(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
31 August 2017 (31.08.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/146766 A1

(51) **International Patent Classification**:
H04L 5/00 (2006.01) ***H04W 72/00*** (2009.01)
H04W 52/40 (2009.01)

(21) **International Application Number**:
PCT/US2016/040884

(22) **International Filing Date**:
1 July 2016 (01.07.2016)

(25) **Filing Language**: English

(26) **Publication Language**: English

(30) **Priority Data**:
62/300,563 26 February 2016 (26.02.2016) US

(71) **Applicant**: **INTEL IP CORPORATION** [US/US]; 2200 Mission College Boulevard, Santa Clara, California 95054 (US).

(72) **Inventors**: **CHANG, Wenting**; 8F, Raycom Infotech Park A, No2, Kexueyuan South Road, Beijing 100190 (CN). **ZHU, Yuan**; Room 605, Building 16, Mo Li Yuan, Bei Yuan Jia Yuan, Chao Yang District, beijing 100012 (CN). **XIONG, Gang**; 16682 NW Arizona Dr, Beaverton, Oregon 97006 (US). **ZHANG, Yushu**; 8F, Raycom Info Park A, No.2, Kexueyuan South Road, Haidian District, beijing 100190 (CN). **NAGARAJ, Shirish**; 6436 Paseo Santa Cruz, Pleasanton, California 94566 (US).

(74) **Agent**: **RAYMOND, Andrew D.**; Kacvinsky Daisak Bluni PLLC, c/o CPA Global, 900 Second Avenue South, Suite 600, Minneapolis, Minnesota 55402 (US).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

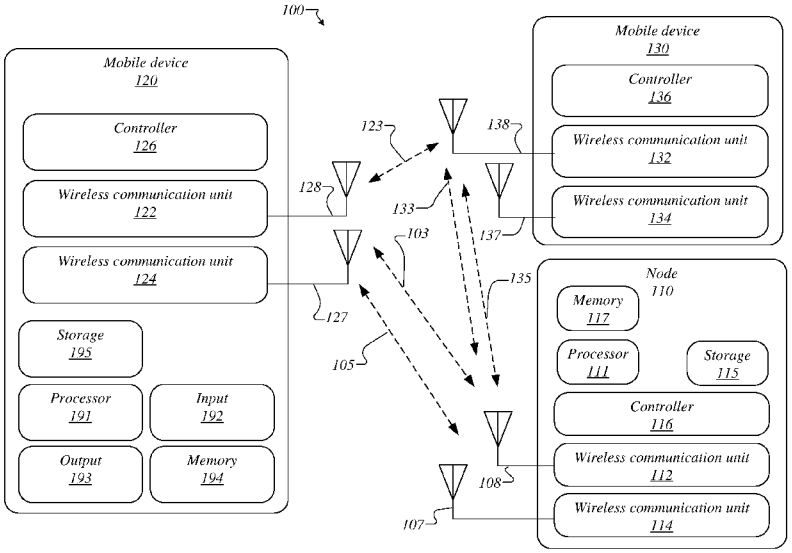
Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

[Continued on next page]

(54) **Title**: FRAME STRUCTURES SOUNDING REFERENCE SIGNALS IN CELLULAR SYSTEMS

FIG. 1



(57) **Abstract**: Technologies described herein provide mechanisms and formats to accomplish the beam switching. In one implementation, a format of an uplink (UL) sounding signal is configured. The UL signal to include a plurality of 5G sounding reference signal (xSRS) ports associated with a symbol of a subframe. The format of the UL sounding signal may be associated with a configuration broadcast communication.

WO 2017/146766 A1

Published:

— *with international search report (Art. 21(3))*

FRAME STRUCTURES SOUNDING REFERENCE SIGNALS IN CELLULAR SYSTEMS

RELATED CASE

This application claims priority to United States Provisional Patent Application Number 62/300,563, filed February 26, 2016, the entirety of which is hereby incorporated by reference.

TECHNICAL FIELD

Embodiments herein generally relate to transmit (Tx) and receive (Rx) beam switching and refinement in network systems. In particular, the present disclosure relates to Tx and Rx beam switching and refinement in 3rd Generation Partnership Project (3GPP) and 5G network systems.

BACKGROUND

Wireless mobile communication technology uses various standards and protocols to transmit data between a node (e.g., a transmission station) and a wireless device (e.g., a mobile device). Standards and protocols that use orthogonal frequency-division multiplexing (OFDM) for signal transmission include the third generation partnership project (3GPP) long term evolution (LTE), the Institute of Electrical and Electronics Engineers (IEEE) 802.16 standard (e.g., 802.16e, 802.16m), which is commonly known to industry groups as WiMAX (Worldwide interoperability for Microwave Access), and the IEEE 802.11 standard, which is commonly known to industry groups as WiFi.

In 3GPP radio access network (RAN) LTE systems, the node in an Evolved Universal Terrestrial Radio Access Network (E-UTRAN) system is referred to as an eNode B (also commonly denoted as evolved Node Bs, enhanced Node Bs, eNodeBs, or eNBs), which communicates with the wireless device, known as a user equipment (UE). The downlink (DL) transmission can be a communication from the node (e.g., eNodeB) to the wireless device (e.g., UE), and the uplink (UL) transmission can be a communication from the wireless device to the node.

In LTE, data can be transmitted from the eNB to the UE via a physical downlink shared channel (PDSCH). A physical uplink control channel (PUCCH) can be used to acknowledge that data was received. Downlink and uplink channels or transmissions can use time-division duplexing (TDD) or frequency-division duplexing (FDD).

In a massive multiple-input multiple-output (MIMO) system, a DL signal may be transmitted using transmitting (Tx) beamforming and received using receiving (Rx) beamforming. Additionally, a UL signal may be transmitted using Tx beamforming and received using Rx beamforming. As a result of user equipment (UE) rotation, movement, and Doppler

frequency shift, the Tx beam, from a node (e.g., eNB), that is preferable at a given time may change (e.g., from one Tx beam to another Tx beam). In addition, an Rx beam, at the UE, that is preferable may also change (e.g., from one Rx beam to another Rx beam). Furthermore, as a result of UE rotation, movement, and Doppler frequency shift, a Tx beam, from the UE, that is preferable at a given time may change (e.g., from one Tx beam to another Tx beam). Still further, as a result of UE rotation, movement, and Doppler frequency shift, an Rx beam, at the node, that is preferable at a given time may change, (e.g., from one Rx beam to another Rx beam).

BRIEF DESCRIPTION OF THE DRAWINGS

Features and advantages of the disclosure will be apparent from the detailed description which follows, taken in conjunction with the accompanying drawings, which together illustrate, by way of example, features of the disclosure; and, wherein:

FIG. 1 schematically illustrates a block diagram of a system, in accordance with some exemplary embodiments.

FIG. 2 illustrates an embodiment where beamforming is utilized between a node and a mobile station through array antennas in a communication system.

FIG. 3 illustrates a first example of a beam switching frame structure that provides uplink (UL) switching and refinement signaling in one symbol.

FIG. 4 illustrates a second example of a beam switching frame structure that provides UL switching and refinement signaling in two symbols.

FIGS. 5 and 6 illustrate exemplary xSRS physical structures that may be used for xSRS communication from a UE to a node.

FIG. 7 illustrates example components of an electronic device.

FIG. 8 illustrates an embodiment of a storage medium.

FIG. 9 illustrates a first exemplary process.

FIG. 10 illustrates a second exemplary process.

Reference will now be made to the exemplary embodiments illustrated and specific language will be used herein to describe the same. It will nevertheless be understood that no limitation of the scope of is thereby intended.

DETAILED DESCRIPTION

Before some embodiments are disclosed and described, it is to be understood that the claimed subject matter is not limited to the particular structures, process operations, or materials disclosed herein, but is extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular examples only and is not intended to be

limiting. The same reference numerals in different drawings represent the same element. Numbers provided in flow charts and processes are provided for clarity in illustrating operations and do not necessarily indicate a particular order or sequence.

An initial overview of technology embodiments is provided below and then specific technology embodiments are described in further detail later. This initial summary is intended to aid readers in understanding the technology more quickly, but is not intended to identify key features or essential features of the technology nor is it intended to limit the scope of the claimed subject matter.

Various embodiments disclosed herein may relate to long term evolution-advanced (LTEa) and/or LTE-advanced pro, and/or fifth generation (5G) system information (SI). A massive multiple input and multiple output (MIMO) may be applied in the 5G system to enhance the coverage and improve the spectrum efficiency. In the massive MIMO system, an eNodeB (eNB) may maintain a plurality of transmitting (Tx) and receiving (Rx) beams. Meanwhile the user equipment (UE) may also maintain a plurality of Tx and Rx beams. Then after initial communication with an eNB, a UE may be able to find out the best downlink (DL) Tx-Rx beam pair. For uplink (UL), the eNB may find the best UL Rx beam by beam scanning based on extended (e.g., 5G) sounding reference signal (xSRS), or more generally based on sounding reference signal (SRS).

As a result of UE movement, the optimum Tx-Rx beam pair for both UL and DL may change. A beam refinement reference signal (BRRS) may be utilized to switch the DL Tx beam and refine the DL Rx beam. The UL Tx beam may be similar or the same as DL Rx beam. The UL Rx beam may be trained or refined by xSRS.

This disclosure describes UL sounding signal subframe embodiments to carry xSRS or SRS. The subframe embodiments to carry xSRS may be formatted or configured by a node, such as a cellular base station, eNB, or the like. The subframe formats to carry xSRS or SRS may be communicated to one or more UEs using a system broadcast message. One or more subframe formats to carry xSRS or SRS may be predefined within a network system.

In one embodiment, xSRS or SRS is provided in one symbol of a subframe based on a subframe format communication, such as a broadcast message communication. Specifically, the xSRS or SRS is provided in one symbol of a slot associated with the subframe. In one implementation, the subframe includes two slots. The xSRS or SRS is provided in one symbol of the second slot of the subframe that includes two slots. In one implementation, the symbol carrying the xSRS or SRS includes a plurality of resource elements. Each resource element may correspond to a subcarrier associated with the subframe. In one implementation, xSRS or SRS is

included in up to eight resource elements of the symbol. These eight resource elements may also be referred to herein to as xSRS or SRS ports. In a particular implementation, the symbol carrying xSRS or SRS includes two xSRS or SRS ports for a current beam used by a UE and two xSRS or SRS ports for a candidate beam for the UE. In one embodiment, the remaining xSRS or SRS ports may be reserved for xSRS or SRS transmission by one or more other UEs. In one implementation, a cyclic prefix (CP) resource block precedes the xSRS or SRS ports.

In another embodiment, xSRS is provided in two symbols of a subframe based on a subframe format communication, such as a broadcast message communication. Specifically, the xSRS or SRS is provided in two symbols of a slot associated with the subframe. In one implementation, the subframe includes two slots. The xSRS or SRS is provided in two symbols of the second slot of the subframe that includes two slots. In one implementation, each of the two symbols carrying the xSRS or SRS includes a plurality of resource elements. Each resource element may correspond to a subcarrier associated with the subframe. In one implementation, xSRS or SRS is included in up to eight resource elements of each of the two symbols. The eight resource elements associated with each of the two symbols may also be referred to herein to as xSRS or SRS ports. In a particular implementation, a first of the two symbols caring the xSRS or SRS includes two xSRS or SRS ports for a current beam used by a UE. The second of the two symbols carrying the xSRS or SRS includes two xSRS or SRS ports for a candidate beam for the UE. In one embodiment, the remaining xSRS or SRS ports associated with each of the two symbols for carrying xSRS or SRS may be reserved for xSRS or SRS transmission by one or more other UEs. In one implementation, a CP resource block precedes the xSRS or SRS ports of each of two symbols.

In one implementation, an xSRS or SRS enabling/triggering field (e.g., using a 1 bit, 2 bit, or 4 bit bitmap) may be included in downlink control information (DCI). A UE may start receiving data samples following an extended Physical Downlink Control Channel (xPDCCH) using the same reception beam that was used to receive the xPDCCH. At the same time, the UE may also attempt to decode the DCI to ascertain the xSRS or SRS bitmap to determine the xSRS or SRS symbol configuration that an eNB is expecting from the UE. In one implementation, a bit "0" represents transmitting xSRS or SRS by the UE on a current beam used by the UE. In another implementation, a bit "1" represents transmitting xSRS or SRS by the UE on a candidate beam for use by the UE. In a more general case, a length of the xSRS or SRS enabling/triggering field (e.g., bitmap) may be defined by $N_{port}/2$, where N_{port} is the number of xSRS or SRS ports in a symbol. At least some embodiments implement one or more xSRS or SRS symbols that include eight xSRS or SRS ports.

