# DEVICES AND METHODS OF COMMUNICATION

## TECHNICAL FIELD

**[0001]** The present disclosure relates to wireless communications, and more specifically to devices and methods of communication for an uplink transmission.

## BACKGROUND

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

**[0003]** For Internet of things (IoT) non-terrestrial network (NTN), it is proposed to support capacity enhancements for uplink. It is expected to study and specify enhancements to enable multiplexing of multiple UEs via an orthogonal cover code (OCC) for a narrow-band physical uplink shared channel (NPUSCH) and a narrow-band physical random access channel (NPRACH).

## SUMMARY

**[0004]** The present disclosure relates to methods, apparatuses, and systems that support an uplink transmission. By applying a multiplexing sequence to a reference signal to process the reference signal and transmitting uplink data with the processed reference signal, multiple UEs may be multiplexed in the same physical resource for an uplink transmission to enhance uplink capacity.

**[0005]** In one aspect, some implementations of the method and apparatuses described herein may comprise: receiving, at a UE from a base station via a transceiver, a configuration for an uplink transmission; processing a reference signal by applying, to the reference signal, a first multiplexing sequence associated with a first spreading factor; and transmitting, to the base station via the transceiver, uplink data with the processed reference signal based on the configuration.

**[0006]** In some implementations of the method and apparatuses described herein, processing the reference signal may comprise: spreading the reference signal in consecutive symbols in time domain based on a set of reference signal sequences, wherein the set of reference signal sequences is determined at least based on a binary sequence and the first multiplexing sequence.

**[0007]** In some implementations of the method and apparatuses described herein, transmitting the uplink data with the processed reference signal may comprise: determining a first set of time domain positions for the reference signal at least based on the first spreading factor; and transmitting the reference signal on the first set of time domain positions.

**[0008]** In some implementations of the method and apparatuses described herein, a length of the first multiplexing sequence may be determined based on the first spreading factor.

**[0009]** In some implementations of the method and apparatuses described herein, a length of the binary sequence may be determined based on at least one of the following: a repetition number for the uplink data, number of slots in a resource unit, number of resource units, or the first spreading factor.

**[0010]** In some implementations of the method and apparatuses described herein, processing the reference signal may comprise: determining the first multiplexing sequence based on a unit matrix.

**[0011]** In some implementations of the method and apparatuses described herein, processing the reference signal may comprise: determining a second set of time domain positions for the reference signal based on at least one of the first spreading factor or an index of the first multiplexing sequence; and muting the reference signal in the second set of time domain positions.

**[0012]** In some implementations of the method and apparatuses described herein, processing the reference signal may comprise: spreading the reference signal in a plurality of resource elements of a resource in a time or frequency domain based on the first multiplexing sequence, wherein a length of the reference signal before the spreading is determined based on an uplink data frequency domain allocation and the first spreading factor.

**[0013]** In some implementations of the method and apparatuses described herein, spreading the reference signal may comprise: determining, based on the length of the reference signal before the spreading, an offset among the plurality of resource elements; and spreading, based on the offset, the reference signal in the plurality of resource elements.

**[0014]** In some implementations of the method and apparatuses described herein, transmitting the uplink data with the processed reference signal may comprise: processing the uplink data by applying, to the uplink data, a second multiplexing sequence associated with a second spreading factor.

**[0015]** Some implementations of the method and apparatuses described herein may further comprise: determining the second spreading factor as the first spreading factor; or determining the first spreading factor based on the second spreading factor and an uplink data frequency domain allocation.

**[0016]** In another aspect, some implementations of the method and apparatuses described herein may comprise: transmitting, at a base station to a UE via a transceiver, a configuration for an uplink transmission; processing a reference signal by applying, to the reference signal, a first multiplexing sequence associated with a first spreading factor; and receiving, from the UE via the transceiver, uplink data based on the processed reference signal and the configuration.

**[0017]** In some implementations of the method and apparatuses described herein, processing the reference signal may comprise: spreading the reference signal in consecutive symbols in time domain based on a set of reference signal sequences, wherein the set of reference signal sequences is determined at least based on a binary sequence and the first multiplexing sequence.

**[0018]** In some implementations of the method and apparatuses described herein, receiving the uplink data with the processed reference signal by: determining a first set of time domain positions for the reference signal at least based on the first spreading factor; and receiving the reference signal on the first set of time domain positions.

**[0019]** In some implementations of the method and apparatuses described herein, a length of the first multiplexing sequence may be determined based on the first spreading factor.

**[0020]** In some implementations of the method and apparatuses described herein, a length of the binary sequence may be determined based on at least one of the following: a repetition number for the uplink data, number of slots in a resource unit, number of resource units, or the first spreading factor.

**[0021]** In some implementations of the method and apparatuses described herein, processing the reference signal may comprise: determining the first multiplexing sequence based on a unit matrix.

**[0022]** In some implementations of the method and apparatuses described herein, processing the reference signal may comprise: determining a second set of time domain positions for the reference signal based on at least one of the first spreading factor or an index of the first multiplexing sequence; and muting the reference signal in the second set of time domain positions.

**[0023]** In some implementations of the method and apparatuses described herein, processing the reference signal may comprise: spreading the reference signal in a plurality of resource elements of a resource in a time or frequency domain based on the first multiplexing sequence, wherein a length of the reference signal before the spreading is determined based on an uplink data frequency domain allocation and the first spreading factor.

**[0024]** In some implementations of the method and apparatuses described herein, spreading the reference signal may comprise: determining, based on the length of the reference signal before the spreading, an offset among the plurality of resource elements; and spreading, based on the offset, the reference signal in the plurality of resource elements.

**[0025]** In some implementations of the method and apparatuses described herein, receiving the uplink data with the processed reference signal may comprise: processing the uplink data by applying, to the uplink data, a second multiplexing sequence associated with a second spreading factor.

**[0026]** Some implementations of the method and apparatuses described herein may further comprise: determining the second spreading factor as the first spreading factor; or determining the first spreading factor based on the second spreading factor and an uplink data frequency domain allocation.

BRIEF DESCRIPTION OF THE DRAWINGS

**[0027]** FIG. 1 illustrates an example of a wireless communications system that supports an uplink transmission in accordance with aspects of the present disclosure.

**[0028]** FIG. 2 illustrates an example of a process that supports an uplink transmission in accordance with aspects of the present disclosure.

**[0029]** FIG. 3A illustrates an example single-tone uplink transmission in accordance with aspects of the present disclosure.

**[0030]** FIG. 3B illustrates another example single-tone uplink transmission in accordance with aspects of the present disclosure.

**[0031]** FIG. 4A illustrates an example multiple-tone uplink transmission in accordance with aspects of the present disclosure.

**[0032]** FIG. 4B illustrates another example multiple-tone uplink transmission in accordance with aspects of the present disclosure.

**[0033]** FIG. 4C illustrates another example multiple-tone uplink transmission in accordance with aspects of the present disclosure.

**[0034]** FIG. 4D illustrates another example multiple-tone uplink transmission in accordance with aspects of the present disclosure.

**[0035]** FIG. 4E illustrates another example multiple-tone uplink transmission in accordance with aspects of the present disclosure.

**[0036]** FIG. 5 illustrates an example of a device that supports an uplink transmission in accordance with aspects of the present disclosure.

**[0037]** FIG. 6 illustrates an example of a processor that supports an uplink transmission in accordance with aspects of the present disclosure.

**[0038]** FIG. 7 illustrates a flowchart of a method that supports an uplink transmission in accordance with aspects of the present disclosure.

**[0039]** FIG. 8 illustrates a flowchart of another method that supports an uplink transmission in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

**[0040]** Principles of the present disclosure will now be described with reference to some embodiments. It is to be understood that these embodiments are described only for the purpose of illustration and help those skilled in the art to understand and implement the present disclosure, without suggesting any limitation as to the scope of the disclosure. The disclosure described herein may be implemented in various manners other than the ones described below.

**[0041]** In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs.

**[0042]** References in the present disclosure to "one embodiment," "an example embodiment," "an embodiment," "some embodiments," and the like indicate that the embodiment(s) described may include a particular feature, structure, or characteristic, but it is not necessary that every embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases do not necessarily refer to the same embodiment(s). Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described. The term "embodiment" may be interchangeably used with "implementation".

