at least one processor may be configured to perform one or more of the functions described herein (e.g., by one or more processors, individually or collectively, executing instructions stored in the at least one memory).

[0173] Additionally, or alternatively, the communications manager **820**, the receiver **810**, the transmitter **815**, or various combinations or components thereof may be implemented in code (e.g., as communications management software or firmware) executed by at least one processor. If implemented in code executed by at least one processor, the functions of the communications manager **820**, the receiver **810**, the transmitter **815**, 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, individually or collectively, a means for performing the functions described in the present disclosure).

[0174] In some examples, the communications manager **820** 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.

[0175] The communications manager **820** may support wireless communications in accordance with examples as disclosed herein. For example, the communications manager **820** is capable of, configured to, or operable to support a means for transmitting a first control signal that indicates a set of delay values corresponding to a set of antenna ports. The communications manager **820** is capable of, configured to, or operable to support a means for transmitting, via at least a first antenna port of the set of antenna ports, a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal. The communications manager **820** is capable of, configured to, or operable to support a means for determining a second delay profile for a DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRS, where the set of DMRS includes the DMRS. The communications manager **820** is capable of, configured to, or operable to support a means for transmitting the set of DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and the set of DMRS.

[0176] By including or configuring the communications manager **820** in accordance with examples as described herein, the device **805** (e.g., at least one processor controlling or otherwise coupled with the receiver **810**, the transmitter **815**, the communications manager **820**, or a combination thereof) may support techniques for reduced processing, more efficient utilization of communication resources.

[0177] FIG. **9** shows a block diagram **900** of a device **905** that supports non-transparent small delay CDD in accordance with one or more aspects of the present disclosure. The device **905** may be an example of aspects of a device **805** or a network entity **105** as described herein. The device **905** may include a receiver **910**, a transmitter **915**, and a communications manager **920**. The device **905**, or one or more components of the device **905** (e.g., the receiver **910**, the transmitter **915**, and the communications manager **920**), may include at least one processor, which may be coupled with at least one memory, to support the described techniques. Each of these components may be in communication with one another (e.g., via one or more buses).

[0178] The receiver **910** 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 **905**. In some examples, the receiver **910** may support obtaining information by receiving signals via one or more antennas. Additionally, or alternatively, the receiver **910** may support obtaining information by receiving signals via one or more wired (e.g., electrical, fiber optic) interfaces, wireless interfaces, or any combination thereof.

[0179] The transmitter **915** may provide a means for outputting (e.g., transmitting, providing, conveying, sending) information generated by other components of the device **905**. For example, the transmitter **915** 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 **915** may support outputting information by transmitting signals via one or more antennas. Additionally, or alternatively, the transmitter **915** 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 **915** and the receiver **910** may be co-located in a transceiver, which may include or be coupled with a modem.

[0180] The device **905**, or various components thereof, may be an example of means for performing various aspects of non-transparent small delay CDD as described herein. For example, the communications manager **920** may include a delay value indication component **925**, a multi-port reference signal component **930**, a delay profile component **935**, a delay value applying component **940**, or any combination thereof. The communications manager **920** may be an example of aspects of a communications manager **820** as described herein. In some examples, the communications manager **920**, 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 **910**, the transmitter **915**, or both. For example, the communications manager **920** may receive information from the receiver **910**, send information to the transmitter **915**, or be integrated in combination with the receiver **910**, the transmitter **915**, or both to obtain information, output information, or perform various other operations as described herein.

[0181] The communications manager **920** may support wireless communications in accordance with examples as disclosed herein. The delay value indication component **925** is capable of, configured to, or operable to support a means for transmitting a first control signal that indicates a set of delay values corresponding to a set of antenna ports. The multi-port reference signal component **930** is capable of, configured to, or operable to support a means for transmitting, via at least a first antenna port of the set of antenna ports, a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal. The delay profile component **935** is capable of, configured to, or operable to support a means for determining a second delay profile for a DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRS, where the set of DMRS includes the DMRS. The delay value applying component **940** is capable of, configured to, or operable to support a means for transmitting the set of DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and the set of DMRS.