The xSRS or SRS ports may be paired together by a high-layer signaling procedure. For example, layer 1 or layer 2 signaling may be used to allocate xSRS or SRS port pairs in the xSRS or SRS symbols. In one example, communication of subframe formats to carry xSRS or SRS (e.g., allocation of xSRS port pairs in xSRS or SRS symbols) is via master information broadcasting (MIB), system information broadcasting (SIB), or radio resource configuration (RRC) signaling.

Reference is now made to **FIG. 1**, which schematically illustrates a block diagram of a communication system 100, in accordance with some exemplary embodiments. As shown in FIG. 1, in some exemplary embodiments, communication system 100 may include one or more wireless communication devices capable of communicating content, data, information and/or signals via a wireless medium. For example, communication system 100 may include one or more wireless communication nodes, e.g., node 110, and one or more mobile devices, e.g., including mobile devices 120 and 130. The wireless medium may include, for example, a radio channel, a cellular channel, an RF channel, a Wireless Fidelity (WiFi) channel, an IR channel, and the like. One or more elements of communication system 100 may optionally be capable of communicating over any suitable wired communication links.

In some exemplary embodiments, node 110, mobile device 120 and/or mobile device 130 may be configured to communicate over one or more wireless communication frequency bands. For example, node 110, mobile device 120 and/or mobile device 130 may communicate over a first frequency band and over a second frequency band, e.g., higher than the first frequency band. In some exemplary embodiments, node 110 may include or may perform the functionality of a Base Station (BS), an Access Point (AP), a WiFi node, a Wimax node, a cellular node, e.g., an eNB, a station, a hot spot, a network controller, and the like. In some exemplary embodiments, mobile devices 120 and/or 130 may include, for example, a UE, a mobile computer, a laptop computer, a notebook computer, a tablet computer, an Ultrabook™ computer, a mobile internet device, a handheld computer, a handheld device, a storage device, a PDA device, a handheld PDA device, an on-board device, an off-board device, a hybrid device (e.g., combining cellular phone functionalities with PDA device functionalities), a consumer device, a vehicular device, a non-vehicular device, a portable device, a mobile phone, a cellular telephone, a PCS device, a mobile or portable GPS device, a DVB device, a relatively small computing device, a non-desktop computer, an Ultra Mobile Device (UMD), an Ultra Mobile PC (UMPC), a Mobile Internet Device (MID), a video device, an audio device, an A/V device, a gaming device, a media player, a Smartphone, or the like.

In some exemplary embodiments, node 110, mobile device 120 and/or mobile device 130 may include one or more wireless communication units to perform wireless communication over the one or more wireless communication frequency bands between node 110, mobile device 120 and/or mobile device 130 and/or with one or more other wireless communication devices. For example, node 110 may include a first wireless communication unit 112 configured to communicate over the first frequency band, and a second wireless communication unit 114 configured to communicate over the second frequency band; mobile device 120 may include a first wireless communication unit 122 configured to communicate over the first frequency band, and a second wireless communication unit 124 configured to communicate over the second frequency band; and/or mobile device 130 may include a first wireless communication unit 132 configured to communicate over the first frequency band, and a second wireless communication unit 134 configured to communicate over the second frequency band.

In some exemplary embodiments, wireless communication units 112, 114, 122, 124, 132 and 134 may include, or may be associated with, one or more antennas. In one example, wireless communicate unit 112 may be associated with one or more antennas 108; wireless communicate unit 114 may be associated with one or more antennas 107; wireless communicate unit 122 may be associated with one or more antennas 128; wireless communicate unit 124 may be associated with one or more antennas 127; wireless communicate unit 132 may be associated with one or more antennas 138; and/or wireless communication unit 134 may be associated with one or more antennas 137.

Antennas 108, 107, 128, 127, 138 and/or 137 may include any type of antennas suitable for transmitting and/or receiving wireless communication signals, blocks, frames, transmission streams, packets, messages and/or data. For example, antennas 108, 107, 128, 127, 138 and/or 137 may include any suitable configuration, structure and/or arrangement of one or more antenna elements, components, units, assemblies and/or arrays. Antennas 108, 107, 128, 127, 138 and/or 137 may include, for example, antennas suitable for directional communication, e.g., using beamforming techniques. For example, antennas 108, 107, 128, 127, 138 and/or 137 may include a phased array antenna, a multiple element antenna, a set of switched beam antennas, and/or the like. In some embodiments, antennas 108, 107, 128, 127, 138 and/or 137 may implement transmit and receive functionalities using separate transmit and receive antenna elements. In some embodiments, antennas 108, 107, 128, 127, 138 and/or 137 may implement transmit and receive functionalities using common and/or integrated transmit/receive elements.

In some exemplary embodiments, mobile devices 120 and/or 130 may also include, for example, a processor 191, an input unit 192, an output unit 193, a memory unit 194, and a

storage unit 195; and/or node 101 may also include, for example, one or more of a processor 111, a memory unit 117, and a storage unit 115. Node 101, mobile device 120 and/or mobile device 130 may optionally include other suitable hardware components and/or software components. In some exemplary embodiments, some or all of the components of node 101, mobile device 120 and/or mobile device 130 may be enclosed in a common housing or packaging, and may be interconnected or operably associated using one or more wired or wireless links. In other embodiments, components of node 101 may be distributed among multiple or separate devices. Processor 111 and/or processor 191 include, for example, a Central Processing Unit (CPU), a Digital Signal Processor (DSP), one or more processor cores, a single-core processor, a dual-core processor, a multiple-core processor, a microprocessor, a host processor, a controller, a plurality of processors or controllers, a chip, a microchip, one or more circuits, circuitry, a logic unit, an Integrated Circuit (IC), an Application-Specific IC (ASIC), or any other suitable multi-purpose or specific processor or controller. For example, processor 111 executes instructions, for example, of an Operating System (OS) of node 110 and/or of one or more suitable applications. Memory unit 117 and/or memory unit 194 include, for example, a Random Access Memory (RAM), a Read Only Memory (ROM), a Dynamic RAM (DRAM), a Synchronous DRAM (SD-RAM), a flash memory, a volatile memory, a non-volatile memory, a cache memory, a buffer, a short term memory unit, a long term memory unit, or other suitable memory units. Storage unit 115 and/or storage unit 195 include, for example, a hard disk drive, a floppy disk drive, a Compact Disk (CD) drive, a CD-ROM drive, a DVD drive, or other suitable removable or non-removable storage units. For example, memory unit 117 and/or storage unit 115, for example, may store data processed by node 101.

Input unit 192 includes, for example, a keyboard, a keypad, a mouse, a touch-screen, a touch-pad, a track-ball, a stylus, a microphone, or other suitable pointing device or input device. Output unit 193 includes, for example, a monitor, a screen, a touch-screen, a flat panel display, a Cathode Ray Tube (CRT) display unit, a Liquid Crystal Display (LCD) display unit, a plasma display unit, one or more audio speakers or earphones, or other suitable output devices.

In some exemplary embodiments, mobile device 120 and node 110 may establish a wireless communication link 105 for communication between mobile device 120 and node 110 over a frequency band. For example, mobile device 120 and node 110 may establish link 105, e.g., upon entering of mobile device 120 into a cell controlled by node 110.

In some exemplary embodiments, mobile device 130 and node 110 may establish a wireless communication link 135 for communication between mobile device 130 and node 110

over a frequency band. For example, mobile device 130 and node 110 may establish link 135, e.g., upon entering of mobile device 130 into a cell controlled by node 110.

In some exemplary embodiments, node 110 may include a wireless communication controller 116 configured to control wireless communication unit 114 to communicate information over a frequency band, e.g., via antennas 107. In some exemplary embodiments, mobile device 120 may include a wireless communication controller 126 configured to control wireless communication unit 124 to communicate information over a frequency band, e.g., via antennas 127. In some exemplary embodiments, controller 116 may control wireless communication unit 114 to communicate information between node 110 and mobile device 120, and to establish a link 103 between node 110 and mobile device 120. In some exemplary embodiments, controller 126 may control wireless communication unit 124 to communicate information between mobile device 120 and node 110, and to establish link 103 between node 110 and mobile device 120.

In some exemplary embodiments, mobile device 130 may include a wireless communication controller 136 configured to control wireless communication unit 134 to communicate information over a frequency band, e.g., via antennas 137. In some exemplary embodiments, controller 136 may control wireless communication unit 134 to communicate information between mobile device 130 and node 110, and to establish a link 133 between node 110 and mobile device 130. In some exemplary embodiments, controller 116 may control wireless communication unit 114 to communicate information between node 110 and mobile device 130, and to establish link 133 between node 110 and mobile device 130.
In some exemplary embodiments, controller 116 may control wireless communication unit 114 to communicate information between node 110 and mobile devices 120 and 130; and to control mobile devices 120 and 130 to establish a link 123 between mobile device 120 and mobile device 130.

In some exemplary embodiments, links 103, 123 and/or 133 may include a direct link, e.g., a P2P link, for example, to enable direct communication between node 110, mobile device 120 and/or mobile device 130. In some exemplary embodiments, links 103, 123 and/or 133 may include a wireless beamformed link.

In one example, the information communicated between node 110 and mobile device 120 may include information with respect to node 110, e.g., supported transmission power levels of node 110, one or more modulation orders of node 110, a number of antennas of antennas 108, a number of antenna elements per antenna of antennas 108, and/or a beamforming capability of wireless communication unit 112; and/or capability information with respect to mobile device

120, e.g., wireless communication unit 122, supported transmission power levels of device 120, one or more modulation orders of device 120, a number of antennas of antennas 128, a number of antenna elements per antenna of antennas 128, and/or a beamforming capability of wireless communication unit 122.

In another example, the information communicated between node 110 and mobile device 120, e.g., via link 105, and/or between node 110 and mobile device 130, e.g., via link 135, to establish link 123, may include information with respect to mobile device 120; and/or information with respect to mobile device 130, e.g., whether device 130 includes e.g., wireless communication unit 132, supported transmission power levels of device 130, one or more modulation orders of device 130, a number of antennas of antennas 138, a number of antenna elements per antenna of antennas 138, and/or a beamforming capability of wireless communication unit 132.

In some exemplary embodiments, the information with respect to a device may include location information corresponding to a location of the device. In one example, the information communicated between node 110 and mobile device 120 may include location information corresponding to a location of node 110, e.g., a location Fix of node 110; and/or location information corresponding to a location of mobile device 120, e.g., a location Fix of mobile device 120. In one example, the information communicated between node 110 and mobile device 120 may include location information corresponding to a location of node 110, e.g., a location Fix of node 110; and/or location information corresponding to a location of mobile device 120, e.g., a location Fix of mobile device 120. In another example, the information communicated between node 110 and mobile device 120, and between node 110 and mobile device 130, e.g., before establishing link 123, may include location information corresponding to a location of device 120, e.g., a location Fix of device 120; and/or location information corresponding to a location of mobile device 130, e.g., a location Fix of mobile device 130.

In one example, node 110 and mobile device 120 may communicate, e.g., before establishing link 103, e.g., via link 105, information including the transmission power levels of node 110 and/or device 120; the modulation orders of node 110 and/or device 120; the number of antennas of antennas 108 and/or 208; the number of antenna elements per antenna of antennas 108 and/or 208; the beamforming capability of wireless communication units 112 and/or 122; and/or the location information corresponding to the location of mobile device 120 and/or node 110.

In some exemplary embodiments, node 110 and/or mobile device 120 may utilize the information corresponding to node 110 and/or device 120 to configure preliminary beamforming

settings of antennas 108 and/or 128 for performing the beamforming training between mobile device 120 and node 110.

In some exemplary embodiments, node 110 and/or mobile device 120 may utilize the location information corresponding to node 110 and/or mobile device 120 and an orientation of mobile device 120 to configure the preliminary beamforming settings of antennas 108 and/or 128.

In some exemplary embodiments, node 110 and/or mobile device 120 may configure the preliminary beamforming settings of antennas 108 and/or 128, such that antennas 108 and 128 may form a directional beam at an estimated direction towards each other.

In one example, controller 116 may estimate a relative location of mobile device 120 with respect to node 110, e.g., based on the location information corresponding to device 120. Controller 116 may configure the beamforming settings of antennas 108 to initiate the beamforming training in a direction directed to the estimated location of mobile device 120. In some exemplary embodiments, controller 126 may estimate a relative location of node 110 with respect to mobile device 120, e.g., based on the location information corresponding to node 110.

In some exemplary embodiments, controller 126 may estimate an orientation of antennas 128 of mobile device 120, e.g., utilizing a compass of mobile device 120, a gyroscope of mobile device 120, and/or any other devices and or methods of estimating the orientation of antennas 128. Controller 126 may configure the beamforming settings of antennas 128 to initiate the beamforming training in a direction directed to the relative location of node 110 based on the relative location of node 110 and the orientation of antennas 128 of device 120.