**[0043]** It shall be understood that although the terms "first" and "second" or the like may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another element. For example, a first element could also be termed as a second element, and similarly, a second element could also be termed as a first element, without departing

from the scope of implementations. As used herein, the term "and/or" includes any and all combinations of one or more of the listed terms.

**[0044]** The terminology used herein is for the purpose of describing particular implementations only and is not intended to be limiting of example implementations. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises", "comprising", "has", "having", "includes" and/or "including", when used herein, specify the presence of stated features, elements, and/or components etc., but do not preclude the presence or addition of one or more other features, elements, components and/ or combinations thereof.

**[0045]** As mentioned above, it is expected to multiplex multiple UEs in the same physical resource for uplink transmission with OCC to enhance uplink capacity.

**[0046]** Embodiments of the present disclosure provide a solution of an uplink transmission. In the solution, a UE may receive a configuration for an uplink transmission from a base station. The UE may process a reference signal by applying a first multiplexing sequence associated with a first spreading factor to the reference signal, and transmit uplink data with the processed reference signal to the base station based on the configuration. In this way, a reference signal for an uplink transmission may be transmitted reliably, and multiplexing of multiple UEs in the same physical resource for the uplink transmission may be enhanced. Thus, uplink capacity may be enhanced.

**[0047]** Aspects of the present disclosure are described in the context of a wireless communications system.

**[0048]** FIG. 1 illustrates an example of a wireless communications system 100 that supports an uplink transmission in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more network entities (also referred to as network equipment (NE)). For convenience, network entities 102-1, 102-2 and 102-3 are shown and are collectively referred to as one or more network entities 102 hereinafter. The wireless communications system 100 may further include one or more UEs 104, a core network 106, and a packet data network 108. The wireless communications system 100 may support various radio access technologies. In some implementations, the wireless communications system 100 may be a 4G network, such

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

**[0049]** The one or more network entities 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the network entities 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a radio access network (RAN), a base transceiver station, an access point, a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. A network entity 102 and a UE 104 may communicate via a communication link 110, which may be a wireless or wired connection. For example, a network entity 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

**[0050]** A network entity 102 may provide one or more geographic coverage areas (also referred to as cells) for which the network entity 102 may support services (e.g., voice, video, packet data, messaging, broadcast, etc.) for one or more UEs 104 within a geographic coverage area. For example, a network entity 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, a network entity 102 may be moveable, for example, a satellite associated with a non-terrestrial network. In some implementations, different geographic coverage areas associated with the same or different radio access technologies may overlap, but the different geographic coverage areas may be associated with different network entities 102. 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.

**[0051]** The one or more UEs 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a mobile device, a wireless device, a remote device, a remote unit, a handheld device, or a subscriber device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an Internet-of-Things (IoT) device, an Internet-of-Everything (IoE) device, or machine-type communication (MTC) device, among other examples. In some implementations, a UE 104 may be stationary in the wireless communications system 100. In some other implementations, a UE 104 may be mobile in the wireless communications system 100.

**[0052]** The one or more UEs 104 may be devices in different forms or having different capabilities. Some examples of UEs 104 are illustrated in FIG. 1. A UE 104 may be capable of communicating with various types of devices, such as the network entities 102, other UEs 104, or network equipment (e.g., the core network 106, the packet data network 108, a relay device, an integrated access and backhaul (IAB) node, or another network equipment), as shown in FIG. 1. Additionally, or alternatively, a UE 104 may support communication with other network entities 102 or UEs 104, which may act as relays in the wireless communications system 100.

**[0053]** A UE 104 may also be able to support wireless communication directly with other UEs 104 over a communication link 114. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link 114 may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

**[0054]** A network entity 102 may support communications with the core network 106, or with another network entity 102, or both. For example, a network entity 102 may interface with the core network 106 through one or more backhaul links 116 (e.g., via an S1, N2, N2, or another network interface). The network entities 102 may

communicate with each other over the backhaul links 116 (e.g., via an X2, Xn, or another network interface). In some implementations, the network entities 102 may communicate with each other directly (e.g., between the network entities 102). In some other implementations, the network entities 102 may communicate with each other or indirectly (e.g., via the core network 106). In some implementations, one or more network entities 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

**[0055]** As an example, the network entity 102-1 may provide a cell 112-1 and the network entity 102-2 may provide a cell 112-2. It is to be understood that each of the network entities 102-1 and 102-2 may provide more cells (not shown).

**[0056]** In an example, the network entity may be a satellite, for example, the network entity 102-3. The network entity 102-3 may have full or part of an eNB/gNB on board. The communication link 110 between the network entity 102-3 and the UE 104, the communication link 116 between the network entity 102-3 and the network entity 102-2, and the communication link 116 between the network entity 102-2 and the core network 106 may be used for an NTN transparent mode. The communication link 110 between the satellite 102-3 and the UE 104, and the communication link 116 between the network entity 102-3 (e.g., with a base station on board) and the core network 106 may be used for a NTN regenerative mode.

**[0057]** In some implementations, a network entity 102 may be configured in a disaggregated architecture, which may be configured to utilize a protocol stack physically or logically distributed among two or more network entities 102, 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 102 may include one or more of a central unit (CU), a distributed unit (DU), a radio unit (RU), a RAN intelligent controller (RIC) (e.g., a near-real time RIC (Near-RT RIC), a non-real time RIC (Non-RT RIC)), a service management and orchestration (SMO) system, or any combination thereof.

**[0058]** An RU 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 TRP. One or more components of the network entities 102 in a disaggregated RAN architecture may be co-located, or one or more components of the network entities 102 may be located in distributed locations (e.g., separate physical locations). In some implementations, one or more network entities 102 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)).

**[0059]** Split of functionality between a CU, a DU, and an RU may be flexible and may support different functionalities depending upon which functions (e.g., network layer functions, protocol layer functions, baseband functions, radio frequency functions, and any combinations thereof) are performed at a CU, a DU, or an RU. For example, a functional split of a protocol stack may be employed between a CU and a DU such that the CU may support one or more layers of the protocol stack and the DU may support one or more different layers of the protocol stack. In some implementations, the CU may host upper protocol layer (e.g., a layer 3 (L3), a layer 2 (L2)) functionality and signaling (e.g., radio resource control (RRC), service data adaption protocol (SDAP), packet data convergence protocol (PDCP)). The CU may be connected to one or more DUs or RUs, and the one or more DUs or RUs may host lower protocol layers, such as a layer 1 (L1) (e.g., physical (PHY) layer) or an 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.

**[0060]** Additionally, or alternatively, a functional split of the protocol stack may be employed between a DU and an RU such that the DU may support one or more layers of the protocol stack and the RU may support one or more different layers of the protocol stack. The DU may support one or multiple different cells (e.g., via one or more RUs). In some implementations, a functional split between a CU and a DU, or between a DU and an RU may be within a protocol layer (e.g., some functions for a protocol layer may be performed by one of a CU, a DU, or an RU, while other functions of the protocol layer are performed by a different one of the CU, the DU, or the RU).

**[0061]** A CU may be functionally split further into CU control plane (CU-CP) and CU user plane (CU-UP) functions. A CU may be connected to one or more DUs via a midhaul communication link (e.g., F1, F1-c, F1-u), and a DU may be connected to one

or more RUs via a fronthaul communication link (e.g., open fronthaul (FH) interface). In some implementations, a midhaul communication link or a fronthaul communication link may be implemented in accordance with an interface (e.g., a channel) between layers of a protocol stack supported by respective network entities 102 that are in communication via such communication links.

**[0062]** The core network 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The core network 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more network entities 102 associated with the core network 106.

**[0063]** The core network 106 may communicate with the packet data network 108 over one or more backhaul links 116 (e.g., via an S1, N2, N2, or another network interface). The packet data network 108 may include an application server 118. In some implementations, one or more UEs 104 may communicate with the application server 118. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the core network 106 via a network entity 102. The core network 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server 118 using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the core network 106 (e.g., one or more network functions of the core network 106).

**[0064]** In the wireless communications system 100, the network entities 102 and the UEs 104 may use resources of the wireless communications system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the network entities 102 and the UEs 104 may support different resource structures. For example, the network entities 102 and the

UEs 104 may support different frame structures. In some implementations, such as in 4G, the network entities 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the network entities 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The network entities 102 and the UEs 104 may support various frame structures based on one or more numerologies.