[0182] FIG. **10** shows a block diagram **1000** of a communications manager **1020** that supports non-transparent small delay CDD in accordance with one or more aspects of the present disclosure. The communications manager **1020** may be an example of aspects of a communications manager **820**, a communications manager **920**, or both, as described herein. The communications manager **1020**, or various components thereof, may be an example of means for performing various aspects of non-transparent small delay CDD as described herein. For example, the communications manager **1020** may include a delay value indication component **1025**, a multi-port reference signal component **1030**, a delay profile component **1035**, a delay value applying component **1040**, or any combination thereof. Each of these components, or components or subcomponents thereof (e.g., one or more processors, one or more memories), 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.

[0183] The communications manager **1020** may support wireless communications in accordance with examples as disclosed herein. The delay value indication component **1025** is capable of, configured to, or operable to support a means for transmitting a first control signal that indicates a set of delay values corresponding to a set of antenna ports. The multi-port reference signal component **1030** is capable of, configured to, or operable to support a means for transmitting, via at least a first antenna port of the set of antenna ports, a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal. The delay profile component **1035** is capable of, configured to, or operable to support a means for determining a second delay profile for a DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRS, where the set of DMRS includes the DMRS. The delay value applying component **1040** is capable of, configured to, or operable to support a means for transmitting the set of DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and the set of DMRS.

[0184] In some examples, to support transmitting the first reference signal, the multi-port reference signal component **1030** is capable of, configured to, or operable to support a means for transmitting the multi-port reference signal via the set of antenna ports, where the first reference signal is the multi-port reference signal.

[0185] In some examples, the multi-port reference signal is a virtual reference signal corresponding to the first reference signal.

[0186] In some examples, a doppler profile of the DMRS corresponds to the first reference signal.

[0187] In some examples, the first control signal indicates the set of delay values from a set of multiple sets of delay values.

[0188] In some examples, the delay value indication component **1025** is capable of, configured to, or operable to support a means for transmitting a second control signal indicating a set of multiple sets of delay values, where the first control signal indicates the set of delay values from the set of multiple sets of delay values.

[0189] In some examples, the delay value applying component **1040** is capable of, configured to, or operable to support a means for transmitting the DMRS via the first antenna port using a delay value of the set of delay values corresponding to the first antenna port.

[0190] In some examples, the delay value applying component **1040** is capable of, configured to, or operable to support a means for receiving an uplink data message, where the set of delay values is applied to the uplink data message.

[0191] In some examples, the delay value applying component **1040** is capable of, configured to, or operable to support a means for transmitting data signaling via the set of antenna ports applying the set of delay values.

[0192] In some examples, the delay value applying component **1040** is capable of, configured to, or operable to support a means for transmitting the DMRS based on the set of delay values and a quantity of layers of the DMRS.

[0193] In some examples, the first control signal indicates that the set of delay values are applied for a data signal associated with the DMRS.

[0194] In some examples, a first quantity of the set of antenna ports, a second quantity of antenna ports associated with the multi-port reference signal, and a third quantity of DMRS in the set of DMRS are the same.

[0195] In some examples, a maximum delay for the set of delay values corresponds to a difference between cyclic prefix length and a maximum quantity of sample delays.

[0196] FIG. **11** shows a diagram of a system **1100** including a device **1105** that supports non-transparent small delay CDD in accordance with one or more aspects of the present disclosure. The device **1105** may be an example of or include the components of a device **805**, a device **905**, or a network entity **105** as described herein. The device **1105** 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 **1105** may include components that support outputting and obtaining communications, such as a communications manager **1120**, a transceiver **1110**, an antenna **1115**, at least one memory **1125**, code **1130**, and at least one processor **1135**. 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 **1140**).