In some exemplary embodiments, mobile device 130 and/or mobile device 120 may utilize the information corresponding to mobile devices 120 and 130 to configure preliminary beamforming settings of antennas 128 and/or 138 for performing beamforming training between mobile devices 120 and 130.

In some exemplary embodiments, mobile device 130 and/or mobile device 120 may configure the preliminary beam forming settings of antennas 138 and/or 128, such that antennas 138 and 128 may form a directional beam towards each other.

In some exemplary embodiments, controller 126 may estimate a relative location of mobile device 130 with respect to mobile device 120, e.g., based on the location information corresponding to mobile device 130.

In some exemplary embodiments, controller 126 may estimate an orientation of antennas 128 of mobile device 120. Controller 126 may configure the beamforming settings of antennas

128 to initiate the beamforming training in a direction directed to the relative location of node 110 based on the relative location of node 110 and the orientation of device 120 and/or a relative direction of link 105.

In some exemplary embodiments, controller 136 may estimate the relative location of mobile device 120 with respect to mobile device 130, e.g., based on the location information corresponding to mobile device 120.

In some exemplary embodiments, controller 136 may estimate an orientation of antennas 138 of mobile device 130, e.g., based on a compass of mobile device 130, a gyroscope of mobile device 130, and/or any other devices and or methods of estimating the orientation of antennas 138. Controller 136 may configure the beamforming settings of antennas 138 to initiate the beamforming training in a direction directed to the relative location of node 110 based on the relative location of node 110 and the orientation of device 120 and/or based on a relative direction of link 135.

In some exemplary embodiments, node 110, mobile device 120 and/or mobile device 130 may utilize links 105 and/or 135 for communicating information corresponding to the beamforming training between node 110, mobile device 120 and/or mobile device 130.
In one example, node 110, mobile device 120 and/or mobile device 130 may utilize links 105 and/or 135 for performing the beamforming training, for example, after configuring the preliminary beamforming settings of antennas 108, 128 and/or 138.

In some exemplary embodiments, controller 116 may control wireless communication unit 112 to use the Tx beamforming setting for transmitting to device 130 over link 133. For example, controller 116 may adjust beamforming settings of antennas 108 according to the Tx beamforming settings to transmit to device 130 over link 133.

In some exemplary embodiments, controller 126 may control wireless communication unit 122 to use the Tx beamforming setting for transmitting to node 110 over link 103. For example, controller 126 may adjust beamforming settings of antennas 128 according to the Tx beamforming setting to transmit to node 110 over link 103.

In some exemplary embodiments, controller 116 may control wireless communication unit 114 to transmit to mobile device 120 via link 105 an instruction to transmit the beamforming training signals to mobile device 130 according to the plurality of different TX beamforming settings of antennas 128. In some exemplary embodiments, controller 116 may control wireless communication unit 114 to transmit to mobile device 130 via link 135 an instruction to receive the beamforming training signals transmitted by device 120. In some exemplary embodiments, controller 116 may control wireless communication unit 114 to transmit to mobile device 120 via

link 105 an instruction to use the Tx beamforming setting of antennas 128 received from mobile device 130, for transmitting to device 130 over link 123.

In some exemplary embodiments, controller 126 may control wireless communication unit 122 to use the Tx beamforming setting of antennas 128 received from mobile device 130. For example, controller 126 may adjust beamforming settings of antennas 128 according to the Tx beamforming settings to transmit to device 130 over link 123.

In some exemplary embodiments, control information corresponding to links 103, 123 and/or 133, e.g., a link adaptation, error control, beamforming adjustments, signal quality feedback and/or the like may be communicated via links 103, 123 and/or 133.

Some exemplary embodiments, e.g., the communication system 100, may be used in conjunction with one or more types of wireless communication signals and/or systems, for example, Radio Frequency (RF), Infra-Red (IR), Frequency-Division Multiplexing (FDM), Orthogonal FDM (OFDM), Time-Division Multiplexing (TDM), Time-Division Multiple Access (TDMA), Extended TDMA (E-TDMA), General Packet Radio Service (GPRS), extended GPRS, Code-Division Multiple Access (CDMA), Wideband CDMA (WCDMA), CDMA 2000, single-carrier CDMA, multi-carrier CDMA, Multi-Carrier Modulation (MDM), Discrete Multi-Tone (DMT), Bluetooth®, Global Positioning System (GPS), Wi-Fi, Wi-Max, ZigBee™, Ultra-Wideband (UWB), Global System for Mobile communication (GSM), 2G, 2.5G, 3G, 3.5G, 4G, Fifth Generation (5G) mobile networks, 3GPP, Long Term Evolution (LTE), LTE advanced (LTEa), Enhanced Data rates for GSM Evolution (EDGE), or the like. Other embodiments may be used in various other devices, systems and/or networks.

The communication system 100 and various exemplary embodiments may include logical channels that are classified into Control Channels and Traffic Channels. Logical control channels may include a broadcast control channel (BCCH), which is the downlink channel for broadcasting system control information, a paging control channel (PCCH), which is the downlink channel that transfers paging information, a multicast control channel (MCCH), which is a point-to-multipoint downlink channel used for transmitting multimedia broadcast and multicast service (MBMS) scheduling and control information for one or several multicast traffic channels (MTCHs). Generally, after establishing radio resource control (RRC) connection, MCCH is only used by the UE that receive MBMS. Dedicated control channel (DCCH) is another logical control channel that is a point-to-point bi-directional channel transmitting dedicated control information, such as user-specific control information used by the user equipment having an RRC connection. Common control channel (CCCH) is also a logical control channel that may be used for random access information. Logical traffic channels may

comprise a dedicated traffic channel (DTCH), which is a point-to-point bi-directional channel dedicated to one user equipment for the transfer of user information. Also, a multicast traffic channel (MTCH) may be used for point-to-multipoint downlink transmission of traffic data.

Furthermore, the communication system 100 and various exemplary embodiments may additionally include logical transport channels that are classified DL and UL. The DL transport channels may include a broadcast channel (BCH), a downlink shared data channel (DL-SDCH), a multicast channel (MCH) and a Paging Channel (PCH). The UL transport channels may include a random access channel (RACH), a request channel (REQCH), an uplink shared data channel (UL-SDCH) and a plurality of physical channels. The physical channels may also include a set of downlink and uplink channels.

The DL physical channels may include at least one of a common pilot channel (CPICH), a synchronization channel (SCH), a common control channel (CCCH), a shared downlink control channel (SDCCH), a multicast control channel (MCCH), a shared uplink assignment channel (SUACH), an acknowledgement channel (ACKCH), a downlink physical shared data channel (DL-PSDCH), an uplink power control channel (UPCCH), a paging indicator channel (PICH), a load indicator channel (LICH), a physical broadcast channel (PBCH), a physical control format indicator channel (PCFICH), a physical downlink control channel (PDCCH), a physical hybrid ARQ indicator channel (PHICH), a physical downlink shared channel (PDSCH) and a physical multicast channel (PMCH). The UL physical channels may include at least one of a physical random access channel (PRACH) and/or xPRACH, a channel quality indicator channel (CQICH), an acknowledgement channel (ACKCH), an antenna subset indicator channel (ASICH), a shared request channel (SREQCH), an uplink physical shared data channel (UL-PSDCH), a broadband pilot channel (BPICH), a physical uplink control channel (PUCCH) and a physical uplink shared channel (PUSCH).

One or more embodiments may use a communication frame structure or subframe that includes one or more of the above-indicated DL physical channels and/or UL physical channels. Moreover, the communication frame structure or subframe may include additional parameters. Such parameters may include an xSRS or SRS, a BRRS, a guard period (GP), and the like.

The xSRS or SRS is used for the node (e.g., eNB) to estimate UL channel/beam quality. In one example, xSRS or SRS may be sent in the last of OFDM symbol of the subframe. In another example, xSRS or SRS may be sent in the last two OFDM symbols of the subframe. The subframes that may carry the xSRS or SRS may be specified in a downlink broadcast message, such as DCI.

In order to achieve faster Rx beam refinement to improve a match of Tx and Rx beams according to the channel in a timely manner, the BRRS can be used. The BRRS can be inserted before a data channel such as a PDSCH or PUSCH. In this way, a receiver can refine an Rx beam based on the BRRS before data reception. In addition, an eNB or a UE can gradually update a Tx or Rx beam to support intra Transmission Point (TP) beam mobility.

In an OFDM system, the signal subcarrier spacing is inversely proportional to the signal time duration. The subcarrier spacing of the BRRS can be larger than that of the following data OFDM symbols (e.g., PDSCH or PUCCH) by a predefined factor so that the total length of the BRRS in the time domain is reduced by the predefined factor. This reduction in the total length or duration of the BRRS enables more Rx beam candidates to be scanned during the limited time period.

Various BRRS transmission formats are contemplated. In one example, a BRRS signal structure with a subcarrier spacing that is four times the sub-carrier spacing of the data OFDM symbols can be used (i.e., the predefined factor is 4). Four BRRS OFDM symbols can be used for the BRRS. One Tx beam can be applied to the four BRRS OFDM symbols. In another example, the BRRS signal structures can have a subcarrier spacing that is four times the sub-carrier spacing of the data OFDM symbols can be used (i.e., the predefined factor is 4). Eight BRRS OFDM symbols can be used for the BRRS. The eNB may use a first Tx beam for the first four OFDM symbols (of the eight BRRS OFDM symbols) and a second Tx beam for the second four OFDM symbols (of the eight BRRS OFDM symbols). The UE can refine the first Rx beam based on the first four OFDM symbols and the second Rx beam based on the second four OFDM symbols. In another example, the BRRS signal structures can have a subcarrier spacing that is four times the sub-carrier spacing of the data OFDM symbols can be used (i.e., the predefined factor is 4). Eight BRRS OFDM symbols can be used for the BRRS. One Tx beam can be applied to the eight BRRS OFDM symbols.

A BRRS enabling/triggering field (e.g., using 1 or 2 bits) can be included in related downlink control information (DCI). A UE can start receiving the data samples (e.g., extended (e.g., 5G) PDSCH (xPDSCH) or extended (e.g., 5G) PUSCH (xPUSCH)) following an extended physical downlink control channel (xPDCCH) using the same reception beam that was used to receive the xPDCCH. At the same time, the UE can also attempt to decode the DCI. If BRRS enabling/triggering field in the DCI indicates to the UE that there is a BRRS followed by data OFDM symbols, the UE can start Rx beam refinement using those BRRS symbols and the resulting refined Rx beam can be used to receive the data OFDM symbols. Otherwise, the UE can simply use the most current Rx beam to receive the data OFDM symbols. In one example, if

the enabling of the BRRS is configured by the DCI of a previous subframe or upper layer signaling, the BRRS may be transmitted before a control channel (e.g., xPDCCH) and the UE can use the current Rx beam to receive control channel.

Various xSRS or SRS transmission formats are contemplated. Embodiments may be described using xSRS. Those embodiments may also use SRS as an alterntive. In one example, in one embodiment, xSRS is provided in one symbol of a subframe. Specifically, the xSRS is provided in one symbol of a slot associated with the subframe. In one implementation, the subframe includes two slots. The xSRS is provided in one symbol of the second slot of the subframe that includes two slots. In one implementation, the symbol carrying the xSRS includes a plurality of resource elements or ports each carrying xSRS. Each resource element may correspond to a subcarrier associated with the subframe. In one implementation, xSRS is included in up to eight xSRS ports of the symbol. In a particular implementation, the symbol carrying xSRS includes two xSRS ports for a current beam used by a UE and two xSRS ports for a candidate beam for the UE. In one embodiment, the remaining xSRS ports may be reserved for xSRS transmission by one or more other UEs. In one implementation, a cyclic prefix (CP) resource block precedes the xSRS ports.

In another embodiment, xSRS is provided in two symbols of a subframe. Specifically, the xSRS is provided in two symbols of a slot associated with the subframe. In one implementation, the subframe includes two slots. The xSRS is provided in two symbols of the second slot of the subframe that includes two slots. In one implementation, each of the two symbols carrying the xSRS includes a plurality of resource elements or ports each carrying xSRS. Each resource element may correspond to a subcarrier associated with the subframe. In one implementation, xSRS is included in up to eight resource elements of each of the two symbols. In a particular implementation, a first of the two symbols caring the xSRS includes two xSRS ports for a current beam used by a UE. The second of the two symbols carrying the xSRS includes two xSRS ports for a candidate beam for the UE. In one embodiment, the remaining xSRS ports associated with each of the two symbols for carrying xSRS may be reserved for xSRS transmission by one or more other UEs. In one implementation, a CP resource block precedes the xSRS ports of each of two symbols.