**[0065]** One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing (SCS) and a cyclic prefix. A first numerology (e.g., $\mu$=0) may be associated with a first SCS (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., $\mu$=0) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., $\mu$=1) may be associated with a second SCS (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., $\mu$=2) may be associated with a third SCS (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., $\mu$=3) may be associated with a fourth SCS (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., $\mu$=4) may be associated with a fifth SCS (e.g., 240 kHz) and a normal cyclic prefix.

**[0066]** A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1ms duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

**[0067]** Additionally or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., $\mu$=0, $\mu$=1, $\mu$=2, $\mu$=3, $\mu$=4) associated with respective SCSs of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per

subframe, respectively. Each slot may include a number (e.g., quantity) of symbols (e.g., OFDM symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz SCS), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., $\mu$=0) associated with a first SCS (e.g., 15 kHz) may be used interchangeably between subframes and slots.

**[0068]** In the wireless communications system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the network entities 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the network entities 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the network entities 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

**[0069]** FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., $\mu$=0), which includes 15 kHz SCS; a second numerology (e.g., $\mu$=1), which includes 30 kHz SCS; and a third numerology (e.g., $\mu$=2), which includes 60 kHz SCS. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., $\mu$=2), which includes 60 kHz SCS; and a fourth numerology (e.g., $\mu$=3), which includes 120 kHz SCS.

**[0070]** As known, uplink transmissions from different UEs may be multiplexed at the same physical resource for uplink transmission, e.g., the same time-frequency resource in scheduled uplink resources or preconfigured uplink resources (PURs). A

multiplexing sequence may be applied for the uplink transmissions (cyclically if necessary) to differentiate UEs, e.g., beginning from a reference time slot (or an absolute slot, e.g., slot#0). Regarding a PUR, it may be a dedicated PUR where uplink time-frequency resources may be used exclusively by one UE at a time, or a shared PUR where the same uplink time-frequency resources may be used simultaneously by one or more UEs, e.g., up to two UEs.

**[0071]** An exemplary uplink transmission for which a multiplexing sequence is applied may include one or more of the following: physical uplink shared channel (PUSCH) transmission (also referred to as PUSCH herein); or an uplink reference signal transmission, e.g., demodulation reference signals (DMRSs) for PUSCH; or an uplink preamble (e.g., a preamble of random access channel (RACH) or physical random access channels (PRACH), etc.). Taking IoT NTN especially for narrow-band (NB) IoT (NBIoT) as an example, an uplink transmission may be a NPUSCH (e.g., NPUSCH format 1 (which is for uplink data and is not for feedback information)), or a NPRACH (e.g., the preamble of NPRACH), or a NPUSCH DMRS which is a special type of physical layer signal which functions as a reference signal for decoding NPUSCH.

**[0072]** In order to support a large number of UEs in multiple cells, a large number of different DMRS sequences for decoding an uplink data are needed. However, transmissions of the DMRS sequences may be overlapped on the same physical resource.

**[0073]** In view of the above, embodiments of the present disclosure provide a solution of a reference signal transmission in an uplink transmission. In the context of the present disclosure, the term 'reference signal' may refer to DMRS or any other suitable reference signals used for decoding uplink data. That is, the present solution may be applied to a transmission of any suitable reference signals including but not limiting to DMRS. The solution will be described in details with reference to FIGs. 2 to 4E.

**[0074]** FIG. 2 illustrates an example of a process 200 that supports an uplink transmission in accordance with aspects of the present disclosure. For the purpose of discussion, the process 200 will be described with reference to FIG. 1. The process 200 may involve the UE 104 and the network entity 102 (e.g., the network entity 102-1) as

illustrated in FIG. 1. It is to be understood that the steps and the order of the steps in FIG. 2 are merely for illustration, and not for limitation.

**[0075]** As shown in FIG. 2, the network entity 102 may transmit 210 a configuration for an uplink transmission to the UE 104. In some embodiments, the configuration for the uplink transmission may comprise a configuration for a reference signal (e.g., DMRS) transmission and a configuration for an uplink data transmission. It is to be understood that the configuration for the uplink transmission may comprise any combinations of the above information or any other suitable information or information combinations.

**[0076]** In some embodiments, the configuration for the reference signal transmission may indicate a spreading factor (for convenience, also referred to as a first spreading factor herein) for a reference signal. In some embodiments, the configuration for a reference signal transmission may indicate a multiplexing sequence (for convenience, also referred to as a first multiplexing sequence herein) associated with the first spreading factor. In some embodiments, the configuration for the reference signal transmission may indicate a physical resource used for the reference signal transmission. In some embodiments, the configuration for the reference signal transmission may indicate one or more parameters related to generation of a reference signal sequence. It is to be understood that the configuration for the reference signal transmission may comprise any combinations of the above information or any other suitable information or information combinations.

**[0077]** In some embodiments, the configuration for the uplink data transmission may indicate a spreading factor (for convenience, also referred to as a second spreading factor herein) for uplink data. In some embodiments, the configuration for the uplink data transmission may indicate a multiplexing sequence (for convenience, also referred to as a second multiplexing sequence herein) associated with the second spreading factor. In some embodiments, the configuration for the uplink data transmission may indicate a physical resource used for the uplink data transmission. It is to be understood that the configuration for the uplink data transmission may comprise any combinations of the above information or any other suitable information or information combinations.

**[0078]** Continuing to refer to FIG. 2, the UE 104 may process 220 the reference signal by applying the first multiplexing sequence to the reference signal. The first

multiplexing sequence is associated with the first spreading factor. In some embodiments, the UE 104 may determine the first spreading factor (i.e., a spreading factor of a reference signal) at least based on the second spreading factor (i.e., a spreading factor of uplink data). In some embodiments, the second spreading factor may be determined by a higher layer parameter or any other suitable ways.

**[0079]** In some embodiments, the UE 104 may determine the second spreading factor as the first spreading factor. In some embodiments, the UE 104 may determine the first spreading factor based on the second spreading factor and an uplink data frequency domain allocation (e.g., a number of subcarriers). For example, the first spreading factor may be determined based on an equation (1) below.

$$\text{if } M_{occ,data} \times K = N_{sc},\ M_{occ} = M_{occ,data}; \text{ else } M_{occ} = N_{sc} \quad (1)$$

where $M_{occ,data}$ denotes the second spreading factor, $K$ denotes a positive integer, $N_{sc}$ denotes the uplink data frequency domain allocation, and $M_{occ}$ denotes the first spreading factor. In this example, it is assumed that $N_{sc} \geq M_{occ,data}$.

**[0080]** For illustration, an example values of the first spreading factor determined by the second spreading factor and uplink data frequency domain may be described in Table 1 below.

Table 1

| $N_{sc} \backslash M_{occ,data}$ | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 1 | X | X | X |
| 3 | | 3 | 3 | X |
| 6 | | 2 | 3 | 6 |
| 12 | | 2 | 3 | 4 |

In the Table 1, for some configurations of $N_{sc}$ and $M_{occ,data}$, X indicates that an uplink transmission with an OCC operation is not supported under these configurations. In this case, it is possible to fallback to an uplink transmission without an OCC operation. It is to be understood that these values in the Table 1 are merely examples, and the present disclosure is not limited in this regard.

**[0081]** Continuing to refer to FIG. 2, in some embodiments, the UE 104 may spread 221 the reference signal in consecutive symbols in time domain based on the first multiplexing sequence. In this way, reference signals from difference UEs may be multiplexed on the same physical resource.

**[0082]** In some embodiments, the first multiplexing sequence may be associated with information of the UE 104, e.g., an identity (ID) of the UE 104, a cell-radio network temporary identity (C-RNTI), or a RRC configuration specific to the UE 104. In some embodiments, the first multiplexing sequence may comprise Walsh codes. In some embodiments, the first multiplexing sequence may comprise discrete Fourier transform (DFT) sequences.

**[0083]** In some embodiments, for a single-tone case, the UE 104 may spread the reference signal in consecutive symbols in time domain based on a reference signal sequence. In some embodiments for a multiple-tone case, the UE 104 may spread the reference signal in consecutive symbols in time domain based on a plurality of reference signal sequences.