[0197] The transceiver **1110** may support bi-directional communications via wired links, wireless links, or both as described herein. In some examples, the transceiver **1110** may include a wired transceiver and may communicate bi-directionally with another wired transceiver. Additionally, or alternatively, in some examples, the transceiver **1110** may include a wireless transceiver and may communicate bi-directionally with another wireless transceiver. In some examples, the device **1105** may include one or more antennas **1115**, which may be capable of transmitting or receiving wireless transmissions (e.g., concurrently). The transceiver **1110** may also include a modem to modulate signals, to provide the modulated signals for transmission (e.g., by one or more antennas **1115**, by a wired transmitter), to receive modulated signals (e.g., from one or more antennas **1115**, from a wired receiver), and to demodulate signals. In some implementations, the transceiver **1110** may include one or more interfaces, such as one or more interfaces coupled with the one or more antennas **1115** that are configured to support various receiving or obtaining operations, or one or more interfaces coupled with the one or more antennas **1115** that are configured to support various transmitting or outputting operations, or a combination thereof. In some implementations, the transceiver **1110** may include or be configured for coupling with one or more processors or one or more memory components that are operable to perform or support operations based on received or obtained information or signals, or to generate information or other signals for transmission or other outputting, or any combination thereof. In some implementations, the transceiver **1110**, or the transceiver **1110** and the one or more antennas **1115**, or the transceiver **1110** and the one or more antennas **1115** and one or more processors or one or more memory components (e.g., the at least one processor **1135**, the at least one memory **1125**, or both), may be included in a chip or chip assembly that is installed in the device **1105**. In some examples, the transceiver **1110** 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**).

[0198] The at least one memory **1125** may include RAM, ROM, or any combination thereof. The at least one memory **1125** may store computer-readable, computer-executable code **1130** including instructions that, when executed by one or more of the at least one processor **1135**, cause the device **1105** to perform various functions described herein. The code **1130** may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some cases, the code **1130** may not be directly executable by a processor of the at least one processor **1135** but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some cases, the at least one memory **1125** may contain, among other things, a BIOS which may control basic hardware or software operation such as the interaction with peripheral components or devices. In some examples, the at least one processor **1135** may include multiple processors and the at least one memory **1125** may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories which may, individually or collectively, be configured to perform various functions herein (for example, as part of a processing system).

[0199] The at least one processor **1135** 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 at least one processor **1135** may be configured to operate a memory array using a memory controller. In some other cases, a memory controller may be integrated into one or more of the at least one processor **1135**. The at least one processor **1135** may be configured to execute computer-readable instructions stored in a memory (e.g., one or more of the at least one memory **1125**) to cause the device **1105** to perform various functions (e.g., functions or tasks supporting non-transparent small delay CDD). For example, the device **1105** or a component of the device **1105** may include at least one processor **1135** and at least one memory **1125** coupled with one or more of the at least one processor **1135**, the at least one processor **1135** and the at least one memory **1125** configured to perform various functions described herein. The at least one processor **1135** 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 **1130**) to perform the functions of the device **1105**. The at least one processor **1135** may be any one or more suitable processors capable of executing scripts or instructions of one or more software programs stored in the device **1105** (such as within one or more of the at least one memory **1125**). In some examples, the at least one processor **1135** may include multiple processors and the at least one memory **1125** may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein. In some examples, the at least one processor **1135** may be a component of a processing system, which may refer to a system (such as a series) of machines, circuitry (including, for example, one or both of processor circuitry (which may include the at least one processor **1135**) and memory circuitry (which may include the at least one memory **1125**)), or components, that receives or obtains inputs and processes the inputs to produce, generate, or obtain a set of outputs. The processing system may be configured to perform one or more of the functions described herein. For example, the at least one processor **1135** or a processing system including the at least one processor **1135** may be configured to, configurable to, or operable to cause the device **1105** to perform one or more of the functions described herein. Further, as described herein, being "configured to," being "configurable to," and being "operable to" may be used interchangeably and may be associated with a capability, when executing code stored in the at least one memory **1125** or otherwise, to perform one or more of the functions described herein.

[0200] In some examples, a bus **1140** may support communications of (e.g., within) a protocol layer of a protocol stack. In some examples, a bus **1140** 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 **1105**, or between different components of the device **1105** that may be co-located or located in different locations (e.g., where the device **1105** may refer to a system in which one or more of the communications manager **1120**, the transceiver **1110**, the at least one memory **1125**, the code **1130**, and the at least one processor **1135** may be located in one of the different components or divided between different components).