In one implementation, an xSRS enabling/triggering field (e.g., using a 1 bit or 2 bit bitmap) may be included in downlink control information (DCI). A UE may start receiving data samples following an extended Physical Downlink Control Channel (xPDCCH) using the same reception beam that was used to receive the xPDCCH. At the same time, the UE may also attempt to decode the DCI to ascertain the xSRS bitmap to determine the xSRS symbol

configuration that an eNB is expecting from the UE. In one implementation, a bit "0" represents transmitting xSRS by the UE on a current beam used by the UE. In another implementation, a bit "1" represents transmitting xSRS by the UE on a candidate beam for use by the UE. In a more general case, a length of the xSRS enabling/triggering field (e.g., bitmap) may be defined by $N_{port}/2$, where N_{port} is the number of xSRS ports in a symbol.

At least some embodiments implement one or more xSRS symbols that include eight xSRS ports. The xSRS ports may be paired together by a high-layer signaling procedure. For example, layer 1 or layer 2 signaling may be used to allocate xSRS port pairs in the xSRS symbols.

In another implementation, xSRS symbol format is predefined. In particular, a beam identification may be ascertained based on the received UL signal including at least one of the xSRS symbol configurations discussed herein.

FIG. 2 illustrates an embodiment where beamforming is utilized between the node 110 and the mobile device 120, through an array antennas in the communication system 100. As illustrated, the node 110 can transmit data while changing the direction of a downlink transmission beam (Tx1, Tx2, or Tx3) by using a plurality of array antennas. The mobile device 120 can also receive data while changing the direction of a receive beam (Rx1, Rx2, or Rx3). The number of transmission beams and receive beams is merely temporary.

In the communication system 100 using beamforming, each of the node 110 and the mobile device 120 transmits and receives data by selecting the direction of a Tx beam and the direction of a Rx beam. Each of the node 110 and the mobile device 120 may select an appropriate Tx/Rx beam pair from among various directions of Tx beams and various directions of Rx beams. Selection or beam switching of the appropriate Tx/Rx beam pair may be based on a determination of an optimal channel environment. Beam switching is applicable not only to a DL channel over which data is transmitted from the node 110 to the mobile device 120, but also to a UL channel over which data is transmitted from the mobile device 120 to the none 110.

The UL beam switching and refinement may rely on xSRS. Hence, in some embodiments, to provide the UL beam switching and refinement, xSRS may be located in at least one symbol associated with a subframe. **FIG. 3** illustrates a first example of a beam switching frame structure 300 that provides UL switching and refinement signaling in one symbol. In one embodiment, the frame structure 300 includes a subframe 302. The subframe 302 includes a first slot 304 and a second slot 306. A symbol 308 is shown in the second slot 306. The symbol 308 may be the last symbol in the slot 306. A plurality of symbols, which are not illustrated, may be in each of the first slot 304 and the second slot 306. The symbol 308 may

include a plurality of resource elements where each of the plurality of resource elements corresponds to a radio subcarrier. In one embodiment, the symbol 308 includes a plurality of xSRS ports 310. Each of the xSRS ports 310 may be associated with a single resource element of the symbol 308. Multiple other resource elements 312 may be associated with the symbol 308. In one embodiment, a total of eight xSRS ports 310 is included in the symbol 308. However, each of the eight xSRS ports 310 must not be used simultaneously.

In a particular implementation, the symbol 308 carrying xSRS includes two xSRS ports 314 for a current beam used by a UE and two xSRS ports 316 for a candidate beam for the UE. In one embodiment, the remaining xSRS ports 310 may be reserved for xSRS transmission by one or more other UEs. In one implementation, a cyclic prefix (CP) resource block may proceed the xSRS ports 310.

In one implementation, an xSRS enabling/triggering field (e.g., using a 1 bit, 2 bit, or 4 bit bitmap) may be included in DCI. A UE may start receiving data samples xPDCCH using the same reception beam that was used to receive the xPDCCH. At the same time, the UE may also attempt to decode the DCI to ascertain the xSRS bitmap to determine the xSRS symbol configuration that an eNB is expecting from the UE. In one implementation, a bit "0" represents transmitting xSRS by the UE on a current beam used by the UE. In another implementation, a bit "1" represents transmitting xSRS by the UE on a candidate beam for use by the UE. In a more general case, a length of the xSRS enabling/triggering field (e.g., bitmap) may be defined by $N_{port}/2$, where N_{port} is the number of xSRS ports in a symbol.

At least some embodiments implement one or more xSRS symbols that include eight xSRS ports. The xSRS ports may be paired together by a high-layer signaling procedure. For example, layer 1 or layer 2 signaling may be used to allocate xSRS port pairs in the xSRS symbols. In one example, allocation of xSRS port pairs in xSRS symbols is via MIB, SIB, or RRC signaling.

The UL beam switching and refinement may rely on xSRS. Hence, in some embodiments, to provide the UL beam switching and refinement, xSRS may be located in at least two symbols associated with a subframe. **FIG. 4** illustrates a second example of a beam switching frame structure 400 that provides UL switching and refinement signaling in two symbols. In one embodiment, the frame structure 400 includes a subframe 402. The subframe 402 includes a first slot 404 and a second slot 406. A symbol 408 is shown in the second slot 406. The symbol 408 may be the second to last symbol in the slot 406. The symbol 408 may include a plurality of resource elements where each of the plurality of resource elements corresponds to a radio subcarrier. In one embodiment, the symbol 408 includes a plurality of

xSRS ports 410. Each of the xSRS ports 410 may be associated with a single resource element of the symbol 408. Multiple other resource elements 412 may be associated with the symbol 408. In one embodiment, a total of eight xSRS ports 410 is included in the symbol 408.

Furthermore, a symbol 416 is shown in the second slot 406. The symbol 416 may be the last symbol in the slot 406. The symbol 416 may include a plurality of resource elements where each of the plurality of resource elements corresponds to a radio subcarrier. In one embodiment, the symbol 416 includes a plurality of xSRS ports 418. Each of the xSRS ports 418 may be associated with a single resource element of the symbol 416. Multiple other resource elements 420 may be associated with the symbol 416. In one embodiment, a total of eight xSRS ports 418 is included in the symbol 416.

A plurality of other symbols, which are not illustrated, may be in each of the first slot 404 and the second slot 406.

In one embodiment, the symbol 408 includes xSRS for current beam used by a UE, and the symbol 416 includes xSRS for a candidate beam for the UE.

In a particular implementation, the symbol 408 carrying xSRS includes two xSRS ports 414 for a current beam used by a UE. In one embodiment, the remaining xSRS ports 410 may be reserved for xSRS transmission by one or more other UEs. In one implementation, a cyclic prefix (CP) resource block may proceed the xSRS ports 410.

In a particular implementation, the symbol 416 carrying xSRS includes two xSRS ports 422 for a candidate beam for use by the UE. In one embodiment, the remaining xSRS ports 418 may be reserved for xSRS transmission by one or more other UEs. In one implementation, a cyclic prefix (CP) resource block may proceed the xSRS ports 418.

In one implementation, an xSRS enabling/triggering field (e.g., using a 1 bit, 2 bit, or 4 bit bitmap) may be included in DCI. A UE may start receiving data samples xPDCCH using the same reception beam that was used to receive the xPDCCH. At the same time, the UE may also attempt to decode the DCI to ascertain the xSRS bitmap to determine the xSRS symbol configuration that an eNB is expecting from the UE. In one implementation, a bit "0" represents transmitting xSRS by the UE on a current beam used by the UE. In another implementation, a bit "1" represents transmitting xSRS by the UE on a candidate beam for use by the UE. In a more general case, a length of the xSRS enabling/triggering field (e.g., bitmap) may be defined by $N_{port}/2$, where N_{port} is the number of xSRS ports in a symbol.

At least some embodiments implement one or more xSRS symbols that include eight xSRS ports. The xSRS ports may be paired together by a high-layer signaling procedure. For example, layer 1 or layer 2 signaling may be used to allocate xSRS port pairs in the xSRS

symbols. In one example, allocation of xSRS port pairs in xSRS symbols is via MIB, SIB, or RRC signaling.

FIGS. 5 and 6 illustrate exemplary xSRS physical structures that may be used for xSRS communication from a UE to a node (e.g., eNB). Referring to FIG. 5, an exemplary xSRS physical structure 500 includes at least a CP section 502 and a plurality of xSRS sections 504-510. xSRS sections 504 and 506 correspond to a current beam of a UE and xSRS sections 508 and 510 correspond to candidate beam for use by the UE. Generally, the exemplary xSRS physical structure 500 may be used in connection with the embodiment illustrated in FIG. 3. Additional xSRS sections may be included in the exemplary xSRS physical structure 500 to achieve xSRS redundancy. Referring to FIG. 6, an exemplary xSRS physical structure 600 includes a first CP section 602 and a second CP section 604. A plurality of xSRS sections 606 and 608 follow the first CP section 602. Similarly, a plurality of xSRS sections 610 and 612 follow the second CP section 604. xSRS sections 606 and 608 correspond to a current beam of a UE and xSRS sections 610 and 612 correspond to candidate beam for use by the UE. Generally, the exemplary xSRS physical structure 600 may be used in connection with the embodiment illustrated in FIG. 4. Additional xSRS sections may be included in the exemplary xSRS physical structure 600 to achieve xSRS redundancy.

As used herein, the term "circuitry" may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some embodiments, the circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some embodiments, circuitry may include logic, at least partially operable in hardware. Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software.

FIG. 7 illustrates example components of an electronic device 700. In embodiments, the electronic device 700 may, implement, be incorporated into, or otherwise be a part of a UE, a node such as an eNB, some other equipment capable of performing similar operations, or some combination thereof. In some embodiments, the UE device 700 may include application circuitry 702, baseband circuitry 704, Radio Frequency (RF) circuitry 706, front-end module (FEM) circuitry 708 and one or more antennas 710, coupled together at least as shown.

The application circuitry 702 may include one or more application processors. For example, the application circuitry 702 may include circuitry such as, but not limited to, one or

more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with and/or may include memory/storage (e.g., memory/storage 704g or 706e) and may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

The baseband circuitry 704 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 704 may include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of the RF circuitry 706 and to generate baseband signals for a transmit signal path of the RF circuitry 706. Baseband processing circuity 704 may interface with the application circuitry 702 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 706. For example, in some embodiments, the baseband circuitry 704 may include a second generation (2G) baseband processor 704a, third generation (3G) baseband processor 704b, fourth generation (4G) baseband processor 704c, and/or other baseband processor(s) 704d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 704 (e.g., one or more of baseband processors 704a-d) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 706. The radio control functions may include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 704 may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 704 may include convolution, tail-biting convolution, turbo, Viterbi, and/or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

In some embodiments, the baseband circuitry 704 may include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access network (EUTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 704e of the baseband circuitry 704 may be configured to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP

and/or RRC layers. In some embodiments, the baseband circuitry may include one or more audio digital signal processor(s) (DSP) 704f. The audio DSP(s) 704f may be include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 704 and the application circuitry 702 may be implemented together such as, for example, on a system on a chip (SOC).

In some embodiments, the baseband circuitry 704 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 704 may support communication with an evolved universal terrestrial radio access network (EUTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 704 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

The baseband circuitry 704 may be coupled with and/or may include memory/storage (e.g., memory/storage 704g) and may be configured to execute instructions stored in the memory/storage to enable various, processes, applications to run.

RF circuitry 706 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 706 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 706 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 708 and provide baseband signals to the baseband circuitry 704. RF circuitry 706 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 704 and provide RF output signals to the FEM circuitry 708 for transmission. In some embodiments, the RF circuitry 706 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 706 may include mixer circuitry 706a, amplifier circuitry 706b and filter circuitry 706c. The transmit signal path of the RF circuitry 706 may include filter circuitry 706c and mixer circuitry 706a. RF circuitry 706 may also include synthesizer circuitry 706d for synthesizing a frequency for use by the mixer circuitry 706a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 706a of the receive signal path may be configured to down-convert RF signals received from the FEM

circuitry 708 based on the synthesized frequency provided by synthesizer circuitry 706d. The amplifier circuitry 706b may be configured to amplify the down-converted signals and the filter circuitry 706c may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals may be provided to the baseband circuitry 704 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 706a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

In some embodiments, the mixer circuitry 706a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 706d to generate RF output signals for the FEM circuitry 708. The baseband signals may be provided by the baseband circuitry 704 and may be filtered by filter circuitry 706c. The filter circuitry 706c may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

In some embodiments, the mixer circuitry 706a of the receive signal path and the mixer circuitry 706a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and/or upconversion respectively. In some embodiments, the mixer circuitry 706a of the receive signal path and the mixer circuitry 706a of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 706a of the receive signal path and the mixer circuitry 706a may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 706a of the receive signal path and the mixer circuitry 706a of the transmit signal path may be configured for super-heterodyne operation.

In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 706 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 704 may include a digital baseband interface to communicate with the RF circuitry 706.