**[0084]** In some embodiments, a reference signal sequence for the uplink transmission may be pre-processed by the first multiplexing sequence with the first spreading factor. In some embodiments, the reference signal sequence may be determined at least based on a binary sequence and the first multiplexing sequence. In some embodiments, a length of the binary sequence may be determined based on at least one of the following: a repetition number for the uplink data, number of slots in a resource unit (RU), number of RUs, or the first spreading factor. In some embodiments, a length of the first multiplexing sequence may be determined based on the first spreading factor.

**[0085]** For example, the reference signal sequence for single subcarrier (e.g., for NPUSCH) may be determined based on an equation (2) below.

$$\bar{r}_u(M_{occ}n + m) = \frac{1}{\sqrt{2}}(1 + j)\big(1 - 2c(n)\big)w(n \bmod 16)v(m)$$

$$\text{where } 0 \le n < \left\lceil M_{\text{rep}}^{\text{NPUSCH}} N_{\text{slots}}^{\text{UL}} N_{\text{RU}} / M_{occ} \right\rceil,\ 0 \le m < M_{occ} \qquad (2)$$

where $\bar{r}_u()$ denotes the reference signal sequence for single subcarrier, $c()$ denotes the binary sequence, $j$ denotes an imaginary part of a complex, $w()$ denotes an orthogonal

sequence related to cell ID information, $v()$ denotes the first multiplexing sequence, $m$ denotes the m$^{th}$ element of the first multiplexing sequence, $M_{occ}$ denotes the first spreading factor, $M_{\text{rep}}^{\text{NPUSCH}}$ denotes the repetition number for the uplink data, $N_{\text{slots}}^{\text{UL}}$ denotes the number of slots in a RU, and $N_{\text{RU}}$ denotes the number of RUs.

**[0086]** In some embodiments, the binary sequence $c(n)$ may be defined as a scrambling sequence, and may be initialized with $c_{init} = 25$ (as an example) at a start of a NPUSCH transmission. The length of $c(n)$ may be determined by the first spreading factor $M_{occ}$ (e.g., $M_{\text{rep}}^{\text{NPUSCH}} N_{\text{slots}}^{\text{UL}} N_{\text{RU}} / M_{occ}$). In some embodiments, a ceiling operation ceil(x) may be used upon determination of the length of $c(n)$.

**[0087]** In some embodiments, an example of $w(n)$ may be defined as shown in Table 2. For example, $u = cellID \bmod 16$, where $cellID$ denotes a cell ID. It is to be understood that $w(n)$ may adopt any other suitable forms, and the present disclosure does not limit this aspect.

Table 2

| $u$ | $w(0), \ldots, w(15)$ | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | -1 | 1 | -1 | 1 | -1 | 1 | -1 | 1 | -1 | 1 | -1 | 1 | -1 | 1 | -1 |
| 2 | 1 | 1 | -1 | -1 | 1 | 1 | -1 | -1 | 1 | 1 | -1 | -1 | 1 | 1 | -1 | -1 |
| 3 | 1 | -1 | -1 | 1 | 1 | -1 | -1 | 1 | 1 | -1 | -1 | 1 | 1 | -1 | -1 | 1 |
| 4 | 1 | 1 | 1 | 1 | -1 | -1 | -1 | -1 | 1 | 1 | 1 | 1 | -1 | -1 | -1 | -1 |
| 5 | 1 | -1 | 1 | -1 | -1 | 1 | -1 | 1 | 1 | -1 | 1 | -1 | -1 | 1 | -1 | 1 |
| 6 | 1 | 1 | -1 | -1 | -1 | -1 | 1 | 1 | 1 | 1 | -1 | -1 | -1 | -1 | 1 | 1 |
| 7 | 1 | -1 | -1 | 1 | -1 | 1 | 1 | -1 | 1 | -1 | -1 | 1 | -1 | 1 | 1 | -1 |
| 8 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| 9 | 1 | -1 | 1 | -1 | 1 | -1 | 1 | -1 | -1 | 1 | -1 | 1 | -1 | 1 | -1 | 1 |
| 10 | 1 | 1 | -1 | -1 | 1 | 1 | -1 | -1 | -1 | -1 | 1 | 1 | -1 | -1 | 1 | 1 |
| 11 | 1 | -1 | -1 | 1 | 1 | -1 | -1 | 1 | -1 | 1 | 1 | -1 | -1 | 1 | 1 | -1 |
| 12 | 1 | 1 | 1 | 1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | 1 | 1 | 1 | 1 |
| 13 | 1 | -1 | 1 | -1 | -1 | 1 | -1 | 1 | -1 | 1 | -1 | 1 | 1 | -1 | 1 | -1 |
| 14 | 1 | 1 | -1 | -1 | -1 | -1 | 1 | 1 | -1 | -1 | 1 | 1 | 1 | 1 | -1 | -1 |
| 15 | 1 | -1 | -1 | 1 | -1 | 1 | 1 | -1 | -1 | 1 | 1 | -1 | 1 | -1 | -1 | 1 |

**[0088]** In some embodiments, an example of $v(m)$ as a Walsh code may be defined as shown in Table 3. It is to be understood that $v(m)$ may adopt any other suitable forms, and the present disclosure does not limit this aspect.

Table 3

| $Va(0)$ | $v(0)$ | $v(1)$ | $v(2)$ | $v(3)$ |
|---|---|---|---|---|
| $a = 0$ | 1 | 1 | 1 | 1 |
| $a = 1$ | 1 | $-1$ | 1 | $-1$ |

| | | | | |
|---|---|---|---|---|
| $a = 2$ | 1 | 1 | $-1$ | $-1$ |
| $a = 3$ | 1 | $-1$ | $-1$ | 1 |

**[0089]** In some embodiments, $N_{\text{slots}}^{\text{UL}}$ may be 16 for NPUSCH format 1 in a single tone case. In some embodiments, $N_{\text{RU}}$ may be configured by a higher layer as $\{1,2,3,4,5,6,8\}$.

**[0090]** It is to be understood that the equation (2) is merely for illustration, and is not intended to limit the present disclosure. Any other suitable forms may also be feasible.

**[0091]** For illustration, some examples will be described in connection with FIG. 3A. FIG. 3A illustrates an example single-tone uplink transmission 300A in accordance with aspects of the present disclosure. In this example, SCS is 15KHz.

**[0092]** As shown in FIG. 3A, in an uplink transmission 310, $M_{occ} = 2$, and each reference signal symbol set comprises two symbols. An OCC operation may be performed for reference signals on the two symbols. Starting symbol indexes corresponding to reference signal symbol sets 311, 312 and 313 are determined as 6, 20 and 34 respectively. Other symbols are used for carrying uplink data.

**[0093]** Continuing to refer to FIG. 3A, in an uplink transmission 320, $M_{occ} = 3$, and each reference signal symbol set comprise three symbols. An OCC operation may be performed for reference signals on the three symbols. Starting symbol indexes corresponding to reference signal symbol sets 321 and 322 are determined as 9 and 30 respectively. Other symbols are used for carrying uplink data.

**[0094]** Continuing to refer to FIG. 3A, in an uplink transmission 330, $M_{occ} = 4$, and each reference signal symbol set comprise four symbols. An OCC operation may be performed for reference signals on the four symbols. Starting symbol indexes corresponding to reference signal symbol sets 331 and 332 are determined as 12 and 40 respectively. Other symbols are used for carrying uplink data. It is to be understood that the reference signal symbol set 332 may also comprise four symbols, and only parts of the reference signal symbol set 332 are shown here.

**[0095]** Returning to FIG. 2, in some embodiments, the UE 104 may determine 222 the first multiplexing sequence based on a unit matrix. The first multiplexing sequence

may be determined so that reference signal transmissions from difference UEs may not be overlapped on the same resource. For example, multiplexed sequences applied for different UEs may be determined as {1 0 0 0}; {0 1 0 0}; {0 0 1 0}; {0 0 0 1}. One of the multiplexing sequences may be determined based on an index of the first multiplexing sequence (denoted as $m_{occ}$ herein). For example, for $m_{occ}$=1, {0 1 0 0} may be determined as the first multiplexing sequence for the reference signal.

**[0096]** With reference to FIG. 2, in some embodiments, the UE 104 may mute 223 the reference signal in a set of time domain positions (for convenience, also referred to as a second set of time domain positions herein). The second set of time domain positions may be determined so that reference signal transmissions from difference UEs may not be overlapped on the physical resource.