[0201] In some examples, the communications manager **1120** 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 **1120** may manage the transfer of data communications for client devices, such as one or more UEs **115**. In some examples, the communications manager **1120** 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 **1120** may support an X2 interface within an LTE/LTE-A wireless communications network technology to provide communication between network entities **105**.

[0202] The communications manager **1120** may support wireless communications in accordance with examples as disclosed herein. For example, the communications manager **1120** is capable of, configured to, or operable to support a means for transmitting a first control signal that indicates a set of delay values corresponding to a set of antenna ports. The communications manager **1120** is capable of, configured to, or operable to support a means for transmitting, via at least a first antenna port of the set of antenna ports, a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal. The communications manager **1120** is capable of, configured to, or operable to support a means for determining a second delay profile for a DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRS, where the set of DMRS includes the DMRS. The communications manager **1120** is capable of, configured to, or operable to support a means for transmitting a DMRS of a set of DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and the set of DMRS.

[0203] By including or configuring the communications manager **1120** in accordance with examples as described herein, the device **1105** may support techniques for improved communication reliability, more efficient utilization of communication resources, and improved transmit diversity.

[0204] 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 transceiver **1110**, the one or more antennas **1115** (e.g., where applicable), or any combination thereof. Although the communications manager **1120** is illustrated as a separate component, in some examples, one or more functions described with reference to the communications manager **1120** may be supported by or performed by the transceiver **1110**, one or more of the at least one processor **1135**, one or more of the at least one memory **1125**, the code **1130**, or any combination thereof (for example, by a processing system including at least a portion of the at least one processor **1135**, the at least one memory **1125**, the code **1130**, or any combination thereof). For example, the code **1130** may include instructions executable by one or more of the at least one processor **1135** to cause the device **1105** to perform various aspects of non-transparent small delay CDD as described herein, or the at least one processor **1135** and the at least one memory **1125** may be otherwise configured to, individually or collectively, perform or support such operations.

[0205] FIG. **12** shows a flowchart illustrating a method **1200** that supports non-transparent small delay CDD in accordance with one or more aspects of the present disclosure. The operations of the method **1200** may be implemented by a UE or its components as described herein. For example, the operations of the method **1200** may be performed by a UE **115** as described with reference to FIGS. **1** through **7**. 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.

[0206] At **1205**, the method may include receiving a first control signal that indicates a set of delay values corresponding to a set of antenna ports. The operations of **1205** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1205** may be performed by a delay value indication component **625** as described with reference to FIG. **6**.

[0207] At **1210**, the method may include receiving a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal. The operations of **1210** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1210** may be performed by a multi-port reference signal component **630** as described with reference to FIG. **6**.

[0208] At **1215**, the method may include determining a second delay profile for a DMRS based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of DMRS, where the set of DMRS includes the DMRS. The operations of **1215** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1215** may be performed by a delay profile component **635** as described with reference to FIG. **6**.

[0209] At **1220**, the method may include performing a channel estimation on the DMRS based on the set of delay values and the second delay profile. The operations of **1220** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1220** may be performed by a channel estimation component **640** as described with reference to FIG. **6**.

[0210] FIG. **13** shows a flowchart illustrating a method **1300** that supports non-transparent small delay cyclic delay diversity in accordance with one or more aspects of the present disclosure. The operations of the method **1300** may be implemented by a network entity or its components as described herein. For example, the operations of the method **1300** may be performed by a network entity as described with reference to FIGS. **1** through **3** and **8** through **11**. 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.

[0211] At **1305**, the method may include transmitting a first control signal that indicates a set of delay values corresponding to a set of antenna ports. The operations of **1305** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1305** may be performed by a delay value indication component **1025** as described with reference to FIG. **10**.

[0212] At **1310**, the method may include transmitting, via at least a first antenna port of the set of antenna ports, a first reference signal that has a first delay profile, where the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal. The operations of **1310** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1310** may be performed by a multi-port reference signal component **1030** as described with reference to FIG. **10**.

[0213] At **1315**, the method may include determining a second delay profile for a demodulation reference signal based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of demodulation reference signals, where the set of demodulation reference signals includes the demodulation reference signal. The operations of **1315** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1315** may be performed by a delay profile component **1035** as described with reference to FIG. **10**.