In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

In some embodiments, the synthesizer circuitry 706d may be a fractional-N synthesizer or a fractional N/N+1 synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 706d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

The synthesizer circuitry 706d may be configured to synthesize an output frequency for use by the mixer circuitry 706a of the RF circuitry 706 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 706d may be a fractional N/N+1 synthesizer.

In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 704 or the applications processor 702 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 702. Synthesizer circuitry 706d of the RF circuitry 706 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or N+1 (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements may be configured to break a VCO period up into Nd equal packets of phase, where Nd is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

In some embodiments, synthesizer circuitry 706d may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency may be a LO frequency (fLO). In some embodiments, the RF circuitry 706 may include an IQ/polar converter.

FEM circuitry 708 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 710, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 706 for further processing. FEM circuitry 708 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 706 for transmission by one or more of the one or more antennas 710.

In some embodiments, the FEM circuitry 708 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry may include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 706). The transmit signal path of the FEM circuitry 708 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 706), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 710.

In some embodiments, the electronic device 700 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface. For example, the RF circuitry 706 may be coupled with and/or may include memory/storage (e.g., memory/storage 706e) and may be configured to execute instructions stored in the memory/storage.

In embodiments where the electronic device 700 is, implements, is incorporated into, or is otherwise part of a UE, the RF circuitry 706 may receive a long term evolution (LTE) subframe that includes a BRRS. The baseband circuitry 704 may be to determine a value of the BRRS and switch a DL Tx beam based on the value of the BRRS.

In embodiments where the electronic device 700 is, implements, is incorporated into, or is otherwise part of a eNodeB (eNB), network node, or cellular base station, RF circuitry 706 may be receive a long term evolution (LTE) subframe that includes extended (e.g, 5G) xSRS. The baseband circuitry 704 may be to determine a value of the xSRS within the LTE subframe and refine UL Rx beam based on the value of the xSRS.

FIG. 8 illustrates an embodiment of a storage medium 800. The storage medium 800 may comprise an article of manufacture. In one embodiment, the storage medium 800 may comprise any non-transitory computer readable medium or machine readable medium, such as an optical, magnetic or semiconductor storage. The storage medium may store various types of computer executable instructions, such as instructions 802 to implement one or more of logic flows described herein. Examples of a computer readable or machine readable storage medium

may include any tangible media capable of storing electronic data, including volatile memory or non-volatile memory, removable or non-removable memory, erasable or non-erasable memory, writeable or re-writeable memory, and so forth. Examples of computer executable instructions may include any suitable type of code, such as source code, compiled code, interpreted code, executable code, static code, dynamic code, object-oriented code, visual code, and the like. The embodiments are not limited in this context.

In some embodiments, the electronic device of FIG. 8 may be configured to perform one or more processes, techniques, and/or methods as described herein, or portions thereof. One such process is depicted in **FIG. 9**. For example, the process may include, at 902, configuring or causing to configure a format of an uplink (UL) sounding signal. The UL sounding signal is to include at least a plurality of 5G sounding reference signal (xSRS) ports associated with a symbol of a subframe. At 904, the process may further include associating or causing to associate the format of the UL sounding signal with a configuration broadcast communication. The configuration broadcast communication, at 904, may be processed or encoded as broadcast channel data for transmission to a UE.

In some embodiments, the electronic device of FIG. 8 may be configured to perform one or more processes, techniques, and/or methods as described herein, or portions thereof. One such process is depicted in FIG. **10**. For example, the process may include, at 1002, identifying or causing to identify a format of an uplink (UL) sounding signal in a configuration broadcast communication. The configuration broadcast communication, at 1002, may be received as encoded broadcast channel data associated with a transmission from a base station. At 1004, the process may further include generating or causing to generate an UL sounding signal based on the format. The UL sounding signal to include a plurality of 5G sounding reference signal (xSRS) ports associated with a symbol of a subframe.

Various embodiments may be implemented using hardware elements, software elements, or a combination of both. Examples of hardware elements may include processors, microprocessors, circuits, circuit elements (e.g., transistors, resistors, capacitors, inductors, and so forth), integrated circuits, application specific integrated circuits (ASIC), programmable logic devices (PLD), digital signal processors (DSP), field programmable gate array (FPGA), logic gates, registers, semiconductor device, chips, microchips, chip sets, and so forth. Examples of software may include software components, programs, applications, computer programs, application programs, system programs, machine programs, operating system software, middleware, firmware, software modules, routines, subroutines, functions, methods, procedures, software interfaces, application program interfaces (API), instruction sets, computing code,

computer code, code segments, computer code segments, words, values, symbols, or any combination thereof. Determining whether an embodiment is implemented using hardware elements and/or software elements may vary in accordance with any number of factors, such as desired computational rate, power levels, heat tolerances, processing cycle budget, input data rates, output data rates, memory resources, data bus speeds and other design or performance constraints.

One or more aspects of at least one embodiment may be implemented by representative instructions stored on a machine-readable medium which represents various logic within the processor, which when read by a machine causes the machine to fabricate logic to perform the techniques described herein. Such representations, known as "IP cores" may be stored on a tangible, machine readable medium and supplied to various customers or manufacturing facilities to load into the fabrication machines that actually make the logic or processor. Some embodiments may be implemented, for example, using a machine-readable medium or article which may store an instruction or a set of instructions that, if executed by a machine, may cause the machine to perform a method and/or operations in accordance with the embodiments. Such a machine may include, for example, any suitable processing platform, computing platform, computing device, processing device, computing system, processing system, computer, processor, or the like, and may be implemented using any suitable combination of hardware and/or software. The machine-readable medium or article may include, for example, any suitable type of memory unit, memory device, memory article, memory medium, storage device, storage article, storage medium and/or storage unit, for example, memory, removable or non-removable media, erasable or non-erasable media, writeable or re-writeable media, digital or analog media, hard disk, floppy disk, Compact Disk Read Only Memory (CD-ROM), Compact Disk Recordable (CD-R), Compact Disk Rewriteable (CD-RW), optical disk, magnetic media, magneto-optical media, removable memory cards or disks, various types of Digital Versatile Disk (DVD), a tape, a cassette, or the like. The instructions may include any suitable type of code, such as source code, compiled code, interpreted code, executable code, static code, dynamic code, encrypted code, and the like, implemented using any suitable high-level, low-level, object-oriented, visual, compiled and/or interpreted programming language.

Numerous specific details have been set forth herein to provide a thorough understanding of the embodiments. It will be understood by those skilled in the art, however, that the embodiments may be practiced without these specific details. In other instances, well-known operations, components, and circuits have not been described in detail so as not to obscure the

embodiments. It can be appreciated that the specific structural and functional details disclosed herein may be representative and do not necessarily limit the scope of the embodiments. Some embodiments may be described using the expression "coupled" and "connected" along with their derivatives. These terms are not intended as synonyms for each other. For example, some embodiments may be described using the terms “connected” and/or “coupled” to indicate that two or more elements are in direct physical or electrical contact with each other. The term "coupled," however, may also mean that two or more elements are not in direct contact with each other, but yet still co-operate or interact with each other.

Unless specifically stated otherwise, it may be appreciated that terms such as “processing,” “computing,” “calculating,” “determining,” or the like, refer to the action and/or processes of a computer or computing system, or similar electronic computing device, that manipulates and/or transforms data represented as physical quantities (e.g., electronic) within the computing system’s registers and/or memories into other data similarly represented as physical quantities within the computing system’s memories, registers or other such information storage, transmission or display devices. The embodiments are not limited in this context.

It should be noted that the methods described herein do not have to be executed in the order described, or in any particular order. Moreover, various activities described with respect to the methods identified herein can be executed in serial or parallel fashion.

Although specific embodiments have been illustrated and described herein, it should be appreciated that any arrangement calculated to achieve the same purpose may be substituted for the specific embodiments shown. This disclosure is intended to cover any and all adaptations or variations of various embodiments. It is to be understood that the above description has been made in an illustrative fashion, and not a restrictive one. Combinations of the above embodiments, and other embodiments not specifically described herein will be apparent to those of skill in the art upon reviewing the above description. Thus, the scope of various embodiments includes any other applications in which the above compositions, structures, and methods are used.

What has been described above includes examples of the disclosed architecture, system, devices, processes, structure, and functions. It is, of course, not possible to describe every conceivable combination of components and/or methodologies, but one of ordinary skill in the art may recognize that many further combinations and permutations are possible. Accordingly, the novel architecture is intended to embrace all such alterations, modifications and variations that fall within the spirit and scope of the appended claims. The detailed disclosure now turns to

providing examples that pertain to further embodiments. The examples provided below are not intended to be limiting.

Example 1. An apparatus of a base station, comprising: at least one memory; and logic, at least a portion of which is implemented in baseband circuitry comprising one or more processors coupled to the at least one memory, the logic to: configure a format of an uplink (UL) sounding signal, the UL sounding signal to include a plurality of sounding reference signal (SRS) ports associated with a symbol of a subframe; and associate the format of the UL sounding signal with a configuration broadcast communication.

Example 2. The apparatus according to Example 1, each of the plurality of SRS ports is to be associated with a resource element of the symbol of the subframe.

Example 3. The apparatus according to Example 2, the resource element is to correspond to a subcarrier.

Example 4. The apparatus according to Example 1, 2 or 3, the format of the UL sounding signal is predefined.

Example 5. The apparatus according to Example 1, 2, 3, or 4, at least two of the plurality of SRS ports are paired together and are to correspond to a first UL transmit (Tx) beam.

Example 6. The apparatus according to Example 1, 2, 3, 4, or 5, at least another two of the priority of SRS ports are paired together and are to correspond to a second UL transmit (Tx) beam.

Example 7. The apparatus according to Example 1, the uplink sounding signal is to include a second plurality of SRS ports associated with a second symbol of the subframe.

Example 8. The apparatus according to Example 7, at least two of the second plurality of SRS ports are paired together and are to correspond to a second UL transmit (Tx) beam.

Example 9. The apparatus according to Example 8, the second plurality of SRS ports includes eight SRS ports associated with the second symbol of the subframe.

Example 10. The apparatus according to Example 1, the plurality of SRS ports includes eight SRS ports associated with the symbol of the subframe.

Example 11. The apparatus according to Example 1, the configuration broadcast communication is downlink control information (DCI), master information broadcasting (MIB), system information broadcasting (SIB), or radio resource control (RRC) signaling, and the plurality of SRS ports are fifth generation (5G) xSRS ports.

Example 12. At least one machine-readable storage medium comprising instructions that when executed by a computing device, cause the computing device to: configure a format of an uplink (UL) sounding signal, the UL sounding signal to include a plurality of 5G sounding

reference signal (xSRS) ports associated with a symbol of a subframe; and associate the format of the UL sounding signal to a configuration broadcast communication.

Example 13. The least one machine-readable storage medium of Example 12, each of the plurality of 5G xSRS ports is to be associated with a resource element of the symbol of the subframe.

Example 14. The least one machine-readable storage medium of Example 13, the resource element is to correspond to a subcarrier.

Example 15. The least one machine-readable storage medium of Example 12, 13 or 14, the format of the UL sounding signal is predefined.

Example 16. The least one machine-readable storage medium of Example 12, 13, 14, or 15, at least two of the plurality of 5G xSRS ports are paired together and are to correspond to a first UL transmit (Tx) beam.

Example 17. The least one machine-readable storage medium of Example 12, 13, 14, 15 or 16, at least another two of the priority of 5G xSRS ports are paired together and are to correspond to a second UL transmit (Tx) beam.

Example 18. The least one machine-readable storage medium of Example 12, the uplink sounding signal is to include a second plurality of 5G xSRS ports associated with a second symbol of the subframe.

Example 19. The least one machine-readable storage medium of Example 18, at least two of the second plurality of 5G xSRS ports are paired together and are to correspond to a second UL Tx beam.

Example 20. The least one machine-readable storage medium of Example 19, the second plurality of 5G xSRS ports includes eight xSRS ports associated with the second symbol of the subframe.

Example 21. The least one machine-readable storage medium of Example 12, the plurality of 5G xSRS ports includes eight xSRS ports associated with the symbol of the subframe.

Example 22. The least one machine-readable storage medium of Example 12, the configuration broadcast communication is downlink control information (DCI), master information broadcasting (MIB), system information broadcasting (SIB), or radio resource control (RRC) signaling.

Example 23. An apparatus of a user equipment (UE), comprising: at least one memory; and logic, at least a portion of which is implemented in baseband circuitry comprising one or more processors coupled to the at least one memory, the logic to: identify a format of an uplink

(UL) sounding signal in a configuration broadcast communication; and generate an UL sounding signal based on the format, the UL sounding signal to include a plurality of 5G sounding reference signal (xSRS) ports associated with a symbol of a subframe.