**[0097]** In some embodiments, the UE 104 may determine the second set of time domain positions based on at least one of the first spreading factor or an index of the first multiplexing sequence (e.g., $m_{occ}$=1). For example, a reference signal symbol may be muted when a slot index meets an equation (3) below.

$$n \bmod M_{occ} = K, \ where \ K \neq m_{occ} \qquad (3)$$

where $n$ denotes the slot index, $M_{occ}$ denotes the first spreading factor, and $m_{occ}$ denotes an index of the first multiplexing sequence.

**[0098]** It is to be understood that the equation (3) is merely for illustration, and is not intended to limit the present disclosure. Any other suitable forms may also be feasible.

**[0099]** For illustration, some example uplink transmissions will be described in connection with FIG. 3B. FIG. 3B illustrates another example single-tone uplink transmission 300B in accordance with aspects of the present disclosure. In this example, SCS is 15KHz.

**[0100]** As shown in FIG. 3B, in an uplink transmission 340, $M_{occ} = 2$, and there is a single reference signal symbol within each slot. By muting reference signal symbols within slots #1, #3 and #5 for UE#1 and muting reference signal symbols within slots #0, #2 and #4 for UE#2, reference signal transmissions of UE#1 and UE#2 may be differentiated.

**[0101]** Continuing to refer to FIG. 3B, in an uplink transmission 350, $M_{occ} = 3$, and there is a single reference signal symbol within each slot. By muting reference signal symbols within slots #1, #2, #4 and #5 for UE#1, muting reference signal symbols within slots #0, #2, #3 and #5 for UE#2, and muting reference signal symbols within slots #0, #1, #3 and #4 for UE#3, reference signal transmissions of UE#1, UE#2 and UE#3 may be differentiated.

**[0102]** Returning to FIG. 2, in some embodiments, the UE 104 may spread 234 the reference signal in a plurality of resource elements of a resource in a time or frequency domain based on the first multiplexing sequence.

**[0103]** In some embodiments, the UE 104 may determine a length of the reference signal before spreading based on the uplink data frequency domain allocation and the first spreading factor. In other words, the length of the reference signal before spreading may be scaled by the spreading factor of the reference signal. For example, the length of the reference signal before spreading may be determined based on an equation (4) below.

$$L_{rs} = N_{sc}/M_{occ} \tag{4}$$

where $L_{rs}$ denotes the length of the reference signal before spreading, $N_{sc}$ denotes the uplink data frequency domain allocation, $M_{occ}$ denotes the first spreading factor.

**[0104]** It is to be understood that the equation (4) is merely for illustration, and is not intended to limit the present disclosure. Any other suitable forms may also be feasible.

**[0105]** In some embodiments, the UE 104 may determine an offset among the plurality of resource elements based on the length of the reference signal before spreading, and spread the reference signal in the plurality of resource elements based on the offset.

**[0106]** In some embodiments, the reference signal sequence for multiple tones may be determined based on an equation (5) below.

$$r_u(nM_{occ} + m) = e^{j\alpha n} e^{j\frac{\phi(n)\pi}{4}} v(m)$$

$$\text{where } 0 \le n < N_{sc}^{RU}/M_{occ},\ 0 \le m < M_{occ} \tag{5}$$

where $r_u()$ denotes the reference signal sequence for multiple tones, $\phi()$ denotes a predefined value corresponding to a value of $N_{\text{sc}}^{\text{RU}}/M_{occ}$, $v()$ denotes the first multiplexing sequence, $N_{\text{sc}}^{\text{RU}}$ denotes number of subcarriers for a RU, $M_{occ}$ denotes the first spreading factor, $j$ denotes an imaginary part of a complex, $m$ denotes the m$^{\text{th}}$ element of the first multiplexing sequence, and $\alpha$ denotes a cyclic shift value configured by higher layer parameters.

**[0107]** It is to be understood that the equation (5) is merely for illustration, and is not intended to limit the present disclosure. Any other suitable forms may also be feasible.

**[0108]** In some embodiments, an OCC operation for the reference signal may be performed/spreaded in $M_{occ}$ resource elements before DFT precoding, and the offset among these resource elements may be $L_{rs}$ or 1. In some embodiments, the OCC operation for the reference signal may be performed within 2 consecutive resource elements. In some embodiments, the OCC operation for the reference signal may be performed within 2 consecutive resource elements with offset of $L_{rs}$.

**[0109]** In some embodiments, the UE 104 may process the uplink data by applying the second multiplexing sequence associated with the second spreading factor to the uplink data. In some embodiments, the UE 104 may spread the uplink data across symbols in time domain. In some embodiments, the UE 104 may spread the uplink data per symbol in time domain with the second multiplexing sequence. For example, the uplink data after spreading may be determined based on an equation (6) below.

$$S(n'M_{occ,data} + m') = s(n') * v'(m'), \text{ where } 0 \leq m' < M_{occ,data} \quad (6)$$

where $S()$ denotes the uplink data after spreading with the second multiplexing sequence, $s()$ denotes the uplink data before spreading, $M_{occ,data}$ denotes the second spreading factor, $v'()$ denotes the second multiplexing sequence, and $m'$ denotes the $m'$ $^{\text{th}}$ element of the second multiplexing sequence.

**[0110]** In another example, the uplink data after spreading may be determined based on an equation (7) below.

$$S(n'M_{occ,data}N_{sc} + iN_{sc} + m') = s(n'N_{sc} + m') * v'(i)\ m' = 0,1,\ldots N_{sc}\text{-}1$$

$$\text{where } i = 0,1,\ldots M_{OCC,data}\text{-}1 \quad (7)$$

where $S()$ denotes the uplink data after spreading with the second multiplexing sequence, $s()$ denotes the uplink data before spreading, $M_{occ,data}$ denotes the second spreading factor, $v'()$ denotes the second multiplexing sequence, and $m'$ denotes the $m'^{\text{th}}$ element of the second multiplexing sequence.

**[0111]** It is to be understood that the equations (6) and (7) are merely for illustration, and is not intended to limit the present disclosure. Any other suitable forms may also be feasible.

**[0112]** For illustration, some example uplink transmissions will be described in connection with FIGs. 4A to 4E. FIG. 4A illustrates an example multiple-tone uplink transmission 400A in accordance with aspects of the present disclosure. In this example, UE is configured with data spreading, $M_{occ,data} = 2$, and $N_{sc} = 6$. Thus, $M_{occ} = 2$, and the length of the reference signal before spreading for each symbol is 3 (i.e., $L_{rs} = 3$). The length of the reference signal after spreading for each symbol is equal to $N_{sc}$ (i.e., 6). As shown in FIG. 4A, an OCC operation for the reference signal may be performed in two resource elements (e.g., samples) before DFT precoding, and the offset among the two resource elements is $L_{rs}$. An OCC operation for the uplink data may be performed across two symbols (e.g., two consecutive symbols).

**[0113]** FIG. 4B illustrates another example multiple-tone uplink transmission 400B in accordance with aspects of the present disclosure. In this example, UE is configured with data spreading, $M_{occ,data} = 3$, and $N_{sc} = 6$. Thus, $M_{occ} = 3$, and the length of the reference signal before spreading for each symbol is 2 (i.e., $L_{rs} = 2$). The length of the reference signal after spreading for each symbol is equal to $N_{sc}$ (i.e., 6). As shown in FIG. 4B, an OCC operation for the reference signal may be performed in three consecutive resource elements (e.g., samples) before DFT precoding, and the offset among the resource elements is 1. An OCC operation for the uplink data may be performed among three consecutive symbols.

**[0114]** FIG. 4C illustrates another example multiple-tone uplink transmission 400C in accordance with aspects of the present disclosure. In this example, UE is configured with data spreading, $M_{occ,data} = 4$, and $N_{sc} = 12$. Thus, $M_{occ} = 4$, and the length of the reference signal before spreading for each symbol is 3 (i.e., $L_{rs} = 3$). The length of the reference signal after spreading for each symbol is equal to $N_{sc}$ (i.e., 12). As shown in FIG. 4C, an OCC operation for the reference signal may be performed in 4 consecutive

resource elements (e.g., samples) before DFT precoding, and the offset among the resource elements is 1. An OCC operation for the uplink data may be performed among 4 consecutive symbols.