[0214] At **1320**, the method may include transmitting the set of demodulation reference signals based on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and the set of demodulation reference signals. The operations of **1320** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1320** may be performed by a delay value applying component **1040** as described with reference to FIG. **10**.

[0215] The following provides an overview of aspects of the present disclosure:

[0216] Aspect 1: A method for wireless communications at a UE, comprising: receiving a first control signal that indicates a set of delay values corresponding to a set of antenna ports; receiving a first reference signal that has a first delay profile, wherein the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal; determining a second delay profile for a demodulation reference signal based at least in part on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of demodulation reference signals, wherein the set of demodulation reference signals comprises the demodulation reference signal; and performing a channel estimation on the demodulation reference signal based at least in part on the set of delay values and the second delay profile.

[0217] Aspect 2: The method of aspect 1, wherein receiving the first reference signal comprises: receiving the multi-port reference signal via the set of antenna ports, wherein the first reference signal is the multi-port reference signal.

[0218] Aspect 3: The method of any of aspects 1 through 2, wherein the multi-port reference signal is a virtual reference signal corresponding to the first reference signal.

[0219] Aspect 4: The method of any of aspects 1 through 3, wherein a doppler profile of the demodulation reference signal corresponds to the first reference signal.

[0220] Aspect 5: The method of any of aspects 1 through 4, further comprising: mapping the multi-port reference signal to the set of demodulation reference signals based at least in part on the set of delay values.

[0221] Aspect 6: The method of any of aspects 1 through 5, wherein the first control signal indicates the set of delay values from a plurality of sets of delay values.

[0222] Aspect 7: The method of any of aspects 1 through 6, further comprising: receiving a second control signal indicating a plurality of sets of delay values, wherein the first control signal indicates the set of delay values from the plurality of sets of delay values.

[0223] Aspect 8: The method of any of aspects 1 through 7, further comprising: receiving the demodulation reference signal via an antenna port of the set of antenna ports, wherein performing the channel estimation is based at least in part on a delay value of the set of delay values corresponding to the antenna port and the second delay profile of the demodulation reference signal.

[0224] Aspect 9: The method of any of aspects 1 through 8, further comprising: transmitting an uplink data message applying the set of delay values.

[0225] Aspect 10: The method of any of aspects 1 through 9, further comprising: receiving data signaling via the set of antenna ports; and decoding the data signaling based at least in part on performing the channel estimation on the demodulation reference signal.

[0226] Aspect 11: The method of any of aspects 1 through 10, further comprising: receiving the demodulation reference signal based at least in part on the set of delay values and a quantity of layers of the demodulation reference signal.

[0227] Aspect 12: The method of any of aspects 1 through 11, wherein the first control signal indicates that the set of delay values are applied for a data signal associated with the demodulation reference signal.

[0228] Aspect 13: The method of any of aspects 1 through 12, wherein a first quantity of the set of antenna ports, a second quantity of antenna ports associated with the multi-port reference signal, and a third quantity of demodulation reference signals in the set of demodulation reference signals are the same.

[0229] Aspect 14: The method of any of aspects 1 through 13, wherein the first control signal indicates a mapping between the set of delay values and the set of antenna ports.

[0230] Aspect 15: The method of any of aspects 1 through 14, wherein a maximum delay for the set of delay values corresponds to a difference between cyclic prefix length and a maximum quantity of sample delays.

[0231] Aspect 16: A method for wireless communications at a network entity, comprising: transmitting a first control signal that indicates a set of delay values corresponding to a set of antenna ports; transmitting, via at least a first antenna port of the set of antenna ports, a first reference signal that has a first delay profile, wherein the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal; determining a second delay profile for a demodulation reference signal based at least in part on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of demodulation reference signals, wherein the set of demodulation reference signals comprises the demodulation reference signal; and transmitting the set of demodulation reference signals based at least in part on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and the set of demodulation reference signals.

[0232] Aspect 17: The method of aspect 16, wherein transmitting the first reference signal comprises: transmitting the multi-port reference signal via the set of antenna ports, wherein the first reference signal is the multi-port reference signal.