Example 24. The apparatus according to Example 23, at least two of the plurality of 5G xSRS ports are paired together and are to correspond to a first UL transmit (Tx) beam.

Example 25. The apparatus according to Example 23, at least two of the plurality of 5G xSRS ports are paired together and are to correspond to a first UL transmit (Tx) beam, and another at least two of the plurality of 5G xSRS ports are paired together and are to correspond to a second UL TX beam.

Example 26. A method, comprising: configuring, by way of baseband circuitry, a format of an uplink (UL) sounding signal, the UL sounding signal to include a plurality of 5G sounding reference signal (xSRS) ports associated with a symbol of a subframe; and associating the format of the UL sounding signal with a configuration broadcast communication.

Example 27. A method according to Example 26, associating each of the plurality of 5G xSRS ports with a resource element of the symbol of the subframe.

Example 28. A method according to Example 27, the resource element is to correspond to a subcarrier.

Example 29. A method according to Example 26, 27 or 28, the format of the UL sounding signal is predefined.

Example 30. A method according to Example 26, 27, 28, or 29, at least two of the plurality of 5G xSRS ports are paired together and are to correspond to a first UL transmit (Tx) beam.

Example 31. A method according to Example 26, 27, 28, 29, or 30, at least another two of the priority of 5G xSRS ports are paired together and are to correspond to a second UL Tx beam.

Example 32. A method according to Example 26, the uplink sounding signal is to include a second plurality of 5G xSRS ports associated with a second symbol of the subframe.

Example 33. A method according to Example 26, at least two of the second plurality of 5G xSRS ports are paired together and are to correspond to a second UL transmit (Tx) beam.

Example 34. A method according to Example 33, the second plurality of 5G xSRS ports includes eight xSRS ports associated with the second symbol of the subframe.

Example 35. A method according to Example 26, the plurality of 5G xSRS ports includes eight xSRS ports associated with the symbol of the subframe.

Example 36. A method according to Example 26, the configuration broadcast communication is downlink control information (DCI), master information broadcasting (MIB), system information broadcasting (SIB), or radio resource control (RRC) signaling.

Example 37. An apparatus of a base station, comprising: at least one memory; and logic, at least a portion of which is implemented in baseband circuitry comprising one or more processors coupled to the at least one memory, the logic to: configure a format of an uplink (UL) sounding signal, the UL sounding signal to include a plurality of sounding reference signal (SRS) ports associated with a symbol of a subframe; and associate the format of the UL sounding signal with a configuration broadcast communication.

Example 38. The apparatus according to Example 37, each of the plurality of SRS ports is to be associated with a resource element of the symbol of the subframe.

Example 39. The apparatus according to Example 38, the resource element is to correspond to a subcarrier.

Example 40. The apparatus according to Example 37, the format of the UL sounding signal is predefined.

Example 41. The apparatus according to Example 37, at least two of the plurality of SRS ports are paired together and are to correspond to a first UL transmit (Tx) beam.

Example 42. The apparatus according to Example 37, at least another two of the priority of SRS ports are paired together and are to correspond to a second UL Tx beam.

Example 43. The apparatus according to Example 37, the uplink sounding signal is to include a second plurality of SRS ports associated with a second symbol of the subframe.

Example 44. The apparatus according to Example 43, at least two of the second plurality of SRS ports are paired together and are to correspond to a second UL transmit (Tx) beam.

Example 45. The apparatus according to Example 44, the second plurality of 5G xSRS ports includes eight SRS ports associated with the second symbol of the subframe.

Example 46. The apparatus according to Example 37, the plurality of SRS ports includes eight SRS ports associated with the symbol of the subframe.

Example 47. The apparatus according to Example 37, the configuration broadcast communication is downlink control information (DCI), master information broadcasting (MIB), system information broadcasting (SIB), or radio resource control (RRC) signaling, and the plurality of SRS ports are fifth generation (5G) xSRS ports.

Example 48. At least one machine-readable storage medium comprising instructions that when executed by a computing device, cause the computing device to: configure a format of an uplink (UL) sounding signal, the UL sounding signal to include a plurality of 5G sounding

reference signal (xSRS) ports associated with a symbol of a subframe; and associate the format of the UL sounding signal to a configuration broadcast communication.

Example 49. The least one machine-readable storage medium of Example 48, each of the plurality of 5G xSRS ports is to be associated with a resource element of the symbol of the subframe.

Example 50. The least one machine-readable storage medium of Example 49, the resource element is to correspond to a subcarrier.

Example 51. The least one machine-readable storage medium of Example 48, the format of the UL sounding signal is predefined.

Example 52. The least one machine-readable storage medium of Example 48, at least two of the plurality of 5G xSRS ports are paired together and are to correspond to a first UL transmit (Tx) beam.

Example 53. The least one machine-readable storage medium of Example 48, at least another two of the priority of 5G xSRS ports are paired together and are to correspond to a second UL Tx beam.

Example 54. The least one machine-readable storage medium of Example 48, the uplink sounding signal is to include a second plurality of 5G xSRS ports associated with a second symbol of the subframe.

Example 55. The least one machine-readable storage medium of Example 54, at least two of the second plurality of 5G xSRS ports are paired together and are to correspond to a second UL Tx beam.

Example 56. The least one machine-readable storage medium of Example 55, the second plurality of 5G xSRS ports includes eight xSRS ports associated with the second symbol of the subframe.

Example 57. The least one machine-readable storage medium of Example 48, the plurality of 5G xSRS ports includes eight xSRS ports associated with the symbol of the subframe.

Example 58. The least one machine-readable storage medium of Example 48, the configuration broadcast communication is downlink control information (DCI), master information broadcasting (MIB), system information broadcasting (SIB), or radio resource control (RRC) signaling.

Example 59. An apparatus of a user equipment (UE), comprising: at least one memory; and logic, at least a portion of which is implemented in baseband circuitry comprising one or more processors coupled to the at least one memory, the logic to: identify a format of an uplink

(UL) sounding signal in a configuration broadcast communication; and generate an UL sounding signal based on the format, the UL sounding signal to include a plurality of 5G sounding reference signal (xSRS) ports associated with a symbol of a subframe.

Example 60. The apparatus according to Example 59, at least two of the plurality of 5G xSRS ports are paired together and are to correspond to a first UL transmit (Tx) beam.

Example 61. The apparatus according to Example 59, at least two of the plurality of 5G xSRS ports are paired together and are to correspond to a first UL transmit (Tx) beam, and another at least two of the plurality of 5G xSRS ports are paired together and are to correspond to a second UL TX beam.

Example 62. An apparatus, comprising: means to configure a format of an uplink (UL) sounding signal, the UL sounding signal to include a plurality of 5G sounding reference signal (xSRS) ports associated with a symbol of a subframe; and means to associate the format of the UL sounding signal with a configuration broadcast communication.

Example 63. The apparatus according to Example 62, means to associate each of the plurality of 5G xSRS ports with a resource element of the symbol of the subframe.

Example 64. The apparatus according to Example 63, the resource element is to correspond to a subcarrier.

Example 65. The apparatus according to Example 62, 63, or 64 the format of the UL sounding signal is predefined.

Example 66. The apparatus according to Example 62, 63, 64, or 65, at least two of the plurality of 5G xSRS ports are paired together and are to correspond to a first UL transmit (Tx) beam.

Example 67. The apparatus according to Example 62, 63, 64, 65, or 66, at least another two of the priority of 5G xSRS ports are paired together and are to correspond to a second UL Tx beam.

Example 68. The apparatus according to Example 62, the uplink sounding signal is to include a second plurality of 5G xSRS ports associated with a second symbol of the subframe.

Example 69. The apparatus according to Example 62, at least two of the second plurality of 5G xSRS ports are paired together and are to correspond to a second UL transmit (Tx) beam.

Example 70. The apparatus according to Example 69, the second plurality of 5G xSRS ports includes eight xSRS ports associated with the second symbol of the subframe.

Example 71. The apparatus according to Example 62, the plurality of 5G xSRS ports includes eight xSRS ports associated with the symbol of the subframe.

Example 72. The apparatus according to Example 62, the configuration broadcast communication is downlink control information (DCI), master information broadcasting (MIB), system information broadcasting (SIB), or radio resource control (RRC) signaling.

It is emphasized that the Abstract of the Disclosure is provided to comply with 37 C.F.R. § 1.72(b), requiring an abstract that will allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description, it can be seen that various features are grouped together in a single embodiment for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed embodiments require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter lies in less than all features of a single disclosed embodiment. Thus the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separate preferred embodiment. In the appended claims, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein," respectively. Moreover, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects.

Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

CLAIMS

What is claimed is:

1. An apparatus of a base station, comprising:

at least one memory; and

logic, at least a portion of which is implemented in baseband circuitry comprising one or more processors coupled to the at least one memory, the logic to:

configure a format of an uplink (UL) sounding signal, the UL sounding signal to include a plurality of sounding reference signal (SRS) ports associated with a symbol of a subframe;

associate the format of the UL sounding signal with a configuration broadcast communication; and

encode the configuration broadcast communication for transmission.

2. The apparatus according to claim 1, each of the plurality of SRS ports is to be associated with a resource element of the symbol of the subframe.

3. The apparatus according to claim 2, the resource element is to correspond to a subcarrier.

4. The apparatus according to claim 1, 2 or 3, the format of the UL sounding signal is predefined.

5. The apparatus according to claim 1, 2, 3, or 4, at least two of the plurality of SRS ports are paired together and are to correspond to a first UL transmit (Tx) beam.

6. The apparatus according to claim 1, 2, 3, 4, or 5, at least another two of the priority of SRS ports are paired together and are to correspond to a second UL transmit (Tx) beam.

7. The apparatus according to claim 1, the uplink sounding signal is to include a second plurality of SRS ports associated with a second symbol of the subframe.

8. The apparatus according to claim 7, at least two of the second plurality of SRS ports are paired together and are to correspond to a second UL transmit (Tx) beam.

9. The apparatus according to claim 8, the second plurality of SRS ports includes eight SRS ports associated with the second symbol of the subframe.

10. The apparatus according to claim 1, the plurality of SRS ports includes eight SRS ports associated with the symbol of the subframe.

11. The apparatus according to claim 1, the configuration broadcast communication is downlink control information (DCI), master information broadcasting (MIB), system

information broadcasting (SIB), or radio resource control (RRC) signaling, and the plurality of SRS ports are fifth generation (5G) xSRS ports.

12. At least one machine-readable storage medium comprising instructions that when executed by a computing device, cause the computing device to:

configure a format of an uplink (UL) sounding signal, the UL sounding signal to include a plurality of fifth generation (5G) sounding reference signal (xSRS) ports associated with a symbol of a subframe; and

associate the format of the UL sounding signal to a configuration broadcast communication.

13. The at least one machine-readable storage medium of claim 12, each of the plurality of 5G xSRS ports is to be associated with a resource element of the symbol of the subframe.

14. The at least one machine-readable storage medium of claim 13, the resource element is to correspond to a subcarrier.

15. The at least one machine-readable storage medium of claim 12, 13 or 14, the format of the UL sounding signal is predefined.

16. The at least one machine-readable storage medium of claim 12, 13, 14, or 15, at least two of the plurality of 5G xSRS ports are paired together and are to correspond to a first UL transmit (Tx) beam.

17. The at least one machine-readable storage medium of claim 12, 13, 14, 15 or 16, at least another two of the priority of 5G xSRS ports are paired together and are to correspond to a second UL transmit (Tx) beam.

18. The at least one machine-readable storage medium of claim 12, the uplink sounding signal is to include a second plurality of 5G xSRS ports associated with a second symbol of the subframe.

19. The at least one machine-readable storage medium of claim 18, at least two of the second plurality of 5G xSRS ports are paired together and are to correspond to a second UL Tx beam.

20. The at least one machine-readable storage medium of claim 19, the second plurality of 5G xSRS ports includes eight 5G xSRS ports associated with the second symbol of the subframe.

21. The at least one machine-readable storage medium of claim 12, the plurality of 5G xSRS ports includes eight 5G xSRS ports associated with the symbol of the subframe.

22. The at least one machine-readable storage medium of claim 12, the configuration broadcast communication is downlink control information (DCI), master information

broadcasting (MIB), system information broadcasting (SIB), or radio resource control (RRC) signaling.

23. An apparatus of a user equipment (UE), comprising:

at least one memory; and

logic, at least a portion of which is implemented in baseband circuitry comprising one or more processors coupled to the at least one memory, the logic to:

identify a format of an uplink (UL) sounding signal in a configuration broadcast communication; and

generate an UL sounding signal based on the format, the UL sounding signal to include a plurality of fifth generation (5G) sounding reference signal (xSRS) ports associated with a symbol of a subframe.

24. The apparatus according to claim 23, at least two of the plurality of 5G xSRS ports are paired together and are to correspond to a first UL transmit (Tx) beam.