**[0115]** FIG. 4D illustrates another example multiple-tone uplink transmission 400D in accordance with aspects of the present disclosure. In this example, UE is configured with data spreading, $M_{occ,data} = 2$, and $N_{sc} = 12$. Thus, $M_{occ} = 2$, and the length of the reference signal before spreading for each symbol is 6 (i.e., $L_{rs} = 6$). The length of the reference signal after spreading for each symbol is equal to $N_{sc}$ (i.e., 12). As shown in FIG. 4D, an OCC operation for the reference signal may be performed in 2 resource elements (e.g., samples) before DFT precoding, and the offset among the resource elements is $L_{rs}$. An OCC operation for the uplink data may be performed among 2 symbols.

**[0116]** FIG. 4E illustrates another example multiple-tone uplink transmission 400E in accordance with aspects of the present disclosure. In this example, UE is configured with data spreading, $M_{occ,data} = 2$, and $N_{sc} = 6$. Thus, $M_{occ} = 3$, and the length of the reference signal for each symbol is 3 (i.e., $L_{rs} = 3$). As shown in FIG. 4E, the remaining resource elements in a reference signal symbol is muted. A position of the reference signal is determined by an index of the first multiplexing sequence. An OCC operation for the uplink data may be performed among 2 symbols.

**[0117]** Continuing to refer to FIG. 2, the UE 104 may transmit 230 uplink data with the processed reference signal. In some embodiments, the UE 104 may transmit the processed reference signal on a physical resource. In some embodiments, the UE 104 may determine a set of time domain positions (for convenience, also referred to as a first set of time domain positions herein) for the reference signal, and transmit the reference signal (i.e., the reference signal sequence(s)) on the first set of time domain positions.

**[0118]** In some embodiments, the UE 104 may determine the first set of time domain positions for the reference signal at least based on the first spreading factor. In some embodiments, the reference signal may be mapped to a symbol index, and the mapped symbol index may be determined based on the first spreading factor and an index of a reference signal symbol set. Each reference signal symbol set may comprise $M_{occ}$ reference signal symbols.

**[0119]** For example, for a SCS of 15KHz, mapped symbol indexes may be determined based on an equation (8) below.

$$l = M_{occ} \times P \times k + M_{occ} \times Q, M_{occ} \times P \times k + M_{occ} \times Q + 1, \ldots, M_{occ} \times P \times k + M_{occ} \times Q + (M_{occ} - 1) \quad (8)$$

where $l$ denotes the mapped symbol index, $M_{occ}$ denotes the first spreading factor, $k$ denotes the $k^{th}$ reference signal symbol set for the uplink transmission, $P$ denotes number of symbols within an uplink slot (e.g., $P$ =7), and $Q$ denotes a symbol index for a reference signal within an uplink slot (e.g., $Q$=3).

**[0120]** In another example, for a SCS of 3.75KHz, mapped symbol indexes may be determined based on an equation (9) below.

$$l = M_{occ} \times P \times k + M_{occ} \times Q, M_{occ} \times P \times k + M_{occ} \times Q + 1, \ldots, M_{occ} \times P \times k + M_{occ} \times Q + (M_{occ} - 1) \quad (9)$$

where $l$ denotes the mapped symbol index, $M_{occ}$ denotes the first spreading factor, $k$ denotes the $k^{th}$ reference signal symbol set for the uplink transmission (e.g., $k \geq 0$), $P$ denotes number of symbols within an uplink slot (e.g., $P$ =7), and $Q$ denotes a symbol index for a reference signal within an uplink slot (e.g., $Q$=4).

**[0121]** In other words, consecutive symbols may be used for the reference signal transmission (e.g., reference signal symbol set), and reference signals within a reference signal symbol set may be multiplexed with the first multiplexing sequence. For example, for a SCS of 15KHz, a symbol index of the first reference signal (i.e., a starting reference signal) in a reference signal symbol set may be determined by an equation (10) below. A period of the reference signal (e.g., reference signal symbol set) may be $(M_{occ} \times 7)$ symbols.

$$l = M_{occ} \times P \times k + M_{occ} \times Q \quad (10)$$

where $l$ denotes the mapped symbol index, $M_{occ}$ denotes the first spreading factor, $k$ denotes the kth reference signal symbol set for the uplink transmission, $P$ denotes number of symbols within an uplink slot (e.g., $P$ =7), and $Q$ denotes a symbol index for a reference signal within the uplink slot (e.g., $Q$=3).

**[0122]** It is to be understood that the equations (8) to (10) are merely for illustration, and is not intended to limit the present disclosure. Any other suitable forms may also be feasible.

**[0123]** Continuing to refer to FIG. 2, the network entity 102 may perform 240 a decoding operation on the received uplink transmission. In some embodiments, the network entity 102 may process 241 the reference signal by applying the first multiplexing sequence to the reference signal.

**[0124]** In some embodiments, the network entity 102 may spread the reference signal in consecutive symbols in time domain based on a set of reference signal sequences. The set of reference signal sequences may be determined at least based on a binary sequence and the first multiplexing sequence. In some embodiments, a length of the first multiplexing sequence may be determined based on the first spreading factor. In some embodiments, a length of the binary sequence may be determined based on at least one of the following: a repetition number for the uplink data, number of slots in a resource unit, number of resource units, or the first spreading factor.

**[0125]** In some embodiments, the network entity 102 may determine the first multiplexing sequence based on a unit matrix.

**[0126]** In some embodiments, the network entity 102 may determine the second set of time domain positions for the reference signal based on at least one of the first spreading factor or an index of the first multiplexing sequence; and mute the reference signal in the second set of time domain positions.

**[0127]** In some embodiments, the network entity 102 may spread the reference signal in a plurality of resource elements of a resource in a time or frequency domain based on the first multiplexing sequence. A length of the reference signal before the spreading may be determined based on an uplink data frequency domain allocation and the first spreading factor. In some embodiments, the network entity 102 may determine an offset among the plurality of resource elements based on the length of the reference signal before the spreading. Based on the offset, the network entity 102 may spread the reference signal in the plurality of resource elements.

**[0128]** With reference to FIG. 2, the network entity 102 may receive or determine 242 the uplink data based on the processed reference signal and the configuration. In

some embodiments, the network entity 102 may determine the first set of time domain positions for the reference signal at least based on the first spreading factor, and receive the reference signal on the first set of time domain positions. In some embodiments, the network entity 102 may process or obtain the uplink data by applying the second multiplexing sequence associated with the second spreading factor to the received uplink data.

**[0129]** It is to be understood that some of the steps 241 and 242 may be carried out similarly as that described for the UE 104 in the step 220, and thus other details are not repeated here for conciseness.

**[0130]** So far, a solution for an uplink transmission is described. With the process 200, a reference signal for an uplink transmission may be transmitted reliably, and multiplexing of multiple UEs in the same physical resource for the uplink transmission may be enhanced. Thus, uplink capacity may be enhanced. It is to be understood that operations in the process 200 may be carried out separately or in any suitable combinations.

**[0131]** FIG. 5 illustrates an example of a device 500 that supports an uplink transmission in accordance with aspects of the present disclosure. The device 500 may be an example of the UE 104 as described herein. The device 500 may support wireless communication with one or more network entities 102, UEs 104, or any combination thereof. The device 500 may include components for bi-directional communications including components for transmitting and receiving communications, such as a processor 502, a memory 504, a transceiver 506, and, optionally, an I/O controller 508. These components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

**[0132]** The processor 502, the memory 504, the transceiver 506, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. For example, the processor 502, the memory 504, the transceiver 506, or various combinations or components thereof may support a method for performing one or more of the operations described herein.

**[0133]** In some implementations, the processor 502, the memory 504, the transceiver 506, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA) or other programmable logic device, a discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure. In some implementations, the processor 502 and the memory 504 coupled with the processor 502 may be configured to perform one or more of the functions described herein (e.g., executing, by the processor 502, instructions stored in the memory 504).