[0233] Aspect 18: The method of any of aspects 16 through 17, wherein the multi-port reference signal is a virtual reference signal corresponding to the first reference signal.

[0234] Aspect 19: The method of any of aspects 16 through 18, wherein a doppler profile of the demodulation reference signal corresponds to the first reference signal.

[0235] Aspect 20: The method of any of aspects 16 through 19, wherein the first control signal indicates the set of delay values from a plurality of sets of delay values.

[0236] Aspect 21: The method of any of aspects 16 through 20, further comprising: transmitting a second control signal indicating a plurality of sets of delay values, wherein the first control signal indicates the set of delay values from the plurality of sets of delay values.

[0237] Aspect 22: The method of any of aspects 16 through 21, further comprising: transmitting the demodulation reference signal via the first antenna port using a delay value of the set of delay values corresponding to the first antenna port.

[0238] Aspect 23: The method of any of aspects 16 through 22, further comprising: receiving an uplink data message, wherein the set of delay values is applied to the uplink data message.

[0239] Aspect 24: The method of any of aspects 16 through 23, further comprising: transmitting data signaling via the set of antenna ports applying the set of delay values.

[0240] Aspect 25: The method of any of aspects 16 through 24, further comprising: transmitting the demodulation reference signal based at least in part on the set of delay values and a quantity of layers of the demodulation reference signal.

[0241] Aspect 26: The method of any of aspects 16 through 25, wherein the first control signal indicates that the set of delay values are applied for a data signal associated with the demodulation reference signal.

[0242] Aspect 27: The method of any of aspects 16 through 26, wherein a first quantity of the set of antenna ports, a second quantity of antenna ports associated with the multi-port reference signal, and a third quantity of demodulation reference signals in the set of demodulation reference signals are the same.

[0243] Aspect 28: The method of any of aspects 16 through 27, wherein a maximum delay for the set of delay values corresponds to a difference between cyclic prefix length and a maximum quantity of sample delays.

[0244] Aspect 29: A UE for wireless communications, comprising one or more memories storing processor-executable code, and one or more processors coupled with the one or more memories and individually or collectively operable to execute the code to cause the UE to perform a method of any of aspects 1 through 15.

[0245] Aspect 30: A UE for wireless communications, comprising at least one means for performing a method of any of aspects 1 through 15.

[0246] Aspect 31: A non-transitory computer-readable medium storing code for wireless communications, the code comprising instructions executable by one or more processors to perform a method of any of aspects 1 through 15.

[0247] Aspect 32: A network entity for wireless communications, comprising one or more memories storing processor-executable code, and one or more processors coupled with the one or more memories and individually or collectively operable to execute the code to cause the network entity to perform a method of any of aspects 16 through 28.

[0248] Aspect 33: A network entity for wireless communications, comprising at least one means for performing a method of any of aspects 16 through 28.

[0249] Aspect 34: A non-transitory computer-readable medium storing code for wireless communications, the code comprising instructions executable by one or more processors to perform a method of any of aspects 16 through 28.

[0250] 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.

[0251] 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.

[0252] 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.

[0253] The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed using 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). Any functions or operations described herein as being capable of being performed by a processor may be performed by multiple processors that, individually or collectively, are capable of performing the described functions or operations.

[0254] The functions described herein may be implemented using hardware, software executed by a processor, firmware, or any combination thereof. If implemented using software executed by a processor, the functions may be stored as or transmitted using one or more instructions or code of 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.

[0255] 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 location 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. Disks may reproduce data magnetically, and discs may reproduce data optically using lasers. Combinations of the above are also included within the scope of computer-readable media. Any functions or operations described herein as being capable of being performed by a memory may be performed by multiple memories that, individually or collectively, are capable of performing the described functions or operations.

[0256] 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."