25. The apparatus according to claim 23, at least two of the plurality of 5G xSRS ports are paired together and are to correspond to a first UL transmit (Tx) beam, and another at least two of the plurality of 5G xSRS ports are paired together and are to correspond to a second UL TX beam.

FIG. 1

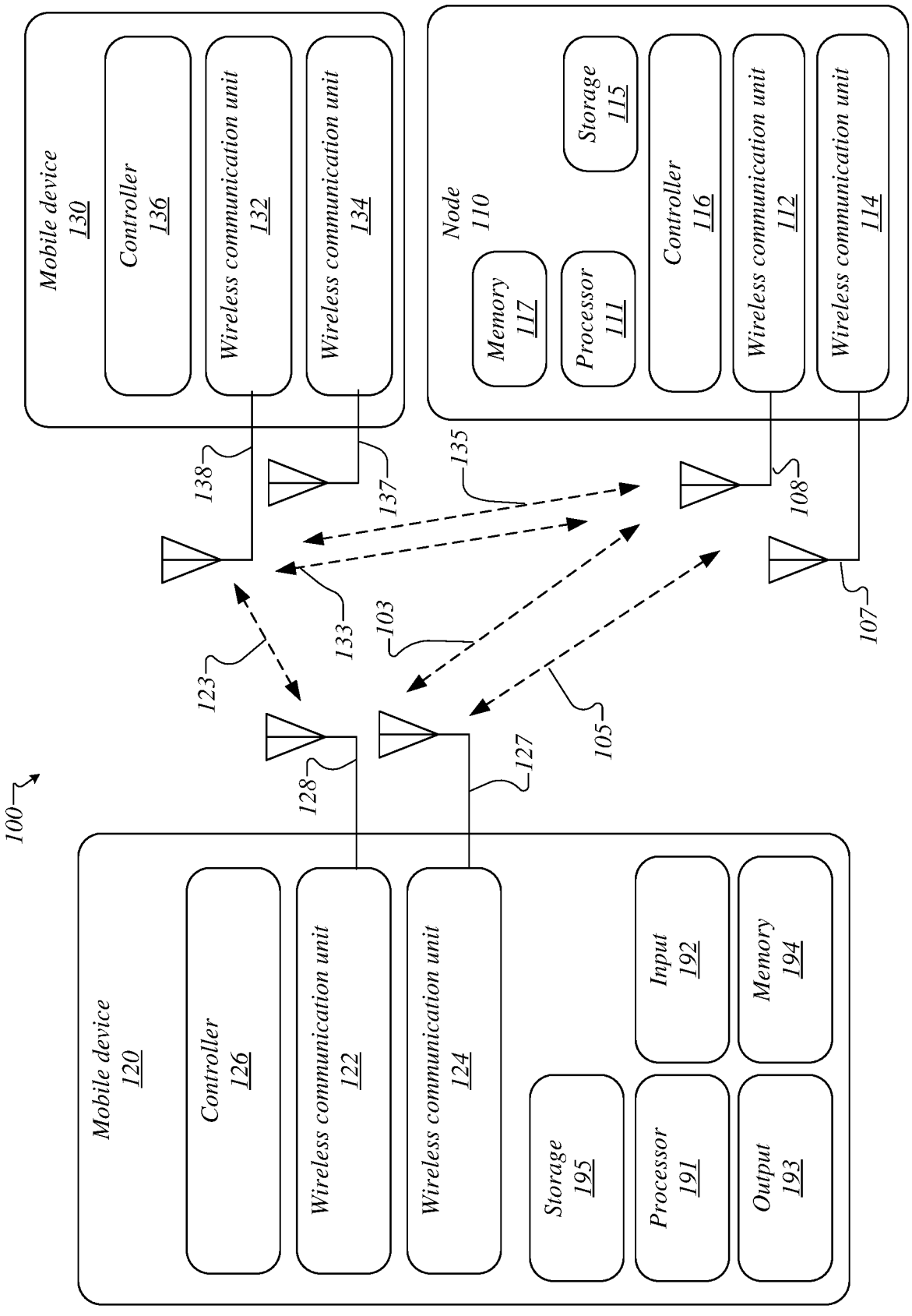

100
Mobile device 120
Controller 126
Wireless communication unit 122
Wireless communication unit 124
Storage 195
Processor 191
Output 193
Input 192
Memory 194
Mobile device 130
Controller 136
Wireless communication unit 132
Wireless communication unit 134
Node 110
Memory 117
Processor 111
Storage 115
Controller 116
Wireless communication unit 112
Wireless communication unit 114
123
128
127
133
103
105
135
138
137
108
107