**[0134]** For example, the processor 502 may support wireless communication at the device 500 in accordance with examples as disclosed herein. In some embodiments where the device 500 is implemented as the UE 104, the processor 502 may be configured to operable to support a means for receiving a configuration for an uplink transmission from a base station; processing a reference signal by applying a first multiplexing sequence associated with a first spreading factor to the reference signal; and transmitting uplink data with the processed reference signal to the base station based on the configuration. In some embodiments where the device 500 is implemented as the network entity 102, the processor 502 may be configured to operable to support a means for transmitting a configuration for an uplink transmission to a UE; processing a reference signal by applying a first multiplexing sequence associated with a first spreading factor to the reference signal; and receiving uplink data from the UE based on the processed reference signal and the configuration.

**[0135]** The processor 502 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 implementations, the processor 502 may be configured to operate a memory array using a memory controller. In some other implementations, a memory controller may be integrated into the processor 502. The processor 502 may be configured to execute computer-readable instructions stored in a memory (e.g., the memory 504) to cause the device 500 to perform various functions of the present disclosure.

**[0136]** The memory 504 may include random access memory (RAM) and read-only memory (ROM). The memory 504 may store computer-readable, computer-executable code including instructions that, when executed by the processor 502 cause the device 500 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some implementations, the code may not be directly executable by the processor 502 but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some implementations, the memory 504 may include, 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.

**[0137]** The I/O controller 508 may manage input and output signals for the device 500. The I/O controller 508 may also manage peripherals not integrated into the device 500. In some implementations, the I/O controller 508 may represent a physical connection or port to an external peripheral. In some implementations, the I/O controller 508 may utilize an operating system such as iOS®, ANDROID®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. In some implementations, the I/O controller 508 may be implemented as part of a processor, such as the processor 506. In some implementations, a user may interact with the device 500 via the I/O controller 508 or via hardware components controlled by the I/O controller 508.

**[0138]** In some implementations, the device 500 may include a single antenna 510. However, in some other implementations, the device 500 may have more than one antenna 510 (i.e., multiple antennas), including multiple antenna panels or antenna arrays, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver 506 may communicate bi-directionally, via the one or more antennas 510, wired, or wireless links as described herein. For example, the transceiver 506 may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver 506 may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas 510 for transmission, and to demodulate packets received from the one or more antennas 510. The transceiver 506 may include one or more transmit chains, one or more receive chains, or a combination thereof.

**[0139]** A transmit chain may be configured to generate and transmit signals (e.g., control information, data, packets). The transmit chain may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmit chain may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmit chain may also include one or more antennas 510 for transmitting the amplified signal into the air or wireless medium.

**[0140]** A receive chain may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receive chain may include one or more antennas 510 for receive the signal over the air or wireless medium. The receive chain may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receive chain may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receive chain may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

**[0141]** FIG. 6 illustrates an example of a processor 600 that supports an uplink transmission in accordance with aspects of the present disclosure. The processor 600 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 600 may include a controller 602 configured to perform various operations in accordance with examples as described herein. The processor 600 may optionally include at least one memory 604, such as L1/L2/L3 cache. Additionally, or alternatively, the processor 600 may optionally include one or more arithmetic-logic units (ALUs) 606. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

**[0142]** The processor 600 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 600) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

**[0143]** The controller 602 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 600 to cause the processor 600 to support various operations in accordance with examples as described herein. For example, the controller 602 may operate as a control unit of the processor 600, generating control signals that manage the operation of various components of the processor 600. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

**[0144]** The controller 602 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 604 and determine subsequent instruction(s) to be executed to cause the processor 600 to support various operations in accordance with examples as described herein. The controller 602 may be configured to track memory address of instructions associated with the memory 604. The controller 602 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 602 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 600 to cause the processor 600 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 602 may be configured to manage flow of data within the processor 600. The controller 602 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 600.

**[0145]** The memory 604 may include one or more caches (e.g., memory local to or included in the processor 600 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementation, the memory 604 may reside within or on a processor chipset (e.g., local to the processor 600). In some other implementations, the memory 604 may reside external to the processor chipset (e.g., remote to the processor 600).

**[0146]** The memory 604 may store computer-readable, computer-executable code including instructions that, when executed by the processor 600, cause the processor 600 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 602 and/or the processor 600 may be configured to execute computer-readable instructions stored in the memory 604 to cause the processor 600 to perform various functions. For example, the processor 600 and/or the controller 602 may be coupled with or to the memory 604, and the processor 600, the controller 602, and the memory 604 may be configured to perform various functions described herein. In some examples, the processor 600 may include multiple processors and the memory 604 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

**[0147]** The one or more ALUs 606 may be configured to support various operations in accordance with examples as described herein. In some implementation, the one or more ALUs 606 may reside within or on a processor chipset (e.g., the processor 600). In some other implementations, the one or more ALUs 606 may reside external to the processor chipset (e.g., the processor 600). One or more ALUs 606 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 606 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 606 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 606 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 606 to handle conditional operations, comparisons, and bitwise operations.

**[0148]** The processor 600 may support wireless communication in accordance with examples as disclosed herein. In some embodiments where the processor 600 is implemented at the UE 104, the processor 600 may be configured to operable to support a means for receiving, at a UE from a base station, a configuration for an uplink transmission; processing a reference signal by applying a first multiplexing sequence associated with a first spreading factor to the reference signal; and transmitting uplink data with the processed reference signal to the base station based on the configuration. In some embodiments where the processor 600 is implemented at the network entity 102, the processor 600 may be configured to operable to support a means for transmitting a configuration for an uplink transmission to a UE; processing a reference signal by applying a first multiplexing sequence associated with a first spreading factor to the reference signal; and receiving uplink data from the UE based on the processed reference signal and the configuration.

**[0149]** FIG. 7 illustrates a flowchart of a method 700 that supports an uplink transmission in accordance with aspects of the present disclosure. The operations of the method 700 may be implemented by a device or its components as described herein. For example, the operations of the method 700 may be performed by the UE 104 as described herein. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

**[0150]** At block 710, the method 700 may include receiving a configuration for an uplink transmission from the network entity 102. The operations of 710 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 710 may be performed by a device as described with reference to FIG. 1.

**[0151]** At block 720, the method 700 may include processing a reference signal by applying a first multiplexing sequence associated with a first spreading factor to the reference signal. The operations of 720 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 720 may be performed by a device as described with reference to FIG. 1.

**[0152]** In some embodiments, processing the reference signal may comprise: spreading the reference signal in consecutive symbols in time domain based on a set of reference signal sequences, wherein the set of reference signal sequences is determined at least based on a binary sequence and the first multiplexing sequence. In some embodiments, a length of the first multiplexing sequence may be determined based on the first spreading factor. In some embodiments, a length of the binary sequence may be determined based on at least one of the following: a repetition number for the uplink data, number of slots in a resource unit, number of resource units, or the first spreading factor.

**[0153]** In some embodiments, processing the reference signal may comprise: determining the first multiplexing sequence based on a unit matrix.

**[0154]** In some embodiments, processing the reference signal may comprise: determining a second set of time domain positions for the reference signal based on at least one of the first spreading factor or an index of the first multiplexing sequence; and muting the reference signal in the second set of time domain positions.

**[0155]** In some embodiments, processing the reference signal may comprise: spreading the reference signal in a plurality of resource elements of a resource in a time or frequency domain based on the first multiplexing sequence, wherein a length of the reference signal before the spreading is determined based on an uplink data frequency domain allocation and the first spreading factor. In some embodiments, spreading the reference signal may comprise: determining, based on the length of the reference signal before the spreading, an offset among the plurality of resource elements; and spreading, based on the offset, the reference signal in the plurality of resource elements.

**[0156]** At block 730, the method 700 may include transmitting uplink data with the processed reference signal to the base station based on the configuration. The operations of 730 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 730 may be performed by a device as described with reference to FIG. 1.

**[0157]** In some embodiments, transmitting the uplink data with the processed reference signal may comprise: determining a first set of time domain positions for the reference signal at least based on the first spreading factor; and transmitting the reference signal on the first set of time domain positions.

**[0158]** In some embodiments, transmitting the uplink data with the processed reference signal may comprise: processing the uplink data by applying, to the uplink data, a second multiplexing sequence associated with a second spreading factor.

**[0159]** In some embodiments, the method 700 may further comprise: determining the second spreading factor as the first spreading factor; or determining the first spreading factor based on the second spreading factor and an uplink data frequency domain allocation.