[0257] As used herein, including in the claims, the article "a" before a noun is open-ended and understood to refer to "at least one" of those nouns or "one or more" of those nouns. Thus, the terms "a," "at least one," "one or more," "at least one of one or more" may be interchangeable. For example, if a claim recites "a component" that performs one or more functions, each of the individual functions may be performed by a single component or by any combination of multiple components. Thus, the term "a component" having characteristics or performing functions may refer to "at least one of one or more components" having a particular characteristic or performing a particular function. Subsequent reference to a component introduced with the article "a" using the terms "the" or "said" may refer to any or all of the one or more components. For example, a component introduced with the article "a" may be understood to mean "one or more components," and referring to "the component" subsequently in the claims may be understood to be equivalent to referring to "at least one of the one or more components." Similarly, subsequent reference to a component introduced as "one or more components" using the terms "the" or "said" may refer to any or all of the one or more components. For example, referring to "the one or more components" subsequently in the claims may be understood to be equivalent to referring to "at least one of the one or more components."

[0258] 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 (e.g., receiving information), accessing (e.g., accessing data stored in memory) and the like. Also, "determining" can include resolving, obtaining, selecting, choosing, establishing, and other such similar actions.

[0259] 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.

[0260] 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.

[0261] 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. A user equipment (UE), comprising:

one or more memories storing processor-executable code; and

one or more processors coupled with the one or more memories and individually or collectively operable to execute the code to cause the UE to:

receive a first control signal that indicates a set of delay values corresponding to a set of antenna ports;

receive a first reference signal that has a first delay profile, wherein the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal;

determine a second delay profile for a demodulation reference signal based at least in part on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of demodulation reference signals, wherein the set of demodulation reference signals comprises the demodulation reference signal; and

perform a channel estimation on the demodulation reference signal based at least in part on the set of delay values and the second delay profile.

2. The UE of claim **1**, wherein, to receive the first reference signal, the one or more processors are individually or collectively operable to execute the code to cause the UE to:

receive the multi-port reference signal via the set of antenna ports, wherein the first reference signal is the multi-port reference signal.

3. The UE of claim **1**, wherein the multi-port reference signal is a virtual reference signal corresponding to the first reference signal.

4. The UE of claim **1**, wherein a doppler profile of the demodulation reference signal corresponds to the first reference signal.

5. The UE of claim **1**, wherein the one or more processors are individually or collectively further operable to execute the code to cause the UE to:

map the multi-port reference signal to the set of demodulation reference signals based at least in part on the set of delay values.

6. The UE of claim **1**, wherein the first control signal indicates the set of delay values from a plurality of sets of delay values.

7. The UE of claim **1**, wherein the one or more processors are individually or collectively further operable to execute the code to cause the UE to:

receive a second control signal indicating a plurality of sets of delay values, wherein the first control signal indicates the set of delay values from the plurality of sets of delay values.

8. The UE of claim **1**, wherein the one or more processors are individually or collectively further operable to execute the code to cause the UE to:

receive the demodulation reference signal via an antenna port of the set of antenna ports, wherein performing the channel estimation is based at least in part on a delay value of the set of delay values corresponding to the antenna port and the second delay profile of the demodulation reference signal.

9. The UE of claim **1**, wherein the one or more processors are individually or collectively further operable to execute the code to cause the UE to:

transmit an uplink data message applying the set of delay values.

10. The UE of claim **1**, wherein the one or more processors are individually or collectively further operable to execute the code to cause the UE to:

receive data signaling via the set of antenna ports; and

decode the data signaling based at least in part on performing the channel estimation on the demodulation reference signal.

11. The UE of claim **1**, wherein the one or more processors are individually or collectively further operable to execute the code to cause the UE to:

receive the demodulation reference signal based at least in part on the set of delay values and a quantity of layers of the demodulation reference signal.

12. The UE of claim **1**, wherein the first control signal indicates that the set of delay values are applied for a data signal associated with the demodulation reference signal.

13. The UE of claim **1**, wherein a first quantity of the set of antenna ports, a second quantity of antenna ports associated with the multi-port reference signal, and a third quantity of demodulation reference signals in the set of demodulation reference signals are the same.

14. The UE of claim **1**, wherein the first control signal indicates a mapping between the set of delay values and the set of antenna ports.

15. The UE of claim **1**, wherein a maximum delay for the set of delay values corresponds to a difference between cyclic prefix length and a maximum quantity of sample delays.