FIG. 2

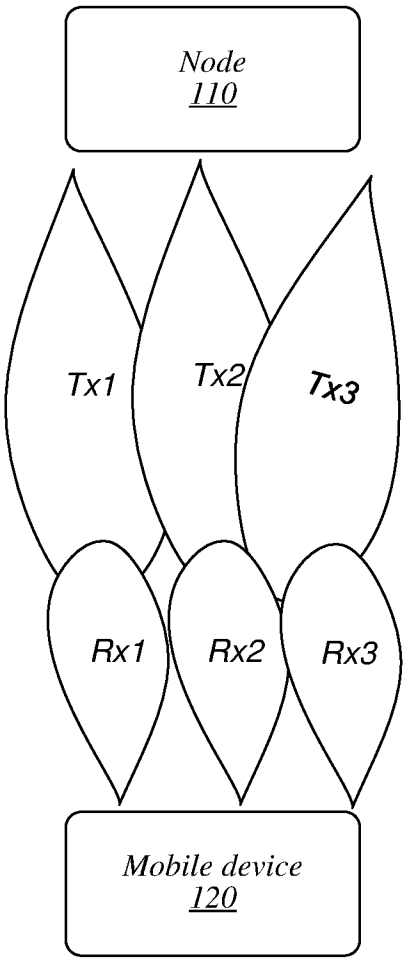


FIG. 3

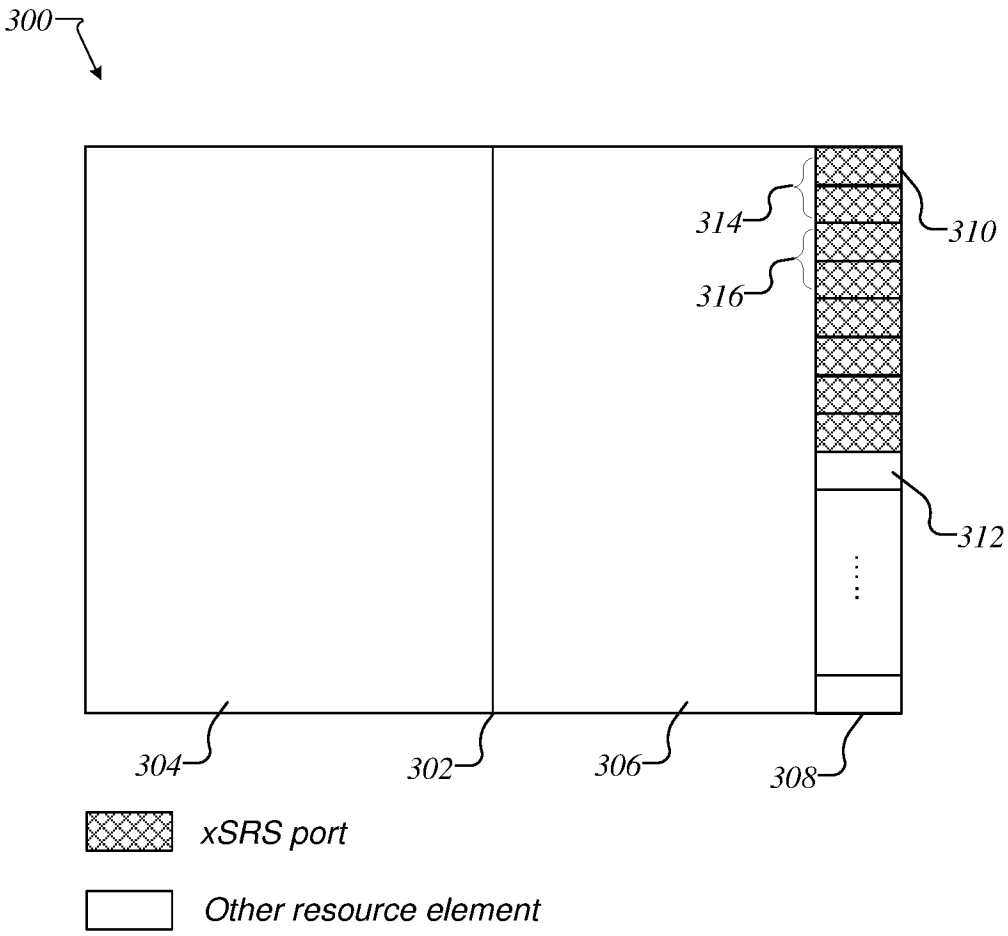

300
314
310
316
312
304
302
306
308
xSRS port
Other resource element

FIG. 4

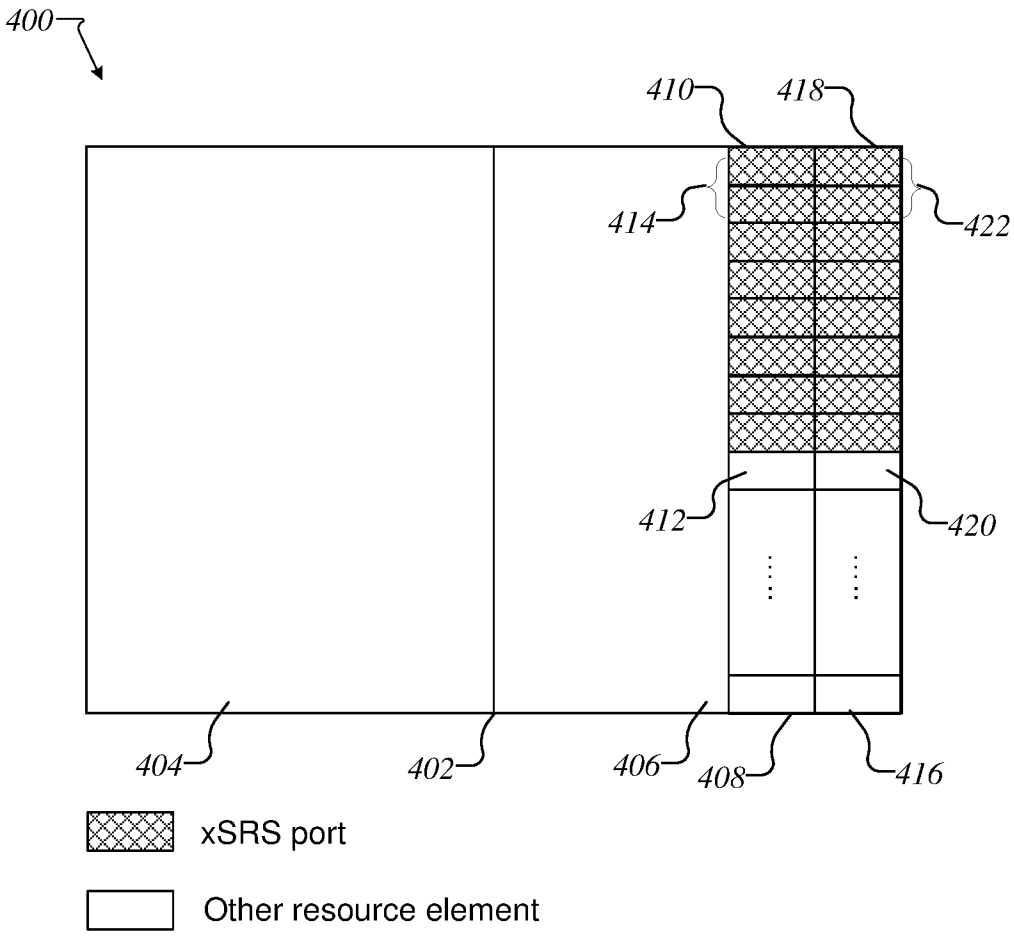

400
410
418
414
422
412
420
404
402
406
408
416
xSRS port
Other resource element

FIG. 5

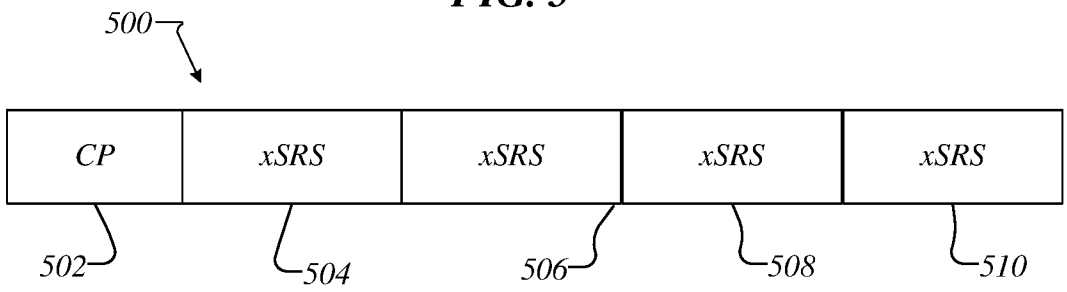

500
CP
xSRS
xSRS
xSRS
xSRS
502
504
506
508
510

FIG. 6

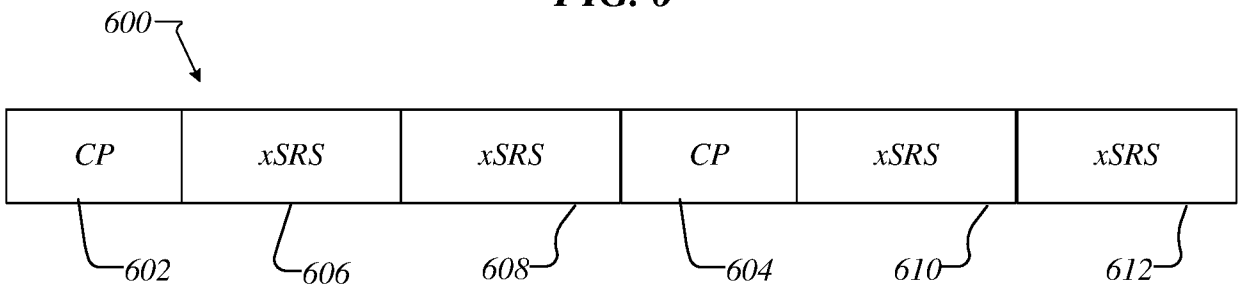

600
CP
xSRS
xSRS
CP
xSRS
xSRS
602
606
608
604
610
612

FIG. 7

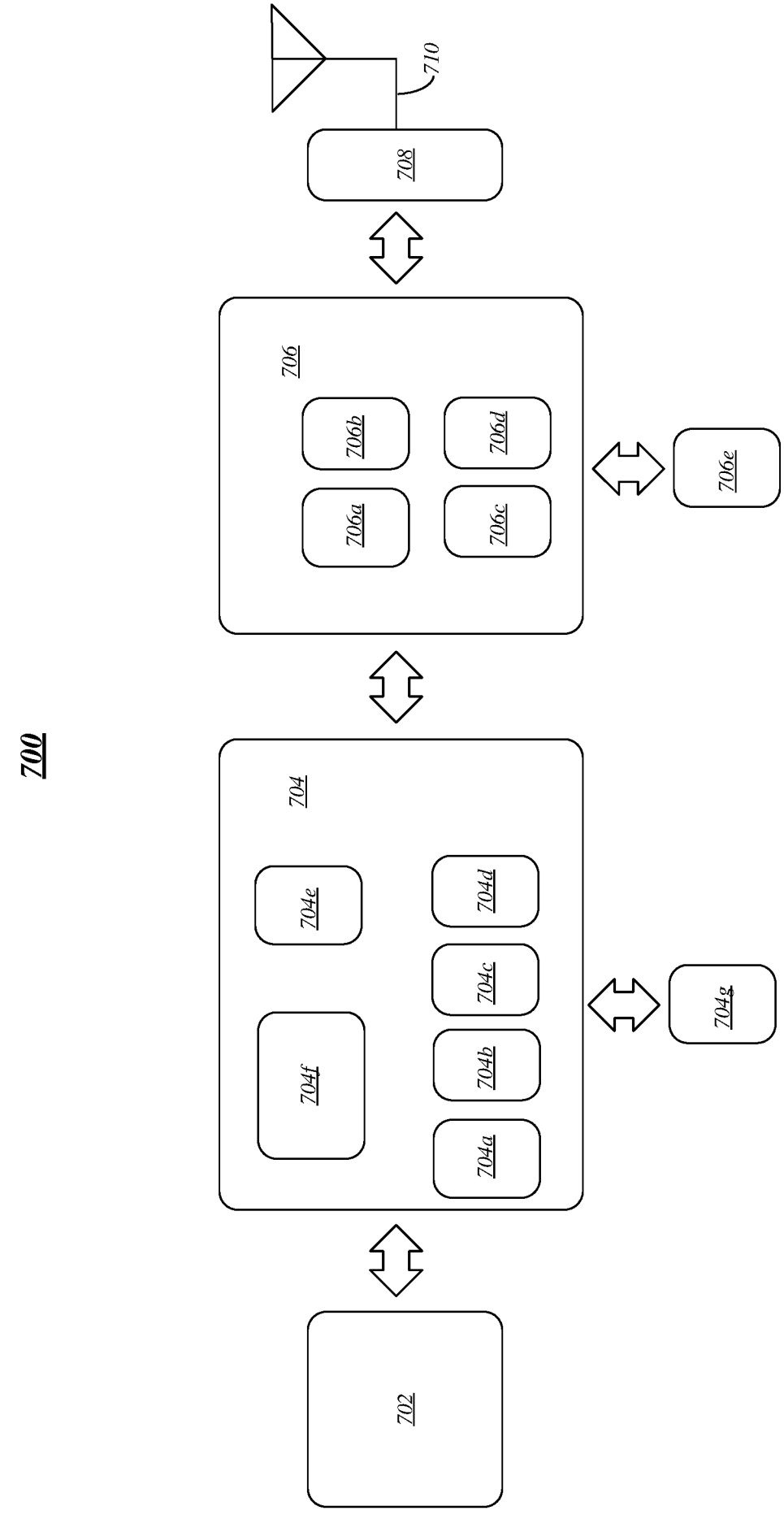

700
710
708
706
706a
706b
706c
706d
706e
704
704a
704b
704c
704d
704e
704f
704g
702

FIG. 8

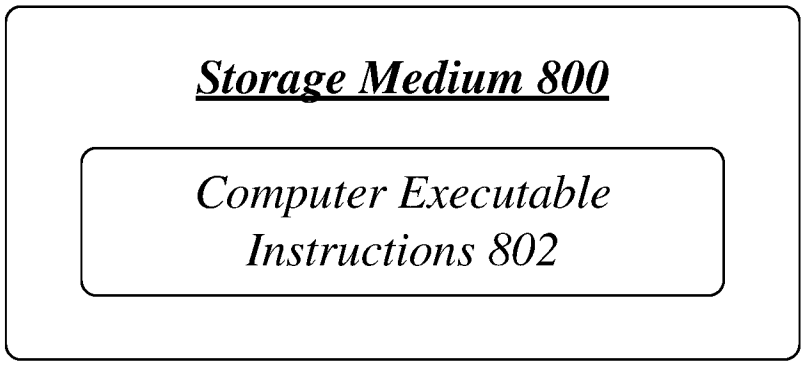


FIG. 9

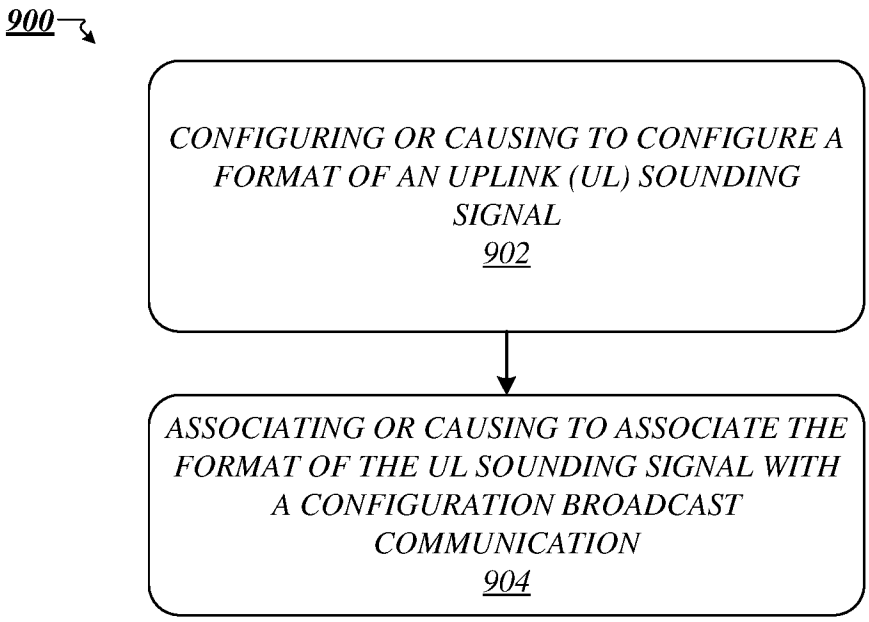
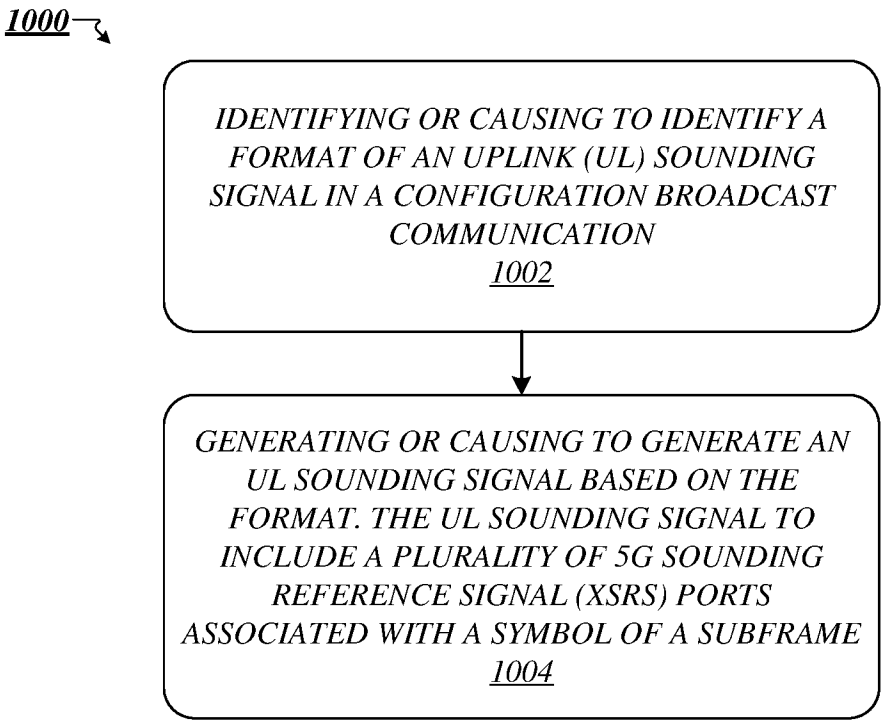

900
CONFIGURING OR CAUSING TO CONFIGURE A FORMAT OF AN UPLINK (UL) SOUNDING SIGNAL
902
ASSOCIATING OR CAUSING TO ASSOCIATE THE FORMAT OF THE UL SOUNDING SIGNAL WITH A CONFIGURATION BROADCAST COMMUNICATION
904

FIG. 10


1000
IDENTIFYING OR CAUSING TO IDENTIFY A FORMAT OF AN UPLINK (UL) SOUNDING SIGNAL IN A CONFIGURATION BROADCAST COMMUNICATION
1002
GENERATING OR CAUSING TO GENERATE AN UL SOUNDING SIGNAL BASED ON THE FORMAT. THE UL SOUNDING SIGNAL TO INCLUDE A PLURALITY OF 5G SOUNDING REFERENCE SIGNAL (XSRS) PORTS ASSOCIATED WITH A SYMBOL OF A SUBFRAME
1004

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/040884

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L5/00 H04W52/40 H04W72/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 763 470 A1 (SHARP KK [JP]) 6 August 2014 (2014-08-06) paragraph [0054] paragraph [0050] paragraph [0072] figure 2 paragraph [0390] paragraph [0067] -----	1-25
X	US 2014/241242 A1 (JOSIAM KAUSHIK MORAPAKKAM [US] ET AL) 28 August 2014 (2014-08-28) paragraph [0006] paragraph [0007] - paragraph [0009] paragraph [0011] -----	1-25

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 October 2016	25/10/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Anghel, Paul

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2016/040884

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2763470 A1	06-08-2014	CN 103843422 A	04-06-2014
		EP 2763470 A1	06-08-2014
		JP 5813444 B2	17-11-2015
		JP 2013077926 A	25-04-2013
		US 2014226551 A1	14-08-2014
		WO 2013047129 A1	04-04-2013
US 2014241242 A1	28-08-2014	CN 105103261 A	25-11-2015
		EP 2962321 A1	06-01-2016
		JP 2016514406 A	19-05-2016
		KR 20140107117 A	04-09-2014
		US 2014241242 A1	28-08-2014
		WO 2014133311 A1	04-09-2014