**[0160]** FIG. 8 illustrates a flowchart of another method 800 that supports an uplink transmission in accordance with aspects of the present disclosure. The operations of the method 800 may be implemented by a device or its components as described herein. For example, the operations of the method 800 may be performed by the network entity 102 as described herein. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

**[0161]** At block 810, the method 800 may include transmitting a configuration for an uplink transmission to the UE 104. The operations of 810 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 810 may be performed by a device as described with reference to FIG. 1.

**[0162]** At block 820, the method 800 may include processing a reference signal by applying a first multiplexing sequence associated with a first spreading factor to the reference signal. The operations of 820 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 820 may be performed by a device as described with reference to FIG. 1.

**[0163]** In some embodiments, processing the reference signal may comprise: spreading the reference signal in consecutive symbols in time domain based on a set of reference signal sequences, wherein the set of reference signal sequences is determined at least based on a binary sequence and the first multiplexing sequence. In some embodiments, a length of the first multiplexing sequence may be determined based on the first spreading factor. In some embodiments, a length of the binary sequence may be determined based on at least one of the following: a repetition number for the uplink

data, number of slots in a resource unit, number of resource units, or the first spreading factor.

**[0164]** In some embodiments, processing the reference signal may comprise: determining the first multiplexing sequence based on a unit matrix.

**[0165]** In some embodiments, processing the reference signal may comprise: determining a second set of time domain positions for the reference signal based on at least one of the first spreading factor or an index of the first multiplexing sequence; and muting the reference signal in the second set of time domain positions.

**[0166]** In some embodiments, processing the reference signal may comprise: spreading the reference signal in a plurality of resource elements of a resource in a time or frequency domain based on the first multiplexing sequence, wherein a length of the reference signal before the spreading is determined based on an uplink data frequency domain allocation and the first spreading factor. In some embodiments, spreading the reference signal may comprise: determining, based on the length of the reference signal before the spreading, an offset among the plurality of resource elements; and spreading, based on the offset, the reference signal in the plurality of resource elements.

**[0167]** At block 830, the method 800 may include receiving uplink data from the UE 104 based on the processed reference signal and the configuration. The operations of 830 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 830 may be performed by a device as described with reference to FIG. 1.

**[0168]** In some embodiments, receiving the uplink data with the processed reference signal may comprise: determining a first set of time domain positions for the reference signal at least based on the first spreading factor; and receiving the reference signal on the first set of time domain positions.

**[0169]** In some embodiments, receiving the uplink data with the processed reference signal may comprise: processing the uplink data by applying a second multiplexing sequence associated with a second spreading factor to the uplink data.

**[0170]** In some embodiments, the method 800 may further comprise: determining the second spreading factor as the first spreading factor; or determining the first

spreading factor based on the second spreading factor and an uplink data frequency domain allocation.

**[0171]** It is to be understood that the operations of the methods 700 and 800 correspond to that described in connection with FIGs. 2 to 4E, and thus other details are not repeated here for conciseness.

**[0172]** It should be noted that the methods described herein describes 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.

**[0173]** The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, a CPU, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

**[0174]** The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software, functions described herein may be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

**[0175]** Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be

any available medium that may be accessed by a general-purpose or special-purpose computer. By way of example, 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.

**[0176]** As used herein, including in the claims, an article "a" before an element is unrestricted and understood to refer to "at least one" of those elements or "one or more" of those elements. The terms "a," "at least one," "one or more," and "at least one of one or more" may be interchangeable. As used herein, including in the claims, "or" as used in a list of items (e.g., a list of items prefaced by a phrase such as "at least one of" or "one or more of" or "one or both of") indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase "based on" shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as "based on condition A" may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase "based on" shall be construed in the same manner as the phrase "based at least in part on. Further, as used herein, including in the claims, a "set" may include one or more elements.

**[0177]** The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

# CLAIMS

What is claimed is:

1. A user equipment, comprising:

a processor; and

a transceiver coupled to the processor,

wherein the processor is configured to:

receive, from a base station via the transceiver, a configuration for an uplink transmission;

process a reference signal by applying, to the reference signal, a first multiplexing sequence associated with a first spreading factor; and

transmit, to the base station via the transceiver, uplink data with the processed reference signal based on the configuration.

2. The user equipment of claim 1, wherein the processor is configured to process the reference signal by:

spreading the reference signal in consecutive symbols in time domain based on a set of reference signal sequences, wherein the set of reference signal sequences is determined at least based on a binary sequence and the first multiplexing sequence.

3. The user equipment of claim 2, wherein the processor is configured to transmit the uplink data with the processed reference signal by:

determining a first set of time domain positions for the reference signal at least based on the first spreading factor; and

transmitting the reference signal on the first set of time domain positions.

4. The user equipment of claim 2, wherein a length of the first multiplexing sequence is determined based on the first spreading factor.

5. The user equipment of claim 2, wherein a length of the binary sequence is determined based on at least one of the following: a repetition number for the uplink data, number of slots in a resource unit, number of resource units, or the first spreading factor.

6. The user equipment of claim 1, wherein the processor is configured to process the reference signal by:

determining the first multiplexing sequence based on a unit matrix.

7. The user equipment of claim 1, wherein the processor is configured to process the reference signal by:

determining a second set of time domain positions for the reference signal based on at least one of the first spreading factor or an index of the first multiplexing sequence; and

muting the reference signal in the second set of time domain positions.

8. The user equipment of claim 1, wherein the processor is configured to process the reference signal by:

spreading the reference signal in a plurality of resource elements of a resource in a time or frequency domain based on the first multiplexing sequence, wherein a length of the reference signal before the spreading is determined based on an uplink data frequency domain allocation and the first spreading factor.

9. The user equipment of claim 8, wherein the processor is configured to spread the reference signal by:

determining, based on the length of the reference signal before the spreading, an offset among the plurality of resource elements; and

spreading, based on the offset, the reference signal in the plurality of resource elements.

10. The user equipment of claim 1, wherein the processor is configured to transmit the uplink data with the processed reference signal by:

processing the uplink data by applying, to the uplink data, a second multiplexing sequence associated with a second spreading factor.

11. The user equipment of claim 10, wherein the processor is further configured to:

determine the second spreading factor as the first spreading factor; or

determine the first spreading factor based on the second spreading factor and an uplink data frequency domain allocation.

12. A base station, comprising:

a processor; and

a transceiver coupled to the processor,

wherein the processor is configured to:

transmit, to a user equipment via the transceiver, a configuration for an uplink transmission;

process a reference signal by applying, to the reference signal, a first multiplexing sequence associated with a first spreading factor; and

receive, from the user equipment via the transceiver, uplink data based on the processed reference signal and the configuration.

13. The base station of claim 12, wherein the processor is configured to process the reference signal by:

spreading the reference signal in consecutive symbols in time domain based on a set of reference signal sequences, wherein the set of reference signal sequences is determined at least based on a binary sequence and the first multiplexing sequence.

14. The base station of claim 13, wherein the processor is configured to receive the uplink data with the processed reference signal by:

determining a first set of time domain positions for the reference signal at least based on the first spreading factor; and

receiving the reference signal on the first set of time domain positions.

15. The base station of claim 13, wherein a length of the first multiplexing sequence is determined based on the first spreading factor.

16. The base station of claim 13, wherein a length of the binary sequence is determined based on at least one of the following: a repetition number for the uplink data, number of slots in a resource unit, number of resource units, or the first spreading factor.

17. The base station of claim 12, wherein the processor is configured to process the reference signal by:

determining the first multiplexing sequence based on a unit matrix.

18. The base station of claim 12, wherein the processor is configured to process the reference signal by:

determining a second set of time domain positions for the reference signal based on at least one of the first spreading factor or an index of the first multiplexing sequence; and

muting the reference signal in the second set of time domain positions.

19. A processor for wireless communication, comprising:

at least one memory; and

a controller coupled with the at least one memory and configured to cause the processor to:

receive, from a base station, a configuration for an uplink transmission;

process a reference signal by applying, to the reference signal, a first multiplexing sequence associated with a first spreading factor; and

transmit, to the base station, uplink data with the processed reference signal based on the configuration.

20. A method performed by a user equipment, the method comprising:

receiving, from a base station, a configuration for an uplink transmission;

processing a reference signal by applying, to the reference signal, a first multiplexing sequence associated with a first spreading factor; and

transmitting, to the base station, uplink data with the processed reference signal based on the configuration.