16. A network entity, comprising:

one or more memories storing processor-executable code; and

one or more processors coupled with the one or more memories and individually or collectively operable to execute the code to cause the network entity to:

transmit a first control signal that indicates a set of delay values corresponding to a set of antenna ports;

transmit, via at least a first antenna port of the set of antenna ports, a first reference signal that has a first delay profile, wherein the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal;

determine a second delay profile for a demodulation reference signal based at least in part on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of demodulation reference signals, wherein the set of demodulation reference signals comprises the demodulation reference signal; and

transmit the set of demodulation reference signals based at least in part on the first delay profile of the first reference signal, the set of delay values, and the antenna port mapping between the multi-port reference signal and the set of demodulation reference signals.

17. The network entity of claim **16**, wherein, to transmit the first reference signal, the one or more processors are individually or collectively operable to execute the code to cause the network entity to:

transmit the multi-port reference signal via the set of antenna ports, wherein the first reference signal is the multi-port reference signal.

18. The network entity of claim **16**, wherein the multi-port reference signal is a virtual reference signal corresponding to the first reference signal.

19. The network entity of claim **16**, wherein a doppler profile of the demodulation reference signal corresponds to the first reference signal.

20. The network entity of claim **16**, wherein the first control signal indicates the set of delay values from a plurality of sets of delay values.

21. The network entity of claim **16**, wherein the one or more processors are individually or collectively further operable to execute the code to cause the network entity to:

transmit a second control signal indicating a plurality of sets of delay values, wherein the first control signal indicates the set of delay values from the plurality of sets of delay values.

22. The network entity of claim **16**, wherein the one or more processors are individually or collectively further operable to execute the code to cause the network entity to:

transmit the demodulation reference signal via the first antenna port using a delay value of the set of delay values corresponding to the first antenna port.

23. The network entity of claim **16**, wherein the one or more processors are individually or collectively further operable to execute the code to cause the network entity to:

receive an uplink data message, wherein the set of delay values is applied to the uplink data message.

24. The network entity of claim **16**, wherein the one or more processors are individually or collectively further operable to execute the code to cause the network entity to:

transmit data signaling via the set of antenna ports applying the set of delay values.

25. The network entity of claim **16**, wherein the one or more processors are individually or collectively further operable to execute the code to cause the network entity to:

transmit the demodulation reference signal based at least in part on the set of delay values and a quantity of layers of the demodulation reference signal.

26. The network entity of claim **16**, wherein the first control signal indicates that the set of delay values are applied for a data signal associated with the demodulation reference signal.

27. The network entity of claim **16**, wherein a first quantity of the set of antenna ports, a second quantity of antenna ports associated with the multi-port reference signal, and a third quantity of demodulation reference signals in the set of demodulation reference signals are the same.

28. The network entity of claim **16**, wherein a maximum delay for the set of delay values corresponds to a difference between cyclic prefix length and a maximum quantity of sample delays.

29. A method for wireless communications at a user equipment (UE), comprising:

receiving a first control signal that indicates a set of delay values corresponding to a set of antenna ports;

receiving a first reference signal that has a first delay profile, wherein the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal;

determining a second delay profile for a demodulation reference signal based at least in part on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of demodulation reference signals, wherein the set of demodulation reference signals comprises the demodulation reference signal; and

performing a channel estimation on the demodulation reference signal based at least in part on the set of delay values and the second delay profile.

30. A method for wireless communications at a network entity, comprising:

transmitting a first control signal that indicates a set of delay values corresponding to a set of antenna ports;

transmitting, via at least a first antenna port of the set of antenna ports, a first reference signal that has a first delay profile, wherein the first reference signal is a multi-port reference signal or is associated with the multi-port reference signal;

determining a second delay profile for a demodulation reference signal based at least in part on the first delay profile of the first reference signal, the set of delay values, and an antenna port mapping between the multi-port reference signal and a set of demodulation reference signals, wherein the set of demodulation reference signals comprises the demodulation reference signal; and

transmitting the set of demodulation reference signals based at least in part on the first delay profile of the first reference signal, the set of delay values, and the antenna port mapping between the multi-port reference signal and the set of demodulation reference signals.

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